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Level II Ergonomic Analyses, Dover AFB, DE

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13. ABSTRACT *(Maximum 200 words)*
The results of ten ergonomic evaluations conducted in the EMS ISO Dock, the EMS Structural Maintenance Shop, and the APS Special Handling Shop at Dover AFB are described. The evaluations were performed as part of an Air Mobility Command-sponsored effort to identify, evaluate, and control hazards for work-related musculoskeletal disorders. The report identifies key risk factors associated with various jobs in each shop, the underlying cause of the hazard, control options to reduce or eliminate the hazard, and the expected impacts of each control measure.

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APPENDICES

1.0 INTRODUCTION

EARTH TECH was tasked to provide support to Headquarters Air Mobility Command in the implementation of standardized ergonomic methodologies and management tools in order to minimize or eliminate work-related musculoskeletal disorders (WMDs) associated with routine exposure to ergonomic risk factors at Air Force installations. A portion of this task was accomplished in the performance of Level II Ergonomic Analyses at Dover AFB. These Ergonomic Analyses were accomplished by one of EARTH TECH's critical subcontractors, The Joyce Institute/A Unit of Arthur D. Little, Inc.

The work was performed in accordance with the Statement of Work (SOW) dated 21 August 1995, Delivery Order 0002, Contract F41624-95-D-9016. This Implementation Visit Report (CDRL A003) is submitted in accordance with paragraph 3.2.3 of the SOW.

1.1 Purpose of the Level II Ergonomic Analyses

The Level II Ergonomic Analyses were performed as part of an overall effort to identify, assess, and control employee exposure to ergonomic hazards. The primary objectives of the efforts were to:

- Perform a Level II Ergonomic Analyses of three industrial shops and 10 jobs;
- Develop a realistic menu of controls for the ergonomic problems identified during the analyses; and
- Perform passive Level II Ergonomic Analyses training of BEF personnel.

While the intent was to provide the Dover AFB Bioenvironmental Engineering Flight (BEF) with job-specific controls that can be implemented to effectively minimize or eliminate employee exposure to ergonomic hazards, the analyses results and controls may also serve as the basis for developing additional industrial case studies for the Level I Guide for Maintenance and Inspection Work Areas.

1.2 Approach

The processes used to select the three industrial shops and 10 jobs and to conduct the Level II Ergonomic Analyses are described in the following sections.

1.2.1 Initial Shop Selection and Administration of the Job Requirements and Physical Demands Survey

The Dover AFB BEF identified five industrial shops as Potential Ergonomic Problem Areas (PEPAs), based on previous injury/illness history or the presence of signal risk factors. In order to determine if these shops should be classified as Ergonomic Problem Areas (EPRAs) and included in the Level II Ergonomic Analyses, Dover AFB Public Health (PH) administered the Job Requirements and Physical Demands (JR/PD) Survey (USAF, 1996). The shops and results of the JR/PD Survey are shown in **Table 1.1**. A blank copy of the JR/PD Survey is provided in **Appendix A**.

Table 1.1. PEPA Shops and Results of the JR/PD Survey

Shop Name	Workplace Identifier	Survey Participation	Ergonomics Priority Rating and Shop Classification*
EMS ISO Dock	0052-FAPH-051A	88% (77 of 88)	7 - EPRA
EMS Structural Maintenance	0052-FACC-014A	87% (74 of 85)	7 - EPRA
APS Special Handling	0052-XXXX-057A	83% (19 of 23)	7 - EPRA
APS Passenger Services	0052-XXXX-060A	89% (32 of 36)	4 - Non-EPRA
APS MMHSM	0052-XXCA-058A	40% (4 of 10)	3 - Non-EPRA

* A score of 5 or greater on the JR/PD indicates an EPRA, when psychosocial and individual factors have not reached a level to impact the score. It should be noted that due to the low participation, the results from APS MMHSM may not be representative of the shop in general.

Based on the JR/PD Survey results, EMS ISO Dock, EMS Structural Maintenance, and Aerial Port Squadron Special Handling were the shops selected for the Level II Ergonomic Analyses.

1.2.2 Initial List Priority Jobs

An Ergonomist from the Joyce Institute reviewed individual employee responses to Part III and Part IV of the JR/PD Surveys from the three selected shops. For each shop, the Ergonomist listed jobs/tasks and tabulated the number of responses about similar jobs. The jobs identified by the greatest number of employees were selected and included on an initial list of priority jobs shown in **Table 1.2**. This list was then submitted to Capt R. Marchioni on 30 September 1996 for discussion.

Table 1.2. Preliminary Prioritized Task List for Level II Ergonomic Analyses

Within Shop Priority	Job/Task Name
ISO Dock - 1	Changing pylon clamps
ISO Dock - 2	Changing tires
ISO Dock - 3	Removing/installing underfloor panels
ISO Dock - 4	Removing/installing wing slats
ISO Dock - (alternate)	Hanging cowl doors
S. Maintenance - 1	Repairing blown floor/heater ducts
S. Maintenance - 2	Changing brackets and inspection in the t-tail
S. Maintenance - 3	Bilge inspections
S. Maintenance - 4	Sanding and painting
S. Maintenance - (alternate)	Drilling and riveting
Special Handling - 1	Building/tying down/netting pallets
Special Handling - 2	Boxing mail
Special Handling - (alternate)	Placing regular mail in tri-wall boxes

1.2.3 Final Job Selection

The Ergonomist met with Capt R. Marchioni and toured each of the shops. The jobs from Table 1.2 were discussed with the respective shop supervisors and shown to the Ergonomist. In most cases, jobs not included in the study were eliminated because they were similar to another job on the list (e.g., removing/installing wing slats was similar to hanging cowl doors). In one instance, the shop supervisor identified a job which had not been specifically mentioned prior to the site visit.

In summary, the final list of jobs was selected based on the JR/PD Survey results, and direct input from BEF, shop supervisors, and employees. The final list is shown in **Table 1.3**.

Table 1.3. Jobs Included in the Level II Ergonomic Analyses

Shop Name	Actual Job Name	Rationale for Inclusion
EMS ISO Dock	Change Pylon Clamps Extend/Retract Stand Slides Remove/Install Aircraft Tires Remove/Install Cowl Doors Remove/Install Underfloor Panels	Critical Task: Lifting/Exertion Critical Task: Lifting/Exertion Critical Task: Lifting/Exertion Critical Task: Lifting/Exertion High frequency of occurrence on JR/PD
EMS Structural Maintenance	Paint Aircraft Components Repair Blown Heater/Floor Ducts Sand Paint Off Aircraft	Critical Task: Frequency* Critical Task: Frequency (drilling/riveting)* Critical Task: Frequency
APS Special Handling	Build-Up/Tie-down Pallets Pack Tri-Wall Containers with Mail	Critical Task: Frequency/Lifting/Exertion* Critical Task: Frequency/Lifting/Exertion*

* Considered to be routine as defined by the JR/PD (occurs three or more days per week)

Tasks which occur greater than 10% of the work time are considered to be critical tasks. In addition, tasks in which lifting or exertion occurs are also considered to be critical tasks.

Four of the 10 jobs selected were routine tasks. In maintenance and inspection activities, it is common for non-routine tasks to be a source of WMDs. This is largely because the lifting and high forces which occur in these types of jobs do not require a large amount of exposure to be a source of injuries.

All but one of the jobs selected contained critical tasks. The one that did not, removing/installing underfloor panels, was included because of the large numbers of personnel who cited this activity on the JR/PD. A Level II analysis is an appropriate tool for evaluating jobs which are not explained clearly by other input.

1.2.4 Data Collection and Evaluation

The data collection and evaluation process was designed to address, at a minimum, the items described in Paragraph 4.5.2 of AFOSH Standard 48-3, Draft, May 1996. These items are also listed in Appendix E.

The following data collection methods were used by the Ergonomist:

- videotaped the job in progress or a representative demonstration (when appropriate);
- interviewed the employee or supervisor to collect process-specific or other background information;
- completed one or more detailed task analyses methods:
  - performed elemental task analyses;
  - measured grip force;
  - analyzed dynamic tasks;
  - measured push/pull force;
  - analyzed biomechanical lifting; and
  - measured vibration.*

**As indicated in the Pre-Test Survey Report, vibration measurement was limited to use of the Bruel and Kjaer Type 2513 Integrating Vibration Meter with a hand/arm transducer set.*

Not every analysis method is appropriate for every type of work. **Figure 1.1** shows the overall ergonomic problem solving process. **Figure 1.2** shows the Level II analysis process. This provides the rationale used in selecting Level II analysis methods for specific jobs/tasks. Additional information on the Level II analysis methods is provided in **Appendix B**.

BEF representatives accompanied the Ergonomist and, in some cases, assisted with the data collection process in order to receive passive training in Level II data collection techniques.

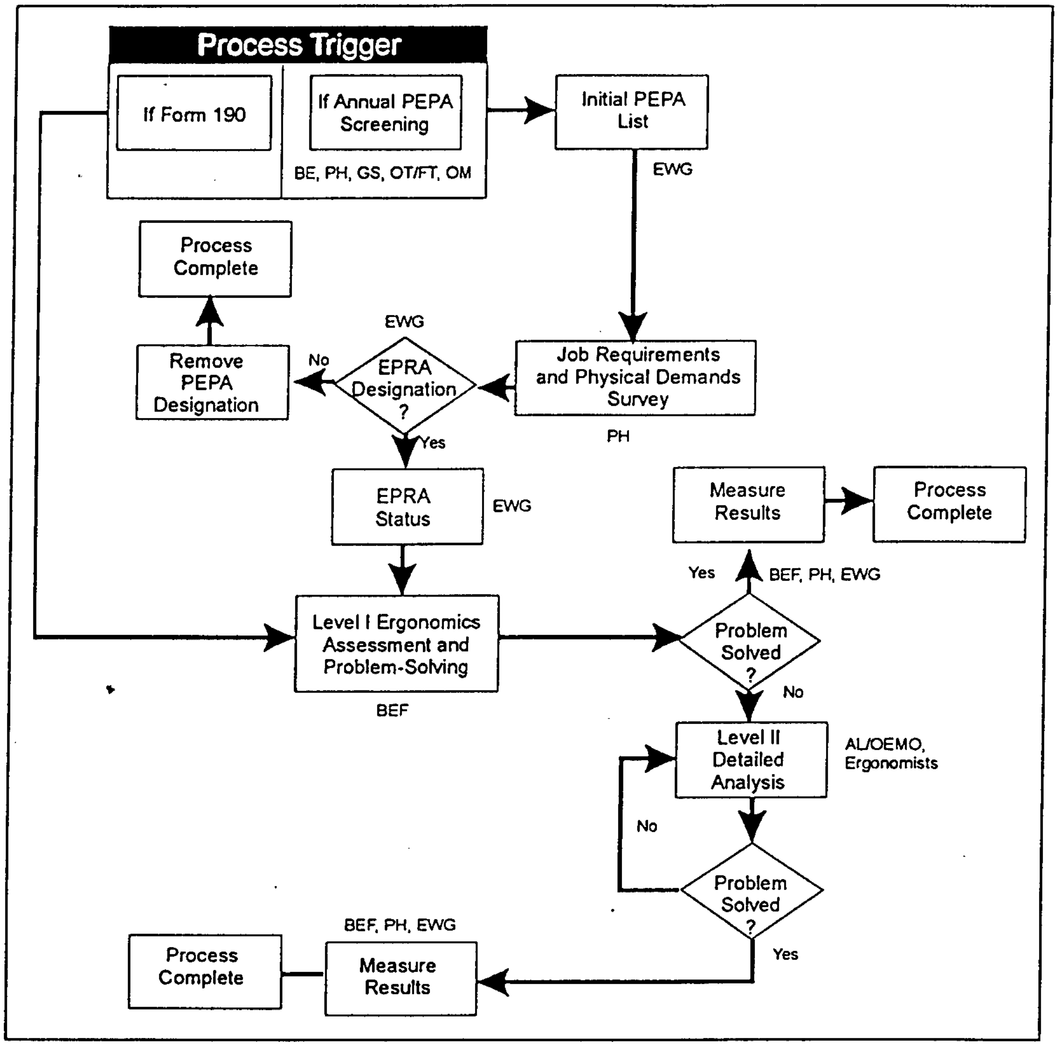


Figure 1.1. Overall Ergonomic Problem-Solving Process

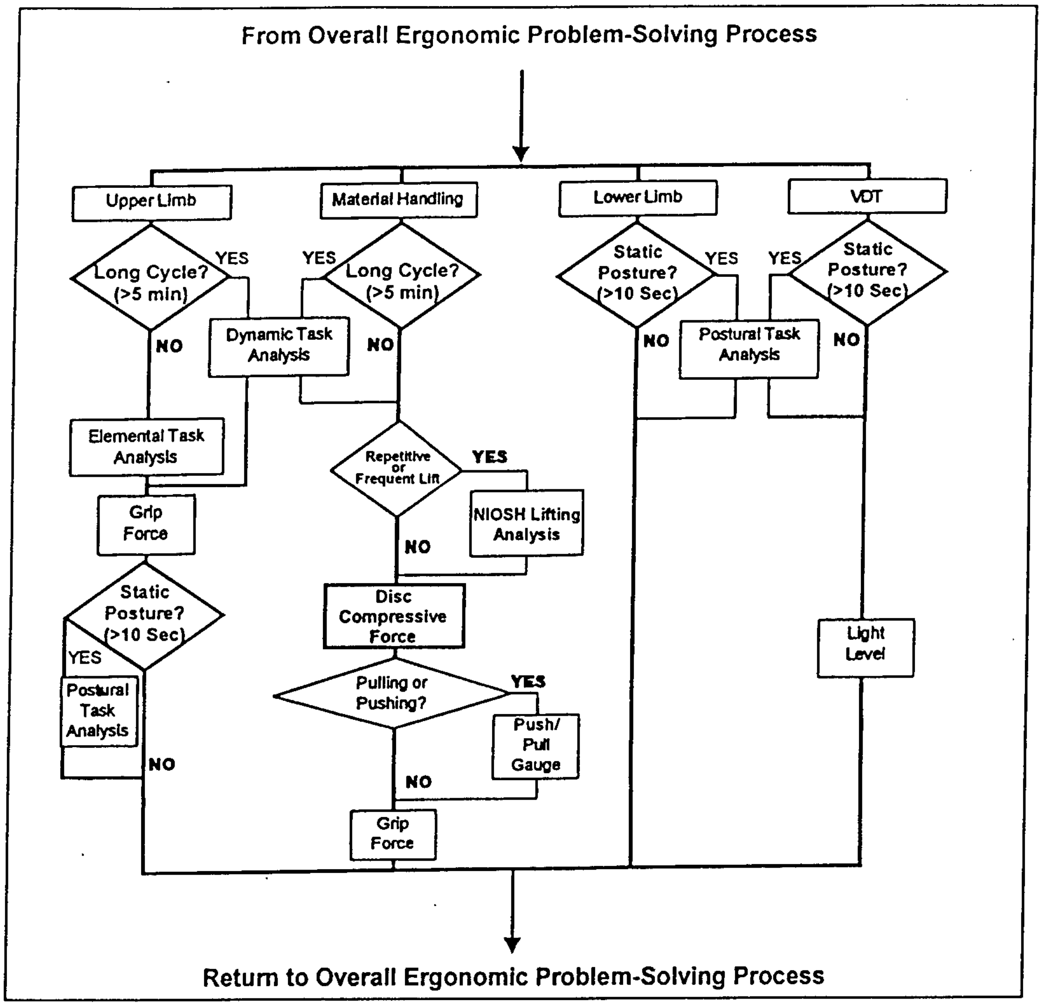


Figure 1.2. Level II Detailed Analysis Process

1.2.5 Rationale for Findings

An overall risk rating is provided for each job/task in the Job Overview Section of the Level II Ergonomic Analysis results for that job (Sections 2.0, 3.0, and 4.0). This overall risk rating is based upon the results of the individual task analysis methods used. Each individual task analysis method also was given a risk rating. These individual risk ratings are presented with the results of each task analysis method.

The determination of the risk rating for a particular task analysis method was based on the following decision criteria:

- High Risk The recommended maximum criteria for the analysis method is exceeded and [the total percentage of work time spent performing the job/task is >50% or excessive forces (>50 lb) occur in the task];

- Medium Risk The recommended maximum criteria for the analysis method is exceeded but [the total percentage of work time spent performing the job/task is 10-50% and excessive forces (>50 lb) do not occur in the task];
- Low Risk The recommended maximum criteria for the analysis method is not exceeded.

Individual risk rating for each analysis method are combined to determine the overall risk rating for the job/task in the following manner:

- High Risk At least one detailed task analysis method produced a High risk rating.
- Medium Risk At least one detailed task analysis method produced a Medium risk rating but no High risk ratings were produced.
- Low Risk There were no Medium or High risk ratings for any of the task analysis methods used.

These decision criteria are based on the Level I Ergonomics Analysis Guide for Maintenance and Inspection Areas. This was done in order to maintain a consistency between Level I and Level II analyses in terms of risk assessment of job/tasks.

1.2.6 Identification of Control Measures

The Ergonomist developed control measures to address the ergonomic problems identified during the data evaluation phase. Control measures were also designed to include input or suggestions provided by shop personnel. Special focus was kept on identifying realistic controls that could be implemented by BEF and the respective shops. While the intent was to identify controls which would reduce employee exposure to ergonomic hazards, the Ergonomist made every attempt to include control options that may improve operation efficiency. In cases where the Ergonomist has identified a device or piece of equipment that may be considered for purchase, selected vendor sources are provided in this report.

1.3 Structure of the Report

This Level II Ergonomic Analyses report is comprised of four sections, including one section devoted to each shop, and one section containing conclusions.

Section 2.0 presents the Level II Ergonomic Analyses results for the APS Special Handling shop. This section is designed to first present information common to the entire shop, such as a shop-specific executive summary, results from the JR/PD Survey, historical data on injuries/illnesses, and shop demographics. This shop-specific information is followed by the Level II Ergonomic Analyses results for each job study within the shop. This structure was designed for distribution flexibility. It also enables BES to distribute results in different ways. BEF may elect to provide Section 2.0 in its entirety to the shop and/or provide information on each job separately.

Section 3.0 presents the Level II Ergonomic Analyses results for the EMS ISO Dock. The structure is the same as Section 2.0.

Section 4.0 presents the Level II Ergonomic Analyses results for the EMS Structural Maintenance. The structure is the same as Sections 2.0 and 3.0.

Section 5.0 summarizes the overall results of the Level II Ergonomic Analyses. In this section, the Ergonomist also provides general comments and suggestions for facilitating an effective implementation and measuring the impact of the controls on employee health/safety as well as shop operational performance.

2.0 APS SPECIAL HANDLING & WAREHOUSE SHOP

The following sections present information obtained during the Level II Ergonomic Analyses conducted for the APS Special Handling (0052-XXXX-057A) shop at Dover Air Force Base (AFB).

2.1 Executive Summary

This report contains the results of Level II Ergonomic Analyses of several activities performed for the APS Special Handling shop. The following jobs were identified as a high priority through analyses of the Job Requirements and Physical Demands (JR/PD) Survey for the APS Special Handling shop:

- Pallet Build-Up/Tie-Down; and
- Pack Tri-Wall Containers.

The ergonomist, through observation of the job tasks and interviews with employees and supervisors, determined the critical tasks in each job based on the criteria established in the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas.

Pallet Build-Up/Tie-Down is comprised of the following critical tasks:

- Manually transfer cargo (Lifting)*;
- Pull nets out of tri-wall boxes (Lifting)*;
- Attach side nets (Tying/Twisting/Wrapping)*;
- Throw/place top nets (Lifting)*; and
- Tighten nets down (Tying/Twisting/Wrapping)*.

Pack Tri-Wall Containers has one critical task:

- Load cargo into tri-wall container (Lifting)*.

All six critical tasks were also selected as routine tasks by more than 20% of the participants in the JR/PD survey for this shop.

* The tasks is parentheses are the corresponding standard task categories used in the JR/PD survey.

2.1.1 Findings and Recommendations: Pallet Build-Up/Tie-Down

The following information summarizes the results of the Level II Ergonomic Analyses for the pallet build-up tie-down job.

Job:	Pallet Build-Up/Tie-Down
HEG:	Process Cargo for Airlift (Warehouse) and Process Cargo for Airlift (Special Handling)
Survey Date:	15 October 1996
Overall Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Job:	Repeated/static bending for approximately 50% of work time. Excessive lifting forces during manual handling.
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Dynamic Task Analysis, NIOSH Lifting Analysis, Biomechanical Lifting Analysis, Postural Analysis and Force Analysis, and excessive forces (> 50 lb.) occurring in the job.

Table 2.1 summarizes the results of the Level II Ergonomic Analysis for the critical task: Manually transfer cargo.

Table 2.1. Summary of Results of Level II Ergonomic Analyses for the Critical Task: Manually Transfer Cargo

Task:	Manually transfer cargo
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Repeated bending and excessive lifting forces during manual handling
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Dynamic Task Analysis, NIOSH Lifting Analysis, and Biomechanical Lifting Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Repeated bending of the back	• Manual handling of items • Skids/pallet on floor	Short-Term • Place input skids on stacks of pallet or on heavy duty tables (ENG) • Conduct ergonomics training for employees (WPR) • Encourage personnel to avoid completing paperwork in a bent position (WPR)	• Moderate reduction in repeated bending of the back • Minor reduction in repeated bending of the back • Minor reduction in repeated bending of the back
		Long-Term • Provide lift tables for the input skids and the pallet (ENG)	• Major reduction in repeated bending of the back

Table 2.1. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Manually Transfer Cargo (cont'd).

Task:	Manually transfer cargo
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Repeated bending and excessive lifting forces during manual handling
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Dynamic Task Analysis, NIOSH Lifting Analysis, and Biomechanical Lifting Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Excessive lifting forces	• Heavy cargo handled manually	Short-Term • Conduct ergonomics training for employees (WPR)	• Minor reduction in excessive forces to the back
		Long-Term • Provide a mechanical lifting device for handling cargo over 50 lb (ENG) • Provide the necessary tools, resources, and training to make it easier for personnel to strap heavy items to skids to avoid manual handling (ADM)	• Major reduction in excessive forces to the back • Potential measurable reduction in build-up time requirements
		• Set-up an initiative to influence suppliers to plan all items greater than 50 lb to be fork truck moveable (ADM)	• Major reduction in excessive forces to the back • Potential measurable reduction in build-up time requirements

* See Appendix C for explanation of risk factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

Table 2.2 summarizes the results of the Level II Ergonomic Analysis for the critical task: Pull nets out of tri-wall boxes.

Table 2.2. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Pull Nets Out of Tri-Wall Boxes (cont'd).

Task:	Pull nets out of tri-wall boxes
Risk Rating:	MEDIUM
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Excessive pulling forces
Results of Level II Analysis:	The MEDIUM risk rating was a result of exceeded guidelines for Force Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Excessive pulling forces	• Storage method • Nets tend to be tangled in boxes	Short-Term • Maintain balanced body position while pulling (WPR) • Dump nets out onto a table to untangle (WPR) • Conduct ergonomics training for employees (WPR) Long-Term • Investigate alternative storage container for nets (ENG)	• Minor reduction in excessive forces to the back • Minor reduction in excessive forces to the back • Minor reduction in excessive forces to the back • Major reduction in excessive forces to the back • Potential measurable reduction in build-up time requirements

* See Appendix C for explanation of risk factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

Table 2.3 summarizes the results of the Level II Ergonomic Analysis for the critical task: Attach side nets.

Table 2.3. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Attach Side Nets.

Task:	Attach Side Nets
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Static bending while laying out and attaching side nets
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Dynamic Task Analysis and Postural Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Static bending of the back	• Untangling nets on floor • Pallets on floor	Short-Term • Encourage personnel to vary body positions while attaching side nets (WPR) • Untangle/spread out nets on a large table instead of on the floor (WPR) • Conduct ergonomics training for employees (WPR) Long-Term • Provide lift tables to raise the height of the pallet while attaching side nets (e.g., adjustable height lift table) (ENG)	• Minor reduction in static bending of the back • Moderate reduction in static bending of the back • Minor reduction in static bending of the back • Major reduction in static bending of the back • Potential measurable reduction in tie-down time requirements

* See Appendix C for explanation of risk factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

Table 2.4 summarizes the results of the Level II Ergonomic Analysis for the critical task: Throw/place top nets.

Table 2.4. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Throw/Place Top Nets.

Task:	Throw/place top nets
Risk Rating:	HIGH
Primary Body Region of Concern:	Shoulder/Neck, Back/Torso
Most Hazardous Aspects of the Task:	High speed movements and excessive forces in the back and shoulder while throwing and placing top nets
Results of Level II Analysis:	The HIGH risk rating was a result of injury data, employee comments, and jobs factors

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• High speed movements and excessive forces in the back and shoulder	• Finished pallets are typically 100" high • Personnel must place net on top of high stack of cargo • Weight of top net (45 lbs.)	Short-Term • Use a fork truck to assist in the task of placing the top net (WPR) • Use technique straps to pull the top net over the stack (WPR) • Conduct ergonomics training for employees (WPR) Long-Term • Provide a device to place the top net over the pallet (using either a fork truck or a rolling frame) (ENG) • Provide a pit for the pallet which would allow the stack to be lowered when the top net is being attached (ENG)	• Major reduction in excessive forces to the back and shoulder • Minor reduction in excessive forces to the back and shoulder • Minor reduction in excessive forces to the back and shoulder • Major reduction in excessive forces to the back and shoulder • Potential measurable reduction in tie-down times

* See Appendix C for explanation of risk factors

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

Table 2.5 summarizes the results of the Level II Ergonomic Analysis for the critical task: Tighten nets down.

Table 2.5. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Tighten Nets Down.

Task:	Tighten nets down
Risk Rating:	MEDIUM
Primary Body Region of Concern:	Shoulder/Neck, Hands/Wrists/Arms
Most Hazardous Aspects of the Task:	Excessive pulling forces
Results of Level II Analysis:	The MEDIUM risk rating was a result of exceeded guidelines for Force Analysis

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Excessive pulling forces	• Design of clamps/straps	Short-Term	
		• Repair or replace damaged straps, clamps, or hooks (WPR)	• Minor reduction in excessive forces to the back
		• Maintain balanced body position while pulling (WPR)	• Minor reduction in excessive forces to the back
		• Use straps with ratchet tightening mechanisms only (WPR)	• Moderate reduction in excessive forces to the back
		• Conduct ergonomics training for employees (WPR)	Minor reduction in excessive forces to the back
		Long-Term	
		• Investigate alternative approaches for bundling cargo (ENG)	• Major reduction in excessive forces to the back • Potential measurable reduction in build-up time requirements

* See Appendix C for explanation of risk factors

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

2.1.2 Findings and Recommendations: Pack Tri-Wall Container

The following information summarizes the results Level II Ergonomic Analysis for the job of packing tri-wall containers with cargo.

Job:	Pack Tri-Wall Container
HEG:	Process Cargo for Airlift (Warehouse) and Process Cargo for Airlift (Special Handling)
Survey Date:	30 October 1996
Overall Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Job:	Repeated bending and excessive lifting forces during loading of cargo into tri-wall containers
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines or NIOSH Lifting Analysis and Biomechanical Lifting Analysis and excessive forces (> 50 lb) occurring in the job.

Table 2.6 summarizes the results of the Level II Ergonomic Analyses for the critical task: Load cargo into tri-wall containers.

Table 2.6. Summary of Results of Level II Ergonomic Analyses for the Critical Task: Load Cargo into Tri-Wall Containers.

Task:	Load cargo into tri-wall containers
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Repeated bending and excessive lifting forces during loading of cargo into tri-wall containers
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for NIOSH Lifting Analysis, Biomechanical Lifting Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Repetitive forward bending of the back • Excessive lifting forces	• Cargo packed into large, deep containers with no side access • Container placed at floor level	Short-Term • Conduct ergonomics training for employees (WPR) • Encourage change in employee techniques (WPR)	• Minor reduction in excessive forces to the back
		Long-Term • Modify the tri-wall container to have drop down flaps on both sides	• Moderate reduction in forward bending and excessive forces to the back
		• Provide containers with side access (e.g., reusable containers) (ENG) • Provide lift table for containers (ENG)	• Major reduction in forward bending and excessive forces to the back • Potential measurable reduction in packing time requirements • Potential return on investment for container and packaging material costs

* See Appendix C for explanation of risk factors

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

2.1.3 Other Jobs/Activities Identified as Candidates for Ergonomics Attention

In addition to the jobs assessed in this project, there are other jobs/activities identified during data collection which may warrant ergonomic attention. We recommend that a Level I analysis be completed for these activities. **Table 2.7** lists these jobs or activities and explains the source.

Table 2.7. Summary of Additional Jobs Identified

Job/Activities	Source	Comments
Handling mail bags	• APS employee comments • Identified during data collection.	This operation is a variation on the two jobs covered in this report. While the recommendations given may apply to handling mail bags as well, the job should be observed to determine if a separate analysis is needed.
Pushing pallets on aircraft	• APS employee comments • Identified during data collection.	n/a
Manually carrying cargo into aircraft	• APS supervisor comments • Identified during data collection.	n/a
Surface freight activities	• APS supervisor comments • Identified during data collection.	n/a

2.2 Background

The following sections provide background information on the shop as well as results of the JR/PD Survey and review of Mishap Data for that shop.

2.2.1 Summary of Results of JR/PD Survey

The JR/PD Survey was administered to employees from the APS Special Handling shop and scored by the Dover AFB Public Health (PH). The Survey response rate was 83%. The Overall Priority rating was 7, indicating that the shop should be considered for Ergonomic Problem Area (EPRA) status.

Results indicated that the highest employee-reported job factor exposures were in the legs/feet, back/torso, and shoulder/neck areas. The highest employee-reported discomfort was for the same body regions. The Survey indicated that any job stress factors are of minimal concern and that employees were not likely to over-rate job factor exposure or discomfort due to job pressures. In addition, seven employees have received attention from a health care provider for their physical discomfort or potentially job-related conditions.

Although the JR/PD Survey results apply only to the shop as a whole, several job activities were specifically noted as among their most difficult, awkward, or physically demanding tasks by the highest number of employees. Two of these tasks were confirmed and agreed upon by the Dover AFB Bioenvironmental Engineering Flight (BEF) for inclusion in the Level II Ergonomic Analyses. The activities and the approximate number of times that the activities were noted on the JR/PD Survey are shown in **Table 2.8**

Table 2.8. Job Selection Based on Results of JR/PD Survey and BEF Approval

Job/Work Activity	Proportion of Shop Personnel Who Noted the Activity
Build-Up/Tie-Down (netting pallets)	22% (5/23)*
Pack Tri-Wall Containers/Mail	17% (4/23)*

* Number of personnel who noted the activity/number of personnel in the shop.

Both jobs received a similar number of comments from employees. In addition, heavy lifting/pushing also received significant comments. The first two jobs were selected since heavy lifting/pushing activities are included in the performance of these jobs. Additional explanation for final job selection is provided in Section 1.2.3.

According to the BEF, no previous ergonomic analyses or lighting surveys have been completed for these work activities.

The Level II Ergonomic Analysis was performed for each of these job activities and results are provided in sections 2.5 and 2.6.

The shop demographics based on the results of the JR/PD Survey are shown below.

Gender:	21% Female	79% Male
Group:	16% Civilian	84% Military
Length of Service (Base):	5%<1 Yr.	95%>1 Yr.
Length of Service (Shop):	5%<1 Yr.	95%>1 Yr.
Age:	<20 Yrs.	5%
	21-30 Yrs.	58%
	31-40 Yrs.	26%
	>40 Yrs.	11%

2.2.2 Historical Data on Injuries and Illnesses

Table 2.9 summarizes the results of a review of mishap statistics (1994-1996) for the APS Special Handling shop. The data was provided by the Dover AFB Safety Office. Table 2.3 presents the most common workplace factors/causes of musculoskeletal injuries (such as sprain/strain, repetitive strain illness, and hernia) that were recorded in the injury data.

Table 2.9. Results of Review of Mishap Data for APS Special Handling

Expected Workplace Factor/Cause	Type of Injury	Body Regions	Number of Recorded Incidents
Pushing pallets	Sprain/Strain	Back/Torso, Hand/Wrist/Arm	9
Lifting heavy boxes/heavy items	Sprain/Strain	Back/Torso	4
Build-up/tie-down (netting pallets)	Sprain/Strain, Abrasions	Shoulder/Neck, Head/Eye	3

Pushing pallets was noted as a major source of injuries. Several of these injuries specified pushing pallets on and off aircraft. This issue was not explicitly identified in comments by employees on the JR/PD Survey. It is an area of concern and, while other jobs were evaluated as a part of this report, the issue of pushing pallets deserves further attention and analysis.

Several injuries associated with lifting heavy boxes were also noted. Lifting heavy boxes occurs in both the build-up/tie-down and packing tri-wall containers operations. There were also several injuries associated with handling the top and side nets which occur as a part of the build-up/tie-down operation.

2.2.3 Workplace Description

The Work Objective for Aerial Port Squadron (APS) is to process cargo for airlift.

The Aerial Port has approximately 80 personnel working on three shifts. There is regular rotation from one shift to another.

The following Homogeneous Exposure Groups (HEGs) were identified in the APS:

- Process Cargo for Airlift (Warehouse);
- Process Cargo for Airlift (Special Handling);
- Surface Freight Personnel;
- Aircraft Loaders;
- Passenger Services;
- Fleet Services; and
- Food Services.

Critical tasks for Process Cargo for Airlift (Warehouse) and Process Cargo for Airlift (Special Handling) are presented in Sections 2.3 and 2.4.

2.3 Pallet Build-Up/Tie-Down

2.3.1 Job Overview

Overall Risk Rating:	**HIGH**
Workplace:	APS Special Handling
Workplace Identifier:	0052-XXXX-057A
Job Title:	Pallet Build-Up/Tie-Down
HEG:	Process Cargo for Airlift (Warehouse) and Process Cargo for Airlift (Special Handling)
Survey Date:	15 October 1996

2.3.2 Job Description

2.3.2.1 Job Objective

The purpose of the pallet build-up/tie-down is to prepare wide varieties of cargo for airlift. This job is performed by both Warehouse and Special Handling personnel. The tasks performed by each group are essentially the same. Warehouse personnel were the focus of this analysis because they perform this job more frequently.

2.3.2.2 Job Frequency and Duration

For warehouse personnel, 20 - 21 pallets per day are built-up/tied-down on the day shift. Approximately 10 pallets are completed on each night shift. Each person typically prepares between two to four pallets per day. There are specific military activities or seasonal events that result in higher volumes of cargo.

Individual pallet build-ups/tie-downs can take 1/2 hour to 3 hours depending on the size of items to be handled and the complexity/special requirements of the cargo. In general, pallets with higher numbers of individual items require more time to build.

The entire job of pallet build/tie-down requires approximately 3 - 6 hours per day. Other jobs which are performed include: tracking/documentation (computer work) and packing tri-wall containers. For warehouse personnel, approximately 50%-75% of the total proportion of work time is spent performing pallet build-up/tie-down.

2.3.2.3 Schedules and Shift/Work Rotation

There are three shifts in the Aerial Port. This job is performed on a 24 hour basis. Each shift is approximately eight hours in length. Generally, rotation across shifts does not occur. Typically, lunch breaks last about one hour and there is no formal break schedule.

2.3.2.4 Number of People Performing Job

On the day shift, there are typically 10 - 11 warehouse personnel (three civilian, seven to eight military). There are typically three to four personnel on each night shift.

2.3.2.5 Job Activity/Task Breakdown

Table 2.10 provides a listing of the basic tasks which occur in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work personnel spend performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 2.10. Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Stage input skids and build-up pallets (using fork truck to transport skids and pallets);	<10%	
Manually transfer of cargo to build-up pallet; • checking documentation on items; • manually lifting items from skids; • manually placing items on the pallet;	20-40%	Critical Task
Pull nets out of tri-wall boxes	<10%	Critical Task (Exertion)
Attach side nets; • separating and laying out nets; • attaching the nets to the pallet;	20%	Critical Task
Throw/place top nets	<10%	Critical Task (Exertion)
Tighten nets down	<10%	Critical Task (Exertion)
Complete documentation; and	<10%	
Transfer finished pallet to staging area for transport.	<10%	

* Total percentage of work time spent performing the task.

2.3.2.6 Critical Tasks

The critical tasks that were identified in this job are:

- Manually transfer items to the build-up pallet (Lifting);
- Pull nets out of tri-wall boxes;
- Attach and tighten side nets and top nets (Tying/Twisting/Wrapping);
- Throw/place top nets; and
- Tighten nets down.

Lifting and Tying/Twisting/Wrapping are the corresponding standard task categories used in the JR/PD and Level I Guide.

2.3.3 Work Area, Materials, and Components

2.3.3.1 Workstation and Equipment Descriptions

Personnel build-up and tie-down pallets in the middle of an open floor. Input items are placed on skids at floor level. The build-up pallet is also at floor level. Fork trucks are used to move pallets and skids around. Skids stacked with various materials are placed adjacent to the build-up skid.

2.3.3.2 Materials and Part(s) Processed

The materials handled come in a wide variety of shapes, sizes, and compositions including boxes, loose items, and irregularly shaped items.

2.3.3.3 Description of Hand Tools Used

Side nets and top nets are used to secure materials on the pallet. Alternatively, straps are sometimes used instead of top nets.

2.3.3.4 Environmental Conditions

No environmental factors were identified that have a significant impact on musculoskeletal risk. The ergonomist queried about environmental issues covered in the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas. One employee expressed concerns with air quality associated with exhaust from fork trucks. This concern was relayed to the BEF.

2.3.3.5 Personal Protective Equipment Required

Leather work gloves are often worn while performing these tasks. While gloves provide protection to the hands, they also tend to increase the grip forces required. This is particularly true when the gloves are not properly sized or if the design of the glove causes a build-up of perspiration inside the glove.

2.3.3.6 Productivity and Quality Requirements

Due to the wide variety of materials handled, the volume of materials to be shipped, and the urgency of the shipment, productivity requirements change on a daily basis. Situations occur in which preparing pallets of materials for delivery within a specified time frame would be critical. From a quality of work standpoint, the main issue involves proper stacking of materials to avoid movement or damage of materials in transit.

2.3.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there are aspects of the tasks which make the job more difficult.

2.3.4.1 Personnel Comments

The following comments were obtained from personnel in the APS Special Handling shop regarding the pallet build-up/tie-down:

General

- "We have a lot of people with back strain."
- Several persons mentioned the quality of team work in this area as being a strong positive.

Handling of Items

- "Household goods are a particular problem. Anything heavy which is not banded to a skid is a problem. If a heavy piece does not have rails to allow a fork truck to pick it up, it must be handled manually."
- "We have a policy that if anybody needs help with moving heavy boxes or other tasks, others must stop what they are doing to provide assistance."
- "In the past, we have had to re-pack tires from New Cumberland because they shifted during transport. Those tires can weigh 250 pounds each. We have informed New Cumberland and it appears this problem is being corrected."
- "The amount of weight handled varies dramatically. There is no limit on the amount of weight that could be handled manually."

Tie Down/Throwing Top Nets

- "Throwing a top net over a 100-inch pallet is not safe at all."
- "We want to avoid having to climb on the pallet. However, this is sometimes necessary to get the top net over."
- "People get hit in the face and cut by the hooks on the top net while throwing it."
- "There is a pit that we could use to lower the pallet and attach the top net but there is a gap around it and people kept falling in so they told us not to use it." Note: This pit also seems to be in a position which might cause it to restrict the flow of traffic in and out of the warehouse.
- "Some clamps are harder to work with."

Personnel Recommendations

- "It would be nice if we did build-ups at the scales. It has a lift which lowers the stack into the floor."
- One person indicated that the New Cumberland facility has pits which allow fork truck access on all four sides and that allow the top net to be placed when the top of the pallet is lowered to ground level.

- One person suggested using ladders and straps to toss the net over the top instead of throwing the entire net. This person also suggested lift tables in a different location and clamps which are easy to open and close.
- Another person suggested providing box gripping mechanisms to the fork trucks to assist in handling heavy items.
- One person has a technique for placing the top net which involves using straps to pull the top net over the stack. There is a tendency for the top net to become caught on the cargo as it is being pulled over.

2.3.4.2 Personnel Ratings of Perceived Discomfort

Two employees were interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. **Table 2.11** and **Table 2.12** indicate those body regions where pain/discomfort was indicated as well as discomfort intensity scores (The Joyce Institute, 1996).

Table 2.11. Body Regions with Pain/Discomfort: Person #1

Body Region Specified	Discomfort Intensity Score on a 1-5 scale
Back/Torso	4-5

Table 2.12. Body Regions with Pain/Discomfort: Person #2

Body Region Specified	Discomfort Intensity Score on a 1-5 scale
Back/Torso	4
Legs/Feet	4
Shoulder/Neck	3
Hands/Wrists/Arms	3

One person reported pain in various regions of the back and rated it a 4 or 5 on a 1-5 intensity scale. This person suggested that back pain and injuries were common in this job. This person also reported ear discomfort and possible hearing loss associated with loud noises occurring in the warehouse. The other person reported discomfort in several regions of the body including the neck, shoulder, back, wrists, thighs, and knees. The ratings varied between 3 and 4 on the 1-5 intensity scale with the highest ratings given for the lower back and knees. This person associated the majority of discomfort with throwing top nets over high pallets and tying down high pallets.

Overall, this information suggests that work related pain/discomfort, particularly in the back, is common in this area.

2.3.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomic Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in **Appendix B** along with a description of the methods.

Table 2.13 below lists the analysis methods employed for each critical task.

Table 2.13. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Manually transfer of cargo to build-up pallet	Dynamic Task Analysis, NIOSH Lifting Analysis, Biomechanical Lifting Analysis
Pull nets out of tri-wall boxes	Dynamic Task Analysis, Force Analysis
Attach side nets	Dynamic Task Analysis, Postural Analysis
Throw/place top nets	Dynamic Task Analysis, Force Analysis
Attaching clamps and tightening straps	Dynamic Task Analysis, Force Analysis

The Dynamic Task Analysis incorporates all tasks performed in the job.

2.3.5.1 Dynamic Task Analysis

A dynamic task analysis was performed for the entire job of pallet build-up and tie-down. This analysis estimates the proportion of task time personnel spend in different awkward postures or exposed to other job factors.

The major awkward body posture of note is forward bending. **Table 2.14** shows those aspects of the job in which awkward forward bending occurs.

Table 2.14. Awkward Back Postures/Movements in Build-Up/Tie-Down

Task Step	Back/Torso Position
Stage input skids and build-up pallets (using fork truck to transport skids and pallets)	
Manually transfer cargo to build-up pallet • checking documentation on items • manually lifting items from skids (low locations only) • manually placing items on the pallet (low locations only)	Forward Bending Occurs
Pull nets out of tri-wall boxes	Forward Bending Occurs
Attach side nets • separating and laying out nets • attaching the nets to the pallet	Forward Bending Occurs
Throw/place top nets	Twisting of the Lower Back
Tighten nets down	
Complete documentation	
Transfer finished pallet to staging area for transport	

Table 2.15 shows the major result of the Dynamic Task Analysis.

Table 2.15. Dynamic Task Analysis Results

Job Factor	Measured Percentage of Total Work Time*	Recommended Maximum Percentage of Total Work Time
Forward bending	50%	33% (Keyserling et al, 1993)

▒ = *exceeded maximum recommended percentage of total task time*

The major finding from this analysis was that awkward back postures occur with an excessively high frequency. **In the build-up/tie-down job alone, the person is required to be in an awkward back posture approximately 50% of the time**

An additional 30% of the work time associated with this work involves a seated posture. This includes driving the fork truck and doing computer work. Seated postures can also stressful on the back.

Conclusion: High Risk; Awkward forward bending occurs approximately 50% of work time.

2.3.5.2 Postural Analysis

Critical Task: Attach side nets

A postural analysis was conducted on static postures which occur while working with side nets. In particular, continuous awkward back postures occur while laying out side nets and top nets and while attaching side nets, as shown in **Table 2.16** and **Figure 2.1.**

Table 2.16. Measured Forward Bending Angle vs. Maximum Recommended Forward Bending Angle

Activity	Measured Forward Bending Angle	Maximum Recommended Forward Bending Angle
Bending to attach side net	90 degrees	20 degrees (McAtammey & Corlett, 1993)

This is an excessive bending posture. In addition, this posture is of particular concern because it is a static posture. Static, continuous muscular effort causes fatigue and tissue damage more quickly because there is a restriction of blood and oxygen to the muscles.

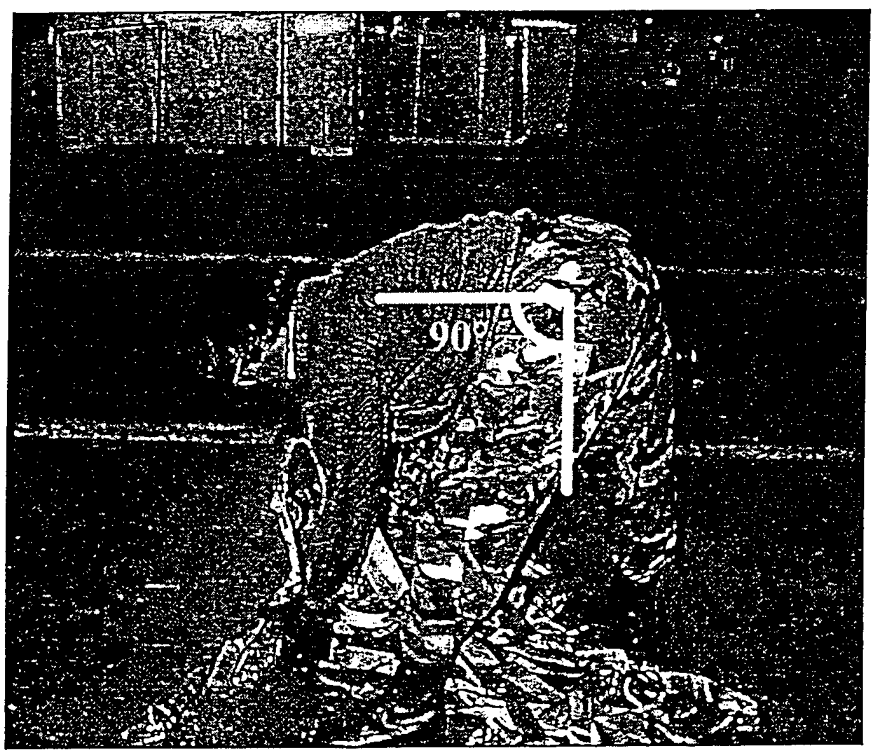


Figure 2.1. Forward Bending Associated with Attaching the Side Net

Conclusion: High Risk; awkward and static back postures.

2.3.5.3 NIOSH 1991 Lifting Analysis

Critical Task: Manually transfer cargo to build-up pallet

A NIOSH 1991 lifting analysis (Waters et al, 1994) was completed for the task of transferring cargo manually from several skids to the build-up pallet. The NIOSH Lifting Analysis provides a Recommended Weight Limit based on: the vertical and horizontal locations of the load, the amount of twisting occurring, the quality of hand holds, and the frequency and duration of the task.

There are several variables that make the NIOSH Lifting Analysis a challenge. First of all, the frequency and overall amount of manual handling varies substantially. Some pallets can be primarily large items attached to skids which can be transferred with a fork truck. Other pallets such as household goods, which are often smaller, are typically handled manually.

In addition, the weights and sizes of items handled manually also vary substantially. One person indicated that personnel are supposed to obtain assistance when handling items greater than 70 pounds (lbs). Not all personnel were aware of this weight limit. However, no mechanical assistance is available for items which are not attached to a skid or have runners attached to allow handling with a fork truck. **Figure 2.2** depicts an item not secured to a skid.

All of these variables create a situation where the lifting demands vary substantially over time.

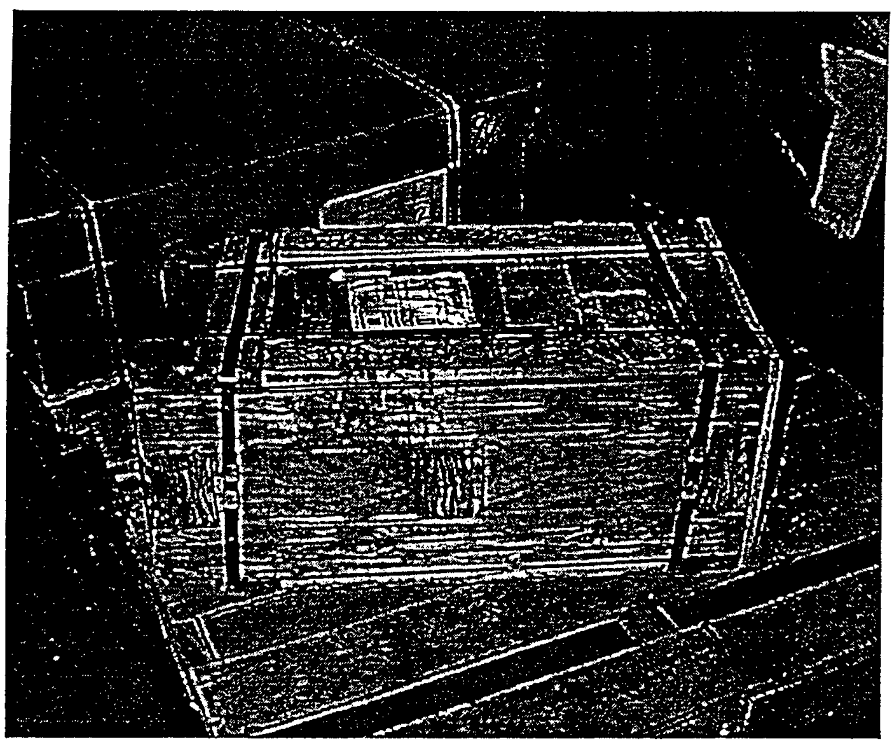


Figure 2.2. Item not secured to skid

Table 2.17 provides the actual weights involved in skid activities and the Recommended Weight Limit (RWL).

Table 2.17. NIOSH Results: Recommended Weight Limit

Activity	Weight Range (lbs)	Recommended Weight Limit (lbs)
Manually transfer cargo to build-up pallet	1-70	14

Conclusion: High Risk; Excessive lifting tasks and forces exceeding 50 lb.

2.3.5.4 Biomechanical Lifting Analysis

Critical Task: Manually transfer cargo to build-up pallet

A biomechanical lifting analysis was performed on the tasks of manually handling items. The computer-based model used for this analysis is a two-dimensional static biomechanical model that estimates the compressive force experienced by the disc at the base of the lumbar region of the spine. This force is calculated based on the measured body posture, estimated object weight, and estimated weight and size of the person's body. The body size and weight estimates are based on a large (95th percentile male) individual because these features represents the worst case for disc compressive force [6] (The Joyce Institute, 1995).

Table 2.18 provides the actual weights involved in skid activities and the maximum recommended weight for various postures.

Table 2.18. Lifting Posture Weight Range vs. Maximum Recommended Weight for Posture

Activity	Weight Range (lbs)	Maximum Recommended Weight for Posture (lbs)
Bottom tier of skid/pallet	1-70	10
Mid-level tier of skid/pallet	1-55	28
Elbow height tier of skid/ pallet	1-55	50

In this lifting posture, boxes exceeding approximately 10 lbs would result in an excessive lifting task using a static biomechanical lifting model. In an upright posture with no reaching, boxes exceeding approximately 50 lbs would result in an excessive lifting task using that same model.

Conclusion: High Risk; Excessive lifting tasks and forces exceeding 50 lb.

2.3.5.5 Force Analysis

Critical Tasks: Pull nets out of tri-wall boxes, tighten nets down, throw/place top nets

Force measurements were obtained for those tasks that seemed to require substantial amounts of force applied with the hands and arms.

2.3.5.5.1 Pull Nets Out of Tri-Wall Boxes

Table 2.19 presents both the pull force measured when personnel pull nets out of tri-wall boxes and the maximum recommended pull force for this activity. Forces were measured using a spring scale. Direct measurements were obtained by using the spring scale to perform the task. Five measurements were taken and the result was obtained by averaging those five measurements.

Table 2.19. Measured Pull Force vs. Maximum Recommended Pull Force

Activity	Measured Pull Force	Maximum Recommended Pull Force
Pulling nets out of tri-wall boxes	50 lbs	25 lbs (Van Cott & Kincade, 1972)

The force required to pull nets out of tri-wall box represents a high force grip. The frequency of the activity varies because the nets are not always stored in the tri-wall boxes. Certainly, however, the frequency is less than 50% of the job time.

Furthermore, removing nets out of tri-wall boxes that have been returned from other locations is time consuming and inefficient. Delays associated with storing the top nets in this manner could have an impact on readiness. (see **Figure 2.3**)

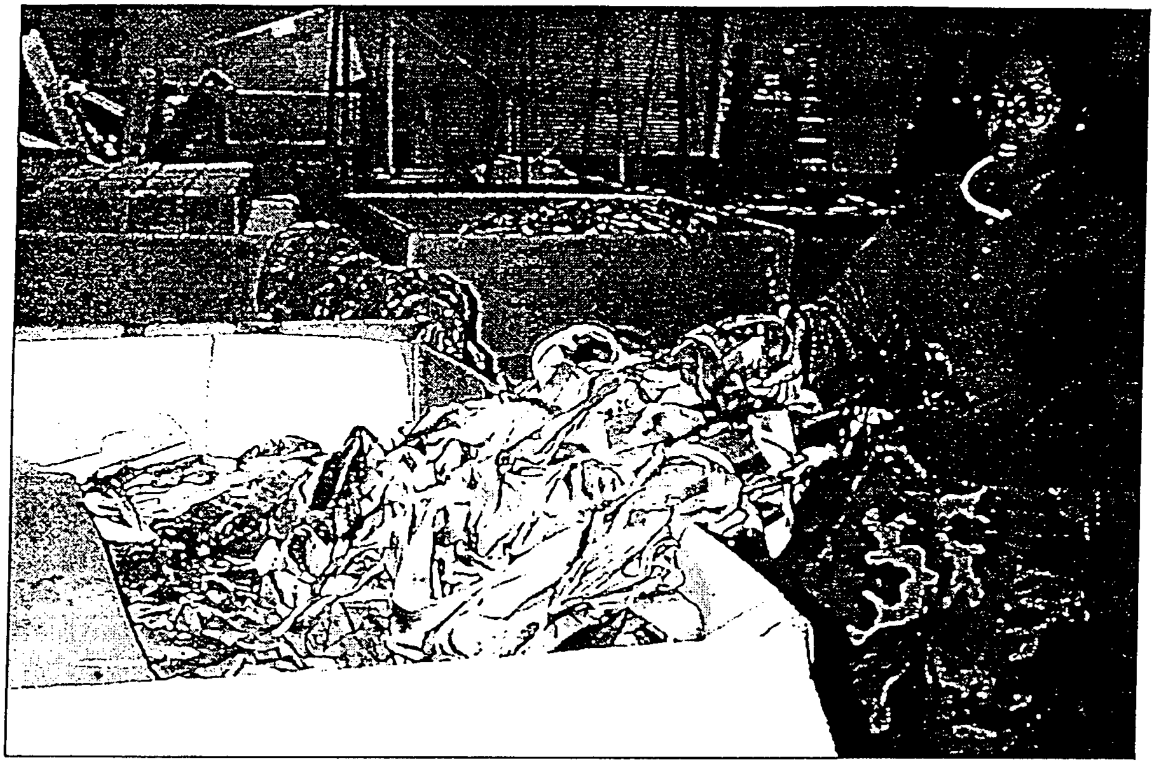


Figure 2.3. High forces associated with dragging nets out of tri-wall boxes

Conclusion: Medium Risk; Excessive forces required to pull nets out of tri-wall boxes, task performed less than 50% of total work time and forces do not normally exceed 50 lb.

2.3.5.5.2 Tighten Nets Down

Forces were measured for the task of tightening straps and clamps while securing nets. Forces were measured using a force dynamometer. Direct measurements were obtained by placing the dynamometer directly on the strap handle and applying the force through the dynamometer. At least five measurements were taken and the result was obtained by taking the average of those five measurements.

Straps are composed of a nylon or canvas material attached by a winch-type device that tightens the loose end of the strap. The name of the primary strap used is the CGU1B strap (see **Figure 2.4**). According to one supervisor, there may be some other commercial straps used as well. However, more specific information on these straps was not available.

Table 2.20 presents the pull force measured when personnel tighten straps as well as the maximum recommended grip force for this activity.

Table 2.20. Measured Pull Force vs. Maximum Recommended Pull Force

Activity	Measured Pull Force	Maximum Recommended Grip Force
Tightening straps with winch mechanism	45 lbs	25 lbs [8]

The average force required to tighten straps was measured at 45 lbs. This represents a high force grip. It was estimated to take 3-5 cranks above 25 lbs for each strap. This equates to 20-35 high force power grips per pallet. This does not approach the criteria of 50% of total work time required to specify High risk.

Figure 2.4. Forces Associated with Tightening Straps

Conclusion: Medium risk; excessive forces required while tightening straps, task performed less than 50% of total work time and forces do not normally exceed 50 lb.

2.3.5.5.3 Throw/Place Top Nets

In order to place the top net on top of the stack, two persons throw the 45 lb top net. In order to generate the momentum to get the top net to the top of the 100" pallet, the persons swing the net back and forth several times.

Due to the high speed movements associated with throwing the top nets and the variables this introduces to shoulder and back forces, it was not feasible to obtain a direct estimate of the force required. Further, there is no known and accepted maximum recommended force guideline for a lateral throwing movement.

So it is necessary to make a decision based on the information available:

- *Personnel comments:* Several persons indicated that throwing the top net was one of the most difficult aspects of the job. Two reasons were given: (1) danger of getting hit/cut by metal hooks while throwing and (2) exertion to the shoulder and back while throwing

- *Existing injuries:* There has been one recorded injury (1994-1996) associated with throwing the top net. This resulted in a strained shoulder. There was also one recorded injury associated with a hook coming loose and hitting a person in the eye. While this was not directly related to throwing the top net, it suggests that the issue of being hit by hooks that is recorded in employee comments is also appearing in injury data.

- *High speed movements:* High speed movements are required to throw the 45 lb top net on top of a 100" pallet. High speed movements are a job factor for the shoulder (See **Appendix C**).

- *High forces:* High shoulder/arm forces are required to throw the 45 lb top net on top of a 100" pallet. High forces are a job factor for the shoulder (See **Appendix C**).

- *Frequency:* The frequency of throwing top-nets is perhaps 2-4 times per day.

Considering that there have been injuries, personnel complaints, and observed job factors in this activity, a high risk rating is recommended based on the professional opinion of the Ergonomist.

Conclusion: High Risk: High speed movements and high forces required to throw top nets on top of stacks.

2.3.6 Overall Findings: Pallet Build-Up/Tie-Down

The following information summarizes the results of the Level II analysis.

The primary body region of concern in this job/task is the back/torso. To a lesser extent, there are risks to the shoulders/neck, knees, and the hands/wrists/arms. As shown in **Table 2.21**, the major job factors are: continuous bending, repetitive bending, high force lifting tasks, and high speed shoulder and back movements. There are also high grip forces occurring in the job. Table 2.21 also summarizes the results of the Level II Ergonomic Analysis for each of the critical tasks and for the job as a whole.

Table 2.21. Summary of Level II Analysis Results

Analysis Method	Critical Tasks	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Dynamic	• Multiple tasks	• High (Back/Torso)	• Forward bending	• Skids and pallets are at floor level
• Postural	• Attach side nets	• High (Back/Torso)	• Continuous forward bending	• Laying out the nets on the floor • Pallet is at floor level • Completing documentation at a low level
• NIOSH • Biomechanical	• Manually transfer cargo to build-up pallet	• High (Back/Torso)	• Repetitive forward bending	• Manual handling of items • Skids and pallets located at floor level
• Force	• Pull nets out of tri-wall boxes	• Medium (Shoulder/ Neck, Hand/Wrist/ Arm)	• High pulling forces	• Storage method • Nets tend to be all tangled up in the tri-wall boxes
• Force	• Tighten nets down	• Medium (Shoulder/ Neck, Hand/Wrist/ Arm)	• High pulling forces	• Design of clamps/straps
• Injury data, comments, job factors	• Throw/ place top nets	• High (Shoulder/ Neck, Back/Torso)	• High force/high speed shoulder and back movements	• Requirement to throw net on top of 100" stack • Height of the stack • Weight of the top net (45 lb.)

Due to the High risk rating for at least one analysis method, the risk rating for the overall job, pallet build-up/tie-down is **High**.

2.3.7 Recommended Control Options: Pallet Build-Up/Tie-Down

The control options are categorized in terms of short-term and long-term controls. **Appendix D** defines these different levels of controls.

The following is a list of control options organized by critical task. The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

2.3.7.1. Manually transfer cargo to build-up pallet

The following are recommended control options for the critical task of manual handling of cargo.

2.3.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Place input skids on stacks of pallets or on heavy duty tables. (ENG)* This would reduce the amount of awkward bending involved in the task. The idea is to place the grasping location at approximately 30 inches (76 cm.) off the ground. A stack of five or six pallets will accomplish this. Keeping the load at this height maximizes the amount of weight the person can lift without creating an excessive lifting task. As a general rule, if the person is upright and not reaching, he/she can lift up to 50 lbs without creating an excessive lifting situation. **Caution!!!: Avoid creating a situation where loads are unstable. This can be prevented by securely strapping stacks of pallets together and making sure the pallets or tables used are in good condition and can support the loads.**

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. In particular, the training could emphasize preferred lifting technique while handling cargo. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

- *Encourage personnel to avoid completing paperwork in a bent position. (WPR)* Encourage personnel to, whenever possible, do paperwork on a stack of cargo which is between elbow and shoulder height. The idea is to eliminate all unnecessary bending from the job. This point could be made as a part of ergonomic training mentioned above.

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves, select gloves which fit appropriately. In addition, use gloves which are breathable to minimize build-up of perspiration.

2.3.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide lift tables for input skids to eliminate bending while retrieving items from pallets.(ENG)* This would eliminate approximately half of the bending associated with the palletizing task. The lift tables should be easily moveable for changing task needs. Lift tables should allow the load to be maintained at least 30 inches (76 cm.) off the ground regardless of the height of material stacked on the pallet. Keeping the load at an appropriate height maximizes the amount of weight the person can lift without creating an excessive lifting task. As a general rule, if the person is upright and not reaching, he/she can lift up to 50 lbs without creating an excessive lifting situation.

  The lift table should be easy to adjust or should adjust automatically. There are many varieties of lift tables on the market (e.g., spring activated, hydraulic, pneumatic, electrical). Three potential sources are provided below.

  1. Advance Lifts, Inc., St. Charles, IL, (708) 584-9881;
  2. Air Technical Industries, Mentor, OH, (216) 951-5191; and
  3. Southworth International Group, Portland, ME, (207) 772-0130.

Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

- *Provide a mechanical lift device to handle items weighing more than 50 lbs. (ENG)* Investigate equipping fork trucks with a box gripping mechanisms to pick up heavy boxes or items. This suggestion was provided by an Aerial Port shop employee. There are a number of different off-the-shelf mechanisms for lifting boxes and other types of cargo. For example, **Figure 2.5** shows vacuum-cup box handlers that could be used for some types of cargo. Three vendor sources for handling equipment for boxes and other components are listed below.

  1. Air Technical Industries, Mentor, OH (216) 951-5191;
  2. Anver Corp., Hudson, MA (502) 568-0221; and
  3. CM Positech, Columbus McKinnon Corp., Inc., Laurens, IA (800) 831-6026.

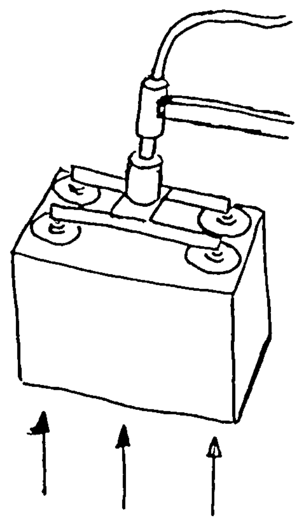


Figure 2.5. Vacuum Cup Box Handling Mechanism

- *Improve the access to resources which would allow warehouse personnel to quickly strap heavy items to pallets to eliminate manual transfers for items weighing more than 50 lbs. (ENG)* While personnel indicated that items can be strapped to the skids currently, there is an impression that the process is time consuming or could be made more convenient. This could be accomplished by setting up a prep station which is dedicated to making cargo "fork lift compatible" by attaching runners or pallets to loads weighing more than 50 lbs or greater than a specified size (oversize items). Using the previous recommendation, providing a mechanical lifting device at that station would allow items to be mechanically transferred to skids or runners. Alternatively, lift devices could be provided at each build-up station as described above. The best alternative would be the one that provides the most efficient flow of cargo through the shop.

2.3.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Conduct a review of Department of Defense transportation policies regarding the shipment of materials. (ADM)* The idea would be to establish a policy that items above a certain weight and size should be equipped to be handled mechanically (e.g., using a fork truck) by attaching runners or placing the item on a skid. A recommended maximum weight for manual handling would be 50 lbs or less. Another part of this initiative would be to increase the number of pieces of cargo which is labeled with an accurate weight. This initiative could have a positive effect in reducing manual materials handling throughout the transportation system. This could also have a desirable impact on process efficiency if larger quantities of cargo are mechanically handled instead of manually handling one piece at a time.

2.3.7.2 Pull Nets Out of Tri-Wall Containers

The following are recommended control options for the critical task of manual handling of cargo.

2.3.7.2.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Obtain assistance to remove nets. (WPR)* Obtain assistance with another person to help untangle the nets while they are being pulled out.

- *Maintain balanced body position using both arms to pull evenly. (WPR)* Avoiding yanking to pull the net clear. Untangle nets with the hands first. The point is to prevent brute force as the means for untangling things.

- *Dump nets out onto a table to untangle. (WPR)* The benefit is that it will loosen nets and provide better access. Use a mechanical device to dump nets out of boxes.

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves. Select gloves which fit appropriately. In addition use gloves which are breathable (minimize build-up of perspiration)

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

2.3.7.2.2 Long-Term Recommendations (Next Fiscal Year)

See long-term recommendations for Coordinated Initiatives.

2.3.7.2.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Investigate alternative storage container for nets which keep the nets organized and untangled. (ENG)* The task of pulling nets out of tri-wall containers is relatively time consuming. It can take several minutes to untangle nets that are all piled together in a tri-wall box. A hanging rack is currently used internally to temporarily store nets. This fixture stores the nets in a way that minimizes tangling. This concept might be applied to shipping containers for nets (i.e., similar to a wardrobe container for clothing). This control would require the cooperation of entities throughout the transportation system. To this extent, it would probably require a review of Department of Defense transportation policies (see

Section 2.3.7.1.3). However, by improving how top nets are stored, this could improve readiness.

2.3.7.3 Attach Side Nets

2.3.7.3.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Encourage personnel to vary body positions while attaching side nets.(WPR)* In general, crouching is better for the spine than forward bending. **Caution!!!: However, crouching and squatting does increase the stress on the knees. Therefore, this recommendation will not ultimately solve the problem: the pallet is at floor level when the side nets are attached** The best advice is to encourage personnel to vary the body position (i.e., crouch sometimes, bend sometimes) to minimize wear and tear on any one portion of the body.

- *Encourage personnel to use tables untangle and lay out nets and straps. (WPR)* This would allow the employee to be in an upright position while laying out the nets. If appropriate tables or other surfaces are not available, provide them. In the interim, encourage personnel to place nets on any appropriate surface while untangling them.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves. Select gloves which fit appropriately. In addition use gloves which are breathable (minimize build-up of perspiration)

2.3.7.3.2 Long-Term Recommendations (Next Fiscal Year)

See long-term recommendations (Coordinated Initiatives).

2.3.7.3.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Provide a lift table for the build-up pallet. (ENG)* If the pits discussed in the previous section are implemented, they should also act as lift tables to raise the base of the pallet to approximately 30 inches (76 cm.) in height in order to eliminate prolonged bending associated with attaching the side nets and repeated bending associated with manually transferring boxes to the lower levels of the pallet. This change would eliminate approximately half of the bending which occurs in the task of manually handling cargo.

2.3.7.4 Throw Top Nets

2.3.7.4.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Investigate the feasibility of using a fork truck to assist in the task of placing the top net. (WPR)* If the fork of the fork truck can clear 100" (the top of the pallet stack) then the fork truck can conceivably be used as an aid for placing the top net (see **Figure 2.6**). The procedure would be as follows: (1) Attach a strap to each corner of the top net, (2) With the fork truck forks in a low position, place the net in an "accordion-folded" position across the forks of the fork truck with the straps hanging off the sides. (3) The fork truck driver would then place the net over the stack while one person is positioned on each side of the stack holding the straps. (4) When the net is in position, the two persons would pull the straps to spread the net out over the top of the stack.

- *If the previous recommendation is not successful, encourage personnel to use straps to pull the top net over the stack as an interim solution.(WPR)* This technique is currently being used by one person in the area. **Caution: There may still be job factors in this solution because the net tends to become snagged on cargo as it is being pull up.** However, it may be preferable (as a short-term solution) to throwing the net.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves. Select gloves which fit appropriately. In addition use gloves which are breathable (minimize build-up of perspiration)

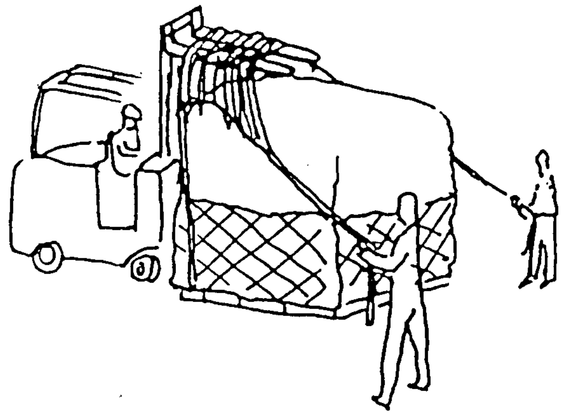


Figure 2.6. Using the fork truck to assist with the placement of the top net

2.3.7.4.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide device to improve ability to slide top net over the stack. (ENG)* Provide a simple fork truck attachment to assist in placing the top nets (see **Figure 2.7**). The purpose of this device would be to provide a way to hold the top net in the open position and place it over the top of the pallet. The idea is to use the fork truck to place the top net on top of the pallet. The attachments could take the form of long poles to hold the top net in an open position. This would allow the net to be placed while the forks are in a low position. The best design would allow for the attachments to be folded up out of the way when not in use.

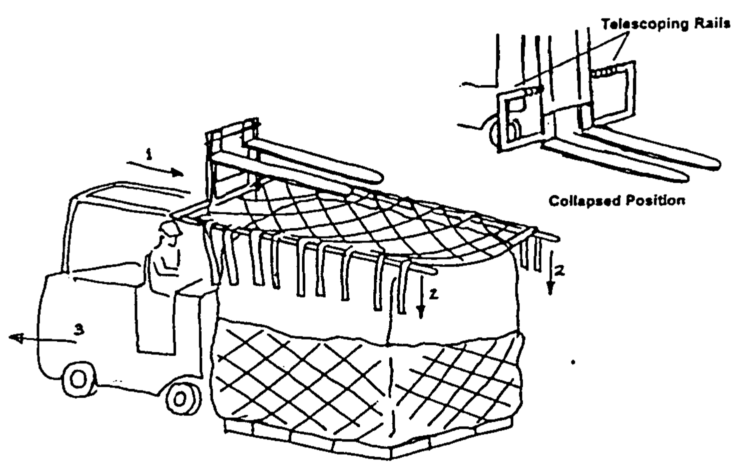


Figure 2.7. Concept for fork truck attachment which would reduce job factors associated with placing the top net (Option A)

A variation on this idea would involve attaching this same device to a rolling framework (see **Figure 2.8**). The top net would be placed with the structure in a collapsed position. The framework would be rolled into position over the pallet prior to attaching the top net. **Caution should be exercised to insure that the rolling structure does not require more than 50 lbs push force in order to move.** A light-weight construction material (e.g., aluminum or fiberglass) and easily rolling wheels are recommended. Option A (Figure 2.7) might be preferred because it would eliminate the need to push a large structure around. In addition, this operation could be more cumbersome and more time consuming for personnel than Option A. According to one supervisor, a device such as this one existed at one time for placing top nets.

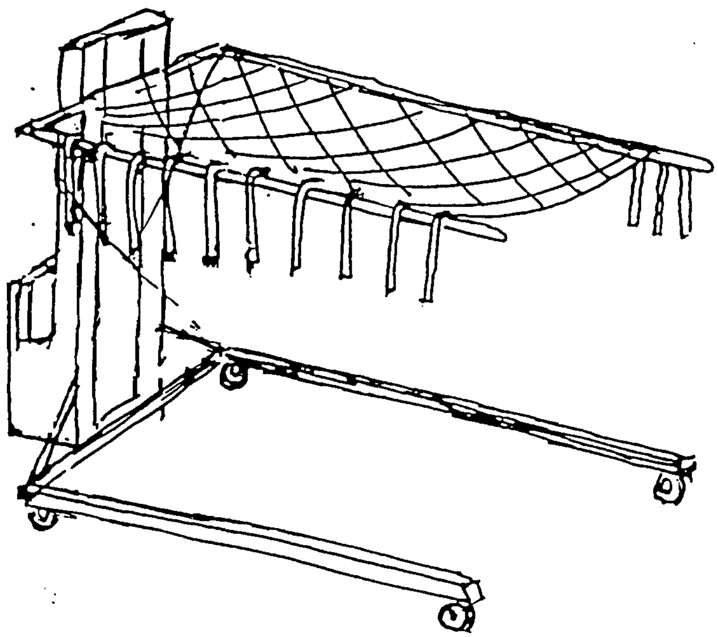


Figure 2.8. Concept for rolling structure which would reduce job factors associated with placing the top net (Option B)

2.3.7.4.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Provide pits for build-up pallets. (ENG)* According to personnel in the APS Special Handling shop, the New Cumberland facility makes use of pits which allow the stack to be lowered prior to placing the top-net. These pits are different than the pit present at Dover AFB. Apparently, the pits at New Cumberland can be accessed on all sides by a fork truck and do not have gaps around the pits which could cause injury. The pits currently used at New Cumberland should be investigated to determine their applicability to Dover AFB. If this control is implemented, it could reduce tie-down times in addition to reducing injury risk.

2.3.7.5 Attaching Clamps and Tightening Straps

2.3.7.5.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Repair or replace damaged straps, hooks, or clamps. (WPR)* Conduct an inspection of existing attachment hooks and clamps to identify ones which are damaged or difficult to engage. Repair or replace these attachment mechanisms.

- *Use straps with ratchet tightening mechanisms only. (ENG)* Avoid use of straps that do not have a racheting mechanism to tighten the strap.

- *Keep the body balanced when pulling. (WPR)* Use whole body while standing straight. Avoid use of one arm to yank the strap.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves. Select gloves which fit appropriately. In addition use gloves which are breathable (minimize build-up of perspiration)

2.3.7.5.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Investigate alternative methods for securing cargo. (ENG)* Look beyond the box of nets and straps. Investigate reusable stretch wrap materials to wrap the stack as it is being built. Inquire into alternative netting designs.

2.3.7.5.3 Long-Term Recommendations (Coordinated Initiatives)

No additional long-term recommendations (coordinated initiatives) are expected to be necessary.

2.4 Pack Tri-Wall Containers

2.4.1 Job Overview

Overall Risk Rating:	**HIGH**
Workplace:	APS Special Handling
Workplace Identifier:	0052-XXXX-057A
Job Title:	Pack Tri-Wall Containers
HEG:	Process Cargo for Airlift (Warehouse) and Process Cargo for Airlift
(Special Handling);	
Survey Date:	30 October 1996

2.4.2 Job Description

2.4.2.1 Job Objective

The objective of the job of packing tri-wall containers is to pack small items which cannot be stacked on a pallet. In addition, tri-wall containers are used for cargo requiring special handling, such as registered mail. The packing of tri-walls is performed in an area dedicated to registered mail and in other areas of the warehouse. This job is performed by both Warehouse and Special Handling personnel. The tasks performed by each group are essentially the same. The focus of this analysis is on the tasks performed by Special Handling in the registered mail area. It was not feasible to observe warehouse personnel performing this job during the data collection.

2.4.2.2 Job Frequency and Duration

In Special Handling, an average of two to three tri-walls are built-up per shift. The volume of tri-wall build-ups varies between zero per week and six to eight per shift. This is due to large fluctuations in mail volume. On average, Special Handling personnel in the Registered Mail area spend approximately 3-4 hours packing tri-wall containers. The remainder of the shift is generally spent completing documentation and building-up pallets.

2.4.2.3 Schedules and Shift/Work Rotation

There are three shifts in the Aerial Port. This job is performed on a 24-hour basis. Each shift is approximately eight hours in length. Generally, rotation across shifts does not occur. Typically, lunch breaks last about one hour and there is no formal break schedule.

2.4.2.4 Number of People Performing Job

Two to three Special Handling personnel typically work on each shift.

2.4.2.5 Job Activity/Task Breakdown

Table 2.22 provides a listing of the basic tasks which occur in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work spent performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 2.22 Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Assemble tri-wall containers	<10%	
Load cargo into tri-wall container • Remove various boxes, bags, and items from shelves and place in the containers • Arrange the items in the container in order to efficiently use space	25%-40%	Critical Task
Close and strap the container	<10%	
Transport the container to be loaded	<10%	

* Percentage of total time spent at work.

2.4.2.6 Critical Tasks

The critical task identified in this job is:

- Load cargo into tri-wall container (Lifting)

Lifting is the corresponding standard task category used in the JR/PD and Level I Guide.

2.4.3 Work Area, Materials, and Components

2.4.3.1 Workstation and Equipment Descriptions

Mail is packed in the tri-wall boxes in the middle of a room. The perimeter of the room is outfitted with storage shelves (three shelves with the following heights: 6.5 inches, 34.5 inches, and 59 inches). Items are typically transferred from the shelves to the container as needed. The tri-wall corrugated container dimensions are 48 inches by 40.5 inches by 37 inches (42 inches counting the skid).

2.4.3.2 Materials and Part(s) Processed

The materials handled come in a wide variety of shapes, sizes, and compositions including boxes, loose items, and irregularly shaped items. Items packed vary greatly in weight. However, items generally weigh less than 55 lbs.

2.4.3.3 Description of Hand Tools Used

A manually operated strapping tool is used to attach straps to the finished containers. Additional information on the strapping tool was not available.

2.4.3.4 Environmental Conditions

Space can be restricted when there are several tri-wall containers in the area and the shelves are full of mail.

2.4.3.5 Personal Protective Equipment Required

No special personal protective equipment is required.

2.4.3.6 Productivity and Quality Requirements

Due to the wide variety of materials handled, the volume of materials to be shipped and the urgency of the shipment, productivity requirements change from day to day. From a quality of work standpoint, the key issues involve protecting the security of the materials and avoiding damage of materials in transit.

2.4.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there are aspects of the tasks which make the job more difficult.

2.4.4.1 Personnel Comments

The following comments were obtained from personnel working in the mail area regarding the packing tasks:

Handling of Items

- "The most difficult items are the magazine boxes, which weigh about 35-50 lbs and are fairly small and hard to put in the bottom of the box."
- "If we have particularly difficult items to pack, one of us will climb in the box and pack that way."

2.4.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. Only one person was available at the time of the visit. **Table 2.23** indicates those body regions where pain/discomfort was indicated as well as discomfort intensity scores and ratings. [3]

Table 2.23. Body Regions with Pain/Discomfort: Person #1

Body Region Specified	Discomfort Score on a 1-5 scale
lower back	1-2
neck	1-2
upper arm	1-2

The person reported pain/discomfort in the lower back, neck, and upper arm and rated it a 1 or 2 on a 1-5 intensity scale. This person also commented that their "back was killing them" and he associated this primarily with lifting heavier boxes.

2.4.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomic Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in **Appendix** B along with a description of the methods.

Table 2.24 below lists the analysis methods employed for each critical task.

Table 2.24. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Load cargo into tri-wall container	Dynamic Task Analysis, NIOSH Lifting Analysis, and Biomechanical Lifting Analysis

The Dynamic Task Analysis incorporates all tasks performed in the job.

2.4.5.1 Dynamic Task Analysis

A dynamic task analysis was performed for the entire job of packing tri-wall containers. This analysis estimates the proportion of task time in different awkward postures or exposed to other job factors.

Table 2.25 shows the result of the Dynamic Task Analysis. The major awkward body posture of note is forward bending.

Table 2.25. Dynamic Task Analysis Results

Job Factor	Measured Percentage of Time Performing Job	Recommended Maximum Percentage of Time Performing Job
Forward bending	15-20%	33% [4]

The analysis shows that while there is some bending in the job, it does not exceed the recommended maximum value.

Conclusion: Low Risk; Recommended maximum value not exceeded.

2.4.5.2 NIOSH 1991 Lifting Analysis

Critical Task: Load cargo into tri-wall container

A NIOSH 1991 lifting analysis [6] was completed for the task of loading cargo into tri-wall containers. The NIOSH Lifting Analysis provides a Recommended Weight Limit based on: the vertical and horizontal locations of the load, the amount of twisting occurring, the quality of hand holds, and the frequency and duration of the task.

There are several variables that make the NIOSH Lifting Analysis a challenge. First of all, the frequency and overall amount of manual handling varies substantially. In addition, the weights and sizes of items handled manually also vary substantially. All of these variables create a situation where the lifting demands vary substantially over time.

Table 2.26 provides the results of the NIOSH analysis. This includes the actual weights involved in the activities and the Recommended Weight Limit (RWL).

Table 2.26. NIOSH Results: Recommended Weight Limits

Activity	Weight Range (lbs)	Recommended Weight Limit (lbs)
Manually transfer cargo to build-up pallet	1-55 lbs	12 lbs

Conclusion: High Risk; NIOSH Lifting Guidelines exceeded.

2.4.5.3 Biomechanical Lifting Analysis

Critical Task: Load cargo into tri-wall container

A biomechanical lifting analysis was performed for the tasks of loading items into tri-wall containers. The computer-based model used for this analysis is a two-dimensional static biomechanical model that estimates the compressive force experienced by the disc at the base of the lumbar region of the spine. This force is calculated based on the measured body posture, estimated object weight, and estimated weight and size of the person's body. The body size and weight estimates are based on a large (95th percentile male) individual because these features represents the worst case for disc compressive force. [6,7]

The frequency of manual handling varies substantially. Some pallets can be primarily large items attached to skids which can be transferred with a fork truck. Other pallets, such as household goods which can be smaller, manually handled items.

The weights of items handled typically range between 1 and 55 lbs. The item sizes vary substantially. **Table 2.27** compares the potential weights handled to the maximum recommended maximum weight to be handled for that location on the container.

Table 2.27. Results of Biomechanical Lifting Analysis

Activity	Potential Weight Range (lbs)	Maximum Recommended Weight for Posture (lbs)
Bottom of the container (near side)	1-55	4
Mid-level of container (far side)	1-55	1
Mid-level of container (near side)	1-55	28
Top of container (near side)	1-55	51

Given that the weights handled generally do not exceed the recommended maximum weight for an optimum posture (51 lbs), this means that the only control necessary to substantially eliminate the job factors is to allow the items to be loaded in an upright body posture without reaching.

Conclusion: High Risk; Excessive disc compressive forces while lifting.

2.4.6 Overall Findings: Pack Tri-Wall Containers

The following information summarizes the results of the Level II analysis.

The primary body region of concern in this job/task is the back/torso. To a lesser extent, there are risks to the shoulders/neck, knees/feet. As shown in **Table 2.28**, the major job factors are: repetitive bending and high force lifting tasks. Table 2.28 also summarizes the results of the Level II analysis for each of the critical tasks and for the job as a whole.

Table 2.28. Summary of Level II Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
Load cargo into tri-wall container	• NIOSH • Biomechanical	• High (Back/Torso)	• Repetitive forward bending	• Depth and size of the tri-wall container • Container located at floor level

Due to the High risk rating for at least one analysis method, the risk rating for the overall job, Pack Tri-Wall Containers is **High**.

2.4.7 Recommended Control Options: Pack Tri-Wall Container

The following is a list of control options organized by critical task. The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

2.4.7.1. Load Cargo into Tri-Wall Container

The following are recommended control options for the critical task of loading cargo into a tri-wall container.

2.4.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Conduct ergonomics training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. In particular, the training could emphasize preferred lifting technique while handling cargo. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

- *Avoid packing box by lifting into far corner. (WPR)* Move around the box to keep arms close while bending.

2.4.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Modify the tri-wall container to have drop down flaps on both sides. (ENG)* By having a side that folds down partially this would allow an improved back posture while loading the container. The larger the flap the better. However, a 12-16 inch flap would make a difference in the amount of bending required. This would also allow a lift-and-tilt table to be more effective (see next recommendation). It is expected that there may be security issues that would prevent the success of this control.

- *Provide a lift table for the shipping container (ENG)* The use of an adjustable height lift table in combination with a reusable container with sides which open would allow personnel to load items without having to bend or reach significantly. Lift tables should allow the load to be maintained at least 30 inches off the ground regardless of the location of material in the container. Keeping the load at an appropriate height maximizes the amount of weight the person can lift without creating an excessive lifting task. As a general rule, if the person is upright and not reaching, he/she can lift up to 50 lbs without creating an excessive lifting situation. **Note: A lift table would have little**

utility in the current situation because of the size of the tri-wall container. A lift and tilt table would help somewhat but the inability to drop a size down partially would limit its effectiveness.

The lift table should be easy to adjust or should adjust automatically. There are many varieties of lift tables on the market (e.g., spring activated, hydraulic, pneumatic, electrical). Three potential sources are provided below.

1. Advance Lifts, Inc., St. Charles, IL, (708) 584-9881;
2. Air Technical Industries, Mentor, OH, (216) 951-5191; and
3. Southworth International Group, Portland, ME, (207) 772-0130.

2.4.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Provide containers with side access.(ENG)* In order to eliminate the job factors present in this activity, the best solution is to provide a container in which one or more side panels can be opened/removed. This would allow personnel to carry items into the container or place items in the container when the item is raised on a lift table. Reusable containers are the typical vehicle for accomplishing this. **Figure 2.9** and **Figure 2.10** provide examples of concepts for containers that would reduce these job factors.

  Ideally, both sides of the container should be able to be opened. This would reduce reaching to place items on the opposite side of the large container. If the container could only open on one side, personnel would have to reach to place items on the opposite side of the container or climb into the container to place items.

  If personnel could be expected to climb in the container to place items, the top of the container should also be removable to prevent prolonged bending of the head and back while working inside the container. Alternatively, if the container is very large (e.g. > 7 feet in height), this could allow personnel to work inside the container without having to crouch.

  According to shop management personnel, there are additional benefits associated with using a reusable container. These benefits include reduced material costs and increased security. If a properly designed container is implemented, it could increase packing speed in addition to reducing injury risk.

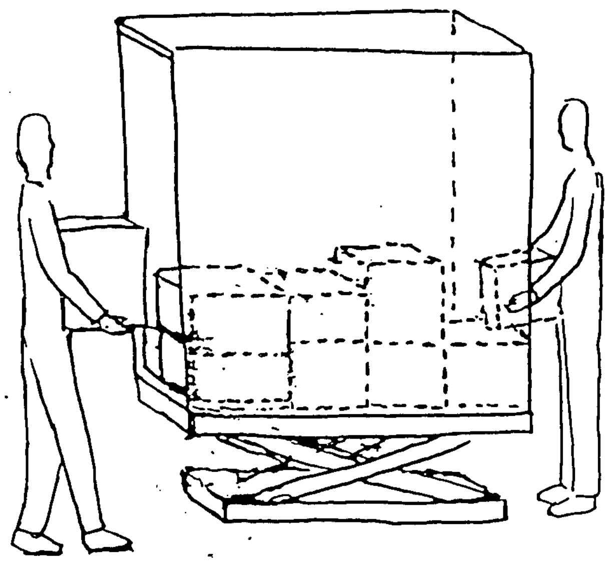


Figure 2.9. Reusable container concept with both sides able to be opened (preferred option)

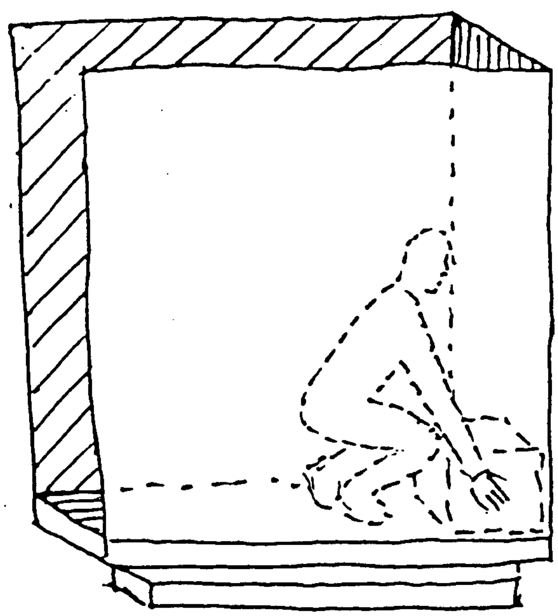


Figure 2.10. Reusable container concept with one open side and one open top

3.0 EMS ISO DOCK

The following sections present information obtained during the Level II Ergonomic Analyses conducted for the EMS ISO Dock (0052-FAPH-051A) at Dover Air Force Base (AFB).

3.1 Executive Summary

This report contains the results of Level II Ergonomic Analyses on several Dover AFB EMS ISO Dock jobs. The following jobs were identified as a high priority through analysis of the Job Requirements and Physical Demands (JR/PD) Survey for the EMS ISO Dock:

- Change Pylon Clamps;
- Extend/Retract Stand Slides;
- Remove/Install Aircraft Tires;
- Remove/Install Cowl Doors; and
- Remove/Install Underfloor Panels.

The Ergonomist, through observation of the job tasks and interviews with employees and supervisors, determined the critical tasks in each job based on the criteria established in the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas.

Four of five jobs selected for the ISO Dock have only one critical task. Remove/Install Aircraft Tires has two critical tasks. The list of critical tasks is as follows:

- Install new clamps (wrenching/racheting)*;
- Extend/retract stand slides (lifting)*;
- Remove/replace tires (lifting)*;
- Roll tire to/from temporary storage (lifting)*;
- Remove/install cowl doors (lifting)*; and
- Remove/install underfloor panels (wrenching/racheting)*.

All six critical tasks were also selected as routine tasks by more than 20% of the participants in the JR/PD survey for this shop.

* The tasks is parentheses are the corresponding standard task categories used in the JR/PD survey.

3.1.1 Findings and Recommendations: Change Pylon Clamps

The following information summarizes the results of the Level II Ergonomic Analysis for the job: Change Pylon Clamps.

Job:	Change Pylon Clamps
HEG:	Wing-Assigned Personnel (C-5 Aircraft)
Survey Date:	15 October 1996
Overall Risk Rating:	MEDIUM
Primary Body Region of Concern:	Knees/Feet, Hands/Wrists/Arms
Most Hazardous Aspects of the Job:	Static squatting/kneeling in a restricted space high force fingertip grips.
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, and Force Analysis.

Table 3.1 summarizes the results of the Level II Ergonomic Analysis for the critical task: Change Pylon Clamps.

Table 3.1. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Change Pylon Clamps

Task:	Change Pylon Clamps
Risk Rating:	HIGH
Primary Body Region of Concern:	Knees/Feet, Hands/Wrists/Arms
Most Hazardous Aspects of the Task:	Static squatting/kneeling in a restricted space and high force fingertip grips.
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, and Force Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Static squatting and constrained legs/feet postures	• Working inside pylon • Restricted space	Short-Term • Provide a padded compressible surface to sit on (ENG) • Rotate personnel through the job (ADM) • Conduct ergonomics training for employees (WPR) Long-Term • Provide a bench to support the head and upper body while changing pylon clamps (ENG)	• Minor reduction of static effort in legs/feet • Minor reduction of static effort in legs/feet • Minor reduction of static effort in legs/feet • Major reduction of static effort in legs/feet
• High force fingertip grips	• Closing hose clamps • Design of hose clamps	Long-Term • Provide clamps that do not require high forces to close or maintain closed (ENG)	• Major reduction in hand forces • Minor reduction in time required to change clamps

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

3.1.2 Findings and Recommendations: Extend/Retract Stand Slides

The following information summarizes the results Level II Ergonomic Analysis for the job: Extend/Retract Stand Slides.

Job:	Extend/Retract Stand Slides
HEG:	Multiple HEGs: Personnel assigned on various portions of C-5 aircraft
Survey Date:	31 October 1996
Overall Risk Rating:	High
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Job:	Excessive forces required to push and pull stand slides
Results of Level II Analysis:	The High risk rating was a result of exceeded guidelines for Push/Pull Force Analysis.

Table 3.2 summarizes the results of the Level II Ergonomic Analysis for the critical task: Extend/Retract Stand Slides.

Table 3.2. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Extend/Retract Stand Slides.

Task:	Extend/Retract Stand Slides
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Excessive forces required to push and pull stand slides
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Push/Pull Force Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Excessive push/pull forces • Awkward back postures	• High forces required to push stand slides • Slides damaged or bent	Short-Term • Replace worn/damaged slides on a more frequent basis (WPR) • Conduct ergonomics training for employees (WPR)	• Minor reduction in time required to move slides • Minor reduction in forces to the back/torso
	• Inadequate footing	Long-Term • Install high friction surfaces adjacent to slides (ENG)	• Moderate reduction in forces to the back/torso • Minor reduction in time required to move slides
		Long-Term • Modify the design/function of slide mechanisms (ENG)	• Major reduction in forces to the back/torso • Major reduction in time required to move slides

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

3.1.3 Findings and Recommendations: Remove/Install Aircraft Tires

The following information summarizes the results Level II Ergonomic Analyses for the job: Remove/Install Aircraft Tires.

Job:	Remove/Install Aircraft Tires
HEG:	Landing-gear assigned personnel (C-5 Aircraft)
Survey Date:	30 October 1996
Overall Risk Rating:	High
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Job:	Excessive lifting forces required to lift tires
Results of Level II Analysis:	The High risk rating was a result of exceeded guidelines for Biomechanical Lifting Analysis.

Table 3.3 summarizes the results of the Level II Ergonomic Analysis for the critical task: remove/replace aircraft tire.

Table 3.3. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Remove/Replace Aircraft Tire

Task:	Remove/Replace Aircraft Tire
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Excessive lifting forces required to lift tires
Results of Level II Analysis:	The High risk rating was a result of exceeded guidelines for Biomechanical Lifting Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Excessive lifting forces • Awkward back movements	• Manual handling of tire • Weight of tire • Restricted space	Short-Term • Encourage personnel to use the existing lift device when feasible (WPR) • Conduct ergonomics training for employees (WPR) Long-Term • Provide a lift device for handling tires which is easier to use (ENG)	• Minor reduction in forces to the back/torso • Minor reduction in forces to the back/torso • Major reduction in forces to the back/torso Potential minor reduction in time required to handle tires

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

3.1.4 Findings and Recommendations: Remove/Install Cowl Doors

The following information summarizes the results Level II Ergonomic Analyses for the job of removing or installing cowl doors.

Job:	Remove/Install Cowl Doors
HEG:	Engine-assigned personnel (C-5 Aircraft)
Survey Date:	31 October 1996
Overall Risk Rating:	HIGH
Primary Body Region of Concern:	Shoulder/Neck, Back/Torso
Most Hazardous Aspects of the Job:	Excessive and static holding forces while handling and supporting cowl door during installation and removal
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Postural Analysis, Biomechanical Lifting Analysis and excessive forces (> 50 lb.) occurring in the job.

Table 3.4 summarizes the results of the Level II Ergonomic Analysis for the critical task: Remove/Install Cowl Doors.

Table 3.4. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Remove/Install Cowl Doors

Task:	Remove/Install Cowl Doors
Risk Rating:	HIGH
Primary Body Region of Concern:	Back/Torso
Most Hazardous Aspects of the Task:	Excessive and static holding forces while handling and supporting cowl door during installation and removal
Results of Level II Analysis:	The HIGH risk rating was a result of exceeded guidelines for Postural Analysis, Biomechanical Lifting Analysis, and excessive forces (> 50 lb.) occurring in the task.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Excessive lifting and static holding forces • Awkward shoulder and back movements	• Supporting weight of door during removal and installation	Short-Term • Use good lifting practices while handling cowl door (WPR)	• Minor reduction in forces to the back/torso
	• Manual handling of cowl door	• Provide a support device to hold the door during installation and removal and allows the door position to be adjusted (ENG)	• Moderate reduction in forces to the back/torso
	• Placing door on floor prior to transport	• Provide a small fixture/ table under the door (ENG)	• Moderate reduction in awkward back movements
		• Conduct ergonomics training for employees (WPR)	• Minor reduction in forces to the back/torso
		Long-Term • Provide a mechanical lift device to handle cowl doors (ENG)	• Major reduction in forces to the back/torso

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

3.1.5 Findings and Recommendations: Remove/Install Underfloor Panels

The following information summarizes the results Level II Ergonomic Analysis for the job: Remove/Install Underfloor Panels.

Job:	Remove/Install Underfloor Panels
HEG:	Fuselage-assigned personnel (C-5 Aircraft)
Survey Date:	31 October 1996
Overall Risk Rating:	MEDIUM
Primary Body Region of Concern:	Shoulder/Neck
Most Hazardous Aspects of the Job:	Static and continuous elevation of arms and head while laying on back and exposure of back/torso to hard edges
Results of Level II Analysis:	The MEDIUM risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, and Force Analysis.

Table 3.5 summarizes the results of the Level II Ergonomic Analysis for the task: Remove/Install Underfloor Panels.

Table 3.5. Summary of Results of Level II Ergonomic Analyses for the Task: Remove/Install Underfloor Panels

Task:	Remove/Install Underfloor Panels
Risk Rating:	MEDIUM
Primary Body Region of Concern:	Shoulder/Neck
Most Hazardous Aspects of the Task:	Static and continuous elevation of arms and head while laying on back and exposure of back/torso to hard edges
Results of Level II Analysis:	The MEDIUM risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, and Force Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Exposure of back/torso to hard edges • Static and continuous elevation of arms and head while laying on back	• Working overhead while laying on back • Restricted space • Large variations in work space	Short-Term • Provide a compressible surface/support to support the neck, back and arms (PPE) • Conduct ergonomics training for employees (WPR) Long-Term • Provide padded clothing (PPE) • Provide support for the head, torso, and arms while working overhead (ENG) • Provide a tool support (ENG) Long-Term • Incorporate forward bulkhead ring into the C-5 to increase maintainability (ENG)	• Moderate reduction in exposure to hard edges for back/torso • Minor reduction in exposure to hard edges for back/torso • Major reduction in exposure to hard edges for back/torso • Major reduction in static effort for shoulders/neck • Major reduction in static effort for shoulders/neck • Major reduction in job factors for all body regions • Major reduction in time required to perform maintenance tasks in the underfloor

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

3.1.6 Other Jobs/Activities Identified as Candidates for Ergonomics Attention

In addition to the jobs assessed in this project, there are other jobs/activities identified during data collection which may warrant ergonomic attention. We recommend that a Level I Ergonomic Analysis be completed for these activities. **Table 3.6** lists these jobs or activities and explains the source.

Table 3.6. Summary of Additional Jobs Identified

Job/Activities	Source	Comments
Pushing stands	• ISO personnel comments • Identified during data collection	Stands must be manually pushed in at the beginning of the week to work on the aircraft and then removed at the end of the week. Potentially high push forces may occur in this job.
Flightline	• ISO personnel comments • Identified during data collection	There may be jobs which are high priority for ergonomic changes on the flight line. The tight time constraints may introduce unique job factors. It was not possible to observe flight line activities during data collection.
Handling wing slats	• ISO personnel comments from the preliminary prioritized list from the JR/PD	This is a lifting job that is similar to handling cowl doors. However, the materials handling needs are likely to be different. The Ergonomist was unable to observe this job during data collection.
Handling aircraft brake assemblies	• ISO personnel comments • Identified during data collection	Brake assemblies (105 lb.) are handled 0-4 times per week by landing gear-assigned personnel.

3.2 Background

The following sections provide background information on the shop as well as results of the JR/PD Survey and review of Mishap Data for the shop.

3.2.1 Summary of Results of JR/PD Survey

The JR/PD Survey was administered to employees from the EMS ISO Dock and scored by the Dover AFB Public Health (PH). Survey response rate was 88%. The Overall Priority Rating was 7, indicating that the shop should be considered for Ergonomic Problem Area (EPRA) status.

Results indicated that the highest employee-reported job factor exposure was in the legs/feet, back/torso, hands/wrists/arms, and shoulder/neck. This is consistent with the wide variety of work types and physical demands found throughout the shop. The highest employee-reported discomfort was for the back/torso and legs/feet body regions. The Survey indicated that any job stress factors are of minimal concern and that employees were not likely to over-rate job factor exposure or discomfort due to job pressures.

Although the JR/PD Survey results apply only to the shop as a whole, several job activities were specifically noted as among the most difficult, awkward, or physically demanding tasks by the highest number of employees. Five of these tasks were confirmed and agreed upon by the Dover AFB Bioenvironmental Engineering Flight (BEF) for inclusion in the Level II Ergonomic Analyses. The activities and the approximate number of times that the activities were noted on the JR/PD Survey are shown in **Table 3.7.**

Table 3.7. Job Selection Based on Results of JR/PD Survey and BES Approval

Job/Work Activity	Proportion of Shop Personnel Who Noted the Activity
Change Pylon Clamps	15% (13/88)
Remove/Install Underfloor Panels	8% (7/88)
Extend/Retract Stand Slides	3% (3/88)
Remove/Install Cowl Doors	3% (3/88)
Remove/Install Aircraft Tires	identified in shop tour

Changing pylon clamps, which is part of a scheduled upgrade for all C-5 aircraft, was noted by 13 employees. This job was selected as a priority for inclusion in the Level II Ergonomic Analyses. Removing or installing underfloor panels and working in the under floor area of C-5 was noted by seven employees. Pushing/pulling slides on work platforms was selected to represent comments from three employees related to difficulties in positioning heavy maintenance stands/setting up aircraft for inspection. Hanging/replacing cowl doors was also mentioned by three employees. In addition, since this job appears to expose employees to ergonomic job factors also found in removing/replacing wing slats, it may be possible to apply the appropriate controls to both jobs. The tire changing job was identified by BES and the shop supervisor during the Ergonomist's initial walk through of the shop.

Additional explanation for final job selection is provided in Section 1.2.3.

According to BEF, no previous ergonomics analyses or lighting surveys have been completed for these work activities.

A Level II Ergonomic Analysis was performed for each of these job activities; results are provided in sections 3.5, 3.6, 3.7, 3.8, and 3.9.

The shop demographics based on the results of the JR/PD Survey are shown below.

Gender:	4% Female	96% Male
Group:	15% Civilian	85% Military
Length of Service (Base):	10%<1 Yr.	90%>1 Yr.
Length of Service (Shop):	18%<1 Yr.	82%>1 Yr.
Age:	<20 Yrs.	12%
	21-30 Yrs.	48%
	31-40 Yrs.	28%
	>40 Yrs.	12%

3.2.2 Historical Data on Injuries and Illnesses

The following table summarizes the results of a review of mishap statistics (1994-1996) for EMS (including ISO Dock and Structural Maintenance). The data was provided by the Dover AFB Safety Office. **Table 3.8** presents the most common workplace factors/causes of musculoskeletal injuries (such as sprain/strain, repetitive strain illness, and hernias) that were recorded in the injury data.

Table 3.8. Results of Review of Mishap Data for EMS

Expected Workplace Factor/Cause	Type of Injury	Body Regions	Number of Recorded Incidents
Lifting a main landing gear piston assembly	Sprain/Strain	Back/Torso	1
Slip in water/hydraulic fluid	Sprain/Strain	Hand/Wrist/Arm	1
Pulling a work table	Sprain/Strain	Hand/Wrist/Arm	1
Lifting an elevator flutter dampener	Sprain/Strain	Back/Torso	1

Generally, there were relatively few sprain/strain injuries identified in EMS (only 7 recordables). In addition, there seemed to be no clear trend in the causes of these injuries. This highlights the value of the JR/PD survey in identifying potential causes of injury even without an injury history.

3.2.3 Workplace Description

The Work Objective for EMS ISO Dock is: Support the mission of the Equipment Maintenance Squadron by maintaining aircraft systems and performing isochronal and special inspections.

The only aircraft serviced in the ISO Dock is the C-5 (both a & b models).

The ISO Dock has approximately 85-90 personnel working on three shifts. There is typically little rotation across shifts. There are roughly 55 personnel assigned to portions of the aircraft on the day shift (excluding supervisors and managers). Another eight work the swing shift and three work the midnight shift. Night shift personnel can work in any area. The remainder are non-assigned personnel working on electronics, hydraulics, structural, or aerial rigging.

The following Homogeneous Exposure Groups (HEGs) were identified in the EMS ISO Dock:

- Wing Assigned;
- Engine Assigned;
- Landing Gear Assigned;
- Fuselage Assigned;
- Tail Assigned;
- Structural;
- Aerial Rigging;
- Electronics;
- Hydraulics; and
- Night Shift Personnel.

Even across HEGs there is substantial overlap of tasks. For instance, most HEGS are involved in similar activities (i.e., prep, inspection, removal/installation of components/panels, repair, lubrication, and post-inspection). Only the components and locations on the aircraft vary. Some jobs (e.g., extending/retracting stand slides) are performed by various assigned personnel around the aircraft.

Critical tasks for the following HEGs and jobs are presented in Sections 3.3 and 3.7:

- HEG: Wing Assigned, (Change Pylon Clamps);
- HEG: Engine Assigned, (Remove/Install Cowl Doors);
- HEG: Landing Gear Assigned, (Remove/Install Aircraft Tires);
- HEG: Fuselage Assigned, (Remove/Install Underfloor Panels); and
- HEG: Multiple HEGs, (Extend/Retract Stand Slides).

3.3 Change Pylon Clamps

3.3.1 Job Overview

Overall Risk Rating:	**MEDIUM**
Workplace:	EMS ISO Dock
Workplace Identifier:	0052-FAPH-051A
Job Title:	Change Pylon Clamps
HEG:	Wing-Assigned Personnel (C-5 Aircraft)
Survey Date:	31 October 1996

3.3.2 Job Description

3.3.2.1 Job Objective

The pylon clamps are changed as part of a scheduled upgrade for all C-5 aircraft. The upgraded clamps are more durable. Changing the pylon clamps is performed in the EMS ISO Dock.

3.3.2.2 Job Frequency and Duration

There are four pylons on the C-5 aircraft. Each person completes about two pylons per week. Typically, the process requires 0.5 - 1.5 hours per pylon to complete, which equates to about three hours per week per person for changing pylon clamps. Usually, there are 12 - 13 clamps per pylon which must be changed. There are also six clamps per wing that must be changed as well. As the new clamps are installed in more aircraft, the frequency of changing the clamps will be reduced. Currently, there is a reduction in this frequency and clamps are changed approximately every other week on average. Ultimately, it is expected that the frequency of clamp changes will be reduced to a new and baseline level.

3.3.2.3 Schedules and Shift/Work Rotation

This task is typically performed during the day shift. There are three, eight hour shifts in the ISO Dock. Breaks are irregular. There is typically very little rotation across shifts.

3.3.2.4 Number of People Performing Job

Two people perform this task.

3.3.2.5 Job Activity/Task Breakdown

Table 3.9 provides a listing of the basic tasks which occur in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work personnel spend performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 3.9. Work Content Matrix

Task Steps	Estimated Task Frequency*	Critical Tasks
Prep materials around opening on pylon	<10%	
Squeeze into the opening of the pylon	<10%	
Remove old clamps	<10%	
Install new clamps	<10%	Critical Task (Exertion)
Exit the hole and clean-up	<10%	

* Total percentage of time at work spent performing the task.

3.3.2.6 Critical Tasks

Installing new clamps (Wrenching/Racheting) is the only critical task identified in this job. Wrenching/Ratcheting is the corresponding standard task categories used in the JR/PD and Level I Guide.

3.3.3 Work Area, Materials, and Components

3.3.3.1 Workstation and Equipment Descriptions

Work is performed on the interior of the pylon. It is necessary for the person to squeeze through a small opening in the top of the pylon. Space is extremely restricted. Most tools or components must be stored outside of the small compartment where the clamps are changed.

3.3.3.2 Materials and Part(s) Processed

As part of the upgrade process, the black hose clamps are being phased out and replaced with yellow hose clamps. The clamps are secured with a bolt and nut. In some cases, several clamps are secured (or butterflied) together.

3.3.3.3 Description of Hand Tools Used

A variety of ratchet wrenches and screwdrivers are used in this task to loosen and tighten fasteners. A hand held flashlight is used to provide additional lighting.

3.3.3.4 Environmental Conditions

The space inside the pylon is highly restricted. There is only enough room for a small person to squat inside the compartment. In addition, the lighting is poor.

3.3.3.5 Personal Protective Equipment Required

No personal protective equipment directly affecting musculoskeletal risk is used.

3.3.3.6 Productivity and Quality Requirements

The clamps must be changed within a certain period of time in order to allow work to proceed. However, the primary factor driving the speed of completion is that personnel try to minimize the length of time they must spend inside the pylon. From a quality of work standpoint, failing to secure a clamp properly or other errors could have significant effects.

3.3.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there were aspects of the tasks which make the job more difficult.

3.3.4.1 Personnel Comments

The following comments were obtained from personnel in the EMS ISO Dock regarding the task of changing pylon clamps:

- "Some people can't even fit in the pylon."
- "You have to kind of sit on your legs."
- "You're going as fast as you can to get out of there because your legs are falling asleep."
- "It's hot in there in the summertime."
- "Dropping tools, nuts, and bolts is a pain because it takes time to find them."

3.3.4.2 Personnel Ratings of Perceived Discomfort

Two people were interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. **Table 3.10** and **Table 3.11** indicate those body regions where pain/discomfort was indicated and provide discomfort intensity scores and ratings. [3]

Table 3.10. Body Regions with Pain/Discomfort: Person #1

Body Region Specified	Discomfort Score (1-5 scale)*
Legs/Feet	4
Back/Torso	3
Hands/Wrists/Arms	2-3

* *A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

Table 3.11. Body Regions with Pain/Discomfort: Person #2

Body Region Specified	Discomfort Score (1-5 scale)*
Knees and Lower Legs	3-4
Hips	3-4
Forearms	2-3

* *A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

One person indicated that the feet were the greatest source of discomfort followed by the lower back and buttocks. This person also mentioned discomfort in the hands and fingers was associated with squeezing clamps. The second person basically echoed the same sources of pain and discomfort. Heat in the summertime was also mentioned as a source of discomfort by both persons.

3.3.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomics Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in Section 1.2.4 along with a description of the methods.

Table 3.12 below lists the analysis methods employed for each critical task.

Table 3.12. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Install new clamps	Dynamic Task Analysis, Postural Analysis, Force Analysis

In this job, the Dynamic Task Analysis and Postural Analysis incorporate all tasks performed in the job.

3.3.5.1. Dynamic Task Analysis

A dynamic task analysis was performed for changing pylon clamps. This analysis estimates the proportion of task time in different awkward postures or exposed to other job factors (see **Table 3.13**). In particular, continuous awkward leg postures (squatting) and high force pinch grips occur while changing clamps (see **Figure 3.1**). [4]

Table 3.13. Results of Dynamic Analysis

Job Factor	Measured Percentage of Total Task Time	Recommended Maximum Percentage of Total Task Time
High Force Pinch Grips	50%	33% [4]
Squatting	100%	33% [4]

▒ = *exceeded maximum recommended forces*

The knee postures may be maintained continuously for up to 1.5 hours. However, the person may exit the pylon occasionally to take a break.

Due to the limited number of hours spent changing clamps per week, the concern is primarily due to more acute reactions to a concentrated exposure over one period of time. This task requires approximately 1.5 hours to complete. Over a 40-hour work week, that is equivalent to 7.5% of total work time on average. Therefore, this situation has a lower risk than those activities which occur every day. However, if all changing of clamps (including wing clamps) on the aircraft in a week is taken into consideration, these job factors could be a higher percentage of total work time.

Conclusion: Medium Risk; Awkward and prolonged body postures with a moderate task frequency.

Figure 3.1. Changing Pylon Clamps

3.3.5.2 Postural Analysis

A postural analysis was conducted on static postures which occur while changing pylon clamps. Analysis results are presented in **Table 3.14.**

Table 3.14. Postural Analysis Results

Body Region	Measured Body Angle	Recommended Maximum Deflection
Knee Posture (lower leg angle measured with respect to upper leg angle)	160° (squatting)	90° [Mattila et al, 1993]

This is an excessive knee posture. This posture is of particular concern because it is a static posture. Static, continuous muscular effort causes fatigue and tissue damage more quickly because there is a restriction of blood and oxygen to the muscles.

Conclusion: Medium risk; awkward and static knee postures (less than 50% of task time).

3.3.5.3 Force Analysis

Critical Task: Install new clamps

The forces required to close the clamps were measured using a force dynamometer (see **Table 3.15**). Direct measurements were obtained by placing the dynamometer directly on the clamp and applying the force through the dynamometer. At least five measurements were taken and the result was obtained by taking the average of those five measurements.

Table 3.15. Force Analysis

Activity	Measured Fingertip Grip Forces	Recommended Maximum Fingertip Grip Forces
Close Hose Clamp	12-15 lbs	2 lbs (Stetson et al, 1991)

[shaded] = exceeded maximum recommended forces

The forces required to close and hold closed the clamps substantially exceeds the maximum recommended fingertip forces.

Conclusion: Medium Risk; Excessive fingertip forces occurring less than 50% of job time.

3.3.6 Overall Findings: Change Pylon Clamps

The following information summarizes the results of the Level II analysis.

The primary body regions of concern in this job/task are the knees/feet and hands/wrists/arms. To a lesser extent, there are risks to the back/torso. As shown in **Table 3.16**, the major job factors are: kneeling/squatting, poor lower back posture, and high force pinch grips. Table 3.16 also summarizes the results of the Level II Ergonomic Analysis for each of the critical tasks and for the job as a whole.

Table 3.16. Summary of Level II Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Multiple tasks	• Dynamic	• Medium (Knees/Feet, Hand/Wrist/ Arm)	• Static squatting/ kneeling • High force pinch (fingertip) grips	• Restricted workspace • Working inside pylon • Closing clamps • Holding clamps closed while inserting fasteners • Design of clamps
• Multiple tasks	• Postural	• Medium (Knees/Feet)	• Static squatting/ kneeling	• Restricted workspace • Working inside pylon
• Install new clamps	• Force	• Medium (Hand/Wrist/ Arm)	• High force pinch grips	• Closing clamps • Holding clamps closed while inserting fasteners • Design of clamps

Due to the Medium risk rating for at least one analysis method, the risk rating for the overall job, change pylon clamps is **Medium**.

3.3.7 Recommended Control Options: Change Pylon Clamps

The control options are categorized in terms of short-term and long-term controls. **Appendix D** defines these different levels of controls.

The following is a list of control options for the entire job (because there is only one critical task). The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

3.3.7.1. Change Pylon Clamps

The following are recommended control options for the job of changing pylon clamps.

3.3.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Provide a padded compressible surface to sit on.(PPE)* One alternative is to provide a padded compressible stool or pad to sit on and to place under the legs. This might help to reduce some of the pressure on the lower legs and buttocks. The idea would be to convert the posture from squatting to more of a sitting posture. The main obstacle is that the pad/stool must fit into the restricted space.

- *Investigate rotating personnel through the job to lessen the impact on any individual.(ADM)* While job rotation does not eliminate the sources of job factors, it does reduce the amount of exposure any one person would have to the job by spreading the load across a larger number of people.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

3.3.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide a bench to support the head and upper body while changing pylon clamps.(ENG)* By mounting a bench across the top of the pylon opening, this would allow a person to change clamps without having to actually climb in to the pylon itself (see **Figure 3.2**). This control option would only be feasible if the clamps are reachable from the top of the pylon. In addition, there will probably need to be some sort of baffle placed in the pylon compartment to hold tools and components and prevent these items from falling down into the base of the pylon. If it is not possible to prevent tools or components from falling beyond an arm's reach, this option may not be feasible. The bench should have the following features:

- provide compressible surfaces to support the upper body and head;
- adjustable in height and angle;
- separate support for the head which is independently adjustable from the torso support; and
- able to be easily transported and repositioned for different tasks.

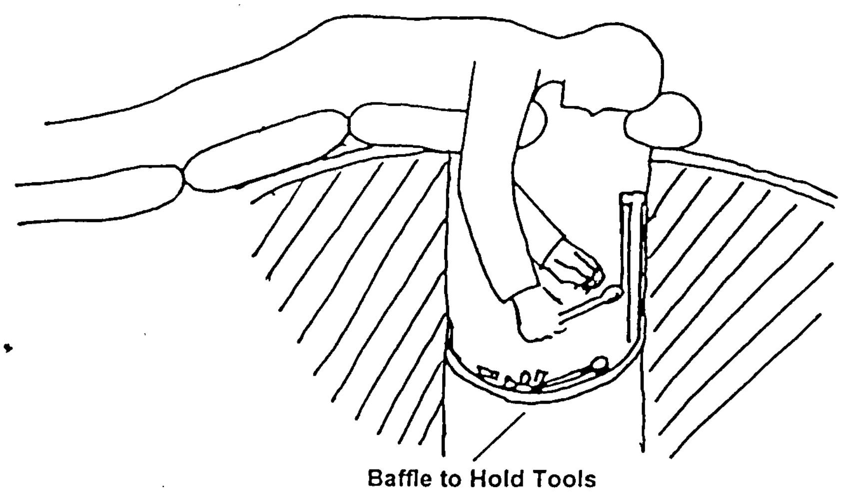


Figure 3.2. Head and torso support device concept

3.3.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Provide clamps that do not require high forces to close or maintain closed. (ENG)* Different possibilities for clamps exist. One alternative is to use hose clamps which are hinged instead of a single band of metal. This would allow the clamp to be closed without any resistance from the clamp.

3.4 Extend/Retract Stand Slides

3.4.1 Job Overview

Overall Risk Rating:	HIGH
Workplace:	ISO Dock
Workplace Identifier:	0052-FAPH-051A
Job Title:	Extend/Retract Stand Slides
HEG:	Multiple HEGs: Personnel assigned on various portions of aircraft (C-5)
Survey Date:	31 October 1996

3.4.2 Job Description

3.4.2.1 Job Objective

Mechanical slides on the stands allow personnel to work close to aircraft in the ISO Dock. The slides are extended early in the week immediately after the aircraft is brought into the hangar. When the servicing of the aircraft is completed, all of the slides are then retracted with similar personnel and time requirements. In addition, a smaller number of slides must be repeatedly extended and retracted during the week. These include the cowl door slides and certain slides adjacent to flaps.

3.4.2.2 Job Frequency and Duration

There are approximately 200 slides on the stands. It takes approximately 3.5 - 4 hours (wing stands) and two hours (tail stands) to complete the job of extending the slides.

3.4.2.3 Schedules and Shift/Work Rotation

This task is typically performed on the day shift. There is typically very little rotation across shifts.

3.4.2.4 Number of People Performing Job

A crew of approximately 15 personnel move the slides on the wing stands. Another 5-8 personnel move the slides on the tail stands. This means that each person extends approximately 10 -20 slides.

3.4.2.5 Job Activity/Task Breakdown

Table 3.17 provides a listing of the basic tasks which occur in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work personnel spend performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 3.17. Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Extend/Retract Stand Slides	10%	Critical Task (Exertion)
• Remove pin		
• Extend or retract stand slides		
• Adjust slide position to line up hole in slide with hole in the stand		
• Place pin		
• Move to the next slide		

* Total percentage of time at work spent performing the task.

3.4.2.6 Critical Tasks

In this case, the critical task is the same as the job, extend/retract stand slides (Lifting). Lifting is the corresponding standard task category used in the JR/PD and Level I Guide for extending and retracting stand slides

3.4.3 Work Area, Materials, and Components

3.4.3.1 Workstation and Equipment Descriptions

The slide and sliding mounting hardware is a fairly rudimentary design. A slide is an inverted U-shaped piece of metal which fits inside an inverted U-shaped metal channel built into the stand. There are no bearings or rails. The slide basically slides in and out of the channel (metal to metal).

There is substantial variability in the force required to extend and retract the slides. There are several variables that determine the amount of force required. Chief among these is the condition of the slide and stand. It is common for slides or stands to become bent or deformed. This causes an increase in interference and friction. A second cause is related to the inclination of certain slides. The slides under the wings are on inclines (to match the profile of the wing). Pushing or pulling a slide up an incline also increases force requirements.

3.4.3.2 Materials and Part(s) Processed

Not applicable.

3.4.3.3 Description of Hand Tools Used

A metal hook which is inserted into a hole in the slide is used to move the slide. The hook weighs approximately 5 lbs and is used to both retract and extend the slide.

3.4.3.4 Environmental Conditions

Greasy, dirty floors on top of the stand reduce foot traction and increase the chance of a fall while moving slides.

Head clearance is restricted in some areas (e.g., under the wing). Head clearance was measured as low as 3 feet 3 inches. More typically vertical clearances are 3 feet 9 inches to 4 feet 6 inches. This means that awkward back postures are required continuously while working under the wing.

3.4.3.5 Personal Protective Equipment Required

Personal protective equipment directly affecting musculoskeletal risk is not used.

3.4.3.6 Productivity and Quality Requirements

While there are no specific productivity requirements, the slides must be moved within a certain period of time in order to allow work to proceed.

3.4.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there were aspects of the tasks which made the job more difficult.

3.4.4.1 Personnel Comments

The following comments were obtained from personnel who perform the task of pushing/pulling the stand slides:

- "The hardest part is lining up the holes."
- "There is a lot of grease. It makes it tougher to get a good foothold."
- "There is a lot of bending required to place or remove the pins."
- "Some slides are much worse than others."
- "I've heard people say they've had back trouble from pushing the slides in/out."

3.4.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. **Table 3.18** indicates those body regions where pain/discomfort was indicated as well as discomfort intensity scores and ratings.

Table 3.18. Body Regions with Pain/Discomfort

Body Region Specified	Discomfort Score (1-5 scale)*
Knee	3

** A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

The person reported pain/discomfort in the knee and rated it a 3 on a 1-5 intensity scale. This person also indicated that pain/discomfort in the back is commonly reported by people who move the stand slides.

3.4.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomic Analysis Methods were employed in order to conduct a detailed analysis. The rationale selecting the appropriate methods for different types of tasks are described in Section 1.2.4 along with a description of the methods.

Table 3.19 below lists the analysis methods employed for each critical task.

Table 3.19. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Extend/Retract Stand Slides	Dynamic Task Analysis and Force Analysis

3.4.5.1. Dynamic Task Analysis

A dynamic task analysis was performed for the job of extending and retracting stand slides. This analysis estimates the proportion of task time spent in different awkward postures or exposed to other risk factors (see **Table 3.20**). In particular, repetitive forward bending occurs while performing this job.

Table 3.20. Results of Dynamic Analysis

Job Factor	Measured Percentage of Total Task Time	Recommended Maximum Percentage of Total Task Time
Forward bending and twisting	50-60%	33% [4]

= *exceeded maximum recommended forces*

The proportion of time in which the employee is bending forward and twisting exceeds the maximum recommended guideline.

<u>**Conclusion: Medium Risk; Awkward and repetitive back postures (occurs less than 50% of the total time at work).**</u>

3.4.5.2 Push/Pull Force Analysis

Force measurements were obtained for the force required to push the slides out or pull them in (see **Table 3.21**). A push/pull gauge was used to measure push/pull forces required. The latest Snook and Ciriello (1994) tables were consulted to establish a maximum recommended push force for this task. The limit value selected from the Snook tables was based on a sustained push by a female worker, a 7-foot push, one push every one minute, and with a hand height of 35 inches. **Figure 3.3** shows a person pushing a slide out.

Table 3.21. Push/Pull Force Analysis

Activity	Measured Push Forces (lbs)	Recommended Maximum Push Forces for Females (lbs)	Recommended Maximum Push Forces for Males (lbs)
Easy to move slide: retract	20	29	35
Easy to move slide: extend	40	29	35
Hard to move slide: retract	80	29	35
Hard to move slide: extend	80-100	29	35

= *exceeded maximum recommended forces*

The slide selected to indicate a lower force slide was in a horizontal area and was in good condition. Even in this case, the force required to extend the slide was marginally excessive. The slide selected as a more difficult slide to move was in an inclined area under the wing and the slide seemed to be slightly warped. The forces required to move the more difficult slide in or out were both clearly excessive. Moving the slide out (which in this case was up the incline) required more force.

A major factor contributing to the difficulty of the task was the lack of foot traction. It is likely that the actual force required to move the slide was higher than the forces reported here because the grease on the floor caused the person to constantly be slipping back. Thus, additional forces are required to maintain footing while moving the slide.

Figure 3.3. Postures Required to Push Slide Out

Conclusion: High Risk; Highly excessive forces are required to push/pull worn/damaged slides, marginally excessive forces are required for pushing most slides.

3.4.6 Overall Findings: Extend/Retract Stand Slides

The following information summarizes the results of the Level II Ergonomic Analysis.

The primary body region of concern in this job/task is the back/torso. To a lesser extent, there are risks to the shoulders/neck, knees, and the hands/wrists/arms. As shown in **Table 3.22**, the major risk factors are: continuous bending, repetitive bending, high force pushing/pulling tasks, and high speed movements. Table 3.22 also summarizes the results of the Level II Ergonomic Analysis.

Table 3.22. Summary of Level II Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Extend/ retract stand slides	• Dynamic	• Medium (Back/Torso)	• Forward bending • Awkward back postures	• Limited vertical clearance (e.g., under wings) • High forces required to push the slide with the hook • Bending over to remove or replace pins
	• Force	• High (Back/Torso)	• Excessive push/pull forces • High speed movements with the back	• High forces required to move slide • Slide or stand is bent or damaged • Design of slides and sliding mechanisms • Pushing or pulling a slide up an incline • Grease on floor/slippery floor conditions • Lining up the holes in the slide and stand

Due to the High risk rating for at least one analysis method, the risk rating for the overall job extend/ retract stand slides is **High**.

3.4.7 Recommended Control Options: Extend/Retract Stand Slides

The control options are categorized in terms of short-term and long-term controls. Appendix D defines these different levels of controls.

The following is a list of control options. The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating the causes. The following list of control options seek to reduce these key job factors.

3.4.7.1. Extend/Retract Stand Slides

3.4.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Repair worn/damaged slides on a more frequent basis.(WPR)* Apparently, repairs to slides and stands have been on-going. However, it appears that slides could be repaired more frequently or more systematically. This should be viewed as a temporary solution until the more fundamental design/function of the slides can be improved. This control option would help to minimize the very high forces but it would not eliminate the marginally excessive forces associated with most of the slides.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

3.4.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Install high friction surface adjacent to slides.(ENG)* Provide a matting or floor covering made of various compositions (depending on various requirements such as the ability of the material to be cleaned or industrial hygiene). This would improve the footing where the slides are extended and retracted. This should also be considered an interim control. However, if manually moved slides are retained for a long period of time, a high friction floor surface would still be desirable. It could take the form of a matting or grating that would be bolted or otherwise fastened to the stands and then removed for clean-up. Beveled edges and a low profile would be necessary to minimize trip hazards. Alternatively, a high friction grit tape could be applied to the deck in front of the stands. This has been done in some areas currently (e.g., around tool boxes). However, tape wears away eventually and makes clean-up difficult. In addition, slippery floor conditions on the stands is an issue which is more significant than movement of the slides. Slippery floor conditions could also lead to slips and falls in general. Consideration should be given to the idea of improving the floor surface on all high priority areas on the stands.

3.4.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Modify the design/function of the slide mechanisms. (ENG)* In order to fully eliminate the excessive push/pull forces associated with moving the slides, the slides must be modified or replaced. There are two basic types of slide designs which should be considered: Easily moveable manual slides and powered/automatic slides.

  - Easily moveable manual slides would involve adding rollers, bearings or lower friction sliding surfaces to reduce the force required to move the slides. The concept would be similar to sliding drawers. The slides would still be manually extended and retracted, but they would be easy to slide.
  - Powered or automatic slides would be similar to the previous concept except that the slides would not be moved manually but would slide in and out via motors. The level of complexity and automation of this type of system varies considerably. Thus, this concept could be as simple as an individual motor for each slide activated individually or as complex as a completely programmable system which would retract/ extend entire banks of slides automatically.

  It must be emphasized that extending or retracting the current slides requires 3.5 - 4 hours and a crew of 15. A system of slides which are easy to extend and retract could substantially reduce the time and personnel requirements. An automatic or semi-automatic system of slides could further reduce time and personnel requirements even more. It seems that the current slides reduce readiness and maintenance efficiency. Conversely, it would be expected that improvements to the slide system could improve readiness and maintenance efficiency.

  Caution: Major safety issues must be factored in to any modification or redesign of the slide system. The current system of slides have an unintentional safety benefit. Because the slides are difficult to move, this reduces the chances that a slide could move unexpectedly and roll out from underneath personnel. If the slide system is revised so that slide is either low force or automatic, safety precautions would need to be designed into the system to prevent this sort of accident. For instance, slides would need to have positive locking mechanisms and lock-outs or interlock devices which would prevent someone from moving the slides while personnel are on the slides.

  Any major modification of the slide system should also modify the locking system. Currently, each slide has a metal bolt which slides through a hole in the slide and the stand to prevent the stand from moving unintentionally. If the slides are made easier to move manually, the locks would need to be updated as well. One example of a lock design is that the slides remain in a locked mode as the default or failure mode. The only way to disengage the brakes would be to insert a tool (similar to the current hook) into the slide and mechanically disengage the slide. There are additional concerns, such as the forces generated by the slide rolling out of control on an inclined portion of the stand.

The following design requirements should be satisfied by any modifications to or replacement of the current slides:

- The slides should not require high forces to extend or retract (either manually or powered).
- The process of extending and retracting the slides should be fast but should not present a safety hazard.
- The slides should be designed to prevent accidental movement of the slide.
- The slides should be designed to prevent a slide sliding/rolling out of control during movement.

After extensive research one source was found. This is not meant to imply preference for this source but only to recognize the scarcity of experienced suppliers for this specific solution. This supplier has experience implementing this type of solution for aircraft.

Materials Handling Systems, Elkridge, MD (410) 379-0070

Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

3.5 Remove/Install Aircraft Tires

3.5.1 Job Overview

Overall Risk Rating:	HIGH
Workplace:	EMS ISO Dock
Workplace Identifier:	0052-FAPH-051A
Job Title:	Remove/Install Aircraft Tires
HEG:	Landing-gear assigned personnel (C-5 aircraft)
Survey Date:	30 October 1996

3.5.2 Job Description

3.5.2.1 Job Objective

The removal and installation of aircraft tires takes place in the EMS ISO Dock. In-board tires on nose landing gear are particularly a challenge because the tire must be slid off a long axle dropping the tire on the ground. In addition to installing and removing tires, other manual handling tasks occur in this area. These include: handling of 105 lb break assemblies up to four times per week, maneuvering (pushing/pulling) stands, rolling tires, and transferring tires in/out of storage racks.

3.5.2.2 Job Frequency and Duration

An average of 5-7 tires are changed per day. However, on a busy day, 10 - 15 tires may be changed.

3.5.2.3 Schedules and Shift/Work Rotation

This task is typically performed on the day shift. There is typically very little rotation across shifts.

3.5.2.4 Number of People Performing Job

Typically, a crew of six performs aircraft tire changes. This means that each person typically handles between one - three tires per day.

3.5.2.5 Job Activity/Task Breakdown

Table 3.23 provides a listing of the basic tasks which are performed in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work personnel spend performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 3.23 Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Remove/Install Aircraft Tires		
• Prep tires for removal/replacement	<10%	
• Remove/replace tire	<10%	Critical Task (Exertion)
• Roll tire to/from temporary storage area (in rack or adjacent to landing gear)	<10%	Critical Task (Exertion)
• Transport tire to/from maintenance location	<10%	

* Total percentage of time at work spent performing the task.

3.5.2.6 Critical Tasks

The critical tasks identified in this job are:

- Remove/replace tire (Lifting)
- Roll tire to/from temporary storage area (Lifting)

Lifting is the corresponding standard task category used in the JR/PD and Level I Guide.

3.5.3 Work Area, Materials, and Components

3.5.3.1 Workstation and Equipment Descriptions

A lift device is provided to handle aircraft tires. See the Equipment Analysis section (3.5.3.3) for an ergonomic evaluation of the lift device.

3.5.3.2 Materials and Part(s) Processed

The aircraft tires handled weigh approximately 325 lbs. When the tire is lifted onto the axle, it is lifted approximately 1/2 inch to a few inches off the ground by two persons.

3.5.3.3 Description of Hand Tools Used

There are no hand tools used which directly affect musculoskeletal risk in this job.

3.5.3.4 Environmental Conditions

Greasy, dirty floors can create less than ideal footing. Work space for in-board tires is severely restricted.

3.5.3.5 Personal Protective Equipment Required

No special Personal Protective Equipment is required for this task.

3.5.3.6 Productivity and Quality Requirements

While there are no specific productivity requirements, the tires must be removed and installed within a certain period of time in order to allow work to proceed.

3.5.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there were aspects of the tasks which make the job more difficult.

3.5.4.1 Personnel Comments

The following comments were obtained from personnel who perform the task of handling aircraft tires:

Lifting Tires

- "More people are hurt pushing stands around than lifting tires."
- "Wouldn't surprise me if lifting caused people's injuries."

Nose Tires

- "The challenge with the nose tires is to avoid bending the false axle to remove the in-board tire. This means that while the tire is being removed or installed it cannot rest on the false axle. If the false axle is damaged, it costs about $600 and is difficult to obtain."

Current Lift Device

- "The lift device is not easily maneuverable in tight spaces."
- "This lift device cannot be used at all on the in-board tires (i.e., Baker tires)."
- "The lift device does not take into consideration the time element."
- One person estimated that a single tire can be replaced manually in between 5-30 minutes while using the lift device requires 30-45 minutes.
- "More people are hurt pushing stands around than lifting tires."

3.5.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. **Table 3.24** indicates those body regions where pain/discomfort was indicated and provides discomfort intensity scores and ratings. [3]

Table 3.24. Body Regions with Pain/Discomfort

Body Region Specified	Discomfort Score (1-5 scale)*
Shoulder	3
Thigh	3

** A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

The person reported pain/discomfort in the shoulder and rated it a 3 on a 1-5 intensity scale. This person also reported pain/discomfort in the thigh which was rated a 3 on the 1-5 intensity scale.

3.5.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomic Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in Section 1.2.4 along with a description of the methods.

Table 3.25 below lists the analysis methods employed for each critical task.

Table 3.25. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Remove/replace tire	Biomechanical Lifting Analysis
Roll tire to/from temporary storage area	Push/Pull Force Analysis

A Dynamic Task Analysis is not performed for manual handling tasks with durations of less than five minutes (See **Appendix B**).

In addition, Section 3.5.5.3 provides an analysis of the existing lift device.

3.5.5.1. Biomechanical Lifting Analysis

Critical Task: Remove/Replace Tire

A biomechanical lifting analysis was performed for the task of handling aircraft tires. The computer-based model used for this analysis is a two-dimensional static biomechanical model that estimates the compressive force experienced by the disc at the base of the lumbar region of the spine. This force is calculated using the measured body posture, estimated object weight, and estimated weight and size of the person's body. The body size and weight estimates are based on a large (95th percentile male) individual because these features represent the worst case for disc compressive force (see **Table 3.26**). [7]

Table 3.26. Biomechanical Lifting Analysis

Activity	Weight of Load Per Person (lbs)	Maximum Recommended Weight for Posture (lbs)
Lifting Tire	162.5	44

▒ = *exceeded maximum recommended forces*

The task of manually handling aircraft tires substantially exceeds the recommended maximum weight for even an optimum posture (51 lbs). This is compounded by the fact that the lifting position and environment are less than optimum. The task of lifting tires requires an awkward back posture, particularly for in-board tires where leg space is extremely restricted (see **Figure 3.4**).

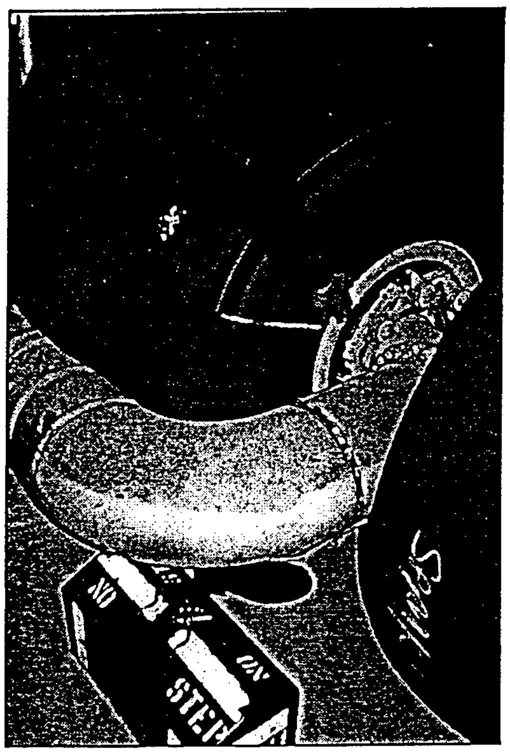


Figure 3.4. Restricted Leg Space While Handling In-Board Tires

<u>Conclusion: High Risk; Excessive forces during manual handling.</u>

3.5.5.2. Push/Pull Force Analysis

Critical Task: Roll Tire To/From Temporary Storage Area

Force measurements were obtained for the force required to roll tires along the floor and in and out of temporary storage racks (see **Table 3.27**). A push/pull gauge was used to measure push/pull forces required. The latest Snook and Ciriello (1994) [10] tables were consulted to establish a maximum recommended push force for this task. The limit value selected from the Snook tables was based on a sustained push by a female worker, a seven-foot push, one push every 30 minutes, and with a hand height of 35 inches.

Table 3.27. Push/Pull Force Analysis

Activity	Measured Push Forces (lbs)	Recommended Maximum Push Forces (lbs)
Push tire along the floor	5 or less	55
Push tire into storage rack	20	55

The forces required to roll the tire into the rack were below the recommended maximum but still substantial. The push forces required to roll tires from one location to another were typically small. However, if a person were to lose control of a tire and it started to fall on its side, the forces could be excessive (up to 160 lbs).

Conclusion: Low Risk; CAUTION! Excessive forces may be caused if tire falls on its side.

3.5.5.3. Equipment Analysis

Critical Task: Remove/Replace Tire

There is currently a lifting device provided for handling aircraft tires; however, it has a number of features which discourage its use:

- There is no mechanism to secure the tire to the wheel with the tire in a vertical orientation (see **Figure 3.5**). This tends to cause the tire to fall over or otherwise be unstable during handling.
- The forward wheels on the lift device do not swivel (see **Figure 3.6**). This substantially increases the time required to line up the lifting device with the axle.
- The lifting device, according to area personnel, cannot be used to replace in-board (i.e., Baker) tires.
- Due to hoses and cables in the workplace, transporting the lift device sometimes involves rolling over hoses and cables.

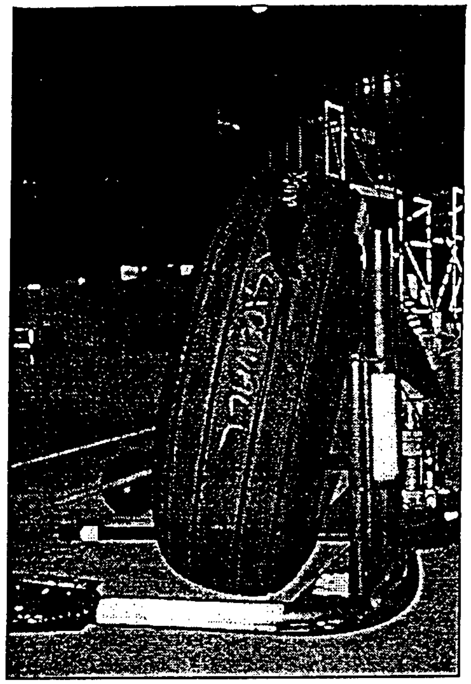


Figure 3.5. Lift device shown holding tire

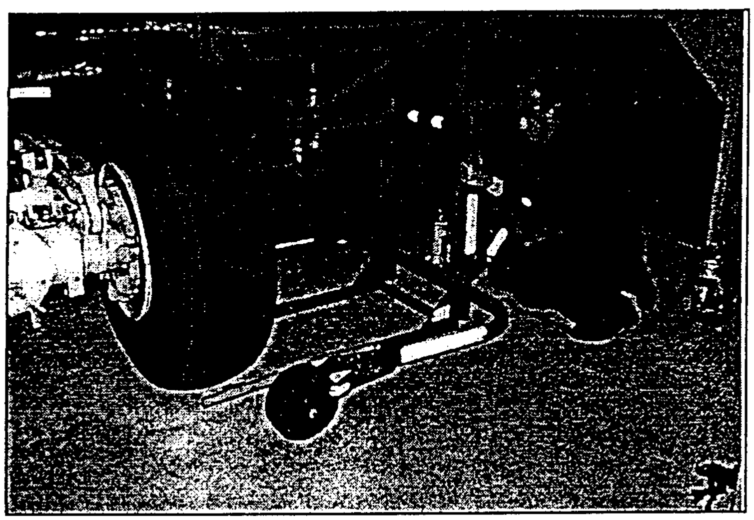


Figure 3.6. Positioning current lift device

<u>Conclusion: Medium Risk; Opportunities exist to improve lift device.</u>

3.5.6 Overall Findings: Remove/Install Aircraft Tires

The following information summarizes the results of the Level II Ergonomic Analysis.

The primary body region of concern in this job/task is the back/torso. To a lesser extent, there are risks to the shoulders/neck, knees, and the hands/wrists/arms. As shown in **Table 3.28**, the major job factors are: excessive lifting forces, awkward back postures, and high speed movements. Table 3.28 also summarizes the results of the Level II analysis for each of the critical tasks and for the job as a whole. The Equipment Analysis in Section 3.5.5.3 is not included in this table because it did not directly measure job factors.

Table 3.28. Summary of Level II Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Remove/ replace tire	• Biomechanical	• High (Back/Torso)	• Excessive lifting forces • Awkward back postures	• Manual handling of tire • Weight of the tire • Restricted space (particularly for in-board tires)
• Roll tire to/from temporary storage area	• Force	• Low	• Tire falling on side during handling	• Manual transport of tire

Due to the High risk rating for at least one analysis method, the risk rating for the overall job, Remove/Install Aircraft Tires is **High**.

3.5.7 Recommended Control Options: Remove/Install Aircraft Tires

The control options are categorized in terms of short-term and long-term controls. **Appendix D** defines these different levels of controls.

The following is a list of control options. The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options to reduce these key job factors.

<u>3.5.7.1. Remove/Replace Tire</u>

3.5.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Encourage personnel to use the existing lift device whenever feasible. (WPR)* Even though the current lift device is slower than manually lifting tires, it does eliminate lifting of tires. Therefore, the existing lift device should be used whenever feasible. For example, use the lift device for outboard tires where space is not as restricted. The idea is to reduce the frequency of manual lifting of tires.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

3.5.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide an efficient and easy to use mechanical lifting device for handling tires.(ENG)* According to ISO Dock personnel, a different lift device is being used by Charleston AFB which is reportedly a better design. A first action item would be to investigate lift devices which are being used by other AFBs. The lift device should have the following features:

  - The lift device should not take significantly more time to use than handling the tire manually.
  - The lift device should provide a way to easily secure the tire during handling and transport.
  - The lift device should not require significant forces to transport (push/pull around). For example, the lift device should be designed so that running over hoses or debris does not result in excessive push/pull forces.
  - The lift device should be maneuverable in very constrained spaces (e.g., the lift device should be designed to remove/install in-board tires as well as out-board tires).

  Three potential sources for vendors who could provide/engineer an appropriate lifting device are provided below.

  Vendor Sources for Lift Device Fabrication/Purchase

  1. CM Positech, Columbus McKinnon Corp., Inc., Laurens, IA (800) 831-6026;
  2. Unidex, Warsaw, NY (716) 786-3170; and
  3. Zimmerman International Corporation, Madison Heights, MI (800) 347-7047.

3.5.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

No additional recommendations (coordinated initiatives) are expected to be necessary.

3.6 Remove/Install Cowl Doors

3.6.1 Job Overview

Overall Risk Rating:	**HIGH**
Workplace:	EMS ISO Dock
Workplace Identifier:	0052-FAPH-051A
Job Title:	Remove/Install Cowl Doors
HEG:	Engine assigned personnel (C-5 aircraft)
Survey Date:	31 October 1996

3.6.2 Job Description

3.6.2.1 Job Objective

Engine cowl doors on the C-5 aircraft must be removed in some cases for servicing. Engine cowl doors are located in lower aft portion of the aircraft. This activity takes place in the EMS ISO Dock.

3.6.2.2 Job Frequency and Duration

An average of four cowl doors per week are removed and reinstalled. The number can range from zero to eight doors per week. There are eight cowl doors on the C-5 aircraft. Since each door must be removed and installed (and thus handled twice), the doors are handled an average of eight times per week.

3.6.2.3 Schedules and Shift/Work Rotation

This task is typically performed during the day shift. There is typically very little rotation across shifts.

3.6.2.4 Number of People Performing Job

A crew of three personnel remove and install cowl doors.

3.6.2.5 Job Activity/Task Breakdown

The task steps for removal and installation of cowl doors are listed below:

Cowl Door Removal

- One person removes hinge fasteners while two other personnel support the door.
- As the final pins are removed, the two personnel lower the door to the floor.
- The cowl door is carried off the platform, down a set of steps and placed on a stand/cart.
- The door is then transported for maintenance.

Cowl Door Installation

- The cowl door is lifted off the cart and carried up the set of steps to the platform.
- The cowl door is lifted into position by two personnel.
- Two personnel support the cowl door while a third person inserts pins needed to hold the cowl door in place.

Table 3.29 provides a listing of the basic tasks which are performed in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work personnel spend performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, *critical tasks* are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 3.29 Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Remove/install cowl doors	<10%	Critical Task (Exertion)
• Holding the door while hinge fasteners are removed/replaced	<10%	N/A
• Lowering the door to the floor/raising the door from the floor	<10%	N/A
• Carrying the door to/from cart.	<10%	N/A
• Transport door on cart .	<10%	N/A

* Total percentage of time at work spent performing the task.

3.6.2.6 Critical Tasks

In this case, the critical task is the same as the job: Remove/Install Cowl Doors (Lifting). Lifting is the corresponding standard task categories used in the JR/PD and Level I Guide.

3.6.3 Work Area, Materials, and Components

3.6.3.1 Workstation and Equipment Descriptions

Engine cowl doors are located in lower aft portion of the aircraft. The cowl doors weigh approximately 125 - 130 lbs.

A stand allows personnel to access the cowl door area. A small set of stairs makes this platform accessible from ground level. There are structural supports in surrounding area, although more clearance exists towards the aft portion of the platform. A strap with a hook on the end (which is secured to a structural support) allows the cowl door to be held open during maintenance.

3.6.3.2 Materials and Part(s) Processed

Not applicable.

3.6.3.3 Description of Hand Tools Used

A number of tools are used to release the cowl door from its hinges. However, none of these directly affect the handling task.

3.6.3.4 Environmental Conditions

Space is somewhat limited on the stand beneath the engine cowl area. In addition, the cowl door must be carried down a small set of stairs.

3.6.3.5 Personal Protective Equipment Required

No special personal protective equipment that directly impacts musculoskeletal risk is required.

3.6.3.6 Productivity and Quality Requirements

While there are no specific productivity requirements, the cowl doors must be removed or installed within a certain period of time in order to allow work to proceed.

3.6.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there are aspects of the tasks which make the job more difficult.

3.6.4.1 Personnel Comments

The following comments were obtained from personnel who install and remove cowl doors:

- "The hardest part of this job is to support the cowl door and adjust the position to allow the hinge pins to be inserted."
- "There are hard edges on the door and a lack of good places to grasp the door during handling."

3.6.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. The person interviewed did not report any discomfort associated with handling cowl doors.

3.6.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomic Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in Section 1.2.4 along with a description of the methods.

Table 3.30 below lists the analysis methods employed for each critical task.

Table 3.30. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Remove/install cowl doors	Biomechanical Lifting Analysis, Postural Analysis, and Force Analysis

A Dynamic Task Analysis is not performed for manual handling tasks with durations of less than five minutes (See **Appendix B**).

3.6.5.1. Biomechanical Lifting Analysis

Critical Task: Remove/install cowl doors

A biomechanical lifting analysis was performed for the task of handling cowl doors. The results of this analysis is presented in **Table 3.31**. The computer-based model used for this analysis is a two-dimensional static biomechanical model that estimates the compressive force experienced by the disc at the base of the lumbar region of the spine. This force is calculated based on the measured body posture, estimated object weight, and estimated weight and size of the person's body. The body size and weight estimates are based on a large (95th percentile male) individual because these features represent the worst case for disc compressive forces.

The biomechanical lifting analysis was performed for two postures: (1) supporting the cowl door while it is being installed or removed (see **Figure 3.7**) and (2) lowering/lifting the cowl door to/from the floor.

Table 3.31. Biomechanical Lifting Analysis

Activity	Weight of Load Per Person (lbs)	Maximum Recommended Weight for Posture (lbs)
Supporting cowl door	65	46-51
Lowering/ lifting cowl door to/from floor level	65	0-1

▒ = *exceeded maximum recommended forces*

The task of manually handling cowl doors exceeds the recommended maximum weight for even an optimum posture (51 lbs). In addition, when the cowl door is lowered to or lifted from the floor, the disc compressive forces rise to 577 kilograms and the recommended maximum weight for that position is 0-1 lbs, while the actual weight handled per person is approximately 65 lbs.

Figure 3.7. Posture Required to Support the Cowl Door While it is Being Installed/Removed

<u>Conclusion: High Risk; Excessive forces during manual handling.</u>

3.6.5.2 Postural Analysis

Critical Task: Remove/Install Cowl Doors

A postural analysis was conducted on static postures which occur while holding up the cowl door while it is being installed or removed (see **Figure 3.7**) The results are presented in **Table 3.32.**

Table 3.32 Postural Analysis Results

Body Region	Measured Body Angle	Recommended Maximum Deflection
Shoulder Posture (measured with respect to vertical)	135°-150°	30° [11]
Neck Posture (measured with respect to the orientation of the upper body)	45° (head tilting back)	10° (any prolonged neck extension should be avoided) [5]

The measured postures exceeded the recommended maximum range for static postures for the shoulder and neck while holding the cowl door for placement. Static muscular fatigue builds-up in a matter of seconds when two people are supporting a 125 lb door in this posture.

<u>Conclusion: Medium Risk: Awkward and prolonged body postures less than 50% of total work time.</u>

3.6.5.3 Force Analysis

Critical Task: Remove/install cowl doors

The forces required to support a cowl door were estimated based on the weight. The forces applied by each hand is at least equal to the weight of the door . Pinch (fingertip) grip forces were used to support the door. The results of the analysis are presented in **Table 3.33**

Table 3.33 Force Analysis

Activity	Measured Fingertip Grip Forces	Recommended Maximum Fingertip Grip Forces
Supporting cowl doors	31 lbs	2 lbs (Stetson et al, 1991)

▩ = *exceeded maximum recommended forces*

The forces required to support the cowl doors substantially exceeds the maximum recommended fingertip forces. In addition, hard/sharp edges on the cowl door and the possible existence of grease further increase the grip forces.

<u>Conclusion: Medium Risk: Excessive fingertip grip forces occurring less than 50% of job time.</u>

3.6.6 Overall Findings: Remove/Install Cowl Doors

The following information summarizes the results of the Level II Ergonomic Analysis.

The primary body regions of concern in this job/task are the shoulder and the back. To a lesser extent, there are risks to the hands/wrists/arms and knees. As shown in **Table 3.34**, the major job factors are: continuous and awkward shoulder postures, continuous supporting of weight, awkward bending, high force lifting tasks, and high force pinch grips. Table 3.34 also summarizes the results of the Level II Ergonomic Analysis for each of the critical tasks and for the job as a whole.

Table 3.34. Summary of Level II Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Remove/ Install Cowl Doors	• Biomechanical	• High (Shoulders and Back	• Excessive lifting forces • Awkward back postures	• Manual handling of cowl doors • Weight of the cowl door • Supporting of cowl door prolonged period of time • Placing cowl door on floor • Lifting cowl door from the floor
• Remove/ Install Cowl Doors	• Postural	• Med (Shoulders/ Neck)	• Static shoulder postures (while supporting heavy load)	• Manually supporting cowl door while it is being installed/removed
• Remove/ Install Cowl Doors	• Force	• Med (Hands/ Wrists/Arms)	• Excessive pinch grip forces	• Supporting of cowl door prolonged period of time • Pinch grip required to support cowl door

Due to the High risk rating for at least one analysis method, the risk rating for the overall job, Remove/Install Cowl Doors is **High**.

3.6.7 Recommended Control Options: Remove/Install Cowl Doors

The control options are categorized in terms of short-term and long-term controls. **Appendix D** defines these different levels of controls.

The following is a list of control options. The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating the causes. The following is a list of control options to reduce these key job factors.

3.6.7.1. Remove/Install Cowl Doors

3.6.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Use good lifting practices while handling cowl door. (WPR)* When lowering the cowl door to the floor, bend the knees, keep the head and torso upright, and maintain an arch in the lower back.

- *Provide a support device to hold the door.(ENG)* The most difficult aspects of this task is supporting the weight of the door while it is being installed/disconnected. A relatively cost-effective solution would be to provide a support device to hold the door up while it is being installed/removed. **Currently, a simple strap is used to hold the door open while the engine is being worked on.** Capitalizing on this concept, the idea would be to provide a similar device which would hold the entire door but also allow the height of the door to be adjusted to facilitate installation. One concept would involve several straps that would attach to the door and also be attached to pulleys with a winch mechanism. An alternative would be to provide a "zero-gravity" balancer which balances the weight of the door yet allows the door to be adjusted up and down. **Figure 3.8** shows an example of this concept. This type of simple lift device would be installed on every cowl door work stand. Care should be taken to make sure that the lift device is stable, safe and does not damage the cowl door.

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves. Select gloves which fit appropriately. In addition use gloves which are breathable (minimize build-up of perspiration)

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

Three potential sources of lift equipment are provided below.

1. Air Technical Industries, Mentor, OH (216)951-5191;
2. CM Positech, Columbus McKinnon Corp., Inc., Laurens, IA, (800) 831-6026; and
3. Zimmerman International Corporation, Madison Heights, MI (800)347-7047.

Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

- *Place a small fixture/table under the door.(ENG)* A small, narrow table or fixture could provide a temporary place to rest the door prior to carrying it off of the stand. If combined with the previous solution, it would eliminate the majority of awkward lifting that currently takes place.

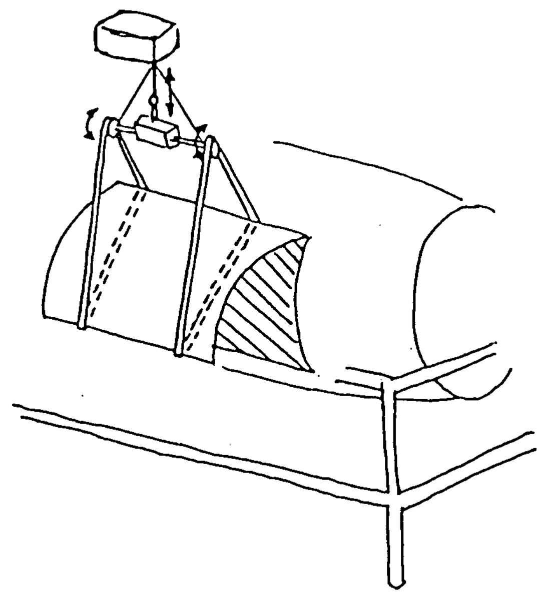


Figure 3.8. Concept for Cowl Door Lift/Balancing Device

3.6.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide an efficient and easy to use mechanical lifting device for cowl doors. (ENG)* While a large overhead crane cannot be used in this area, a small, floor level mechanical device could be provided to handle the cowl doors. A small jib crane could be employed to perform this task. While this is a more expensive control option, it also eliminates all of the manual handling in this task. Figure 3.9 shows a concept of how this lift device could function. The lift device should have the following features:

  - The lift device should transport the cowl door from an installation position to the transport cart and back again.
  - The lift device should not take significantly more time to use than handling the cowl door manually.
  - The lift device should require no more than 50 lbs. of pushing force to start it moving.

- The lift device should hold the cowl door securely.

The device could be either mobile or dedicated to a particular engine cowl depending on which alternative is more feasible. A mobile lift device would be more economical but would require the lift device to be moved to the desired location prior to use. This could discourage its use. A stand-mounted lift device would be simpler but would be required for each cowl door. It might be advantageous to design the lift device to handle a number of aircraft components (not only cowl doors). This would increase its value and practicality.

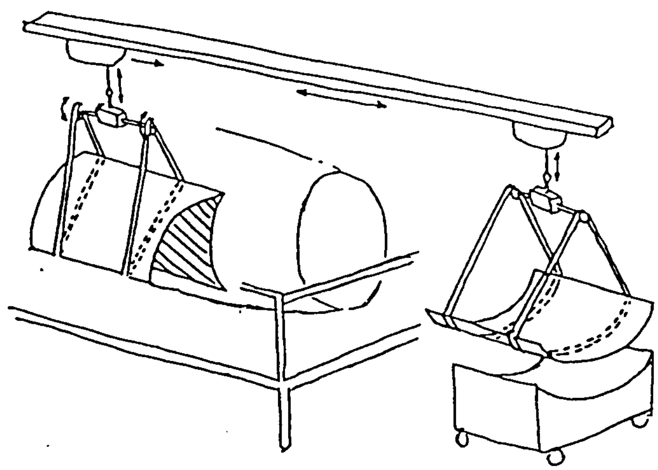


Figure 3.9. Concept for cowl door lift device

Three potential sources are provided below.

1. Air Technical Industries, Mentor, OH (216)951-5191;
2. CM Positech, Columbus McKinnon Corp., Inc., Laurens, IA, (800) 831-6026; and
3. Zimmerman International Corporation, Madison Heights, MI (800)347-7047.

Note: The sources provided in this report have not been evaluated by EARTH TECH and The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

3.6.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

No additional long-term recommendations (coordinated initiatives) are expected to be necessary.

3.7 Remove/Install Underfloor Panels

3.7.1 Job Overview

Overall Risk Rating:	MEDIUM
Workplace:	EMS ISO Dock
Workplace Identifier:	0052-FAPH-051A
Job Title:	Cargo Floor Panel Removal and Reinstallation
HEG:	Fuselage assigned personnel (C-5 Aircraft)
Survey Date:	31 October 1996

3.7.2 Job Description

3.7.2.1 Job Objective

In this operation, it is necessary to remove a portion of the cargo floor panel (otherwise known as an underfloor panel) in order to access certain equipment to perform maintenance. A cargo floor panel is a removable panel at the base of the cargo bay in the C-5 aircraft. It is held in place by a large number of fasteners. This operation is performed in the EMS ISO Dock. Major reasons for removal of the underpanel include: trouble shooting/repairing hydraulic leaks and repairing pressurization heat ducts. Underfloor panel removal is less frequent now because jam nuts on hydraulic lines in these areas have been safety-wired to prevent the nuts from coming loose. However, it still occurs with some regularity.

3.7.2.2 Job Frequency and Duration

Each operation (removal or installation) requires between 4 - 12 hours to complete (with an average time requirement of 8 hours). Over a 40-hour work week, both removal and installation can require 8 - 24 hours (20-60% of work time). However, the task is not performed every week. One supervisor estimated that the underfloor panel must be removed in approximately one out of 10 aircraft. Therefore, the estimated percentage of total time at work that a person would spend in the underfloor would be expected to be less than 10% of the total time at work.

3.7.2.3 Schedules and Shift/Work Rotation

This task is typically performed during the day shift. There is typically very little rotation across shifts.

3.7.2.4 Number of People Performing Job

This operation typically requires two people. One person works above the underfloor and another person works in the underfloor. Both persons remove or install a large number of fasteners during this operation.

3.7.2.5 Job Activity/Task Breakdown

The following activities or task steps were observed in this job:

Removal of Panels

- Collect tools and equipment;
- Attach knee pads;
- Climb into the underfloor area;
- Remove large numbers of fasteners; and
- Remove panels.

Reinstallation of Panels

- Collect tools and equipment;
- Attach knee pads;
- Climb into the underfloor area;
- Reinstall the panels; and
- Install fasteners.

Table 3.35 provides a listing of the basic tasks which occur in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work personnel spend performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, *critical tasks* are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 3.35 Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Climb in and out of underfloor area	<10%	
Remove/install fasteners in the underfloor area	<10%	

* Total percentage of time at work spent performing the task.

3.7.2.6 Critical Tasks

There are no critical tasks identified in this job. However, due to the large number of comments on the JR/PD and the potential existence of job factors, this activity was included in this project. The focus therefore of the analysis will be on the job/task: Remove/Install Underfloor Panels (Wrenching/Racheting)

Wrenching/Racheting is the corresponding standard task category used in the JR/PD and Level I Guide.

3.7.3 Work Area, Materials, and Components

3.7.3.1 Workstation and Equipment Descriptions

Working space is extremely restricted in the underfloor,. In order to access the underfloor panel, the person must crawl on their hands and knees in a small channel (see **Figure 3.10**) and lay on his/her back in one of the side bays of the underfloor area (see **Figure 3.11**). According to personnel, a blanket is used when working on the back in the underfloor.

Figure 3.10. Crawling Into the Underfloor Area

Figure 3.11. Working Overhead While Laying on Back in the Underfloor

3.7.3.2 Materials and Part(s) Processed

A large number of fasteners are removed or installed in order to remove or install the panel.

3.7.3.3 Description of Hand Tools Used

Underfloor fasteners are removed with a battery-powered screwdriver/drill. A hand held flashlight is also used. See the Repair of Floor/Heater Ducts operation (Section 4.4) for more details on tools used in that operation.

3.7.3.4 Environmental Conditions

The interior of the underfloor is dark, and the space is extremely restricted. Wearing a hard hat is not feasible due to the lack of head clearance. This increases the likelihood of bumping the head. The floor contains a number of protrusions (such as small brackets and the ends of fasteners) which can cut the hands or legs. Emergency evacuation of the underfloor area would be time consuming.

3.7.3.5 Personal Protective Equipment Required

Knee pads are critical in this area to protect the knees because it is necessary to crawl on ribs that span the underfloor.

3.7.3.6 Productivity and Quality Requirements

While there are no specific productivity requirements, this operation must be completed within the week-long window for maintenance of the aircraft.

3.7.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there are aspects of the tasks which make the job more difficult.

3.7.4.1 Personnel Comments

The following comments were obtained from personnel in the EMS ISO Dock regarding the task of removing/installing underfloor panels:

- "The main cause of discomfort was associated with working overhead in very restricted space with the arms elevated."
- "Heat is an issue in the summertime. Air conditioners are used in the summer to reduce temperatures in the underfloor."

3.7.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. **Table 3.36** indicates those body regions where pain/discomfort was indicated as well as discomfort intensity scores and ratings.

Table 3.36. Body Regions with Pain/Discomfort

Body Region Specified	Discomfort Score (1-5 scale)*
arms	3-4
neck	2
knees	1-2

* *A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

One person indicated that the arms were the greatest source of discomfort for this job. This is due to working overhead with the arms elevated. This person also mentioned discomfort in the neck associated with the overhead work. Finally, the person did mention knee discomfort but felt the knee pads eliminated most of the discomfort.

3.7.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomic Analysis Methods were employed in order to conduct a detailed analysis. The rationale selecting the appropriate methods for different types of tasks are described in Section 1.2.4 along with a description of the methods.

Table 3.37 below lists the analysis methods employed for each critical task.

Table 3.37. Analysis Methods Employed for the Job

Critical Task	Analysis Methods
Remove/Install Underfloor Panels	Dynamic Task Analysis, Postural Analysis, and Force Analysis

The Dynamic Task Analysis incorporates all tasks performed in the job.

3.7.5.1 Dynamic Task Analysis

A dynamic task analysis was performed for the task of installing/removing underfloor panels (see Table 3.38). This analysis estimates the proportion of task time personnel spend in different awkward postures or exposed to other job factors.

Table 3.38. Dynamic Task Analysis Results

Job Factor	Measured Percentage of Total Task Time	Recommended Maximum Percentage of Total Task Time
Elevation of the arms	60-80%	33% [4]
Elevation of the head and neck	40-50%	33% [4]

▒ = *exceeded maximum recommended percentage of total task time*

The major job factor is to the shoulder/neck area due to the necessity to maintain a static and elevated position of the arms while inserting or removing fasteners.

These postures may be maintained for 60 - 80% of the job time for up to 8 hours. However, the person can periodically climb out to take a break. However, due to the time required to exit and enter the work area, the number of breaks is restricted.

Conclusion: Medium risk; awkward and prolonged body postures less than 50% of total time at work.

3.7.5.2 Postural Analysis

Task: Remove/Install Underfloor Panels

A postural analysis was conducted on static postures which occur during removal/installation of floor panels (see Table 3.39). In particular, continuous arm postures occur while working overhead (see Figure 3.11).

Table 3.39. Postural Analysis Results

Activity	Measured Body Angle	Recommended Maximum Deflection
Shoulder Posture (shoulder angle measured with respect to torso angle)	60-120° (reaching overhead while on back)	30° [5]

▒ = *exceeded maximum recommended deflection*

The measured postures exceeded the recommend maximum range for static postures for the arms.

Conclusion: Medium Risk; Awkward and prolonged body postures less than 50% of total time at work.

3.7.5.3 Force Analysis

Task: Remove/Install Underfloor Panels

The forces required to remove/install fasteners were measured using a force dynamometer (see **Table 3.40**. A power (full hand) grip is used to control the tool. Forces were measured using a force dynamometer. Direct measurements were obtained by placing the dynamometer directly on the tool handle and applying the force through the dynamometer. At least five measurements were taken and the result was obtained by taking the average of those five measurements.

Table 3.40 Force Analysis

Activity	Measured Continuous Power Grip Forces	Recommended Maximum Continuous Power Grip Forces
Removing/installing fasteners	17 lbs	10 lbs (Stetson et al, 1991)

▒ = *exceeded maximum recommended forces*

The forces required to operate the power tool exceeds the maximum recommended power grip forces.

Conclusion: Medium Risk; Excessive power grip forces occurring less than 50% of job time.

3.7.6 Overall Findings: Remove/Install Underfloor Panels

The following information summarizes the results of the Level II analysis.

The primary body region of concern in this job/task is the shoulder/neck To a lesser extent, there are risks to the knees, back/torso, and the hands/wrists/arms. As shown in **Table 3.41**, the major job factors are: static and continuous shoulder and neck postures, excessive grip forces. Table 3.41 summarizes the results of the Level II analysis.

Table 3.41. Summary of Level II Analysis Results

Job/Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Remove/ Install Underfloor Panels	• Dynamic • Postural	• Medium (Shoulder/ Neck)	• Excessive lifting forces • Awkward back postures	• Working overhead while laying on back • Supporting the weight of the tool • Restricted space
	• Grip Force	• Medium (Hands/ Wrists/Arms)		

Due to the High risk rating for at least one analysis method, the risk rating for the overall job, remove/ install underfloor panels is **Medium**.

3.7.7. Recommended Control Options: Remove/Install Underfloor Panels

The control options are categorized in terms of short-term and long-term controls. **Appendix D** defines these different levels of controls.

The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

3.7.7.1. Remove/ Install Underfloor Panels

3.7.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Provide a compressible surface to lay on while working in the underfloor. (ENG)* While it is understood that blankets are occasionally used in the underfloor, review existing equipment to see if pads are adequate or could be improved.

- *Provide small light mounted to a hat or head band. (ENG)* This would make the task easier because it will free the hands up for other tasks. This also allows the light to be more stable and directed where the person is looking.

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

3.7.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide padded clothing for working in the underfloor. (PPE)* Provide clothing which has built in compressible padding to protect the body from hard edges in the underfloor.

- *Provide support for the head, torso, and arms while working overhead. (PPE)* Figure 3.12 provides an example of this concept. This support device should have the following features:

  - Padded-compressible surface to support the head, torso and arms;
  - Able to be easily transported and positioned for work;
  - Easily moldable into different positions to adjust support as needed.

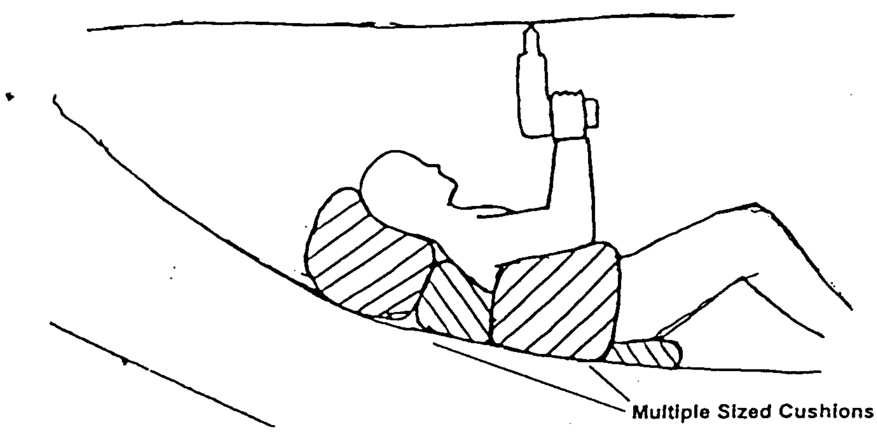


Figure 3.12. Head and torso support device concept

- *Provide a tool support arm supports the tool. (ENG)* The support arm could be mounted to the underfloor panel (e.g., via magnets or clamps). The goal would be to support most of the weight of the tool so the person only needs to reposition and actuate the tool.

  Three potential sources for tool support arms are provided below.

  1. Aimco, Portland, OR, (508) 254-6600;
  2. Coilhose Pneumatics, Middlesex, NJ (908) 752-5000; and
  3. Pate Manufacturing, Wadsworth, IL, (708) 263-9162.

  Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

3.7.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Incorporate the addition of a forward bulkhead ring or rib into planning processes for the C-5 aircraft. (ENG)* Currently, the underfloor panels must be removed to access hydraulic lines, heater ducts or other components. On other aircraft, there is access to the underfloor area via an external port. If this feature were incorporated into this aircraft, this would eliminate the need to remove the underfloor panel to access these areas. It is understood that this is a major change which would require an engineering review prior to implementation. Therefore, it is recommended that this feature be explored as a revision to the existing aircraft or incorporated into plans for future generations of this and other aircraft.

4.0 EMS STRUCTURAL MAINTENANCE

The following sections present information obtained during the Level II Ergonomic Analyses conducted for the EMS Structural Maintenance (0052-FACC-014A) shop at Dover Air Force Base (AFB).

4.1 Executive Summary

This report contains the results of Level II Ergonomic Analyses performed on several Dover AFB EMS Structural Maintenance activities. The following activities were identified as a high priority through analysis of the Job Requirements and Physical Demands (JR/PD) Survey for the EMS Structural Maintenance shop:

- Paint Aircraft Components;
- Repair Blown Floor/Heater Ducts (Drilling/Riveting); and
- Sand Paint Off Aircraft.

The Ergonomist, through observation of the job tasks and interviews with employees and supervisors, determined the critical tasks in each job based on the criteria established in the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas.

Two of the jobs selected have only one critical task. Repair blown floor/heater ducts (Drilling/Riveting) has three critical tasks: The list of critical tasks is as follows:

- Painting (painting)*;
- Drilling (drilling)*;
- Riveting (riveting/bucking)*;
- Cutting (cutting/shearing)*; and
- Sanding (sanding)*.

All five critical tasks were also selected as routine tasks by more than 20% of the participants in the JR/PD survey for this shop.

* The tasks in parentheses are the corresponding standard task categories used in the JR/PD survey.

4.1.1 Findings and Recommendations: Paint Aircraft Components

The following information summarizes the results of the Level II Ergonomic Analyses for the job: Paint Aircraft Components.

Job:	Paint Aircraft Components
HEG:	Painting Aircraft Components in Paint Booths
Survey Date:	1 November 1996
Overall Risk Rating:	MEDIUM
Primary Body Region of Concern:	Hands/Wrists/Arms
Most Hazardous Aspects of the Job:	Repetitive wrist motions and static forces applied with the hands and fingers.
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Elemental Analysis, Force Analysis, and a Hand Tool Evaluation.

Table 4.1 summarizes the results of the Level II Ergonomic Analysis for the critical task: painting.

Table 4.1. Summary of Results of Level II Ergonomic Analysis for the Critical Task: Painting

Task:	Painting
Risk Rating:	MEDIUM
Primary Body Region of Concern:	Hands/Wrists/Arms
Most Hazardous Aspects of the Task:	Repetitive wrist motions and static forces applied with the hands and fingers
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Elemental Analysis, Force Analysis, and a Hand Tool Evaluation.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Repetitive wrist motions • Static hand forces • Exposure to hard edges • Exposure to cold temperatures • Excessive finger movement	• Manual painting task • Supporting weight of paint and paint canister • Weight of gun • Gun is out of balance "front heavy" • Force required to actuate trigger • Hard edges on handle • Metal handle	Short-Term • Alternate between using left and right hand (WPR) • Rotate painting personnel (ADM) • Conduct ergonomics training for employees (WPR) Long-Term • Investigate alternative paint guns (e.g., lighter in weight) (ENG) • Provide a tool balancer to support the weight of the gun (ENG)	• Minor reduction in repetitive wrist motions • Moderate reduction in repetitive wrist motions • Minor reduction in repetitive wrist motions • Major reduction in multiple job factors to the hands/wrists • Moderate reduction in forces to the hands/wrists
• Awkward body (e.g., wrist and shoulder) postures	• Orientation of components	Short-Term • Improve lighting (ENG) • Rotate components to improve body posture (WPR) Long-Term • Provide flexible fixtures for rotating components (ENG)	• Moderate reduction in awkward body postures • Minor reduction in awkward body postures • Major reduction in awkward body postures

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

4.1.2 Findings and Recommendations: Repair Blown Floor/Heater Ducts (Drilling/Riveting)

The following information summarizes the results of the Level II Ergonomic Analysis for the job: Repair Blown Floor/Heater Ducts (Drilling/Riveting).

Job:	Repair Blown Floor/Heater Ducts (Drilling/Riveting)
HEG:	Metal Repair on Aircraft (C-5)
Survey Date:	30 October 1996
Overall Risk Rating:	HIGH
Primary Body Region of Concern:	Shoulders/Neck and Knees/Feet
Most Hazardous Aspects of the Job:	Static and continuous reaching overhead, awkward neck postures, and squatting/kneeling.
Results of Level II Analysis:	The High risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis and Force Analysis.

Table 4.2 summarizes the results of the Level II Ergonomic Analysis for the critical tasks: Drilling, Riveting, and Cutting

Table 4.2. Summary of Results of Level II Ergonomic Analyses for the Critical Tasks: Drilling, Riveting, and Cutting

Task(s):	Drilling, Riveting, and Cutting
Risk Rating:	HIGH
Primary Body Region of Concern:	Shoulders/Neck and Knees/Feet
Most Hazardous Aspects of the Task(s):	Static and continuous reaching overhead, awkward neck postures, and squatting/kneeling.
Results of Level II Analysis:	The High risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, and Force Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Static and continuous reaching overhead • Static and continuous awkward neck postures	• Overhead drilling, riveting, and cutting	Short-Term • Encourage personnel to vary body positions (WPR) • Encourage personnel to take frequent rest pauses (ADM) • Conduct ergonomics training for employees (WPR)	• Minor reduction in static effort in the shoulders/neck and the knees/feet
		Long-Term • Provide a mobile tool balancer (ENG) • Provide flexible arm supports (ENG) • Provide a bench to support the head, arms and upper body (ENG)	• Minor reduction in static effort in the shoulders • Major reduction in static effort in the shoulders/neck and the knees/feet
• Repeated shoulder/arm forces	• Forces required by tools • Weight of tools	Long-Term • Investigate alternative tool designs (ENG) • Provide a mobile tool balancer (ENG)	• Moderate reduction in shoulder/arm forces

* See Appendix C for explanation of job factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

4.1.3 Findings and Recommendations: Sand Paint Off Aircraft

The following information summarizes the results of the Level II Ergonomic Analysis for the job: Sand Paint Off Aircraft.

Job:	Sand Paint Off Aircraft
HEG:	Metal Repair on Aircraft (C-5)
Survey Date:	28 October 1996
Overall Risk Rating:	MEDIUM
Primary Body Region of Concern:	Shoulders/Neck, Hands/Wrists/Arms, and Knees/Feet
Most Hazardous Aspects of the Job:	Static and continuous reaching overhead, forward bending, awkward neck and wrist postures, prolonged hand forces, and exposure to vibration.
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, Grip Force Analysis, and Vibration Analysis.

Table 4.3 summarizes the results of the Level II Ergonomic Analyses for the critical task: sanding.

Table 4.3. Summary of Results of Level II Ergonomic Analyses for the Critical Task: Sanding

Task:	Sanding
Risk Rating:	MEDIUM
Primary Body Region of Concern:	Knees/Feet, Hands/Wrists/Arms
Most Hazardous Aspects of the Task:	Static and continuous reaching overhead, forward bending, and awkward neck and wrist postures.
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis and Grip Force Analysis, Vibration Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Static and continuous reaching overhead • Static and continuous awkward neck postures • Static and continuous kneeling/ squatting • Awkward wrist postures • Static and continuous forward bending	• Overhead sanding • Floor-level sanding	Short-Term • Encourage personnel to vary body positions (WPR) • Encourage personnel to take frequent rest pauses (ADM) • Conduct ergonomic training for employees (WPR) Long-Term • Provide a mobile tool balancer (ENG) • Provide flexible arm supports (ENG) • Provide a bench to support the head, arms and upper body (ENG)	• Minor reduction in static effort in the shoulders/neck and the knees/feet • Minor reduction in static effort in the shoulders • Major reduction in static effort in the shoulders/neck and the knees/feet
• High force fingertip grips		Long-Term • Provide sander with improved handle design (ENG) • Provide a sander with improved vacuum capabilities (ENG) • Investigate alternative vacuum technologies (ENG)	• Moderate reduction in hand forces

Table 4.3 (cont'd). Summary of Results of Level II Ergonomic Analyses for the Critical Task: Sanding

Task:	Sanding
Risk Rating:	MEDIUM
Primary Body Region of Concern:	Knees/Feet, Hands/Wrists/Arms
Most Hazardous Aspects of the Task:	Static and continuous reaching overhead, forward bending, and awkward neck and wrist postures.
Results of Level II Analysis:	The Medium risk rating was a result of exceeded guidelines for Dynamic Task Analysis, Postural Analysis, Grip Force Analysis, and Vibration Analysis.

Key Job Factors*	Key Workplace Causes	Key Control Options	Expected Impacts**
• Exposure to hand/arm vibration		Long-Term • Provide sander with improved vibration dampening capabilities (ENG)	• Moderate reduction in exposure to vibration

* See Appendix C for explanation of risk factors.

** Major reductions indicate an estimated 50% or greater reduction in job factors might be expected with the control. Moderate reductions indicate an estimated 10-50% reduction in job factors might be expected with the control. Minor reductions indicate estimated less than 10% reduction in job factors.

4.1.4 Other Jobs/Activities Identified as Candidates for Ergonomics Attention

In addition to the jobs assessed in this project, there are other jobs/activities identified during data collection which may warrant ergonomic attention. We recommend that a Level I Ergonomic Analysis be completed for these activities. **Table 4.4** lists these jobs or activities and explains the source.

Table 4.4. Summary of Additional Jobs Identified

Job/Activities	Source	Comments
Changing brackets in the T-tails	• Personnel comments from the preliminary prioritized list from the JR/PD	This job appeared on the JR/PD survey. However, this job was not included in the final list of 10 jobs. Potential control options seem to be more limited on this job. The main concerns in this job are the highly restricted spaces.
Bilge inspections	• Personnel comments from the preliminary prioritized list from the JR/PD	This job appeared on the JR/PD survey. However, this job was not included in the final list of 10 jobs. Potential control options seem to be more limited on this job. This job is similar to Remove/Install Underfloor Panels performed by the ISO Dock (See **Section 3.7**). Thus, some of the control options for that job may apply here as well.
Glove box blasting	• Supervisor comments identified during data collection	This job occurs in the main Structural Maintenance shop. The supervisor expressed concerns with the job. There appears to be job factors associated with glove box blasting due to the equipment restrictions.
Handling components in Paint Shop	• Supervisor comments • Identified during data collection	This job occurs in the main paint shop. There may be excessive lifting tasks with transporting large, bulky components in and out of the Paint Shop

4.2 Background

The following sections provide background information on the shop as well as results of the JR/PD Survey and review of Mishap Data for the shop.

4.2.1 Summary of Results of JR/PD Survey

The JR/PD Survey was administered to employees from the EMS Structural Maintenance shop and scored by Dover AFB Public Health (PH). The survey response rate was 87%. The Overall Priority Rating was 7, indicating that the shop should be considered for Ergonomic Problem Area (EPRA) status.

Results indicated that the highest employee-reported job factor exposure was in the hands/wrists/arms, back/torso, and legs/feet. The highest employee-reported discomfort was for these same three body regions. Two other factors are important to note: The Survey indicated that any job stress factors are of minimal concern and that employees were not likely to over-rate job factor exposure or discomfort due to job pressures. In addition, although pre-existing work-related musculoskeletal disorders may have inflated the Overall Priority Rating, a score of 7 was still considered likely to indicate an EPRA.

Although the JR/PD Survey results apply only to the shop as a whole, several job activities were specifically noted as among the most difficult, awkward, or physically demanding tasks by the highest number of employees. The activities and the approximate number of times that the activities were noted on the JR/PD Survey are shown in **Table 4.5.**

Table 4.5. Job Selection Based on Results of JR/PD Survey and Bioenvironmental Engineering Flight Approval

Job/Work Activity	Proportion of Shop Personnel Who Noted the Activity
Repairing blown floor/heater ducts (or) drilling and riveting	20% (17/85)
Sanding	2% (2/85)
Painting	N/A

Repairing blown floor/heater ducts and drilling/riveting combined received the highest number of comments from shop employees. This job was selected as the primary focus for problem-solving in the shop. In addition, while sanding and painting received a low number of specific comments, the tasks were approved by the Bioenvironmental Engineering Flight (BEF) for inclusion in the Level II Ergonomic Analyses since these tasks are common, and it may be possible to apply common solutions to similar tasks throughout the base. Additional explanation for the final job selection is provided in Section 1.2.3.

The BEF completed a general ergonomics survey for Structural Maintenance in July, 1996. This survey provided similar information as the JR/PD but was less detailed and did not provide guidance on job/tasks in the shop to focus on. According to the BEF, no other previous ergonomics analyses or lighting surveys have been completed for these areas.

The Level II Ergonomic Analysis was performed for each of these job activities, and the results are provided in sections 4.5, 4.6, and 4.7.

The shop demographics based on the results of the JR/PD Survey are shown below.

Gender:	3% Female	97% Male
Group:	39% Civilian	61% Military
Length of Service (Base):	7%<1 Yr.	93%>1 Yr.
Length of Service (Shop):	9%<1 Yr.	91%>1 Yr.
Age:	<20 Yrs.	1%
	21-30 Yrs.	38%
	31-40 Yrs.	32%
	>40 Yrs.	29%

4.2.2 Historical Data on Injuries and Illnesses

Table 4.6 summarizes the results of a review of mishap statistics (1994-1996) for EMS (including ISO Dock and Structural Maintenance). The data was provided by the Dover AFB Safety Office. Table 4.3 presents the most common workplace factors/causes of musculoskeletal injuries (such as sprain/strain, repetitive strain illness, and hernia) that were recorded in the injury data.

Table 4.6. Results of Review of Mishap Data for EMS

Expected Workplace Factor/Cause	Type of Injury	Body Regions	Number of Recorded Incidents
Lifting a main landing gear piston assembly	Sprain/Strain	Back/Torso	1
Slip in water/hydraulic fluid	Sprain/Strain	Hand/Wrist/Arm	1
Pulling a work table	Sprain/Strain	Hand/Wrist/Arm	1
Lifting an elevator flutter dampener	Sprain/Strain	Back/Torso	1
Slipped on oil spill and fell	Sprain/Strain	Back/Torso	1
Lifting weights in a strength aptitude test	Sprain/Strain	Hand/Wrist/Arm	1

Generally, there were relatively few sprain/strain injuries identified in EMS (only 6 sprain/strain recordables). In addition, there seemed to be no clear trend in the cause of these injuries. This highlights the value of the JR/PD survey in identifying potential causes of injury even without an injury history.

4.2.3 Workplace Description

Structural Maintenance is responsible for carrying out maintenance and re-fabrication of structural aircraft components. The formal work objective for Structural Maintenance was not available for inclusion in this report.

Structural Maintenance has approximately 72 personnel on day shift, 19 on swing shift and 18 on mid-shift (excluding supervisors and managers).

This project focused on two groups within Structural Maintenance:
ISO/Structural Maintenance (personnel dedicated to the ISO Dock) and the Paint Shop.

Approximately 10 Structural Maintenance personnel (day shift) are dedicated to the ISO Dock. In addition, another three to five Structural Maintenance personnel work in the ISO Dock on each night shift. One Homogeneous Exposure Group (HEG), Metal Repair on Aircraft, was identified in ISO Dock/Structural Maintenance.

The Metal Repair on Aircraft HEG performs the following jobs:

- Drilling/Riveting;
- Patching;
- Sanding;
- Painting; and
- Fiberglassing.

One HEG was identified in the Paint Shop: Painting Aircraft Components in Paint Booths.
The Paint Shop has day shift crew of five personnel; no night shift operations are performed in the Paint Shop. The HEG, Painting Aircraft Components in Paint Booths, performs one job, Paint Aircraft Components.

Critical tasks for Paint Aircraft Components, Drilling, Riveting, and Sanding are presented in Sections 4.3, 4.4, and 4.5.

4.3 Paint Aircraft Components

4.3.1 Job Overview

Overall Risk Rating:	**MEDIUM**
Workplace:	EMS Structural Maintenance
Workplace Identifier:	0052-FACC-014A
Job Title:	Paint Aircraft Components
HEG:	Painting Aircraft Components in Paint Booths
Survey Date:	1 November 1996

4.3.2 Job Description

4.3.2.1 Job Objective

A variety of C-5 aircraft components must be repainted on a periodic basis. Painting is performed both on the C-5 aircraft (outside of the Paint Shop) and in the main Paint Shop. An average of only six hours/week (over a period of two nights) of painting is performed on the aircraft during the night shift. However, the bulk of the painting activity occurs in the main Structural Maintenance Paint Shop. Therefore, the focus of this analysis is on the painting which occurs in the main Structural Maintenance Paint Shop, not the painting that is performed on the aircraft.

4.3.2.2 Job Frequency and Duration

Painting is performed every day of the week. Actual painting occurs for 2 - 3 hours per day. The remainder of the day is spent performing set-up, preparation and clean-up tasks.

4.3.2.3 Schedules and Shift/Work Rotation

This job is performed on the day shift only. The shift is 8 hours long. Breaks are irregular.

4.3.2.4 Number of People Performing Job

The day shift has a crew of five persons; this is the only shift that performs work in the Paint Shop.

4.3.2.5 Job Activity/Task Breakdown

The following task steps occur in this job:

- Set-up paint equipment (e.g., paint gun, paint supply);
- Obtain components;
- Paint components;
- Replace paint supply as needed;
- Transfer components; and
- Clean-up/maintain equipment (e.g., clear paint nozzles).

Table 4.7 provides a listing of the basic tasks which are performed in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time at work spent performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 4.7 Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Paint components	25%-35%	Critical Task
Set-up/clean-up equipment (e.g., paint gun, paint supply)	60%-75%	see note below **
Transport components	<10%	see note below***

* Total percentage of time at work spent performing the task

** Note: Some components are bulky and heavy and could be classified as lifting tasks. However, the Ergonomist was unable to observe handling of large components, and therefore this was not included in the analysis. However, component lifting and handling is a task which is a candidate for further ergonomic attention.

*** Due to scheduling constraints, it was not possible to observe set-up/clean-up activities during on-site data collection. According to area personnel, there are no major sources of discomfort associated with this part of the job. However, a Level I Ergonomic Analysis of this task would address the issue more definitively.

4.3.2.6 Critical Tasks

The critical task, Painting, is the focus of this analysis. Painting is also the corresponding standard task category used in the JR/PD and Level I Guide.

4.3.3. Work Area, Materials, and Components

4.3.3.1 Workstation and Equipment Descriptions

Painting is performed in large paint booths. Components are often hung from or attached to fixtures.

4.3.3.2 Materials and Part(s) Processed

A wide variety of components are painted, including small, large, simple, and complex items.

4.3.3.3 Description of Hand Tools Used

The paint gun is used for a variety of components. The paint gun used is the Air Vector system by Smith Eastern Corporation (Patent # 4,850,809). See the Hand Tool Analysis section (4.3.5.3) for additional information.

4.3.3.4 Environmental Conditions

The potential for exposure to paint fumes above occupational exposure limits necessitates the use of respirators and air exhaust equipment in the paint booths.

4.3.3.5 Personal Protective Equipment Required

Air-supplied respirators are required. Painting gloves are also worn. While gloves provide protection to the hands, they also tend to increase to the grip forces required. This is particularly true when the gloves are not properly sized or if the design of the glove causes a build-up of perspiration inside the glove.

4.3.3.6 Productivity and Quality Requirements

While no specific productivity requirements were identified, there are expected completion times. In addition, there are requirements for paint coverage and quality.

4.3.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there were aspects of the tasks which made the job more difficult.

4.3.4.1 Personnel Comments

The following comments were obtained from personnel in Structural Maintenance regarding painting tasks:

- "The hardest parts to paint are stands which you have to hit from every angle."
- "My arms tend to get a little tired when the (paint supply) cup is full."
- One person commented that the volume and pace of painting is sometimes high.
- "The lighting could be better."
- One person commented that wing slats are one of the more challenging components to paint because they are large and often the entire wing slat has to be painted.

4.3.4.2 Personnel Ratings of Perceived Discomfort

Only one person was available at the time of the on-site data collection; this person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. Table 4.8 indicates those body regions where pain/discomfort was indicated as well as discomfort intensity scores and ratings.

Table 4.8 Body Regions with Pain/Discomfort

Body Region Specified	Discomfort Score (1-5 scale) *
Hands/Wrists/Arms	2-3

* *On the 1-5 scale, a score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

The person reported pain/discomfort in the upper arm and elbow and rated it a 2 or 3 on a 1-5 intensity scale. This person also reported pain/discomfort in the wrist and rated it a 3 on the 1-5 intensity scale.

4.3.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomics Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in **Section 1.2.4**. Appendix B contains specific details on the analysis methods.

Table 4.9 below lists the analysis methods employed for each critical task.

Table 4.9. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Painting	Elemental Task Analysis Grip Force Analysis

In addition, a hand tool evaluation of the paint gun was performed to determine if job factors exist based on the design of the tool.

4.3.5.1 Elemental Task Analysis

As shown **Table 4.10**, an elemental task analysis was performed for the paint booth painting tasks. This analysis specifies upper-limb positions and movements for highly repetitive tasks (with cycle times of less than 5 minutes). A stressful wrist motion (SWM) is defined as the occurrence of a bent wrist with a force applied. In elemental task analysis, the number of SWMs are measured for a particular upper limb intensive task. This is a video-based analysis method.

Table 4.10. Elemental Task Analysis

Activity	Measured # of Stressful Wrist Motions Per Hour	Recommended Maximum # of Stressful Wrist Motions Per Hour
Stressful Wrist Motions associated with painting (averaged over the hours that painting is performed)	2412-3078 swm/hr	1000 swm/hr (Hammer, 1934)
Stressful Wrist Motions associated with painting (average over the entire day)	721-1095 swm/hr	1000 swm/hr

▒ = *exceeded maximum guidelines*

While a person is painting, the number of SWMs is excessive. However, because only 2-3 hours of each day is actually spent painting, the number of SWMs averaged over the entire day only marginally exceeds the guideline. This means that if someone spent more than half of their work time performing only painting tasks, the task would be a High Risk task. Since it seems that less than half of the work time is actually spent painting, this task process is assigned as a Medium Risk for the hands and wrists.

<u>Conclusion: Medium Risk; Repetitive wrist motions less than 50% of total time at work.</u>

4.3.5.2 Force Analysis

Critical Task: Painting

The forces required to press the trigger on the paint gun were measured using a force dynamometer (see **Table 4.11**). Direct measurements were obtained by placing the dynamometer directly on the trigger and applying the force through the dynamometer. Five measurements were taken, and the result was obtained by averaging the five measurements.

Table 4.11. Grip Force Analysis: Squeezing Trigger

Activity	Measured Fingertip Grip Forces	Recommended Maximum Fingertip Grip Forces
Squeezing the trigger on the paint gun	7-8 lbs	2 lbs [9]

▒ = *exceeded maximum recommended forces*

The forces required to squeeze the trigger exceed the maximum recommended fingertip forces.

<u>Conclusion: Medium Risk; Excessive grip forces occurring less than 50% of time at work.</u>

4.3.5.3 Hand Tool/Power Tool Evaluation

The paint gun was evaluated using an ergonomic checksheet for hand tools/power tools. The completed checksheet for this paint gun is presented in **Table 4.12**. **Figure 4.1** provides a photograph of the paint gun. Angles were measured using analysis of videotape and a goniometer when needed. Forces were measured with a dynamometer (See **Section 4.3.5.2**).

The following are the major findings from the checksheet.

Major Positive Features:

- The two-finger trigger is a good feature because it allows force to be distributed over several muscle groups;
- The handle diameter is appropriate to minimize grip forces;
- The gun can be operated with either hand; and
- The gun allows a power or full hand grip to minimize grip forces.

Major Drawbacks:

- The paint canister built into the gun increases weight substantially;
- The paint canister also causes the weight of the gun to be unbalanced (causing it to be "front heavy");
- The handle is bare metal (metal more quickly conducts heat away from the hand which can reduce blood flow);
- There are hard edges on the handle which could contact the hand during operation (exposure to hard edges is a job factors for WMDs); and
- Trigger requires more force to actuate than is recommended. (See **Section 4.3.5.2**)

Figure 4.1. Paint Gun

Conclusion: Medium Risk; Opportunities exist to improve the paint gun.

Table 4.12
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996	**Evaluator:** Van Calvez, The Joyce Institute
Job: Painting Aircraft Components	**Type:** Paint Gun
Manufacturer: Smith Eastern Corporation	**Model Number:** Patent # 4,850,809
Model Name: Air Vector system	**Price:** Information Not Available

Category	Parameter	Measure	Meets Criteria		N/A or Comments
			Yes	No	
General	Handedness	Tool should be easily used with either the left or right hand.	X		
	Repetition	Tool should minimize repetitive movements.		X	
	Ease of Use	Tool should be easy to use.	X		
	Ease of Maintenance	Tool should be easy to maintain.	X		
Grip Angle	Wrist and Arm Posture	Handle angle and location should allow a straight wrist and neutral arm position while the tool is being used.	X	X	Handle is a pistol grip which is good for painting a vertical surface; not as good for horizontal surfaces. Therefore the body posture is dependent upon the orientation of the work
	Back and Neck Posture	Handle angle and location should allow the user to see the work without having to tilt or bend the head or back.	X		

Table 4.12 (cont'd)
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996	**Evaluator:** Van Calvez, The Joyce Institute
Job: Painting Aircraft Components	**Type:** Paint Gun
Manufacturer: Smith Eastern Corporation	**Model Number:** Patent # 4,850,809
Model Name: Air Vector system	**Price:** Information Not Available

Category	Parameter	Measure	Meets Criteria		N/A or Comments
			Yes	No	
Force Requirements	Activation Forces	**Full hand** grip forces required to use tool should be less than 8 lbs (3.6 kg).	X		
		Fingertip grip force required to use tool should be less than 2 lbs (0.91 kg).		X	Trigger force is 7-8 lbs.
	Two hand activation	Tool should allow two hands when applied forces are high or when additional control is needed.			X
	Tool Weight	Tool (and associated cables/hoses) should weigh less than 5 lbs (2.3 kg) or be mechanically supported.	X		Tool weighs 3.5 lbs full of paint but could be lighter.
	Tool Balance	Tool's center of gravity should be close to or at the grip location.		X	
	Cable/Hose Attachment	Cables and hoses should be attached to minimize interference and drag.	X		
	Handle Surface	Grip surfaces should be high friction and slip-resistant. Grip surfaces should be compressible.		X X	Metal handle
	Handle Shape	There should be no hard/sharp edges or abrupt curves that the contact user's hand or body. Avoid ridges or channels for individual fingers.		X	Hard edges present on handle.

Table 4.12 (cont'd)
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996			**Evaluator:** Van Calvez, The Joyce Institute		
Job: Painting Aircraft Components			**Type:** Paint Gun		
Manufacturer: Smith Eastern Corporation			**Model Number:** Patent # 4,850,809		
Model Name: Air Vector system			**Price:** Information Not Available		
Category	**Parameter**	**Measure**	**Meets Criteria**		**N/A or Comments**
			Yes	**No**	
Force Requirements Cont'd	Handle for Torquing Tools	For torquing tools, the handle should be long enough to prevent grip forces above 8 lbs (3.6 kg).			X
	Trigger Force	Force required to activate the trigger should be insignificant (considerably less than 1 lbs or 0.5 kg).		X	Trigger force 7-8 lbs.
	Trigger Function	Tool should avoid continuous activation of a trigger.		X	Continuous activation require.
	Connection Force	Force required to connect/disconnect the power tool should be insignificant.	X		
	Spring Release (Plier-Type Tools)	Plier-type tools should have a spring release mechanism. The spring tension should be minimal.			X
Handle Size	Grip Diameter	Grip Diameter for a full hand grip tool should be between 1-1.5" (2.5-3.8 cm).	X		Grip diameter 1" x 1.5"
		Grip Diameter for a fingertip grip tool should be between 0.25-0.5" (0.6-1.3 cm).			X
		It should also be possible to increase the diameter of the handle if needed.	X		The grip diameter could be increased by attaching material to the handle
	Handle Span on Plier-Type Tools	Plier-type tools should have a span of less than 3" (7.6 cm).	X, marg-inally		Off position for trigger results in a span of approximately 3".
	Total Grip Length	4" (10.2 cm) minimum, 5" (12.7 cm) preferred.	X, marg-inally		The base of the handle is a bit short. Overall length=3.75".

Table 4.12 (cont'd)
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996			**Evaluator:** Van Calvez, The Joyce Institute		
Job: Painting Aircraft Components			**Type:** Paint Gun		
Manufacturer: Smith Eastern Corporation			**Model Number:** Patent # 4,850,809		
Model Name: Air Vector system			**Price:** Information Not Available		
Category	**Parameter**	**Measure**	**Meets Criteria**		**N/A or Comments**
			Yes	**No**	
Trigger/ Buttons	Trigger/ Button Location	Triggers and buttons should be positioned to prevent extension of Fingers or the thumb.	X		
	Trigger/ Button Shape	Trigger should have large smooth curves. No hard edges or points (particularly at the end of the trigger).		X	End of trigger has hard edge.
	Trigger Length	1.5" (3.8 cm) minimum, 2-2.5" (5.1-6.4 cm) preferred.	X		The two finger trigger is a good feature.
	Trigger Width	0.5-1.0" (1.3-2.5 cm).	X		Trigger width is approx. 0.75"
	Trigger Ridge Depth	0.125" - 0.375" (0.318-0.953 cm).		X	Trigger ridge depth is approx. 1.5".
	Trigger Range of Movement	Trigger should have a small range of movement.		X	Range of movement is too large (3").
Misc.	Heat Conduction	Tool handle should be coated or rubberized (tool handles should not be bare metal).		X	Bare metal handle.
	Routing of Air Exhaust	Air powered tools should not blow cold air on hands.			X, no info. available.
	Torque/ Impact	Tool should not expose the user to excessive torque or impact.			X
	Vibration	Tool should not expose the user to excessive vibration.			X

4.3.6 Overall Findings: Paint Aircraft Components

The following information summarizes the results of the Level II Ergonomic Analysis.

The primary body region of concern in this job/task is the hands/wrists. As shown in **Table 4.13**, the major job factors are: repetitive SWMs and static forces applied with the hands and fingers. Table 4.13 also summarizes the results of the Level II Ergonomic Analysis for each of the critical tasks and for the job as a whole.

Table 4.13. Summary of Level II Ergonomic Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Painting	• Elemental	• Medium (Hands/ Wrists/ Arms)	• Repetitive wrist motions	• Manual painting task • Orientation of components
	• Force	• Medium (Hands/ Wrists/ Arms)	• Static forces applied with the hands and fingers	• Supporting weight of paint and paint canister • Weight of gun • Weight of gun out of balance (tool is "front heavy") • Force required to actuate trigger
	• Hand Tool	• Medium (Hands/ Wrists/ Arms)	• Awkward wrist and arm postures • Exposure to hard edges • Exposure to cold temperatures • Excessive finger movement	• Orientation of handle • Hard edges on handle • Metal handle • Excessive range of trigger movement

Due to the Medium risk rating for at least one analysis method, the risk rating for the overall job, Paint Aircraft Components in the Paint Booth is **Medium**.

4.3.7 Recommended Control Options: Paint Aircraft Components

The control options are categorized in terms of short-term and long-term controls. Appendix D defines these different levels of controls.

The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

4.3.7.1. Painting

4.3.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Improve lighting in the paint area.(ENG)* For these types of painting tasks light levels of at least 100-200 foot candles are recommended. As a first step replace all bulbs that are burned out. The second step is be to provide adjustable light fixtures at the workstation. These light fixtures should be moveable to allow personnel to adjust light and minimize shadows.

- *Turn components to improve body posture.(ENG)* Rotate components manually to maintain a straight wrist and to improve back, shoulder, and neck postures. Caution: This recommendation does not apply if a stressful handling task is created in the process of manual repositioning.

- *Encourage employees to alternate between using left and right hand to paint.(WPR)* This would help to minimize the accumulation of physical stress on one hand. Since painting is a skill that requires learned motor coordination, it may take time for personnel to learn to paint effectively with the opposite hand. In addition, since mastering this skill may be more difficult for some personnel than others, it should be a suggestion rather than a job requirement.

- *Investigate the feasibility of rotating painting personnel to other jobs.(ADM)* This would minimize the accumulation of physical stress by having more people perform the task. Caution must be used to ensure that not all of the other jobs on the rotation schedule require similar hand/wrist intensive activities. This is important in order for rotation to be effective.

- *Wear appropriate gloves. (PPE)* To minimize additional forces created by wearing gloves. Select gloves which fit appropriately. In addition use gloves which are breathable (minimize build-up of perspiration)

- *Conduct ergonomic training for employees. (WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting ergonomic training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.

4.3.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Investigate alternative paint guns.(ENG)* Candidates for alternative paint guns should have the following key features:

  - light weight;
  - paint should be stored in an adjacent canister and not built in to the gun;
  - light-touch triggers;
  - easy to clean;
  - no hard edges on the handle; and
  - handle which allows the tool to be held in different ways to encourage a straight wrist while painting components in different orientations (e.g., vertical, horizontal). Handle should have a pistol-grip orientation for vertical surfaces. Handle should have an in-line (straight) grip for horizontal surfaces.

  See the hand tool checksheet (Section 4.3.5.3) for complete specifications of features.

  Three potential sources of paint gun vendors are provided below:

  1. ITW Devilbiss, Maumee, OH, (800) 338-4448 (OMX Spray Gun System);
  2. Graco Inc., Minneapolis, MN, (800) 367-4023; and
  3. Binks Manufacturing, Franklin Park, IL, (800) 99-BINKS.

- *Provide a tool balancer to support the weight of the gun.(ENG)* For some types of components where large, vertical surface areas are painted, it may be effective to provide a tool balancer to support the weight of the tool.

  Three potential sources for tool balancers are provided below.

  1. Aimco, Portland, OR, (508) 254-6600;
  2. Coilhose Pneumatics, Middlesex, NJ (908) 752-5000; and
  3. Pate Manufacturing, Wadsworth, IL, (708) 263-9162.

  Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

- *Provide flexible fixtures for rotating components.(ENG)* When current fixtures cause awkward body postures, provide fixtures that allow large components to be rotated or repositioned. Fixtures usually can be manufactured by a local metal fabricator.

4.3.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

No additional long-term recommendations (coordinated initiatives) are expected to be necessary.

4.4 Repair Blown Floor/Heater Ducts (Drilling/Riveting)

4.4.1 Job Overview

Overall Risk Rating:	HIGH
Workplace:	EMS Structural Maintenance (Sheet Metal)
Workplace Identifier:	0052-FACC-014A
Job Title:	Repair Floor/Heater Ducts
HEG:	Metal Repair on Aircraft (C-5)
Survey Date:	30 October 1996

4.4.2 Job Description

4.4.2.1 Job Objective

One maintenance task performed by Structural Maintenance personnel in the ISO Dock is Drilling/Riveting. This is typically done to remove, repair, and reinstall metal components on the C-5 aircraft. Repair of Blown Floor/Heater Ducts is an example of a job that that involves this task, Drilling/Riveting. In this job, personnel replace a portion of a metal floor duct which has become damaged. Floor ducts are accessed through an opening in bottom of the fuselage. The job is performed by: (1) cutting away the damaged portion of the duct, (2) fabricating a patch, and (3) drilling and riveting the patch into place on the aircraft. Fabricating the patch is considered to be a different job because it is often performed in the main Structural Maintenance Shop. Therefore, it was not included in this analysis.

4.4.2.2 Job Frequency and Duration

The entire job of repairing the ducts takes about 2.5 - 3 hours. On average, two or three ducts per week are repaired in the ISO Dock. Typically, one person repairs no more than one duct per week. According to one area manager, more ducts are repaired on the flightline (up to seven or eight ducts per day) than in the ISO Dock. However, other jobs performed by ISO Dock personnel on the aircraft also involve the task, Drilling/Riveting. It is estimated Drilling/Riveting tasks together comprise approximately 56% of the time at work.

4.4.2.3 Schedules and Shift/Work Rotation

This task can be performed during any of the three, eight-hour shifts. Personnel rotations to other shifts occur on approximately a six-month basis. Breaks are irregular.

4.4.2.4 Number of People Performing Job

Approximately 10 Structural Maintenance personnel (day shift) perform this job. In addition, another three to five Structural Maintenance personnel perform this job on each night shift.

4.4.2.5 Job Activity/Task Breakdown

The following tasks steps were observed during this job:

- Identify damaged floor/heater duct;
- Cut-out and remove damaged section using skin knife;
- Fabricate/repair doubler at the main shop (this task is not included in this evaluation because the focus of this evaluation is drilling and riveting activities on aircraft);
- Layout holes and drill the doubler (typically approximately 80 holes); and
- Install rivets using rivet gun (approximately 80 rivets).

Table 4.14 provides a listing of the basic tasks which occur in this job and the estimated task frequency for each task. Estimated task frequency is the total percentage of time at work spent performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, *critical tasks* are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 4.14. Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Identify damaged floor/heater duct	<10%	
Cut-out and remove damaged section using skin knife	<10%	Critical Task (exertion)
Fabricate/repair doubler at the main shop	n/a	This task is not included in this evaluation (see 4.4.2.1)
Layout holes and drill the doubler	25%	Critical Task
Install rivets using rivet gun	25%	Critical Task

**Total percentage of time at work spent performing the task.*

4.4.2.6 Critical Tasks

The critical tasks that were identified in this job are:

- Drilling;
- Riveting; and
- Cutting (using skin knife).

Drilling/Riveting are the corresponding standard task categories used in the JR/PD and Level I Guide.

4.4.3 *Work Area, Materials, and Components*

4.4.3.1 Workstation and Equipment Descriptions

Work performed on floor/heater ducts is performed directly on the aircraft. The work was performed on a C-5 aircraft during this evaluation. The work space, where the floor/heater ducts are located, is somewhat restricted necessitating the worker to squat or kneel and work overhead while performing the task.

4.4.3.2 Materials and Part(s) Processed

The floor/heater ducts used are basically small pieces of metal which are cut to size in a machining area and then attached to the aircraft with rivets. They typically weigh a few ounces.

4.4.3.3 Description of Hand Tools Used

Several tools are used for this job including: a skin knife, air or battery powered drills, and air or pump-activated rivet guns. Additional information on the tools is provided in the Hand Tool Evaluation below.

4.4.3.4 Environmental Conditions

The restricted space of the work area is the primary environmental factor. The surface where the worker squats or kneels has metal ribs and brackets which limit body positions. There are also ribs and other obstructions overhead.

4.4.3.5 Personal Protective Equipment Required

Safety glasses and hard hats are required. No other special personal protective equipment that impacts musculoskeletal risk is required.

4.4.3.6 Productivity and Quality Requirements

While no specific productivity requirements were identified, the repairs must be completed within a certain period of time in order to allow work on the aircraft to be completed on schedule.

4.4.4 *Informal Interviews*

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there were aspects of the tasks which make the job more difficult.

4.4.4.1 Personnel Comments

The following comments were obtained from personnel in Structural Maintenance regarding sanding tasks:

- "The hardest thing about the job is the awkward position you have to be in for a long period of time."
- "Its also hard on the shoulders to be repetitively pushing up on the drill or the rivet gun."
- "On the flightline, they don't have an air source so they use the pump rivet gun."

4.4.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. Table 4.15 indicates those body regions where pain/discomfort was indicated as well as discomfort intensity scores and ratings. [3]

Table 4.15. Body Regions with Pain/Discomfort

Body Region Specified	Discomfort Score (1-5 scale)*
knees/feet	3
shoulders/neck	4-5

* *A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

The person reported pain/discomfort in the knees and rated both a 3 on a 1-5 intensity scale. This person also reported pain/discomfort in the shoulders which was rated a 4 or 5 on the 1-5 intensity scale.

4.4.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomics Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in **Section 1.2.4. Appendix B** contains specific details on the analysis methods.

Table 4.16 below lists the analysis methods employed for each critical task.

Table 4.16. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Drilling	Dynamic Task Analysis, Postural Analysis, Force Analysis, and Vibration Analysis
Riveting	Dynamic Task Analysis, Postural Analysis, Force Analysis, and Vibration Analysis
Cutting (Using skin knife)	Dynamic Task Analysis, Postural Analysis, and Force Analysis

The Dynamic Task Analysis, Postural Analysis, and Force Analysis incorporate all tasks performed in the job.

4.4.5.1 Dynamic Task Analysis

A dynamic task analysis was performed for all tasks involved in the job, Repair Floor/Heater Ducts (Drilling, Riveting, and Cutting). This analysis estimates the proportion of task time personnel spend in different awkward postures or exposed to other job factors (see **Table 4.17**). [4]

The job, Repair Floor/Heater Ducts, is performed in an area of the aircraft where it is necessary to squat in order to work on the duct.

Table 4.17. Dynamic Task Analysis

Job Factor	Measured Percentage of Total Task Time	Recommended Maximum Percentage of Total Task Time
Elevated arms	70%	33% [4]
Neck extension (tilting the head back)	70%	33% [4]
Squatting	70%	33% [4]
High force hand and shoulder exertions	70%	33% [4]
Kneeling	70%	33% [4]

These postures may be maintained continuously for up to 1.5 hours. However, the person may exit the aircraft occasionally to take a break.

This task requires approximately 2-3 hours to complete. Over a 40-hour work week, this is equivalent to 7.5% of the total work time, on average. However, considering all drilling and riveting activities, these job factors occur greater than 50% of the total work time.

Conclusion: High Risk; Awkward and prolonged body postures greater than 50% of total work time

4.4.5.2 Postural Analysis

A postural analysis was conducted on static postures which occur during the job, Repair Floor/Heater Ducts (see **Table 4.18**). In particular, continuous awkward back postures occur while performing the tasks, Drilling, Riveting and Cutting overhead (see **Figure 4.2**) and at floor level. The postural analysis is completed by use of video-based measurement of body angles using a goniometer.

Table 4.18. Postural Analysis Results

Body Region	Measured Body Angle	Recommended Maximum Deflection
Shoulder Posture (measured with respect to vertical)	90-120° Shoulder flexion	30° [11]
Neck Posture (measured with respect to the orientation of the upper body)	45° Neck extension (head tilting back)	10° (any prolonged neck extension should be avoided) [5]
Knee Posture (lower leg angle measured with respect to upper leg angle, 0° is full extension of the knee)	160° Knee flexion (squatting)	90° [14]

The measured postures exceeded the recommend maximum range for static postures for the shoulder, neck, and knee for overhead cutting, drilling, and riveting of the ducts.

Figure 4.2. Awkward shoulder, neck, and knee postures while working overhead on floor/heater ducts

<u>Conclusion: High Risk; Awkward and prolonged body postures greater than 50% of total work time</u>

4.4.5.3 Vibration Analysis

Critical Tasks: Drilling and Riveting

Acceleration levels were measured while using an air powered drill, battery powered drill, and pneumatic riveter (see **Table 4.19**). Vibration measurement was conducted by using a Bruel and Kjaer Type 2513 Integrating Vibration Meter with a hand/arm transducer set. The transducer was attached to the hand of an employee and the measurements were taken while the tool was in use.

Table 4.19. Acceleration Level Measurements

Tool	Dominant RMS Acceleration (10m/s)	Threshold Limit Values* Dominant RMS Acceleration (m/s2)
Battery powered drill	0.5-0.6	6 [15]
Air powered drill	0.8-0.9	6 [15]
Pneumatic riveter	05-1.0	6 [15]

* *Adapted from the 1988 ACGIH standard on exposure to vibration.*

These results show that the vibration exposure from all three tools are well below the Threshold Limit Values (TLVs).

Conclusion: Low Risk; Vibration levels are well below TLVs.

4.4.5.4 Force Analysis

All critical tasks considered

The forces required to operate the tools used in this task were measured using a force dynamometer (see **Table 4.20**). Dynamic push forces were measured with the tool in a horizontal orientation (i.e., horizontal tool axis). It is expected that forces would be increased somewhat when working overhead (due to overcoming the weight of the tool). **Table 4.20** also summarizes the manufacturer and model number of the tools.

Table 4.20. Force Analysis Results

Tool	Manufacturer/ Model	Model #	Measured Shoulder/Arm Forces	Recommended Maximum Shoulder/Arm Forces
Skin knife	in-house build	n/a	20 lbs	10 lbs [9]
Pneumatic Rivet Gun	Pneumatic Cherry Max	• G 704 B-SR, • G 746	10-12 lbs	10 lbs [9]
Pump Rivet Gun	•Hand Cherry Max	• G 749 A • G 750 • G 36 • G 27	20 lbs	10 lbs [9]
Battery-Powered Drill	Black & Decker Versa Clutch	• 2874	22 lbs	10 lbs [9]
Air-Powered Drill	various manufacturers	• ARO DG051A-30 • ARO 7848 • ARO DGO22B-26 • Cleco 5 DP-25 • Snap-on PDR 3A	17 lbs	10 lbs [9]

Hand tool/power tool evaluations were completed for the major hand tools used in this job. However, the main concerns with the tools have been addressed in terms of the forces required to operate the tools. Therefore, a separate section on hand tool/power tool evaluation is not included because no additional findings resulted from this analysis.

All of the tools, with the possible exception of the pneumatic rivet gun, required excessive shoulder/arm forces (particularly considering the awkward shoulder posture required for overhead work).

Table 4.21 presents the actual weights of the tools included in the force analysis and the recommended maximum tool weights.

Table 4.21. Measured Tool Weight vs. Recommended Maximum Tool Weight

Tool	Measured Weight of Tool	Recommended Maximum Tool Weight/Static Grip Forces
Skin Knife	Several ozs.	5 lbs [4]
Pneumatic Rivet Gun	3 lbs	5 lbs [4]
Pump Rivet Gun	2 lbs	5 lbs [4]
Battery-Powered Drill	5 lbs	5 lbs [4]
Air-Powered Drill	2 lbs	5 lbs [4]

The air-powered drill is lighter and requires less force to use than the battery powered drill. However, the battery-powered drill can be used in more remote locations and does not require an air line.

The pneumatic riveter requires less force to use than the pump riveter. However, the pump riveter can be used in more remote locations and does not require an air line.

<u>Conclusion: High Risk; Tools used for overhead cutting, drilling, and riveting require excessive shoulder/arm forces.</u>

4.4.6 Overall Findings: Repairing Floor/Heater Ducts (Drilling and Riveting)

The following information summarizes the results of the Level II Ergonomic Analysis.

The primary body regions of concern in this job are the shoulders/neck and knees/feet. To a lesser extent, there are risks to the back/torso and the hands/wrists/arms. As shown in **Table 4.22**, the major job factors are: static, awkward shoulder, neck and leg postures, and excessive shoulder/arm forces. Table 4.22 also summarizes the results of the Level II Ergonomic Analysis for each of the critical tasks and for the job as a whole.

Table 4.22. Summary of Level II Ergonomic Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Multiple tasks	• Dynamic • Postural	• High (Shoulders/ Neck and Knees/Feet)	• Static and continuous reaching overhead • Static and continuous awkward neck postures • Static and continuous kneeling/ squatting	• Overhead work • Restricted vertical clearance (i.e., low ceiling)
	• Force	• High (Shoulders/ Neck and Knees/Feet)	• Repeated shoulder/arm forces	• Overhead drilling and riveting • Forces required by tools

Due to the High risk rating for at least one analysis method, the risk rating for the overall job, is **High**.

4.4.7 Recommended Control Options: Repair Blown Floor/Heater Ducts

The control options are categorized in terms of short-term and long-term controls. **Appendix D** defines these different levels of controls.

The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

4.4.7.1. Drilling and Riveting

4.4.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Encourage personnel to vary body positions.(WPR)* Being in any posture over a long period of time can result in build-up of static muscular fatigue. Therefore, it is always a good practice to vary body postures every few minutes. For example, exchanging hands periodically or adjusting hand positions can reduce the fatigue in the hands.

- *Encourage personnel to take frequent rest pauses.(ADM)* Encourage personnel to take rest pauses of 30 seconds to 2 minutes at least once every 15 minutes.

- *Conduct ergonomic training for employees.(WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. In particular, the training should emphasize rest pauses, fatigue reducing exercises, and other health/comfort strategies. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

4.4.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Investigate alternative tool designs.(ENG)* Obtain drilling and riveting tools which incorporate ergonomic design principles. According to the Structural Maintenance tool crib personnel, a more ergonomically-designed air-drill with ergonomic features has been developed and is available. This tool is the Cleco No. 5 Series Drill (Model # 5DP10). See the **Hand Tool/Power Tool Evaluation Worksheet in Section 4.3.5.3** for additional assistance on evaluating and selecting tools.

  Three potential sources for power tools are provided below:

  1. Atlas Copco, Farmington Hills, MI, (800) 859-3746;
  2. Cooper Power Tools, Lexington, SC, (800) 359-1200; and
  3. Ingersoll - Rand Power Tools, Elmhurst, IL, (800) 323-1035.

- *Provide a mobile tool balancer.(ENG)* Consider providing an over-head mounted tool balancer/support for power tools. The tool balancer should have a hook/suction cup that allows the balancer to be repositioned. **Note:** Tool balancers work less effectively in cases when the surface being drilled/riveted is horizontal (as when drilling/riveting heater ducts overhead). Tool balancers are more effective when the surface being drilled/riveted is vertical.

  Three potential sources for tool balancers are provided below.

  1. Aimco, Portland, OR, (508) 254-6600;
  2. Coilhose Pneumatics, Middlesex, NJ (908) 752-5000; and
  3. Pate Manufacturing, Wadsworth, IL, (708) 263-9162.

  Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

4.4.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Provide support for the arms while working overhead.(ENG)* Where drilling and riveting activities require the arms to be held away from the body for prolonged periods and it is not possible to reposition the work (e.g., non-removable section of aircraft), one strategy is to provide support for the arms via mechanical arm rests (see Figure 4.3). These arm rests should have the following features:

  - padded-compressible surface to rest the arms for a variety of work heights;
  - secured to the person so that they move as the person moves;
  - adjustable in height and distance away from the body;
  - light-weight;
  - easy to adjust out of the way if not needed;
  - easy to put on and remove;
  - easily removable in case of emergency;
  - easy to clean; and
  - durable, anti-static materials.

  While arm supports will reduce static effort in the arms, it will not reduce static effort in the neck or lower limbs.

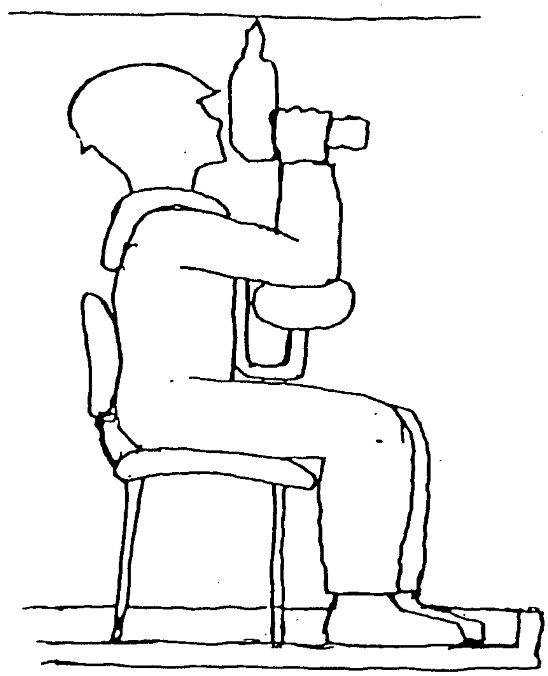


Figure 4.3. Armrest concept

- *Provide a bench to support the head and upper body while performing overhead and floor level work. (ENG)* For prolonged overhead work on horizontal surfaces (where repositioning the work is not possible), a bench which supports the head and upper body could be provided (see **Figure 4.4**). In some cases, this recommendation could be combined with the armrest concept shown above to provide support for the arms, upper body, and head. The bench should have the following features:
  - compressible surfaces to support the upper body and head;
  - adjustable in height and angle of the bench (In some cases, it may be necessary for the bench to be raised within a few feet of an overhead horizontal surface in order to minimize reaching.);
  - separate support for the head which is independently adjustable from the torso support;
  - able to be easily transported and repositioned for different tasks. (i.e., light weight, collapsible); and
  - durable, anti-static materials.

It may be possible to combine the bench to allow it to be used for prolonged floor level work (or below floor level work) as well as overhead work. It is also possible that separate benches will be needed for these different tasks.

Three potential sources for arm and upper body supports are provided below:

1. Corel, Mansfield, OH, (800) 537-5573;
2. David Eric, Inc., Merion, PA, (610) 896-2180; and
3. Eidos Corp, Lincoln, NE (402) 466-1119.

Note: The sources provided in this report have not been evaluated by The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

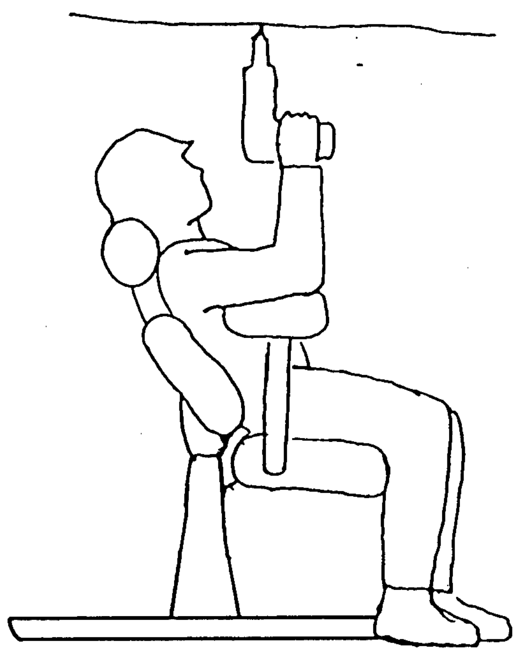


Figure 4.4. Head and torso support device concept

4.5 Sand Paint Off Aircraft

4.5.1 Job Overview

Overall Risk Rating:	**MEDIUM**
Workplace:	EMS Structural Maintenance
Workplace Identifier:	0052-FACC-014A
Job Title:	Sand paint off aircraft
HEG:	Metal Repair on Aircraft (C-5)
Survey Date:	28 October 1996

4.5.2 Work Schedule and Job Activity/Task Breakdown

4.5.2 Job Description

4.5.2.1 Job Objective

Sanding of metal components on aircraft is one of the main functions of Structural Maintenance personnel in the ISO Dock.

4.5.2.2 Job Frequency and Duration

Sanding is predominantly performed one night per week for 4 - 8 hours. During that time, sanding is performed continuously by all employees. On other nights of the week, sanding is performed only occasionally. Continuous sanding of one location can occur for 30 minutes or more (for large areas to be sanded).

4.5.2.3 Schedules and Shift/Work Rotation

Sanding is performed in the ISO Dock on the night shifts. Breaks are irregular. Rotations to other shifts occur on a six-month basis.

4.5.2.4 Number of People Performing Job

Two to three personnel typically perform this task.

4.5.2.5 Job Activity/Task Breakdown

The following activities or tasks were observed during this job:

- Set-up equipment (i.e., sander, dust containment system, supplies);
- Carry equipment to desired location on the aircraft;
- Set up signs and other safety equipment;
- Sand specified area; and
- Move to the next area and repeat.

Table 4.23 provides a listing of the basic tasks which occur in this job and an estimated task frequency for each task. Estimated task frequency is the total percentage of time personnel spend at work performing the task. In the Level I Ergonomics Methodology Guide for Maintenance and Inspection Work Areas, ***critical tasks*** are defined as tasks which occur greater than 10% of the total percentage of work time or those tasks which involve lifting or exertion.

Table 4.23 Work Content Matrix

Task	Estimated Task Frequency*	Critical Tasks
Set-up equipment	<10%	N/A
Carry equipment	<10%	N/A
Set up signs and other safety equipment	<10%	N/A
Sand specified area	25%	Critical Task
Move to the next area and repeat	<10%	N/A

* Total percentage of time at work spent performing the task.

4.5.2.6 Critical Tasks

One critical task, Sanding, is performed in this job.
Sanding is the corresponding standard task categories used in the JR/PD and Level I Guide.

4.5.3 Work Area, Materials, and Components

4.5.3.1 Workstation and Equipment Descriptions

Sanding is performed directly on the aircraft. The work locations and sanding surface vary widely: overhead, floor level, vertical above shoulder height, vertical below shoulder height. The sander is typically held with two hands. Workers use full hand (power) grips to hold the sanders.

A portable vacuum is attached to the sander to reduce dust during sanding.

4.5.3.2 Materials and Part(s) Processed

Sanding media are used and replaced on the orbital sander.

4.5.3.3 Description of Hand Tools Used

The orbital sander used is the Dynabrade Orbital Sander, 57034. The orbital sander must be held at a 45 degree angle to sand properly. See the Hand Tool Analysis section (4.5.5.5) for additional information.

4.5.3.4 Environmental Conditions

The presence of paint dust quantities above occupational exposure levels necessitates the use of respirators.

4.5.3.5 Personal Protective Equipment Required

Air-supplied respirators are required.

4.5.3.6 Productivity and Quality Requirements

While no specific productivity requirements were identified, sanding must be performed within a certain period of time in order to allow other work to proceed.

4.5.4 Informal Interviews

Employees and supervisors were interviewed regarding the job/tasks. In particular, there was a focus on determining if there were aspects of the tasks which made the job more difficult.

4.5.4.1 Personnel Comments

The following comments were obtained from personnel in Structural Maintenance regarding sanding tasks:

Sanding

- "A difficult part of the task involves holding the sander at a 45 degree angle which tends to cause wear and tear to the wrist."
- "There is also quite a bit of vibration from these sanders."

Vacuum Equipment

- "The portable vacuum is cumbersome and awkward."
- "The harness for the portable vacuum is not comfortable. It sticks you in the back. Most people just place the vacuum on the floor next to where they are working instead of wearing the thing."
- "The extra hose associated with the vacuum restricts movement and is also cumbersome."
- "Have seen other equipment which eliminates the extra hose by combining the two hoses into one."
- "It doesn't seem like the vacuum does a very good job. It doesn't seem powerful enough. The holes in the bottom of the sander are too close to the center of the sander. Maybe moving the holes closer to the edges of the sander would improve the vacuum's performance."

4.5.4.2 Personnel Ratings of Perceived Discomfort

One person was interviewed to determine if they experience reoccurring pain or discomfort in any region of the body. Only one person was available at the time of the on-site data collection. **Table 4.24** indicates those body regions where pain/discomfort was indicated as well as discomfort intensity scores and ratings. [3]

Table 4.24. Body Regions with Pain/Discomfort

Body Region Specified	Discomfort Score (1-5 scale)*
mid and lower back	3
upper arms/shoulder	3 or 4

* *A score of 1 = Just Noticeable Discomfort, a score of 3 = Moderate Discomfort, and a score of 5 = Intolerable Pain.*

The person reported pain/discomfort in the mid and lower back and rated it a 3 on a 1-5 intensity scale. This person also reported pain/discomfort in the upper arms/shoulder which was rated a 3 or 4 on the 1-5 intensity scale. The person also reported headaches associated with using a respirator and indicated that the lighting was inadequate in the building.

4.5.5 Results of Level II Ergonomic Analysis

A number of Level II Ergonomics Analysis Methods were employed in order to conduct a detailed analysis. The rationale for selecting the appropriate methods for different types of tasks are described in **Section 1.2.4. Appendix B** contains specific details on the analysis methods.

Table 4.25 below lists the analysis methods employed for each critical task.

Table 4.25. Analysis Methods Employed for Each Critical Task and the Job as a Whole

Critical Task	Analysis Methods
Sanding	Dynamic Task Analysis, Postural Analysis, Grip Force Analysis, and Vibration Analysis

The Dynamic Task Analysis incorporates all tasks performed in the job. In addition, a hand tool evaluation was completed for the orbital sander to identify job factors associated with the design of the tool

4.5.5.1 Dynamic Task Analysis

A dynamic task analysis was performed for the sanding tasks (see **Table 4.26**). This analysis estimates the proportion of task time in different awkward postures or exposed to other job factors. [4]

Due to wide variety of aircraft locations where sanding is performed, a wide variety of body postures occur. **Figure 4.5** shows a typical posture for overhead work.

Table 4.26. Dynamic Task Analysis Results

Job Factor	Measured Percentage of Total Task Time	Recommended Maximum Percentage of Total Task Time
Elevated arms	45%	33% [4]
Forward bending of the back	40%	33% [4]
Awkward neck postures	66%	33% [4]
High force fingertip grips	100%	33% [4]
Kneeling	45%	33% [4]

Due to the limited number of hours spent performing sanding per week, the concern is primarily due to more acute reactions to a concentrated exposure over one shift. Therefore, this situation has a lower risk than those activities which would occur everyday.

Conclusion: Medium Risk; Awkward and prolonged body postures less than 50% of total time at work.

4.5.5.2 Postural Analysis

Critical Task: Sanding

A postural analysis was conducted on static postures which occur during sanding. In particular, continuous awkward back postures occur while sanding overhead (see **Figure 4.5**) and at floor level. **Table 4.27** provides the postural analysis results. Postural analysis is a video-based analysis in which body angles are measured with a protractor.

Table 4.27. Postural Analysis Results

Activity	Measured Body Angle	Recommended Maximum Deflection
Overhead Sanding		
Shoulder Posture	90° Shoulder flexion	30° [11]
Neck Posture	45° Neck extension (head tilting back)	10° (any prolonged neck extension should be avoided) [5]
Wrist Posture	35° wrist extension	10° [4]
Floor Level Sanding		
Back Posture	90°	20° [5]
Neck Posture	25° Neck flexion(head tilting forward)	10° [5]

The measured postures exceeded the recommend maximum range for static postures for the shoulder, neck, and wrist (for overhead sanding) and for the back and neck (for floor level sanding).

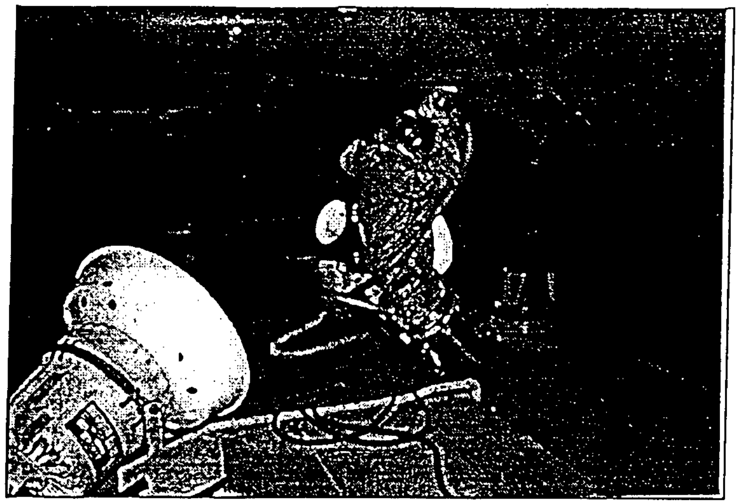


Figure 4.5. Awkward shoulder, neck, and wrist postures while sanding overhead

Conclusion: Medium Risk; Awkward and prolonged body postures less 50% of total time at work.

4.5.5.3 Vibration Analysis

Critical Task: Sanding

As shown in **Table 4.28**, acceleration levels were measured using the orbital sander. The TLVs used in this analysis were drawn from the 1988 ACGIH standard on exposure to vibration[15]. Vibration measurement was conducted by using a Bruel and Kjaer Type 2513 Integrating Vibration Meter with a hand/arm transducer set. The transducer was attached to the hand of an employee and the measurements were taken while the tool was in use.

Table 4.28. Acceleration Level Measurements

Activity	Dominant RMS Acceleration (m/s2)	Threshold Limit Values Dominant RMS Acceleration (m/s2)
1 Day Exposure (8 hr)	7-8	4
Average Daily Exposure (8 hr averaged over a week period)	1.4-1.6	8

▩ = *exceeded threshold limit values*

The vibration exposure for a single day exceeds the threshold limit value. However, if averaged over a period of a week, the threshold limit is then not exceeded. If sanding were performed for a majority of the time, this would be a high risk job.

Conclusion: Medium Risk; Exposure to vibration exceeds TLVs for a one-day exposure but does not exceed TLVs for a daily exposure averaged over a weekly period.

4.5.5.4 Grip Force Analysis

Critical Task: Sanding

The grip forces required to operate the orbital sander were measured using a force dynamometer (see Table 4.29). Fingertip grip forces were measured with the sander facing downward sanding a horizontal piece of metal on a (e.g., the orientation used to sand at floor level).

Table 4.29. Grip Force Analysis Results

Activity	Measured Fingertip Grip Forces	Recommended Maximum Static Fingertip Grip Forces
Operating the orbital sander	10-12 lbs	2 lbs [9]

It is expected that the grip forces would be slightly higher when performing overhead work because the operator would be overcoming the weight of the sander in addition to performing the sanding task see Table 4.30).

Table 4.30. Measured Weight of Orbital Sander vs. Recommended Maximum Weight

Tool	Measured Weight of Tool	Recommended Maximum Tool Weight/Static Grip Forces
Orbital Sander	5 lbs	5 lbs [16]

The weight of the sander is approximately 5 lbs. The grip force is greater than the weight of the sander because the grip force measures the amount of force required while sanding.

Additional weights include:

- air hose for the sander: 3 lbs;
- air hose for the vacuum: 5 lbs; and
- portable vacuum: 20 lbs.

Conclusion: Medium Risk; Recommended maximum fingertip grip forces exceeded and exposure to hard edges less 50% of total time at work.

4.5.5.5 Hand Tool/Power Tool Evaluation

Critical Task: Sanding

The orbital sander was evaluated using an ergonomic checksheet for hand tools/power tools. [13]
The completed checksheet for this sander is presented in Table 4.31. Figure 4.6 provides a photograph of the sander. The orbital sander used is the Dynabrade Orbital Sander, 57034.

The following are the major findings from the checksheet.

Figure 4.6 shows the orbital sander. The shape of the grip requires the operator to use a fingertip grip to control the tool. More muscular force is required to maintain a fingertip grip than for a full hand or power grip (in which there is some overlap of the fingers and thumb).

Major Positive Features:

- high friction slip resistant grip to minimize grip forces; and
- large trigger to spread force over a large surface area of the hand.

Major Drawbacks:

- excessive fingertip forces required to control tool;
- tool weight is marginally excessive; and
- vacuum hose restricts movement.

In addition, the frame of the vacuum assembly has hard edges which press into the skin and it is heavy (20 lbs..). This discourages personnel from wearing the vacuum. This can be seen in **Figure 4.7**.

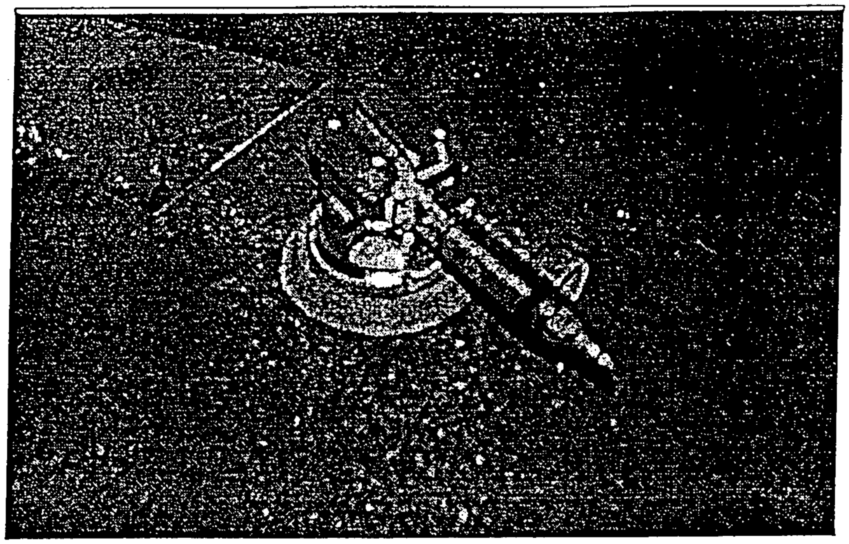


Figure 4.6. Orbital Sander

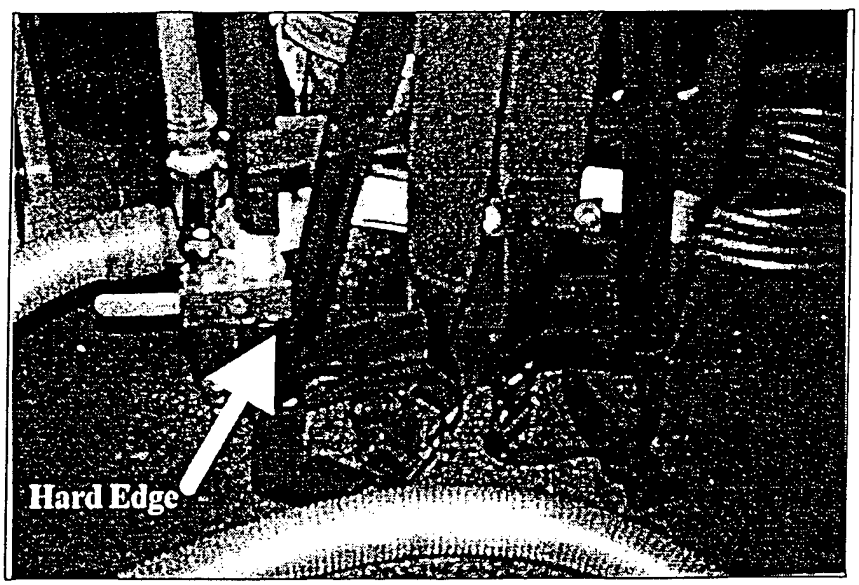


Figure 4.7. Portable vacuum (hard edges left side of picture)

Conclusion: Medium Risk; Opportunities exist to improve the sander.

Table 4.31
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996			Evaluator: Van Calvez, The Joyce Institute		
Job: Sanding Aircraft Components			Type: Orbital Sander		
Manufacturer: Dynabrade			Model Number: 57034		
Model Name: Orbital Sander			Price: Information not available		
Category	Parameter	Measure	Meets Criteria Yes	Meets Criteria No	N/A or Comments
General	Handedness	Tool should be easily used with either the left or right hand.	X		
	Repetition	Tool should minimize repetitive movements.	X		
	Ease of Use	Tool should be easy to use.	X		
	Ease of Maintenance	Tool should be easy to maintain.	X		
Grip Angle	Wrist and Arm Posture	Handle angle and location should allow a straight wrist and neutral arm position while the tool is being used.	X	X	Good for sanding a vertical surface (shoulder high); not as good for overhead surfaces.
	Back and Neck Posture	Handle angle and location should allow the user to see the work without having to tilt or bend the head or back.	X		
Force Requirements	Activation Forces	**Full hand** grip forces required to use tool should be less than 8 lbs (3.6 kg).	X		
		Fingertip grip force required to use tool should be less than 2 lbs (0.91 kg).		X	Continuous applied forces = 10-12 lbs.
	Two hand activation	Tool should allow two hands when applied forces are high or when additional control is needed.	X		
	Tool Weight	Tool (and associated cables/hoses) should weigh less than 5 lbs (2.3 kg) or be mechanically supported.		X	Marginal, tool weighs 5 lbs.
	Tool Balance	Tool's center of gravity should be close to or at the grip location.	X		

Table 4.31 (cont'd)
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996			Evaluator: Van Calvez, The Joyce Institute		
Job: Sanding Aircraft Components			Type: Orbital Sander		
Manufacturer: Dynabrade			Model Number: 57034		
Model Name: Orbital Sander			Price: Information not available		
Category	Parameter	Measure	Meets Criteria		N/A or Comments
			Yes	No	
Force Requirements Cont'd	Cable/Hose Attachment	Cables and hoses should be Attached to minimize interference and drag.		X	Vacuum. Hose restricts movement.
	Handle Surface	Grip surfaces should be high friction and slip-resistant.	X		
		Grip surfaces should be compressible.	X		
	Handle Shape	There should be no hard/sharp edges or abrupt curves that the contact user's hand or body. Avoid ridges or channels for individual fingers.		X	May be exposure to hard edges at base of palm for larger hands.
	Handle for Torquing Tools	For torquing tools, the handle should be long enough to prevent grip forces above 8 lbs (3.6 kg).			X
Force Requirements Cont'd	Trigger Force	Force required to activate the trigger should be insignificant (considerably less than 1 lbs or 0.5 kg).	X		Forces less than 1 lb.
	Trigger Function	Tool should avoid continuous activation of a trigger.	X		Continuous activation required for tool safety, full hand trigger is OK.
	Connection Force	Force required to connect/disconnect the power tool should be insignificant.	X		

Table 4.31 (cont'd)
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996			Evaluator: Van Calvez, The Joyce Institute		
Job: Sanding Aircraft Components			Type: Orbital Sander		
Manufacturer: Dynabrade			Model Number: 57034		
Model Name: Orbital Sander			Price: Information not available		
Category	Parameter	Measure	Meets Criteria		N/A or Comments
			Yes	No	
	Spring Release (Plier-Type Tools)	Plier-type tools should have a spring release mechanism. The spring tension should be minimal.			X
Handle Size	Grip Diameter	Grip Diameter for a full hand grip tool should be between 1-1.5" (2.5-3.8 cm).		X	Grip design requires fingertip grip. Grip dimensions 3"x3"x1 3/4"
		Grip Diameter for a fingertip grip tool should be between 0.25-0.5" (0.6-1.3 cm).			X
		It should also be possible to increase the diameter of the handle if needed.	X		It is possible to add material to the handle but it is not advised
	Handle Span on Plier-Type Tools	Plier-type tools should have a span of less than 3" (7.6 cm).			X
	Total Grip Length	4" (10.2 cm) minimum, 5" (12.7 cm) preferred.		X	3" handle length too short.
Trigger/ Buttons	Trigger/ Button Location	Triggers and buttons should be positioned to prevent extension of fingers or the thumb.	X		
	Trigger/ Button Shape	Trigger should have large smooth curves. No hard edges or points (particularly at the end of the trigger).	X		
	Trigger Length	1.5" (3.8 cm) minimum, 2-2.5" (5.1-6.4 cm) preferred	X		Trigger length 2.5"
	Trigger Width	0.5-1.0" (1.3-2.5 cm).	X		Trigger width 1"
	Trigger Ridge Depth	0.125" - 0.375" (0.318-0.953 cm).			X

Table 4.31 (cont'd)
Hand Tool/Power Tool Evaluation Worksheet

Date: November 27, 1996			**Evaluator:** Van Calvez, The Joyce Institute		
Job: Sanding Aircraft Components			**Type:** Orbital Sander		
Manufacturer: Dynabrade			**Model Number:** 57034		
Model Name: Orbital Sander			**Price:** Information not available		
Category	Parameter	Measure	Meets Criteria		N/A or Comments
			Yes	No	
	Trigger Range of Movement	Trigger should have a small range of movement.	X		Range less than 1"
Misc.	Heat Conduction	Tool handle should be coated or rubberized (tool handles should not be bare metal).	X		
	Routing of Air Exhaust	Air powered tools should not blow cold air on hands.			X, no info. available.
	Torque/ Impact	Tool should not expose the user to excessive torque or impact.		X	
	Vibration	Tool should not expose the user to excessive vibration.	X		

4.5.6 Overall Findings: Sanding Paint Off Aircraft

The following information summarizes the results of the Level II Ergonomic Analysis.

The primary body regions of concern in this job/task are the shoulders/neck, hands/wrists/arms, and knees/feet. To a lesser extent, there is risk to the back/torso as well. As shown in **Table 4.32**, the major job factors are: prolonged and awkward shoulder, back, neck and wrist postures, prolonged hand forces and exposure to vibration. Table 4.32 also summarizes the results of the Level II Ergonomic Analysis for each of the critical tasks and for the job as a whole.

Table 4.32. Summary of Level II Analysis Results

Critical Tasks	Analysis Method	Risk Rating (Body Regions)	Job Factors	Workplace Causes
• Sanding	• Dynamic • Postural	• Medium (Shoulders/ Neck)	• Static and continuous awkward shoulder/ neck postures	• Overhead work • Body posture during overhead work
		• Medium (Hands/ Wrists/Arms)	• Awkward wrist postures	• Holding the orbital grinder at a 45 degree angle to the surface • Sanding a horizontal surface overhead
		• Medium (Back/Torso)	• Static and continuous forward bending	• Sanding at floor level
		• Medium (Knees/Feet)	• Static and continuous kneeling	• Sanding at floor level
	• Grip Force	• Medium (Hands/ Wrists/Arms)	• Static and continuous high force pinch grips	• Design of sander handle • Weight of sander and hoses • Restriction of hoses
	• Vibration	• Medium (Hands/ Wrists/Arms)	• Exposure to vibration to the hand/arm	• Vibration from the orbital sander • Design of sander • Maintenance of sander • Condition of sand paper

Due to the Medium risk rating for at least one analysis method, the risk rating for the overall job is **Medium**.

4.5.7 Recommended Control Options: Sand Aircraft Components

The control options are categorized in terms of short-term and long-term controls. Appendix D defines these different levels of controls.

The goals of corrective actions should involve the elimination or reduction of these job factors by eliminating their causes. The following list of control options seeks to reduce these key job factors.

4.5.7.1 Sanding

4.5.7.1.1 Short-Term Recommendations (Current Fiscal Year)

These are minor modifications that are expected to be within the capabilities of the shop to implement within the current fiscal year.

- *Encourage personnel to vary body positions.(WPR)* Being in any posture over a long period of time can result in build-up of static muscular fatigue. Therefore, it is always a good practice to vary body postures every few minutes. For example, exchanging hands periodically or adjusting hand positions can reduce the fatigue in the hands.

- *Encourage personnel to take frequent rest pauses.(ADM)* Encourage personnel to take rest pauses of 30 seconds to 2 minutes at least once every 15 minutes.

- *Conduct ergonomic training for employees.(WPR)* Provide training to employees in ergonomic principles and work practices. It is recommended that this training include a "hands-on" portion in the shop to allow personnel to have an opportunity to practice good techniques. In particular, the training could emphasize rest pauses, fatigue reducing exercises, and other health/comfort strategies. **Caution!!!: Do not conduct ergonomic training without first implementing at least some workplace controls. Conducting training without implementing appropriate workplace changes can be counter productive because personnel may perceive that management is avoiding its responsibilities.**

4.5.7.1.2 Long-Term Recommendations (Next Fiscal Year)

These are more extensive controls that are expected to be within the capabilities of the shop to implement within the next fiscal year.

- *Provide a sander which incorporates vibration dampening technology.(ENG)* Provide a sander which has vibration dampening mechanisms or materials built into the tool body or handle.

- *Provide a sander with a more appropriate handle design.(ENG)* Provide a sander which allows a power/full-hand grip (i.e., contact with the palm and slight overlap of the thumb over fingers) while using the sander. Provide a sander with an adjustable handle angle to encourage straight wrists for a variety of orientations. Handle should have a pistol-grip orientation for vertical surfaces. Handle should have an in-line (straight) grip for horizontal surfaces.

- *Provide a sander with improved vacuum capabilities.(ENG)* This might include placing the vacuum intake holes on the sander closer to the perimeter on the sanding face. Also consider a 45-degree guide attachment to provide containment for particles and to help guide particles into the vacuum. This guide could also make it easier to hold the sander at a 45-degree angle.

- *Provide a longer hose for the vacuum.(ENG)* This will reduce restriction of movements. In addition, investigate sanders which integrate the vacuum line and air line into one hose.

  Three potential sources for sanders are provided below:

  1. Atlas Copco, Farmington Hills, MI, (800) 859-3746;
  2. Cooper Power Tools, Lexington, SC, (800) 359-1200; and
  3. Ingersoll - Rand Power Tools, Elmhurst, IL, (800) 323-1035.

- *Provide a mobile tool balancer.(ENG)* Consider providing an over-head mounted tool balancer/support for sanders. The tool balancer should have a hook/suction cup that allows the balancer to be repositioned. Note: Tool balancers work less effectively in cases when the surface being sanded is horizontal (e.g., overhead work). Tool balancers are more effective when the surface being sanded is vertical.

  Three potential sources for tool balancers are provided below:

  1. Aimco, Portland, OR, (508) 254-6600;
  2. Coilhose Pneumatics, Middlesex, NJ (908) 752-5000; and
  3. Pate Manufacturing, Wadsworth, IL, (708) 263-9162.

Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

4.5.7.1.3 Long-Term Recommendations (Coordinated Initiatives)

These are major changes that may be beyond the capabilities of the shop to implement alone.

- *Provide support for the arms while sanding overhead.(ENG)* Where sanding activities require the arms to be held away from the body for prolonged periods and it is not possible to reposition the work (e.g., non-removable sections of aircraft), one strategy is to provide support for the arms via mechanical armrests (see **Figure 4.8** for an example of an armrest concept). These arm rests should have the following features:

  - padded-compressible surface to rest the arms for a variety of work heights;
  - secured to the person so that they move as the person moves;
  - adjustable in height and distance away from the body;
  - light-weight;
  - easy to clean and adjust;
  - easy to put on and remove;
  - easily removable in case of emergency; and
  - durable, anti-static material.

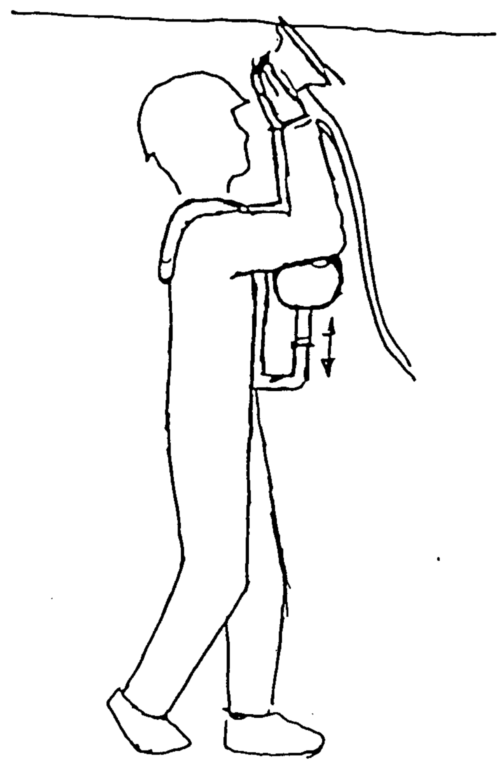


Figure 4.8. Armrest concept

- *Provide a bench to support the head and upper body while performing overhead and floor level work.(ENG)* For prolonged overhead work on horizontal surfaces (where repositioning the work is not possible), a bench which supports the head and upper body could be provided (See Figure 4.9 for an illustration of this concept). In some cases, this recommendation could be combined with the armrest concept described above to provide support for the arms, upper body, and head. The bench should have the following features:

  - provide compressible surfaces to support the upper body and head;
  - adjustable in height and angle of the bench (In some cases, it may be necessary for the bench to be raised within a few feet of an overhead horizontal surface in order to minimize reaching.);
  - separate support for the head which is independently adjustable from the torso support; and
  - easily transported and repositioned for different task (i.e., light weight and foldable).

  It may be possible to combine the bench to allow it to be used for prolonged floor level work (or below floor level work) as well as overhead work. It is also possible that separate benches will be needed for these different tasks.

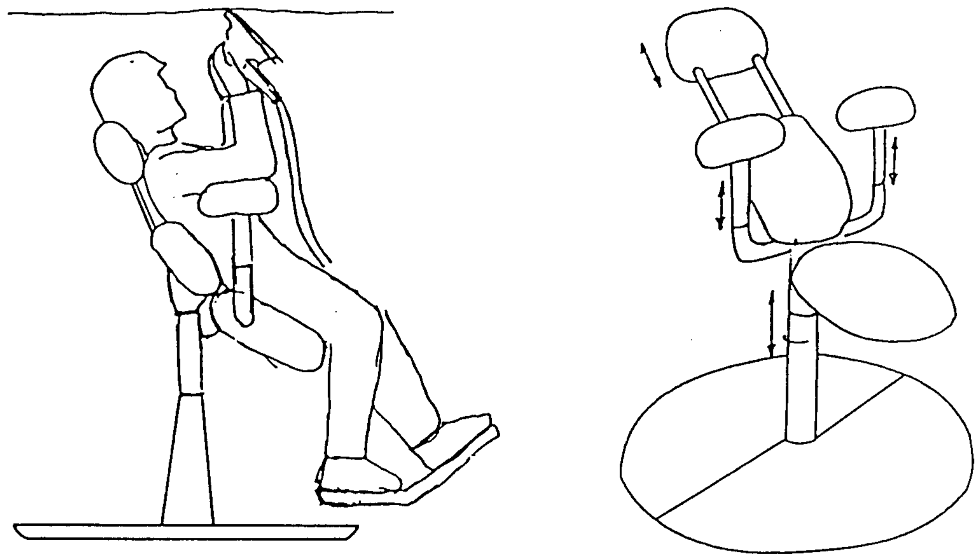


Figure 4.9. Head and torso support device concept

Three potential sources are provided below:

1. Corel, Mansfield, OH, (800) 537-5573;
2. David Eric, Inc., Merion, PA, (610) 896-2180; and
3. Eidos Corp, Lincoln, NE (402) 466-1119.

Note: The sources provided in this report have not been evaluated by EARTH TECH or The Joyce Institute/Arthur D. Little for their quality, cost, or applicability to a particular task. The end-user is responsible for evaluating potential tools/equipment to determine if it meets the technical requirements. Tools/equipment identified may be selected for ergonomic quality *only in relation to a specific task within a given environment.*

- *Investigate alternative vacuum technologies.(ENG)* Consider alternative vacuum systems (such as central vacuums) that do not require personnel to carry a vacuum from location to location.

5.0 CONCLUSION

5.1 Factors for Successful Implementation

Several factors will affect the successful implementation of effective ergonomic controls for the identified risks:

- The ability of shop management and the BEF to successfully involve the people who perform the jobs in the process of implementing controls. In most cases, successful implementation is an on-going communication process that will happen only with continued involvement of the people who perform the jobs.

- The ability to contact other AFBs to obtain information regarding controls currently utilized by these bases. Several existing solutions are being utilized by other bases that could be implemented at Dover.

- The selection of a person (or persons) responsible for following each project through to successful completion.

5.2 Trends from the Results

As the project progressed, it became apparent that several basic types of controls are needed:

- Devices to support the torso, head, or arms while working overhead, at floor level, or in other awkward locations on aircraft.

- Small, easy-to-use mechanical lift devices for handling medium weight components (e.g., 50-300 pounds) in restricted spaces.

- Light-weight, low force, and low vibration power tools for general or specialized tasks.

It is probable that these types of controls would be applicable throughout the Air Force. In some cases, the recommended control may not be commercially available and would require development. However, considering the large population that could potentially benefit, the development of these controls is highly encouraged.

5.3 Final Comment

The Air Force can significantly reduce WMDs and improve operations by implementing many of the control measures that are included in this report.

APPENDIX A

Job Requirements and Physical Demands Survey

JOB REQUIREMENTS AND PHYSICAL DEMANDS SURVEY

ob Requirements and Physical Demands Survey	Date (YYMMDD)	Workplace Identifier:	
(use this space for mechanical imprint)		Base	Organization
		Workplace	
		Bldg. No/Location	Room/Area
		AFSC/Job Series	

Gender:	Female ○	Male ○			
Work Group:	Civilian ○ Grade:__________	Military ○ Rank:__________			
Age Category:	20 and under ○	21-30 ○	31-40 ○	over 40 ○	
Length of service at this base:	less than one year ○	more than one year ○			
Length of time in current shop:	less than one year ○	more than one year ○			
Have you completed this questionnaire before?	Yes ○	No ○			

Part I - Job Factors

This section enables you to describe what is involved in your job. Indicate how long you do this work on approximately a daily basis.

A. DESCRIPTION OF WORK

SHOULDER / NECK

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
1. I work with my hands at or above chest level. *(Figure A.)*	○	○	○	○
2. To get to or to do my work, I must lay on my back or side and work with my arms up.	○	○	○	○
3. I must hold or carry materials (or large stacks of files) during the course of my work.	○	○	○	○
4. I force or yank components or work objects in order to complete a task.	○	○	○	○
5. I reach or hold my arms in front of or behind my body (e.g., using a keyboard, filing, handling parts, performing inspection tasks, pushing or pulling carts, etc.). *(Figures B.)*	○	○	○	○
6. My neck is tipped forward or backward when I work. *(Figure C.)*	○	○	○	○
7. I cradle a phone or other device between my neck and shoulder. *(Figure D.)*	○	○	○	○

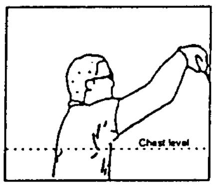


Figure A.

Figure B.

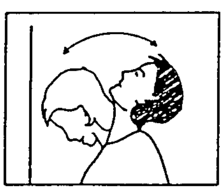


Figure C.

Figure D.

Part I - Job Factors (continued)

HAND/WRIST/ARM

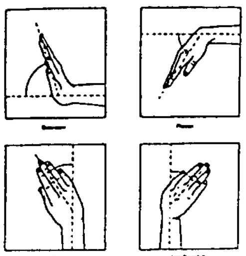


Figure E.

Figure F.

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
8. My wrists are bent (up, down, to the thumb or little finger side) while I work. *(Figure E.)*	O	O	O	O
9. I apply pressure or hold an item/material/tool (e.g., screw driver, spray gun, mouse, etc.) in my hand for longer than 10 seconds at a time.	O	O	O	O
10. My work requires me to use my hands in a way that is similar to wringing out clothes. *(Figure F.)*	O	O	O	O
11. I perform a series of repetitive tasks or movements during the normal course of my work (e.g., using a keyboard, tightening fasteners, cutting meat, etc.).	O	O	O	O
12. The work surface (e.g., desk, bench, etc.) or tool(s) that I use presses into my palm(s), wrist(s), or against the sides of my fingers leaving red marks on or beneath the skin.	O	O	O	O
13. I use my hand/palm like a hammer to do certain aspects of my work.	O	O	O	O
14. My hands and fingers are cold when I work.	O	O	O	O
15. I work at a fast pace to keep up with a machine production quota or performance incentive.	O	O	O	O
16. The tool(s) that I use vibrates and/or jerks my hand(s) and arms(s).	O	O	O	O
17. My work requires that I repeatedly throw or toss items.	O	O	O	O
18. My work requires me to twist my forearms, such as turning a screwdriver.	O	O	O	O
19. I wear gloves that are bulky, or reduce my ability to grip.	O	O	O	O
20. I squeeze or pinch work objects with a force similar to that which is required to open a lid on a new jar.	O	O	O	O
21. I grip work objects or tools as if I am gripping tightly onto a pencil.	O	O	O	O

Part I - Job Factors (continued)

BACK/TORSO

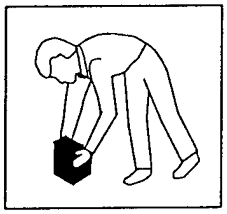


Figure G.

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
22. When I lift, move components, or do other aspects of my work, my hands are lower than my knees. *(Figure G.)*	O	O	O	O
23. I lean forward continually when I work (e.g., when sitting, when standing, when pushing carts, etc.).	O	O	O	O
24. The personal protective equipment or clothing that I wear limits or restricts my movement.	O	O	O	O
25. I repeatedly bend my back (e.g., forward, backward, to the side, or twist) in the course of my work.	O	O	O	O
26. When I lift, my body is twisted and/or I lift quickly. *(Figure H.)*	O	O	O	O

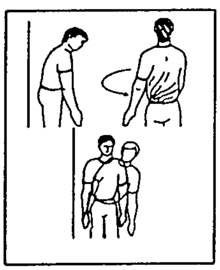


Figure H.

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
27. I can feel vibration through the surface that I stand on or through my seat.	O	O	O	O
28. I lift and/or carry items with one hand. *(Figure I.)*	O	O	O	O

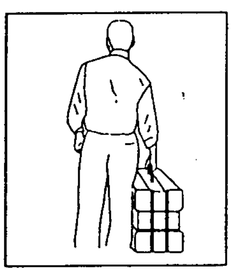


Figure I.

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
29. I lift or handle bulky items.	O	O	O	O
30. I lift materials that weigh more than 25 pounds.	O	O	O	O

Part I - Job Factors (continued)

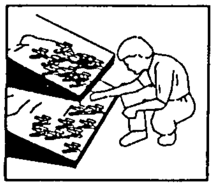


Figure J.

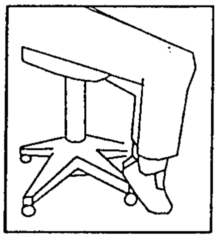


Figure K

LEGS / FEET

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
31. My work requires that I kneel or squat. *(Figure J.)*	O	O	O	O
32. I must constantly move or apply pressure with one or both feet (e.g., using foot pedals, driving, etc.).	O	O	O	O
33. When I'm sitting, I cannot rest both feet flat on the floor. *(Figure K.)*	O	O	O	O
34. I stand on hard surfaces.	O	O	O	O

HEAD / EYES

	Never	0-2 hrs.	2-4 hrs.	4-8 hrs.
35. I can see glare on my computer screen or work surface.	O	O	O	O
36. It is difficult to hear a person on the phone or to concentrate because of other activity, voices, or noise in/near my work area.	O	O	O	O
37. I must look at the monitor screen constantly so that I do not miss important information (radar scope).	O	O	O	O
38. It is difficult to see what I am working with (monitor, paper, parts, etc.).	O	O	O	O

Part I - Job Factors (continued)

B. ORGANIZATIONAL FACTORS

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
39. I often feel unclear on what the scope and responsibilities of my job are.	O	O	O	O	O
40. I often feel that I have too heavy of a workload, one that I could not possibly finish during an ordinary workday.	O	O	O	O	O
41. I often feel that I will not be able to satisfy the conflicting demands of various people around me.	O	O	O	O	O
42. I often find myself unable to get information needed to carry out my job.	O	O	O	O	O
43. I often do not know what my supervisor thinks of me, how he/she evaluates my performance.	O	O	O	O	O
44. I often think that the amount of work I have to do interferes with how well it's done.	O	O	O	O	O

C. PHYSICAL EFFORT

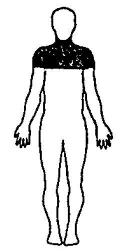
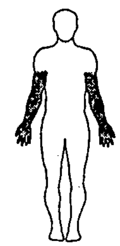
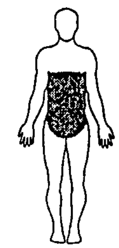
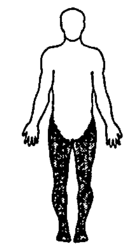
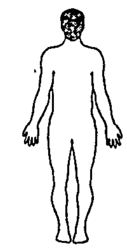
45. How would you describe the physical effort required of your job?

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
No exertion at all	Extremely light		Very light		Light		Somewhat hard		Hard		Very hard		Extremely hard	Maximal exertion
O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Part ... - Your Body's Response to Work Demands

D. DISCOMFORT FACTORS

This section enables you to identify how your body responds to the demands of *your job*. In each section, answer the first question. If the answer is "no" go to the next column.

Question	 Shoulder/Neck	 Hands/Wrists/Arms	 Back/Torso	 Legs/Feet	 Head/Eyes
• In the past 12 months, have you experienced any discomfort, fatigue, numbness, or pain that ***relates to your job***?	46. Yes O No O *If "no", go to question 49*	49. Yes O No O *If "no", go to question 52*	52. Yes O No O *If "no", go to question 55*	55. Yes O No O *If "no", go to question 58*	58. Yes O No O *If "no", go to question 61*
• How often do you experience discomfort, fatigue, numbness, or pain in this region of the body?	47. Daily O Weekly O Monthly O	50. Daily O Weekly O Monthly O	53. Daily O Weekly O Monthly O	56. Daily O Weekly O Monthly O	59. Daily O Weekly O Monthly O
• On average, how severe is the discomfort, fatigue, numbness, or pain in this region of the body?	48. Mild O Moderate O Severe O	51. Mild O Moderate O Severe O	54. Mild O Moderate O Severe O	57. Mild O Moderate O Severe O	60. Mild O Moderate O Severe O

Part II - Your Body's Response to Work Demands (continued)

E. GENERAL QUESTIONS

61. In the past 12 months, have you seen a health care provider for any pain or discomfort that you think **relates to your job**? Yes O No O

62. Do you experience any work-related pain or discomfort that does not improve when you are away from work overnight or over the weekend? Yes O No O

63. In the past 12 months, has any work-related pain or discomfort caused you difficulty in carrying out normal activities (e.g., job, hobby, leisure, etc.)? Yes O No O

64. Has a health care provider ever told you that you have any of the following conditions which you think might be **related to your work**? Yes O No O

- Tendonitis/Tenosynovitis
- Epicondylitis (Tennis Elbow)
- Thoracic Outlet Syndrome
- Ganglion Cyst
- Bursitis
- Back Strain
- Trigger Finger
- Carpal Tunnel Syndrome
- Knee or Ankle Strain
- Overuse Syndrome

65. Do you have or have you ever had one or more of the following conditions? Yes O No O

- Wrist Fracture
- Thyroid Disorder
- Rheumatoid Arthritis
- Hypertension
- Diabetes
- Kidney Disorders
- Gout

Part III - Work Content

The section below will enable you to describe the content of the work that you do in your current shop.

Fill in the box that describes how frequently you do the task listed, based on the following definitions:

- **Routine:** Performed on three or more days per week.
- **Non-routine:** Performed two days a week or less.
- **Seasonal:** Performed only during certain times of the year
- **Never/NA:** You do not perform this type of work.

No.	Type of Work	Work Frequency (Check one)			
		Routine	Non-Routine	Seasonal	Never/NA
66.	abrading	O	O	O	O
67.	baking	O	O	O	O
68.	bolting/screwing	O	O	O	O
69.	calling (telephone use)	O	O	O	O
70.	chipping	O	O	O	O
71.	cleaning by hand	O	O	O	O
72.	cleaning with high pressure equipment	O	O	O	O
73.	coating/immersing	O	O	O	O
74.	cooking	O	O	O	O
75.	copying	O	O	O	O
76.	crimping	O	O	O	O
77.	cutting/shearing	O	O	O	O
78.	drafting/CAD system use	O	O	O	O
79.	drilling	O	O	O	O
80.	driving (vehicles)	O	O	O	O
81.	excavating	O	O	O	O
82.	filing/general administrative	O	O	O	O
83.	flame cutting/arc cutting	O	O	O	O
84.	folding/fitting	O	O	O	O
85.	gluing/laminating	O	O	O	O
86.	grinding/buffing/polishing	O	O	O	O
87.	hammering	O	O	O	O
88.	lifting	O	O	O	O
89.	loading (pallets, trucks, carts, aircraft)	O	O	O	O
90.	lubricating	O	O	O	O

Part III - Work Content (Continued)

No.	Type of Work	Work Frequency (Check one)			
		Routine	Non-Routine	Seasonal	Never/NA
91.	machining	○	○	○	○
92.	masoning	○	○	○	○
93.	melting	○	○	○	○
94.	molding	○	○	○	○
95.	monitoring (visual displays)	○	○	○	○
96.	mousing (for computer work)	○	○	○	○
97.	nailing	○	○	○	○
98.	opening/closing heavy doors	○	○	○	○
99.	packing/packaging	○	○	○	○
100.	painting/spray painting	○	○	○	○
101.	paving	○	○	○	○
102.	pumping (by hand)	○	○	○	○
103.	riveting/bucking	○	○	○	○
104.	sanding	○	○	○	○
105.	sawing	○	○	○	○
106.	scanning (using bar code readers)	○	○	○	○
107.	sewing	○	○	○	○
108.	soldering/brazing	○	○	○	○
109.	stapling	○	○	○	○
110.	stripping/depainting by hand	○	○	○	○
111.	stripping/depainting mechanically	○	○	○	○
112.	transporting loads on non-powered carts	○	○	○	○
113.	turning valves	○	○	○	○
114.	tying/twisting/wrapping	○	○	○	○
115.	typing/keying	○	○	○	○
116.	welding	○	○	○	○
117.	wheeling loads	○	○	○	○
118.	wiring	○	○	○	○
119.	wrenching/ratcheting	○	○	○	○
120.	writing/illustrating	○	○	○	○
	(Write in others)				
121.	______________________	○	○	○	○
122.	______________________	○	○	○	○

Part IV - Process Improvement Opportunities

Think about your job as a whole, including routine, non-routine or seasonal work.

Read the questions listed below and describe the activities that you or your co-workers think place the greatest demands on your body.

1. Which tasks are the most awkward or require you to work in the most uncomfortable positions?

2. Which tasks take the most effort?

3. Are there any tools or pieces of equipment that are notoriously hard to work with? (If so, list them below)

4. If you could make any suggestions that would help you do your job more easily or faster or better, what would you suggest?

Job Requirements and Physical Demands Survey

Scoring Sheets

SCORING SHEET

Although there are many ways to score the survey, we recommend that you work through one survey at a time, completing the parts as indicated. Make sure your tally marks are small enough so you have room for the entire ɔp.

Part I - Job Factors
A - Risk Factor Ratings (Questions 1 - 38)

Step 1	Step 2	Step 3	Step 4
For each body area, count the number of responses in the 2-4 hour column and in the 4-8 hour column. If that number exceeds the criteria number in the box in the upper right, make one tally mark. Place only one mark per survey in each box. Write the total of the tallies in the Total box.	Divide the Total tallies by the number of surveys from one shop.	Multiply that number by 100 to get the percentage.	Write the Risk Factor Rating (Low, Med, High) in the box for each body part using the scale below. Low ≤30% · Med 31 - 60% · High 61+%
Shoulder/Neck Tally Box [2] Questions 1-7 Total	number of surveys ÷ _____ = _____	x 100 = _______%	A.1 Shoulder/Neck Risk Factor Rating [ ]
Hand/Wrist/Arm Tally Box [4] Questions 8-21 Total	number of surveys ÷ _____ = _____	x 100 = _______%	A. 2 Hand/Wrist/Arm Risk Factor Rating [ ]
Back/Torso Tally Box [2] Questions 22-30 Total	number of surveys ÷ _____ = _____	x 100 = _______%	A.3 Back/Torso Risk Factor Rating [ ]
Legs/Feet Tally Box [1] Questions 31-34 Total	number of surveys ÷ _____ = _____	x 100 = _______%	A.4 Legs/Feet Risk Factor Rating [ ]
Head/Eyes Tally Box [1] Questions 35-38 Total	number of surveys ÷ _____ = _____	x 100 = _______%	A.5 Head/Eyes Risk Factor Rating [ ]

SCORING SHEET

Part I - Job Factors
B - Organizational Factors (Questions 39-44)

Step 1	Step 2	Step 3	Step 4	Step 5
For each question that has a response of a 4-Agree or 5-Strongly Agree, make a tally in the tally box. Write the total tallies in the Total box.	Divide by 6	Divide by the number of surveys from one shop.	Multiply that number by 100 to get the percentage.	Write the Organizational Factor Rating (Low, Med, High) in the box based on the scale below: Low ≤30% · Med 31-60% · High 61+%
Tally Box 1 Total	÷ 6 = ______	÷ ______ (number of surveys) = ______	x 100 = ______%	B. Organizational Factor Rating

Part I - Job Factors
C - Physical Effort Score (Question 45)

Step 1	Step 2	Step 3
Write the numeric score (6-20) for each survey in the tally box. Add the numbers and write the total in the total box.	Divide that total by the number of surveys.	Write the average in the Physical Effort box.
Tally Box Total	÷ ____________ (number of surveys) =	C. Physical Effort Factor Score

SCORING SHEET

Part II - The Body's Response to Work Demands - Discomfort Rating (Questions 46 - 60)

Step 1	Step 2	Step 3	Step 4
For each body part, look at the responses to the second and third questions (47 & 48, 50&51, 53&54, 56&57, 59&60). If participants have answered them, then look at the Criteria Table. If the combination of answers fits one of the categories, then make a tally mark in the tally box for each body part. For example: if 47 is "weekly" and 48 is "moderate" then make a tally mark. Count and put total in Total box.	Divide the total tallies by the number of surveys from one shop.	Multiply that number by 100 to get the percentage.	Write the Discomfort Rating (Low, Med, High) in the box for each body part using the scale below. Low ≤30% · Med 31 - 60% · High 61+%

Criteria Table

	Mild	Moderate	Severe
Daily			
Weekly			
Monthly			

Shoulder/Neck Tally Box Question 46-48 Total	number of surveys ÷ _____ = _____ x 100 = _______%	D.1 Shoulder/Neck Discomfort Rating
Hand/Wrist Arm Tally Box Question 49-51 Total	number of surveys ÷ _____ = _____ x 100 = _______%	D.2 Hand/Wrist/Arm Discomfort Rating
Back/Torso Tally Box Question 52-54 Total	number of surveys ÷ _____ = _____ x 100 = _______%	D.3 Back/Torso Discomfort Rating
Legs/Feet Tally Box Question 55-57 Total	number of surveys ÷ _____ = _____ x 100 = _______%	D.4 Legs/Feet Discomfort Rating
Head/Eyes Tally Box Question 58-60 Total	number of surveys ÷ _____ = _____ x 100 = _______%	D.5 Head/Eyes Discomfort Rating

SCORING SHEET

Part II - The Body's Response
E - General Questions (Questions 61 - 65)

Step 1	Step 2
Look at question 61 and tally only the "yes" answers in the tally box for that question. Count and write the total in the total box.	Write the total in the Health Care Provider Visit score box.
Question 61 Tally Box Total	E.1 Health Care Provider Visit Score

Step 1	Step 2	Step 3	Step 4
Look at each question and tally only the "yes" answers in the tally box for that question. Count and write the total in the Total box.	Divide the total tallies for that question by the number of surveys.	Multiply that number by 100 to get the percentage.	Write the shop percentage in the box provided.
Question 62 Tally Box Total	number of surveys ÷ _____ = _____ x 100 =		E.2 Recovery Time Score %
Question 63 Tally Box Total	number of surveys ÷ _____ = _____ x 100 =		E.3 Activity Interruption Score %
Question 64 Tally Box Total	number of surveys ÷ _____ = _____ x 100 =		E.4 Previous Diagnosis %
Question 65 Tally Box Total	number of surveys ÷ _____ = _____ x 100 =		E.5 Contributing Factors Score %

SCORING SHEET

Part III
Work Content (Items 66-122)

Step 1		Step 2	Step 3	Step 4	Step 5
In the space below, list item number(s) and corresponding type(s) of work that are performed on a "Routine" basis.		For each Routine Type of Work, tally the number of responses. Count and write the total in the total box.	Divide the total tallies for each type of work by the number of surveys.	Multiply that number by 100 to get the percentage.	Write in the shop percentile in the box provided.
Item #	Type of Work				
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %
		Tally Box / Total	÷ _______ = _______	X 100	F %

Job Requirements and Physical Demands Survey

Summary Report

SUMMARY REPORT

ERPA Status:		Priority Ranking:		Date:	
Date:		Workplace Identifier:		Base:	
Organization:		Workplace:		Bldg./Location:	
Room/Area		AFSC:		Civilian Job Series:	
Shop Supervisor:		Duty Phone:		Office Symbol:	

Step 1	Step 2	Step 3	
Write in the Risk Factor Rating for Part I, (questions 1-38, Scoring Sheet pg.1)	Write in the Discomfort Rating for Part II, (questions 46-60, Scoring Sheet pg.3)	Look at the "Ranking Matrix" below and enter the **Priority Score** in it's corresponding box.	
A.1	D.1	**Shoulder/Neck =**	
A.2	D.2	**Hands/Wrist/Arms =**	
A.3	D.3	**Back/Torso =**	
A.4	D.4	**Legs/Feet =**	
A.5	D.5	**Head/Eye =**	

Ranking Matrix

Ranking Matrix for Priority Score	Discomfort High	Discomfort Medium	Discomfort Low
Risk Factor High	9	7	4
Risk Factor Medium	8	5	2
Risk Factor Low	6	3	1

Select the HIGHEST score for any body part from Step 3 and enter →

Survey Priority Rank:

SUMMARY REPORT

Step 4

B. Enter Organizational Factor Rating: (Questions 39-44, Scoring Sheet pg. 2) ____ %	**Comments:**

Step 5

C. Enter Physical Effort Factor Score: (Question 45, Scoring Sheet pg.2) ____	**Comments:**

Step 6

E. Enter the score for each of the **General Questions:** (Questions 61-65, Scoring Sheet pg. 4)

E.1 Health Care Provider Score ______	**Comments:**
E.2 Recovery Time Score ______ %	**Comments:**
E.3 Activity Interruption Score ______ %	**Comments:**
E.4 Previous Diagnosis Score ______ %	**Comments:**
E.5 Contributing Factors Score ______ %	**Comments:**

Step 7

F. List below each of the routine types of work which had shop percentage scores over 20%. (Items 66-122, scoring sheet page 5)

Type of Work	%	Type of Work	%

Summary Report

Step 8	
~~Re~~view Part IV (Questions 1-3) to identify tasks, tools, equipment, etc., that employees listed as potential concerns. Comment as appropriate.	**Comments:**
Review Part IV (Question 4) to identify potential improvement opportunities. Comment as appropriate.	**Comments:**
Step 9	
Injury/Illness Data: Review the injury/illness history from this shop. Attach information and comment as appropriate.	**Comments:**

Step 10
Conclusions / Recommendations Summary

Shop Status

Recommendations for follow-up:

LEVEL II ANALYSIS	PRIMARY ANALYSIS PROCESS	M/I	WAREHOUSE	ASSEMBLY
POSTURAL ANALYSIS				
• Applies to jobs which require work in fixed postures • Focuses on upper limb, torso, lower limb	• Use of videotape goniometers and software	XX	N/A	X
DYNAMIC TASK ANALYSIS				
• Applies to jobs with long cycle times (could be used on job which spans several hours) • Focuses on movement of the whole body	• Videotape time-based analysis • Involves dividing a large job into manageable sub tasks that can be analyzed quickly (general hours)	XX	XX	X
ELEMENTAL TASK ANALYSIS				
• Applies to short cycle jobs whose tasks repeat • Focuses on hand/wrist, elbow/shoulder, posture, force, duration, and repetition	• Videotape-based, freeze frame analysis • Involves dividing a short cycle job into sub tasks so rates of repetition can be measured	X	N/A	XX
GRIP FORCE MEASUREMENT				
• Applies to individual sub tasks in a job • Focuses on hand and finger force	• Use of hand and finger dynamometers to estimate grip forces for individual task elements	XX	X	XX
PUSH/PULL ANALYSIS				
• Applies to jobs whose tasks involve pushing or pulling (carts, components, etc.) • Focuses on designing jobs for maximum percent capable in worker population	• Use of push/pull gauge to estimate push/pull forces in a job • Estimates compared to table values	XX	XX	N/A
BIOMECHANICAL LIFTING ANALYSIS				
• Applies to any job which involves lifting • Measures/estimates disc compressive force on L5/S2 disc as measure of risk for low back	• Video-based analysis which uses posture, employee height, weight and object weight to estimate force • Uses software to speed calculations	XX	XX	X

N/A = Not Applicable   X = Limited Application   XX = Applicable to Most Tasks

LEVEL II ANALYSIS	PRIMARY ANALYSIS PROCESS	M/I	WAREHOUSE	ASSEMBLY
NIOSH LIFTING ANALYSIS				
• Applies to jobs which involve repetitive lifting • Provides recommended weight limit for maximum object weight that can be handled	• Observation and measurement using tape measure • Use of software to speed the analysis process	X	XX	N/A
KCAL ENERGY EXPENDITURE ANALYSIS				
• Applies to jobs where employees are under heavy load or for any physically demanding tasks • Provides information on which sub tasks impose highest energy demands	• Videotape and physical work area measurements are necessary • Use of software is required	X	X	N/A

N/A = Not Applicable X = Limited Application XX = Applicable to Most Tasks

APPENDIX B

Level II Analysis Protocols

C.1.0 GENERAL BACKGROUND ON ERGONOMICS

The information in this appendix has been assembled to provide users with limited ergonomics experience a concise introduction to the science of ergonomics and how employees may be impacted when ergonomics is not adequately incorporated into job or workplace design. Users who have more experience may wish to skip this appendix or scan the pages as a refresher.

C.1.1 Purpose of Ergonomics

Ergonomics is the science that addresses workers' job performance and well-being in relation to their job tasks, tool, equipment, and environment. Good ergonomics means designing tasks and the workplace to fit the workers - instead of the other way around.

The sciences on which the practice of ergonomics is based include: biomechanics, psychology, physiology, anthropometry, engineering, and kinesiology. The first three sciences help to define worker capabilities and limitations (e.g., how much hand strength the average male or female possesses). The other three sciences provide guidelines for designing jobs and workplaces to more closely reflect those capabilities and limitations.

The purpose of applying ergonomics in the workplace is to provide a work environment which maximizes the worker's performance while minimizing the risk of illness and injury to the musculoskeletal and visual systems.

C.1.2 Work-Related Musculoskeletal Disorders and Risk Factors.

Many work-related musculoskeletal disorders (WMDs) belong to a class of disorders which are referred to as cumulative trauma disorders (CTDs) or repetitive strain injuries (RSIs).

These types of disorders develop because of an accumulation of stress or damage to the body over time. The body has great recuperative powers if provided with the opportunity to repair itself. However, when job demands are high (e.g., repeated use of awkward positions combined with forceful exertions or high effort) and the recovery time is insufficient, there is an increased likelihood that accumulated damage will lead to a disorder. Figure 2.1 illustrates this relationship.

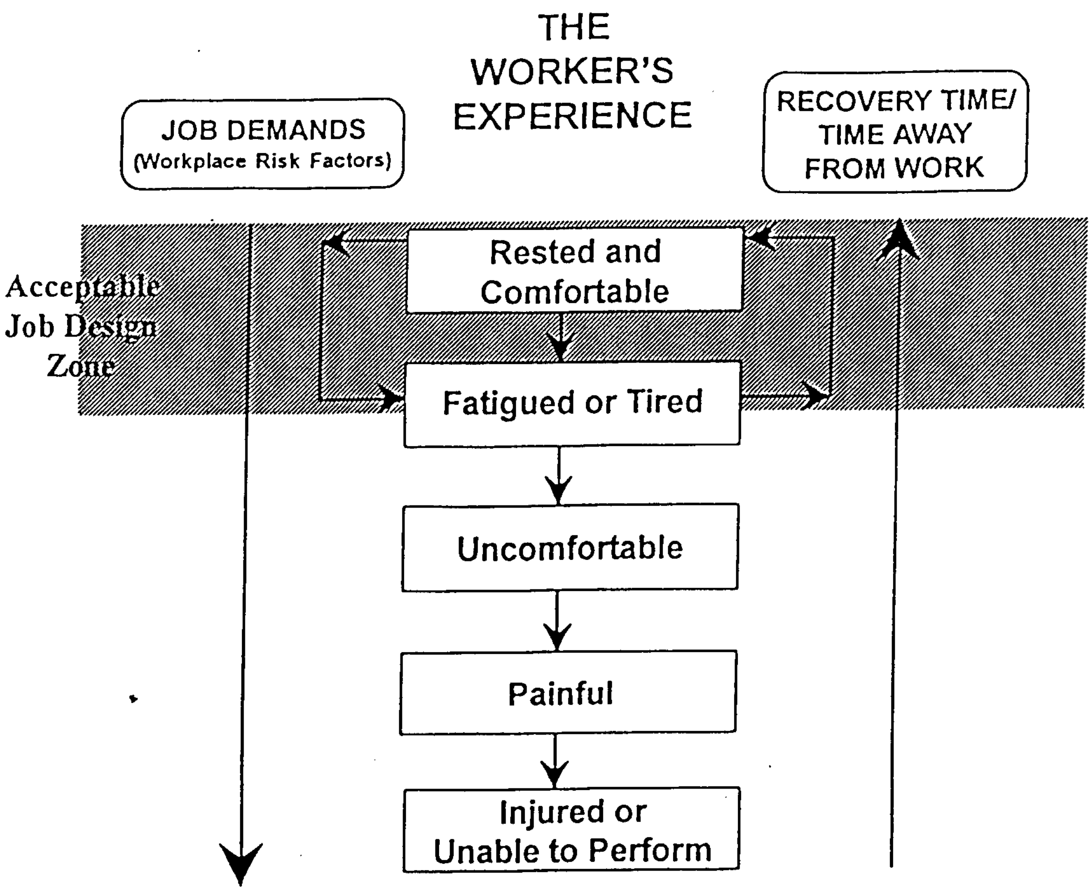


Figure 2.1
The Worker's Experience

Due to the wide variety of demands on the musculoskeletal system from maintenance and inspection work, the reported locations of discomfort and aches and pains can be just as varied. The following sections describe each of the major body regions, the most common WMDs, and the risk factors which impact the associated body region.

C.1.2.1 Shoulder/Neck.

The following sections contain information on shoulder and neck disorders and the associated ergonomic risk factors:

C.1.2.1.1 Disorders

The following are the most common shoulder and neck disorders found in the industrial workplace as shown in Figure 2.2:

- **Bursitis** - an inflammation of the bursa sac (fluid-filled cushion) in the shoulder joint.
- **Tendonitis** - an inflammation of the muscle tendon in various regions of the body, including the upper arm/shoulder region.
- **Rotator Cuff Tendonitis** - an inflammation of the tendons in the shoulder.
- **Thoracic Outlet Syndrome** - characterized by a compression of the nerves and blood vessels between the neck and shoulder.

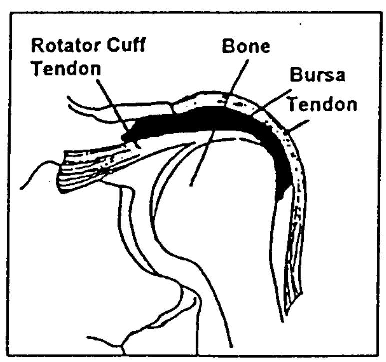


Figure 2.2
Shoulder and Neck Anatomy

C.1.2.1.2 Ergonomics Risk Factors

Several risk factors, common in maintenance and inspection work, have been shown to increase the potential for shoulder/neck/arm disorders.

- stressful positions or movements;
- static (fixed) work;
- heavy or forceful work;

- insufficient recovery or rest pauses; and
- high frequency (repetitive) or high speed movements.

The paragraphs below contain more complete descriptions of these risk factors:

- Stressful positions or movements - During an extreme reach, tendons and a structure called the bursa sac are stretched. The more extreme the reach, the more stress on the shoulder joint. The most stressful shoulder positions are reaching to the side and behind the body and working over shoulder level.

- Static (fixed position) work - Static work refers to "fixed position" work. In cases where the height of the work is too high and the worker must raise his/her arms to hold a position or work on a item, the muscles quickly fatigue.

- Heavy or Forceful work - Forceful work on the shoulder includes push/pull forces. Examples include having to push or pull a loaded cart across the shop floor or holding a bucking bar during a riveting task.

- Insufficient Recovery and Rest Pauses - Fixed-position work often results in static muscular fatigue. Fatigue and/or discomfort in the shoulder and neck regions often develop. If no movement opportunities are built into the actual work, rest pauses can be provided which allow the muscles to recover. Specific exercises and stretches can also be performed during rest pauses to prevent the onset of static muscular fatigue.

- High frequency and/or high speed movements - The repeated use of stressful/awkward positions and/or excessive force is the primary concern. In addition, sudden 'jerky' movements cause shock to the joints.

C.1.2.2 Hands/Wrist/Arm

The following sections contain information on hand, wrist, and arm disorders and the associated ergonomic risk factors:

C.1.2.2.1 Disorders

The following conditions are the most common hand/wrist/arm disorders which may result from industrial work. Figure 2.3 contains a drawing of the hand and wrist anatomy.

- **Tendonitis** - an inflammation of the tendons.

- **Tenosynovitis** - an inflammation of a tendon sheath most commonly at the wrist.

- **Carpal Tunnel Syndrome** - the symptoms are a result of an irritation of the median nerve as it is compressed by surrounding tissue and bony structures in the wrist.

- **De Quervain's Disease** - an irritation of the tendons of the thumb.

- **Trigger Finger** - an inflammation of the tendon at the joint in any finger.

- Ganglion Cysts - inflammation of the tendon sheath. The affected sheath swells due to excess synovial fluid.

- Epicondylitis - a tendon irritation of the forearm muscles at the elbow joint.

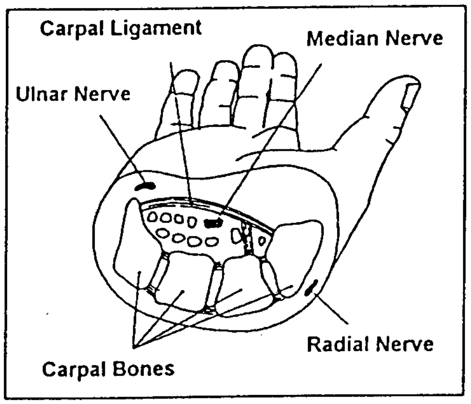


Figure 2.3
Anatomy of the Hand and Wrist

C.1.2.2.2 Risk Factors

The following is a list of the most common causes of hand/wrist/arm disorders, also referred to as "risk factors:"

- stressful positions and movements;
- excessive forces or forceful exertions;
- high frequency or repetitions;
- extreme duration and/or pace of the task;
- external trauma or mechanical stress;
- prolonged exposure to vibration; and
- temperature extremes.

The paragraphs below contain more complete descriptions of the risk factors. There are several points to remember. First, the presence of a risk factor does not necessarily mean that an injury or CTD will develop. Eliminating or even reducing the presence of any one of the risk factors will reduce musculoskeletal stress.

1. Stressful Positions and Movements - When the wrist is bent, the tendons and other soft tissues are under tension and compression. This stress can create microscopic damage that accumulates during the shift and is repaired by the body during the off-shift. If the stress is excessive, the body's repair system can't keep up.

2. Excessive Forces or Forceful Exertions - Examples of forceful exertions include squeezing a manual wire crimper with a tip grip, hammering, or lifting a heavy object.

3. High Frequency or Repetition - Repeating the same task over and over tends to stress the same parts of the body over and over. The concern is not necessarily "repetitive jobs."

Rather, the concern is repeated use of awkward postures and/or forces. If the first two risk factors can be eliminated, the 'frequency' of the task will have less impact on the worker.

4. Extreme Duration and/or Pace of the Task - Workers who perform the same stressful task (e.g. grinding, welding) for the entire shift may be more likely to experience localized fatigue than workers who perform the task for shorter periods of time. The practice of using rest pauses, job rotation, or adding task variety attempt to reduce the overall impact of task-specific stress.

5. External Trauma or Mechanical Stress - The risk factor describes the effect of pressure points on the body. Examples of external trauma are using the hand or palm like a hammer or resting the under-arm region on a blunt edge while performing a repair job on an internal component.

6. Prolonged exposure to vibration - Segmental or "hand/arm" vibration should be considered as a secondary risk factor because there is no conclusive evidence that there is a direct cause/effect relationship between upper limb WMDs (CTDs) and vibration exposure. It is likely, however, that vibration exposure may increase the presence of other risk factors. For example, since workers tend to grip vibrating or "impact" tools more tightly than non-vibrating tools, the "forceful exertion" risk factor may increase. Also, since many vibrating tools (e.g., grinders, sanders, etc.) require the worker to repeatedly bend and/or twist the wrist, the stressful posture/repetition combination of risk factors may increase.

   Special Note. An accurate assessment of vibration exposure and its potential implications in the development of Raynaud's syndrome (VWF-vibration white finger) or WMDs requires the use of sophisticated measurement equipment. If symptoms such as numbness, swelling of hand tissues, or reduced grip strength are reported, you are encouraged to contact AL/OEMO for assistance.

7. Temperature Extremes, especially cold, should also be considered as a secondary risk factor. Exposure to low temperatures can affect dexterity, sensitivity, and grip strength. The fingers and hands may be exposed to cold temperatures when handling cold materials (e.g., frozen meat), working outdoors in cold weather, or when exposed to exhaust air from pneumatic hand tools. Often, however, use of the proper insulating gloves may protect the worker's hands and fingers from exposure to cold.

C.1.2.3 Back/Torso

The following sections contain information on the back and torso disorders and the associated ergonomic risk factors:

C.1.2.3.1 Disorders

The following components are used to understand the various functions of the back/torso anatomy, their function, and associated disorders. Figure 2.4 contains an illustration of the back anatomy.

- Backbone (spine) - the major support structure of the body.
- Vertebrae - the bones which make up the spine.

- Cervical (C1-C7) supports and controls the movement of the head.
- Thoracic (T1-T12) supports the upper body and has limited movement.
- Lumbar (L1-L5) has the greatest flexibility and bridges the upper to lower torso.
- Sacrum tail bone.

- Spinal cord - conducts impulses for movement and sensation (including pain) to and from the head and body.
- Foramen - spaces between the vertebrae through which spinal nerves exit.
- Discs - sponge-like tissues which separate vertebral bones and prevent the vertebrae from grinding against one another.
- Ligaments - attach one vertebra to the next.
- Muscles - provide support and enable the body to move from one posture to another.

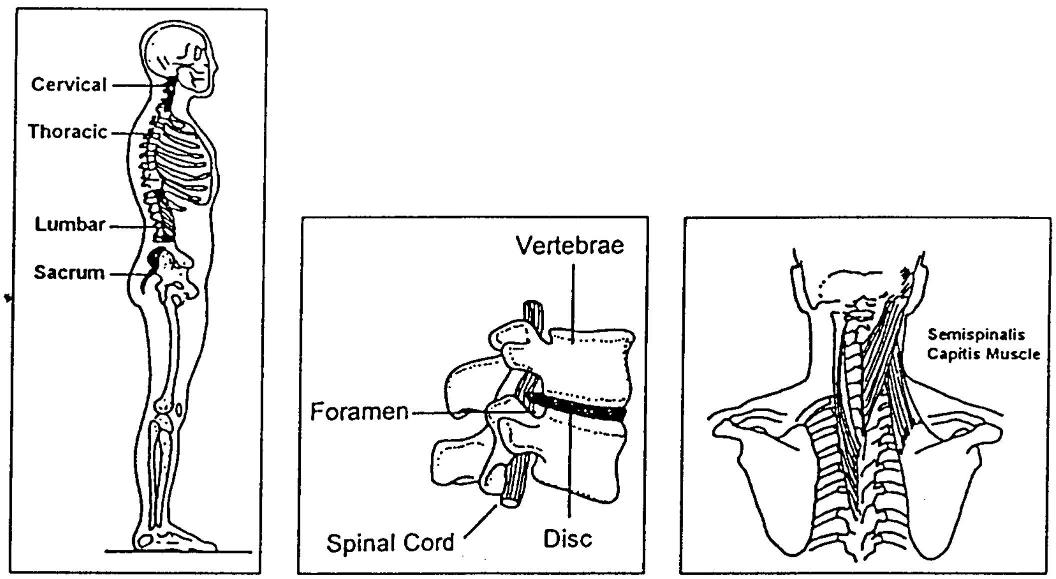


Figure 2.4
Back Anatomy

The following paragraphs discuss the common disorders associated with this area of the body:

- **Disc Degeneration** - with activity, intervetebral discs are stretched, torn, frayed, and worn. This can cause the disc wall to weaken, protrude, and, in some cases, press against the nerves. Weakening of the disc may also cause some narrowing of the space between the vertebra which reduces the size of the hole (foramina) through which the nerve passes as it extends into the legs (as shown in figure 2.5). If the narrowing of this space is significant, pressure may be directed against the nerve.

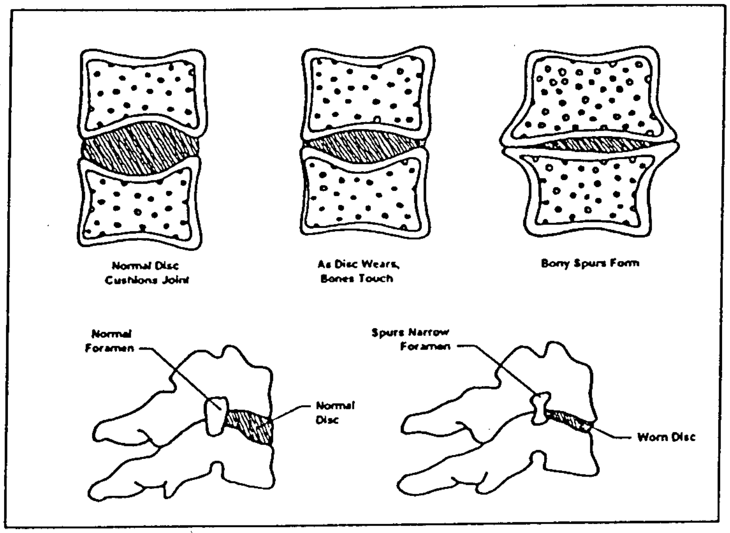


Figure 2.5
Disc Degeneration

- **Strains and sprains** - tearing or stretching of muscles, tendons or ligaments as shown in Figure 2.6.

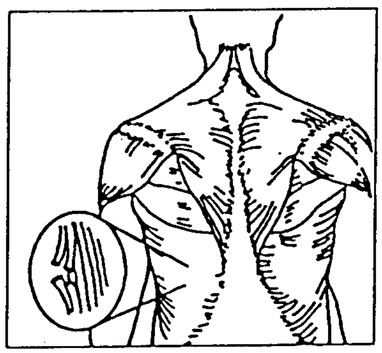


Figure 2.6
Sprains and Strains

C.1.2.3.2 Risk Factors

The following risk factors have been found to be associated with low back pain and back disorders:

- Awkward Postures - The degree or extent of forward bending appears to be the most significant concern. However, twisting and sideways bending also place uneven force on the spinal discs and muscles.

- High Force or Forceful Exertions - Lifting heavy objects or pushing overloaded carts can create an extreme force in the low back. For lifting, the closer to the body that an object can be kept during a lift, the less force that is exerted in the low back. Both object weight and body position affect the amount of force and stress created in the low back.

- Static (fixed position) Work - When someone sits or stands in a fixed position for a long time, demands are placed upon certain muscles to maintain contraction. This may cause fatigue and discomfort in the low back. On the other hand, if the job is modified to give the worker an opportunity to move in a controlled fashion, the weight of the body is shifted between numerous muscle groups. By sharing the load among different muscles over time, one muscle group is allowed time to rest while another is working. This helps reduce the tendency for fatigue.

- High Frequency Lifting - Frequent lifting has been correlated with increased low back injury rates. Studies suggest that using a squat lift (lifting with bent knees and a straight back) puts less pressure on the disc than using a stoop lift (lifting with straight knees and a bent back). Repeatedly bending the spine, especially when twisting is involved, can weaken the disc and lead to injuries such as disc protrusions-a bulging of the outer wall of the disc that can press against the nerve.

- Speed of Movement - The use of smooth body movements during lifting and other materials handling tasks helps reduce the risk of developing low back injury. Jerky or sudden, unexpected movements are associated with high force levels that may create injuries and should be avoided.

- Duration of Lifting - A worker who performs a material handling task continuously over an entire shift may be more likely to experience low back discomfort than a worker who does the job for only two hours. Job rotation can be used to reduce stress to the low back by reducing the duration of exposure to the stressful work.

- Whole-Body Vibration - This is a generalized stressor that impacts virtually the entire body. Although prolonged exposure to whole-body vibration (e.g., standing on or driving large construction equipment) may be related to postural fatigue and low back discomfort, little is actually known about its direct affects. The goal is to control the transfer of energy from the vibrating equipment or surface to the employee.

C.1.2.4 Legs/Feet

The following sections contain information on legs and feet disorders and the associated ergonomic risk factors:

C.1.2.4.1 Disorders

The following conditions are legs and feet disorders associated with standing, kneeling, or bending tasks in maintenance and inspection work areas.

- **Bursitis of the knee** - an inflammation of the bursa sac in the knee joints.

- **Varicose veins** - prolonged pooling of the blood in the vein, especially in the lower leg.

C.1.2.4.2 Risk Factors

The following risk factors have been found to be associated with lower limb disorders:

- Stressful Positions and Movements - Kneeling or bending postures increase pressure inside the knee joint. Forced positions of the knees, such as those used when squatting to work in an area with limited access.

- Static Work (fixed positions) - Prolonged standing or sitting while the back of the knee/thighs are compressed interferes with circulation. When standing in a fixed position, blood collects in the legs causing increased pressure on the blood vessels and joints.

- Excessive Forces - Using the knees to apply pressure to a surface is one example of excessive force. The knee joint is also impacted internally when the worker assumes a kneeling posture.

- External Trauma - Kneeling on a hard or uneven surface may cause immediate discomfort and long-term damage to the soft tissues of the knees.

C.1.2.5 Visual Issues

Eyestrain is less common in industrial tasks than in administrative work. However, maintenance and inspection jobs which require high visual demands may present risk factors which may contribute to eyestrain or decrease the employee's ability to maintain high quality performance. In addition, since computer work may be part of many maintenance and inspection tasks, a discussion of risk factors is warranted.

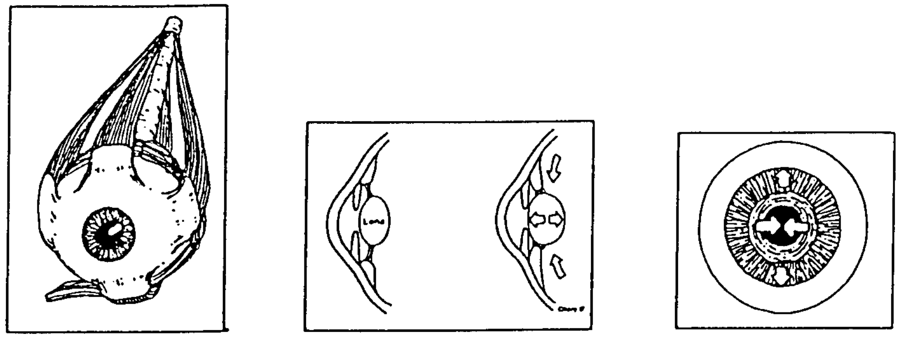
C.1.2.5.1 Visual Complaints

It is important to know the anatomy of the eyes as a foundation for understanding the sources of complaints. Figure 2.7 contains an illustration of the eye anatomy.

- Oculomotor muscles - Control movement side-to-side and up-and-down and are used whenever they are searching or reading documents or screens.

- Ciliary muscles - Control focusing by changing the shape of the lens to hold images in focus. They must adjust for any change in focal length when the eyes are looking at different distances.

- Iris muscles - Control light intake (adjust size of pupils according to light intensity) and are affected by the light from the screen, document or surrounding area.



Oculomotor muscles Ciliary muscles Iris muscles

Figure 2.7
Eye Anatomy

C.1.2.5.2 Risk Factors

Glare on a video display terminal (VDT) screen makes it more difficult for the user to see clearly and easily. Though employees whose tasks have high visual demands complain of visual discomfort, there is no evidence that high visual demands (including VDT use) causes permanent eye damage. The discomfort, however, is real and needs to be addressed. Most of the discomfort results from users having to strain their visual system to compensate for the inadequate viewing conditions, which results in squinting, stretching, etc.

There are two types of **glare**: direct and reflected.

- **Direct glare** is caused by light sources within the visual field. This can cause "disabling glare" because it reduces the contrast at the retina reducing visual performance.

- **Reflected glare** is caused by the light rays bouncing off the surface.

  - Reflected glare can be specular, meaning that the operator can see the reflected image of the light source itself or the image of an object or person.
  - Reflected glare can also be diffused glare. Light bouncing off floor or ceiling lights may be reflected with no clear visible pattern. The background simply appears brighter.

Other visual complaints include:

- **Excessive or Inadequate Ambient Light** - Many workspaces are too bright or dark for easy viewing, causing the user to adapt by overusing his/her eye muscles.

- **Visual Disorders** - The eye does not always function properly. Some of the visual disorders people experience which affects their being able to see properly when working with or without a VDT are: far-sightedness, near-sightedness, and presbyopia.

- **Amount of Visual Demand** - If workers have intense visual tasks all day and are working with tight schedules, they are more likely to have visual problems. The amount of uninterrupted time spent on visually demanding tasks can affect eyestrain.

C.1.3 Conclusion

One of the main purposes of this Guide is to provide you with the specific ergonomics principles which you can apply to 50 of the most common maintenance and inspection tasks in order to reduce or effectively eliminate employee exposure to the risk factors. The intended result is to reduce the potential for WMDs (and visual problems) while maximizing employee performance.

APPENDIX D

Categories of Control Options

Categories of Control Options

Category	Description
Short-Term Modifications (Current Fiscal Year)	These controls represent minor modifications that are expected to be within the capabilities of the shop to implement within the **current fiscal year**. These controls would typically involve no purchases or low cost purchases (e.g., less than $500 total).
Long-Term (Next Fiscal Year)	These are more extensive controls that are expected to be within the capabilities of the shop to implement within the **next fiscal year**. These controls would typically involve purchases of tools/equipment which are currently available on the market or which could be easily manufactured by a local supplier (e.g., $500 or more total).
Long-Term (Coordinated Initiatives)	These are major changes that may be beyond the capabilities of the shop to implement alone. They would typically involve development of tools/equipment which are not currently available on the market. It could also involve coordination among several shops or entities. While the control should still be implemented within the context of the shop, it is expected that the shop will need outside assistance in order to successfully implement the change.

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