VOLUME I

# HUMAN FACTORS ENGINEERING REVIEW AND EVALUATION

# WEAPON SYSTEM 107A-2 LAUNCHER, OSTF AND TF-1

## FINAL REPORT

CONTRACT NUMBER AF 04(647)-138

HUMAN FACTORS ENGINEERING

TECHNICAL STAFF



AMERICAN MACHINE & FOUNDRY COMPANY

GREENWICH ENGINEERING DIVISION

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FINAL REPORT

Contract No. AF 04(647)-138


Leo Bricker
Lewis W. Bennett
Rona Finizie Malhenzie

The Human Factors Engineering Group

Technical Staff


31 January 1962
Volume I
Chapters 1 - 15

Approved: Leo Bricker
Leo Bricker, Supervisor
Human Factors Group
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Approved: R. Vuilleumier
R. O. Vuilleumier
Technical Director
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ABSTRACT

The purpose of this report is to document the AMF Human Factors Engineering effort covering the over-all system review and evaluation of the AMF Launcher System for the 107A-2 Titan Weapon System, OSTF & TF-1. The report has been designed to present summarized human factor data and discussion concerning 30 selected items of launcher equipment. A Summary Checklist of human factors considerations and an illustrated Summary of Inputs was originated and prepared for each item, as well as a tabulated Synopsis which identifies pertinent human factors considerations, type of documentary compliance, human factors criteria for success, documentation of varying methods of human factors participation, type of verification performed, recommendations that were made, and the degree to which they were adopted.

The report is divided into three main sections:

1. an introduction which discusses background information and the format of the report (Chap. 1-7);
2. a major section which contains 30 evaluations and and sets of human factors recommendations for AMF launcher equipment (Chap. 8-26);
3. an Appendix which reproduces 3 typical human factors man-machine analyses for the Titan Launcher.

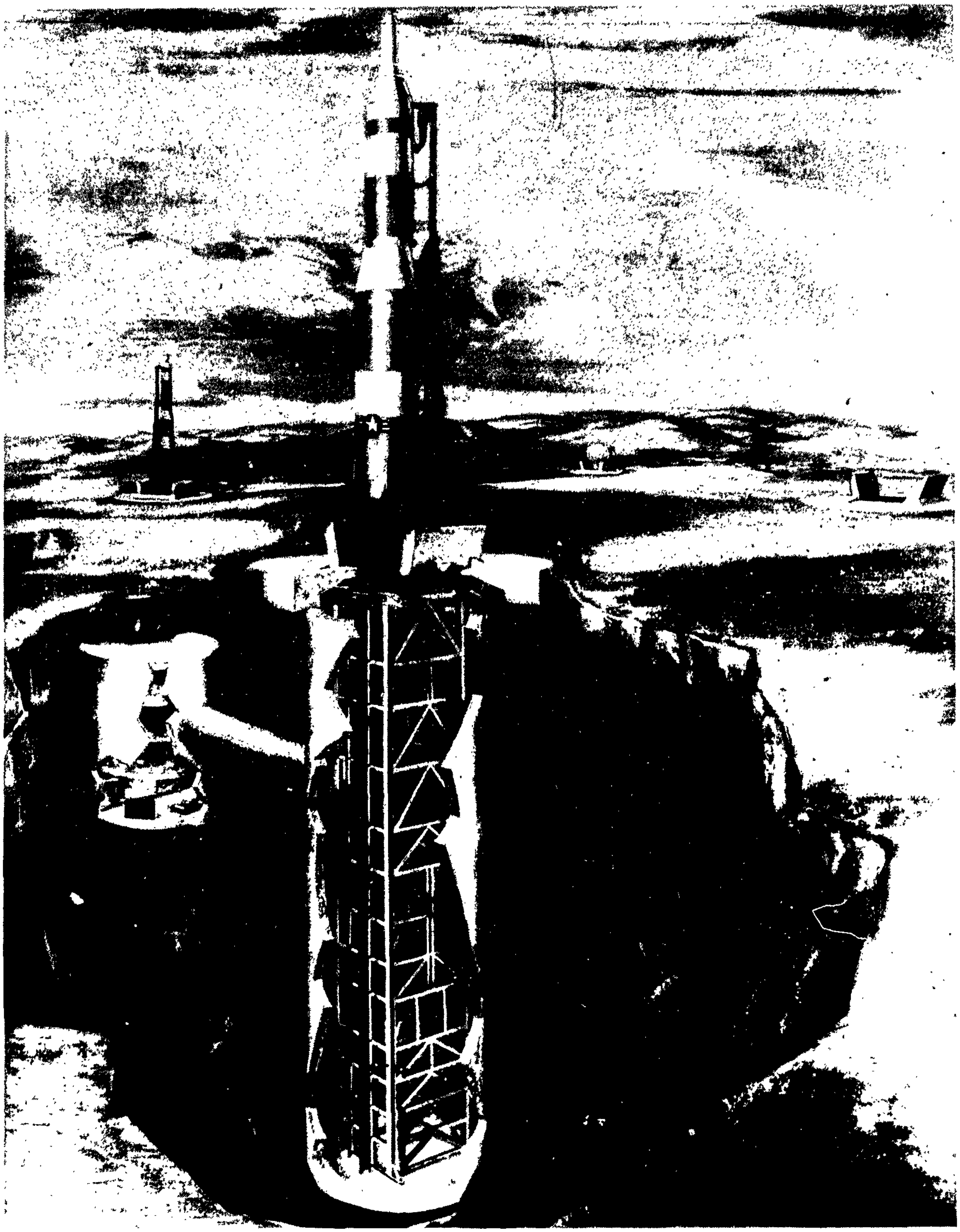
It is expected that this report will be helpful to the Air Force and to all missile manufacturers in future weapon system programs, as it pin-points the type and scope of problems met in systems design of missile hardware.

The results are: several hundred human factors recommendations were made and adopted; only 273 of these were documented, since many were incorporated directly into the design during the early, informal concept phase. Of the 273 recommendations made:

55% were adopted completely

13% were partially adopted

32% were not adopted



# FOREWORD

This document is the Final Report of the Human Factors Engineering Review and Evaluation of the Launcher System designed and developed by American Machine & Foundry Company for the Titan Weapon System 107 A-2 Training Facility (TF-1) at Vandenberg Air Force Base. The final report was prepared by members of the Human Factors Engineering Section, Technical Staff, of the Greenwich Engineering Division.

Although this report concerns itself primarily with the Training Facility, it will also contain special indications of those human factor problem areas or recommendations pertaining to the Operational System Test Facility (OSTF) wherever a difference may exist between OSTF and this presentation for TF-1.

At a later date, this TF report will be followed by a Final Report of the Human Factors Engineering Review and Evaluation of the Operational Base (OB) T-1. The OB T-1 Final Report will be concerned only with those aspects of the launching system which are found to be different from the material presented in this report for TF-1.

# Chapter 1

# Introduction

## CHAPTER I - Introduction

1.0 Subject

This report in 3 volumes, presents AMF's Final Report of the Human Factors Engineering review and evaluation of the Launcher System for the Titan Weapon System 107A-2, OSTF and TF-1.

1.1 Authority For Report

This Human Factors Engineering Final Report has been authorized by, and has been prepared in compliance with:

(1) Air Force Ballistic Missile Technical Directive No. 58-4003, titled "Human Factor Engineering Design," dated 22 December 1958, to Air Force Contract No. AF 33(047)-138.

(2) Paragraph 3.17, "Final Human Engineering Report," of Specification ARS-1001C, Titled "AMF Data Specification, Data Requirements for WS 107A-2 Launcher System," dated 31 December 1959.

1.2 Purpose of Report

The purpose of the final report is to document all Human Factors Engineering effort on the Titan Launcher System. It covers Human Factors participation, findings, criteria and the recommendations which were made for the best application of criteria.

A secondary purpose is to indicate those areas of design, installation, operation and ground support of the Launcher System which could be improved by the incorporation of recommendations which are not now contractually mandatory.

1.3 Human Factors Evaluation Team Members

The following members of the Technical Staff Human Factors group at AMF have participated in the human factors evaluation of the Titan

Launcher System, covering the period from January 1958 to date:

Leo Bricker, Supervisor

Lewis W. Bennett

Harry N. Breeden

Isaac De Botton

Albert A. Glass

William R. Lindroth

Arthur Lyman

Rona F. Malhenzie

Robert J. Murphy

William M. Tamone

Edward Williamson

## 1.4 Scope of the Report

This report is primarily a history of the AMF Human Factors effort on the Titan Launcher System. It should be understood that this is not a report of the "as built" system status, so that a personal appraisal of the net results of the Launcher System in the field installation might not completely indicate the full extent of the effort expended by the AMF Human Factors team over the past 4 years.

## 1.5 Organization of the Report

The report is divided into 5 major sections:

(1) Background information in Chapters 1, 3, 4, 5

(2) Summarization of the evaluation in Chapter 2

(3) The 7 major Human Factors considerations in Chapters 6 and 7

(4) Separate Human Factors Engineering evaluations of the Launcher System equipment, in chapters 8 through 26

(5) Appendix, which appears separately as volume III.

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Volume I

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Volume III

# Chapter II

## Summary

### 1.0 OBJECTIVE

It is the purpose of this report to document all AMF Human Factors Engineering effort on the Titan 107A-2 Launcher System.

This has been accomplished by utilizing the Human Factors team in multiple functions. From a "systems" point of view, team participation covered:

(1) identification of areas of human factors consideration,

(2) notation of documentary compliance, (whether contractual, AFBM 57-8A or other technical documents),

(3) generation of criteria for success,

(4) documentation of methods of application of these criteria,

(5) abstracts of the human factors recommendations,

(6) notation of the method of verification used to support the need for the recommendations,

(7) and lastly, the actual result as to hardware incorporation of the human factor recommendation.

A relative value was assigned each factor for the item under consideration.

### 2.0 FINDINGS

Thirty items of launcher equipment were reviewed and evaluated according to human factors standards. A summary checklist was prepared for each item, indicating which human factors considerations were required, the phase-in stage of the effort, what human factors objectives were involved, and to which models these factors were applicable.

Figure 2-1 presents a composite summary of human factors effort, arranged by human factors categories versus items of launcher equipment. From this figure one can identify those factors which applied most often to the Launcher System, as well as those items of equipment which required the largest range of human factor consideration.

It should be noted, however, that this composite is not intended to show which items of equipment required the greatest expenditure of work effort.

Figure 2-2 ranks the 30 items of AMF equipment in descending order, from those items found to require consideration of the largest number of human factors; namely, the Work Platform and Personnel Elevator, down to the item requiring the smallest number of human factor considerations; namely, the Main Closure Door Klaxon.

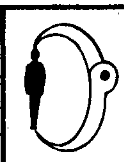
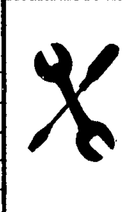
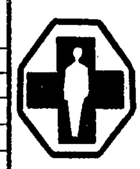
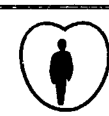
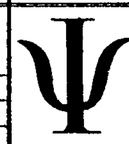
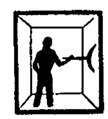
| AMF CHAPTER # | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 15 | 17 | 18 | 13 | 19 | 19 | 20 | 20 | 21 | 22 | 23 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 25 | 26 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ITEM | 1 Communications | 2 Crib Locking System | 3 In-Silo Degreasing | 4 Crib to Silo Bridge | 5 Lifting & Handling Equipment | 6 Trailer, Lift & Maintenance Dolly | 7 GSE Missile Emplacement System | 8 Mobile Work Platform | 9 Tug Truck | 10 Power Pack Room | 11 Launcher Platform | 12 Launcher Platform Accessory Equipment | 13 Logic Rack | 14 Mobile Test Rack | 15 Ground Level Control Station | 16 Tunnel Entrance Control Station | 17 Main Drive | 18 Motor Control Center | 19 Personnel Elevator | 20 Personnel Stairway | 21 Bottom Access Stairway | 22 Emergency Ladder | 23 Guard Rails & Safety Gates | 24 Safety Nets | 25 Main Closure Door Klaxon | 26 Contamination Prevention Procedures | 27 Shower & Eye Wash Station | 28 Human Initiated Failures | 29 Utilities | 30 Work Platforms | TOTAL | |
| 1.0 HUMAN ENGINEERING DESIGN FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 1.1 Anthropometric Compatibility | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | x | x | x | x | x | | | x | x | x | x | 27 | |
| 1.2 Controls and Displays | x | | | | x | x | x | x | | x | | | x | x | x | x | | x | x | | | | | | | | x | x | | x | 15 | |
| 1.3 Fail-Safe Design | | | | | | | | x | x | | x | x | x | x | x | x | | x | x | | | | | | | | | x | | x | 12 | |
| 1.4 Malfunction Detection | | | | | | | | | | | | | x | | | | | | | | | | | | | x | | x | x | x | 5 | |
| 2.0 MAINTENANCE FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 2.1 Access, Visual | | x | | | | | x | | | | | | x | x | | | | | | x | x | | | | | | | x | x | | 8 | |
| 2.2 Access, Servicing | x | x | x | x | | x | x | x | x | x | x | | | x | x | x | x | | x | x | x | | | | | x | | x | x | x | 21 | |
| 2.3 Remove and Replace | | x | x | | x | | | | | x | x | x | x | x | | | x | x | | | x | | | | | x | | x | x | x | 15 | |
| 2.4 Handling, Physical Limitations | | x | x | | x | | x | | x | | | | x | x | x | | | x | x | | x | | | | | | | | x | x | 13 | |
| 2.5 Handling, Transportation | | | | | x | | | | | | | | | | x | | x | x | | | x | | | | | | | | | | 5 | |
| 2.6 Vehicle Maneuverability | | | x | x | | x | | x | x | | | | | x | | x | | | | | | | | | | | | | | | 7 | |
| 3.0 SAFETY FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 3.1 Chemical Decontamination | | | | | | | | | | | | | | | | | | | | | | | | | | | x | | | | 1 | |
| 3.2 Escape Provisions | x | | x | x | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | x | 8 | |
| 3.3 Protection from Entanglement | | | | | | | | | | | | | | | | | x | | | | | | | | | | | | | | 1 | |
| 3.4 Protection from Falling | | x | | x | x | | | x | | x | x | x | | | | | x | | x | x | x | x | x | x | | | | | x | x | 16 | |
| 3.5 Safety Devices (other) | | x | x | | | x | x | x | x | | | | x | x | x | x | x | x | x | | | x | | | | x | | | x | x | 17 | |
| 3.6 Warning Devices | | x | x | | | | | | x | x | | | x | | | | x | x | x | | | | | | x | x | | x | | | 11 | |
| 4.0 PHYSIOLOGICAL FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 4.1 Biological Damage | | | x | | | | | | | | | | | | | | | | | | | | | | | x | x | | | | 3 | |
| 4.2 Vertigo | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.3 Vibration Effects | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5.0 PSYCHOLOGICAL FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 5.1 Fear of Heights | | | | | | | | x | | | | | | | | | | | x | | | | | | | | | | | x | 3 | |
| 5.2 Fear of Being Crushed | | | | | | | x | | | | | | | | | | | | | | | | | | x | | | | | | 2 | |
| 5.3 Fear of Falling | | x | | x | | | x | x | | | x | | | | x | x | | | x | x | x | x | x | x | | | | | x | x | 15 | |
| 5.4 Fear of Isolation | x | | | | | | | | | | | | | | | | | | x | | | x | | | | | | | | | 3 | |
| 5.5 Feeling of Insecurity | | | x | | | | | x | | | | | | | x | | | | | x | x | x | x | x | | x | x | x | | x | 12 | |
| 6.0 ENVIRONMENTAL FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 6.1 Acoustic Energy (noise) | x | | | | | | | | | x | | | | | | | | | | | | | | | | | | | | | 2 | |
| 6.2 Humidity & Temperature | | | | | | | x | | | | | | | | x | | | | | | | | | | | | | | | | 2 | |
| 6.3 Illumination | x | | x | x | x | x | x | | | | | x | | | x | x | | | x | | | | | | | | | | x | x | 12 | |
| 7.0 HUMAN USE FACTORS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |  |
| 7.1 Procedure | | | x | | x | | x | x | | | | | | | | | | | | x | | | | | | x | | x | x | x | 9 | |
| 7.2 Time Study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7.3 Training/Selection | | | | | | | | | | | | | | | | | | | | x | | | | | | x | | x | | | 3 | |
| TOTALS | 7 | 9 | 12 | 7 | 8 | 6 | 11 | 11 | 7 | 7 | 6 | 5 | 9 | 9 | 11 | 8 | 7 | 8 | 13 | 9 | 10 | 7 | 4 | 4 | 2 | 9 | 5 | 11 | 11 | 15 | 248 | |

FIGURE 2-1 Composite summary of areas of AMF Human Factors effort, showing 30 categories of human factors which were considered and 30 of the most critical items or aspects of AMF Launcher Equipment which were involved.

| Rank | Item | No. of Factors Out of 30 Possible |
|---|---|---|
| 1 | Work Platforms | 15 |
| 2 | Personnel Elevator | 13 |
| 3 | In-Silo Degreasing | 12 |
| 4 | GSE Missile Emplacement System | 11 |
| 4 | Mobile Work Platform | 11 |
| 4 | Ground Level Control Station | 11 |
| 4 | Human Initiated Failures | 11 |
| 4 | Utilities | 11 |
| 5 | Bottom Access Stairway | 10 |
| 6 | Crib Locking System | 9 |
| 6 | Logic Racks | 9 |
| 6 | Mobile Test Rack | 9 |
| 6 | Personnel Stairway | 9 |
| 6 | Contamination Prevention Procedures | 9 |
| 7 | Lifting and Handling Equipment | 8 |
| 7 | Tunnel Entrance Control Station | 8 |
| 7 | Motor Control Center | 8 |
| 8 | Communications | 7 |
| 8 | Crib to Silo Bridge | 7 |
| 8 | Tug Truck | 7 |
| 8 | Power Pack Room | 7 |
| 8 | Main Drive | 7 |
| 8 | Emergency Ladder | 7 |
| 9 | Trailer, Lift and Maintenance Dolly | 6 |
| 9 | Launcher Platform | 6 |
| 10 | Shower and Eye Wash Station | 5 |
| 10 | Launcher Platform Accessory Equipment | 5 |
| 11 | Safety Nets | 4 |
| 11 | Guard Rails & Safety Gates | 4 |
| 12 | Main Closure Door Klaxon | 2 |

Figure 2-2 AMF Launcher Equipment ranked in terms of number of human factor areas considered.

Figure 2-3 presents a ranked listing of the categories of human factors effort in terms of (1) the proportion of the 248 items affected by this consideration, (2) the component proportion of the effort which was expended on each category, and (3) the proportion of the 30 items of AMF equipment which were susceptible to that category of human factors scrutiny. It is to be noted that 90% of the equipment was affected by considerations of Anthropometric Compatibility and 70% were affected by consideration of proper Access for Servicing, with the list tapering down to 3 1/3% being affected by consideration of the Fear of Being Crushed.

It should be understood, however, that although this human factors effort was extensive, comprehensive and highly successful in terms of number of recommendations adopted, the work here reviewed and summarized does not include the entire scope of the work done by the Human Factors Engineering Team. Two major reasons account for this discrepancy:

(1) Some items, such as the In-Silo Stage Separation, which consumed great amounts of human factors time and effort, were deleted completely from the Titan program and this effort is reported upon.

(2) Many unrecorded hours of human factors team effort were expended during the early phases of the AMF Titan program. Informal conferences were held with hardware designers during the concept stage, and recommendations were incorporated directly into the work while it was still on the drafting boards. Since these early efforts were not covered by reports or other documentation, they are not included in this summarization.

| Category Of Human Factors Effort | No. of Items Affected | % of Total H.F. Effort Expended | % of Equipment Requiring H.F. Effort |
|---|---|---|---|
| | (f) | (f/248) | (f/30) |
| Anthropometric Compatibility | 27 | 10.890 | 90.0 |
| Maintenance: Servicing Access | 21 | 8.469 | 70.0 |
| Safety Devices (other than itemized) | 17 | 6.855 | 56.66 |
| Safety (Protection from Falling) | 16 | 6.452 | 53.33 |
| Controls & Displays | 15 | 6.049 | 50.00 |
| Maintenance: Remove & Replace | 15 | 6.049 | 50.00 |
| Fear of Falling | 15 | 6.049 | 50.00 |
| Maintenance: Physical Limitations in Handling | 13 | 5.247 | 43.33 |
| Fail Safe Design | 12 | 4.839 | 40.00 |
| Feeling of Insecurity | 12 | 4.839 | 40.00 |
| Illumination | 12 | 4.839 | 40.00 |
| Safety: Warning Devices | 11 | 4.435 | 36.66 |
| Human Usage: Procedure | 9 | 3.629 | 30.00 |
| Maintenance: Visual Access | 8 | 3.225 | 26.66 |
| Safety: Escape Provisions | 8 | 3.225 | 26.66 |
| Maintenance: Ease of Maneuvering Vehicles | 7 | 2.822 | 23.33 |
| Malfunction Detection | 5 | 2.016 | 16.66 |
| Maintenance: Transportation of Handling Equipment | 5 | 2.016 | 16.66 |
| Fear of Isolation | 4 | 1.612 | 13.33 |
| Fear of Heights | 3 | 1.209 | 10.00 |
| Protection from Biological Damage | 3 | 1.209 | 10.00 |
| Human Usage: Training/Selection | 3 | 1.209 | 10.00 |
| Acoustic Energy (Noise) | 2 | .806 | 6.66 |
| Humidity & Temperature | 2 | .806 | 6.66 |
| Safety: Chemical Decontamination | 1 | .403 | 3.33 |
| Safety: Protection from Entanglement | 1 | .403 | 3.33 |
| Fear of Being Crushed | 1 | .403 | 3.33 |
| Totals | 248 | 100.% | |

Figure 2-3 Human Factors Engineering Areas considered for each of the 30 items of equipment evaluated.

Figure 2-4 presents a breakdown of the 273 human factors recommendations which were made in terms of the sub-group totals and the proportion which applied to each of the 27 human factors considerations under study.

In order of activity, the first and second largest categories are nearly equal, with Maintenance Factors totaling 27.5% while Human Engineering Design Factors total 26.1% of the total 273 recommendations. A very close third is Safety Factors with 23.7%. The remaining 22.7% is divided among 4 groups, with Psychological Factors at 11.7%, Environmental Factors at 5.8%, Human Usage Factors at 4.1%, and Physiological Factors at 1.1%.

## 3.0 RESULTS

Analysis of degree of the adoption of the 273 human factors recommendations which were made indicates the following results:

55% of recommendations have been completely adopted,

13% of recommendations have been partially adopted,

32% of recommendations were not adopted.

Investigation disclosed that four major reasons accounted for the non-adoption of 32% and the partial adoption of 13% of the recommendations:

(1) such adoption would have delayed the schedule,

(2) some components were standard parts, and hence exempt,

(3) such requirement was not spelled out in the model specifications,

(4) some recommendations would have required action by other contractors, which AMF could not enforce.

It is anticipated that these outstanding recommendations will be incorporated into the system when redesign of that area is normally undertaken.

| | Recommendations Made | % of Total Recommendations | Sub-Total |
|---|---|---|---|
| MAINTENANCE FACTORS | | | |
| Access, Visual | 7 | 2.6 | |
| Access, Servicing | 28 | 10.3 | |
| Remove and Replace | 17 | 6.2 | |
| Handling, Physical Limitations | 11 | 4.0 | |
| Handling, Transportation | 4 | 1.5 | |
| Vehicle Maneuverability | 8 | 2.9 | 27.5 |
| HUMAN ENGINEERING DESIGN FACTORS | | | |
| Anthropometric Compatibility | 28 | 10.3 | |
| Controls and Displays | 30 | 11.0 | |
| Fail-Safe Design | 10 | 3.7 | |
| Malfunction Detection | 3 | 1.1 | 26.1 |
| SAFETY FACTORS | | | |
| Chemical Decontamination | 1 | .4 | |
| Escape Provisions | 8 | 2.9 | |
| Protection from Entanglement | 2 | .7 | |
| Protection from Falling | 17 | 6.2 | |
| Safety Devices (other) | 26 | 9.5 | |
| Warning Devices | 11 | 4.0 | 23.7 |
| PSYCHOLOGICAL FACTORS | | | |
| Fear of Heights | 2 | .7 | |
| Fear of Being Crushed | 2 | .7 | |
| Fear of Falling | 13 | 4.8 | |
| Fear of Isolation | 3 | 1.1 | |
| Feeling of Insecurity | 12 | 4.4 | 11.7 |
| ENVIRONMENTAL FACTORS | | | |
| Acoustic Energy (noise) | 3 | 1.1 | |
| Humidity & Temperature | 2 | .7 | |
| Illumination | 11 | 4.0 | 5.8 |
| HUMAN USE FACTORS | | | |
| Procedure | 7 | 2.6 | |
| Time Study | 1 | .4 | |
| Training/Selection | 3 | 1.1 | 4.1 |
| PHYSIOLOGICAL FACTORS | | | |
| Biological Damage | 3 | 1.1 | 1.1 |
| Vertigo | | | |
| Virbration Effects | | | |
| Totals | 273 | | 100.0 |

Figure 2-4 Breakdown of 273 human factors recommendations made in terms of each of 30 human factors categories.

# Chapter III

## The Human Factors Engineering Program At AMF

### 1.0 Introduction

In any listing of requirements for systems design, accuracy has the number one priority. It is therefore essential to minimize systems errors and delays. The operator within any system is the least controllable source of errors and, in addition, has the greatest potential for introducing errors. Considering the importance of the operator's role, any degradation in human performance would seriously affect the overall performance of the system. The proper design of operator equipment and procedures and an effective selection and training program can do much to minimize operator errors and delays. The systems which are developed by AMF are designed not only to meet the operational requirements, but also to be compatible with the capabilities and limitations of the operators who are a vital part of that system.

As a fundamental requirement, each element of the sub-system, (human engineering, selection, training, and evaluation), must be considered in a systems framework, with requirements and criteria of effectiveness derived from the objective of the system as a whole. From the systems viewpoint, no basic difference exists between hardware and humans, in that both are considered raw materials which are to be designed, developed, manipulated, stored, tested and evaluated by the research, development, engineering, and production teams. This view enables and facilitates the production of an integrated man-machine relationship which will fulfill the tasks and missions established by the Customer.

The experience that AMF has gained on missile programs such as Talos, Atlas, Titan, Dyna-Soar, and many others is utilized to provide a system of maximum capability with minimum expense based on a cost-versus-utility factor.

The Human Factors Engineering Program at AMF is one of the means of providing a scientific approach to all elements involved in the man-machine relationship to optimize design.

## 2.0 Organization of the Human Factors Engineering Group (HFEG)

### 2.1 Function

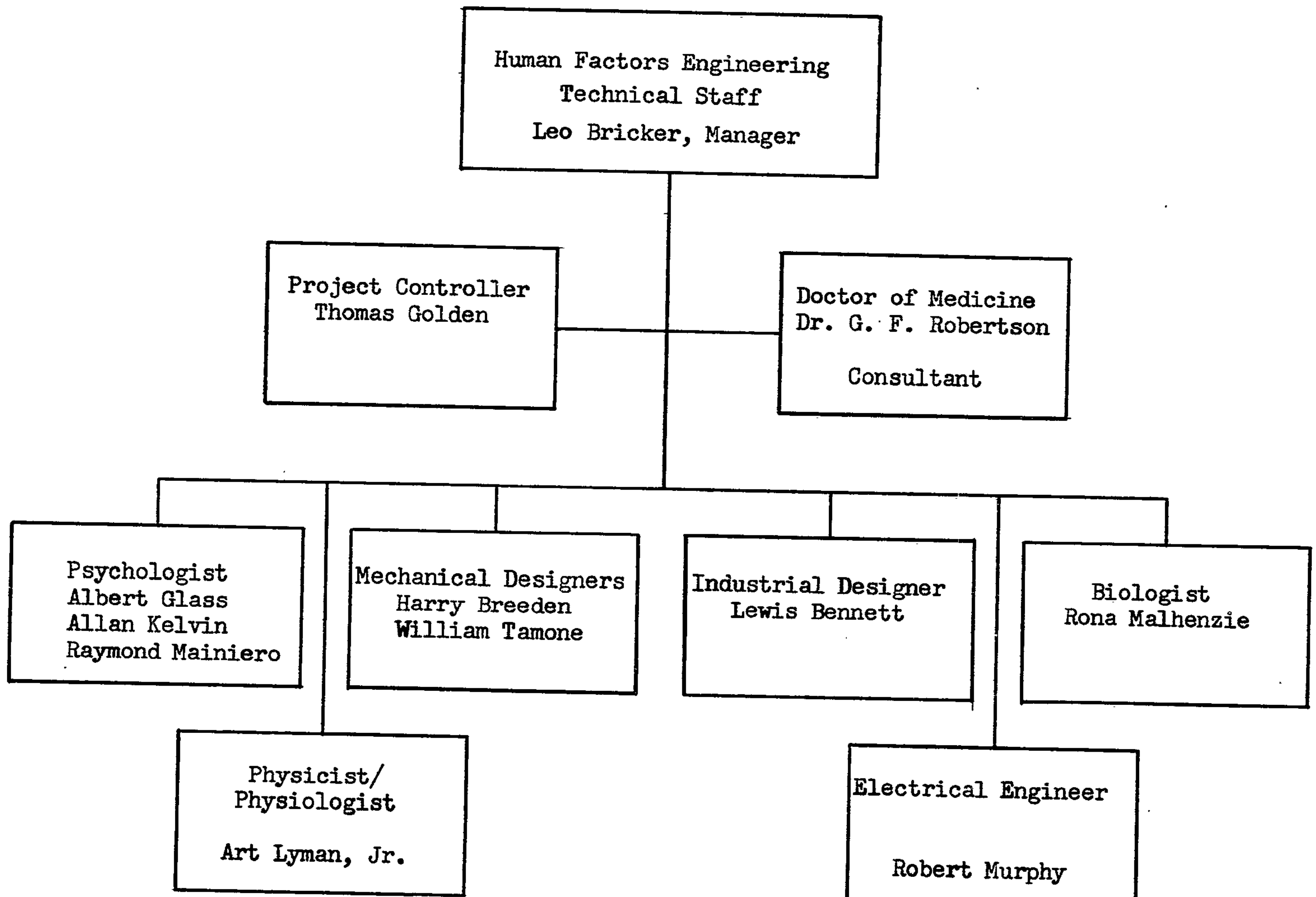
The functional organization chart (see figure 3-1) illustrates the wide range of experience and education within the HFEG. The prime function of the group is to support project engineering by the application of human factors engineering technology to specific hardware designs or studies being performed.

### 2.2 Organization Within AMF/GED

The Human Factors Engineering Group is part of the Technical Staff of the Greenwich Engineering Division. The group is charte to support all activities on all projects within the division and may provide service to any other division, company or governmental agency that requests it. The wide exposure to many programs enables the free interchange of technology from one project to another and builds up experience from one project to another.

### 2.3 Field Representation

The human factors engineer at AMF participates not only in the design of equipment, but also in the field evaluations. Representatives




Functional Organization Chart

FIGURE 3-1

from the group have performed and are performing testing and evaluations at VAFB, Denver, White Sands, Cape Canaveral, and other locations

2.4 Human Factors Areas

A. Life Support

1. Accessibility
2. Air Conditioning
3. Atmosphere Control
4. Fire Hazards
5. Galley Facilities
6. Insulation
7. Radiation Shielding
8. Sanitation
9. Safety and Survival
10. Water Recycling

B. Physiological Factors

1. Acceleration and Deceleration
2. Acoustic Energy Effect
3. Atmosphere
4. Decompression
5. Diet
6. Illness
7. Physical Fatigue
8. Radiation
9. Temperature and Humidity
10. Vibration
11. Weightlessness

C. Psychological and Social Factors

1. Boredom
2. Confinement
3. Crew Interaction
4. Day-Night Cycles
5. Disorientation
6. Isolation
7. Lack of Privacy
8. Leisure and Recreation
9. Lighting and Color Scheme
10. Mental Fatigue
11. Motivation
12. Personnel Selection and Training
13. Neuroses
14. Personality Conflicts
15. Phobias
16. Psychoses
17. Vigilance
18. Weightlessness

## 3.0 Project Participation

The project organization chart (see figure 3-2) is representative of the number and type of projects that were being worked on at one time with the Greenwich Engineering Division. Through the maintained control of all the individuals on the human factors engineering team, the team manager can immediately reassign human factors engineers from one project to another and make available specific skills that may be required on a short time or temporary basis. A description of one facet of another project in which human factors engineering participated in is shown in figure 3-3 and described below.

### 3.1 Talos - Land Based Launcher System (1956-57)

In the design of an information display system, the primary objective is to present the information in a manner which will provide rapid operator comprehension and analysis.

During the early stages of the development of a control system for the land based Talos missile launcher by the American Machine & Foundry Company, the first approach to the operating station layout was the use of conventional standard switches and "bullseye" light indicators. It become apparent that the multitude of lights and switches involved in this complex control system would be difficult for an operator to comprehend. Based on a human engineering study, the readings were reduced to the minimum requirements. In addition, the study specified the maximum space allowed for information displays plus requirements for colors to aid the operator's response.

Human Factors Engineering Project Organization

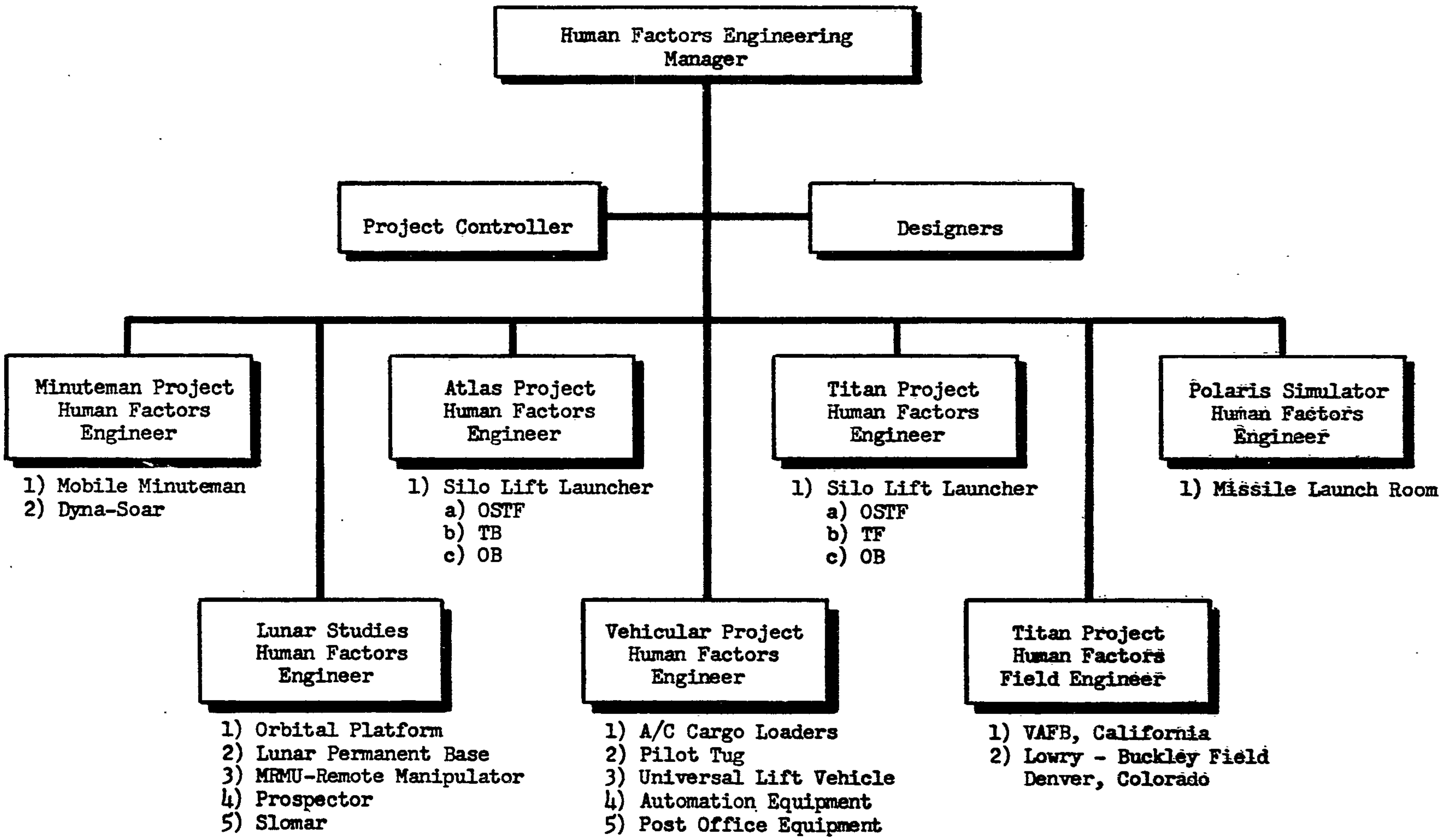
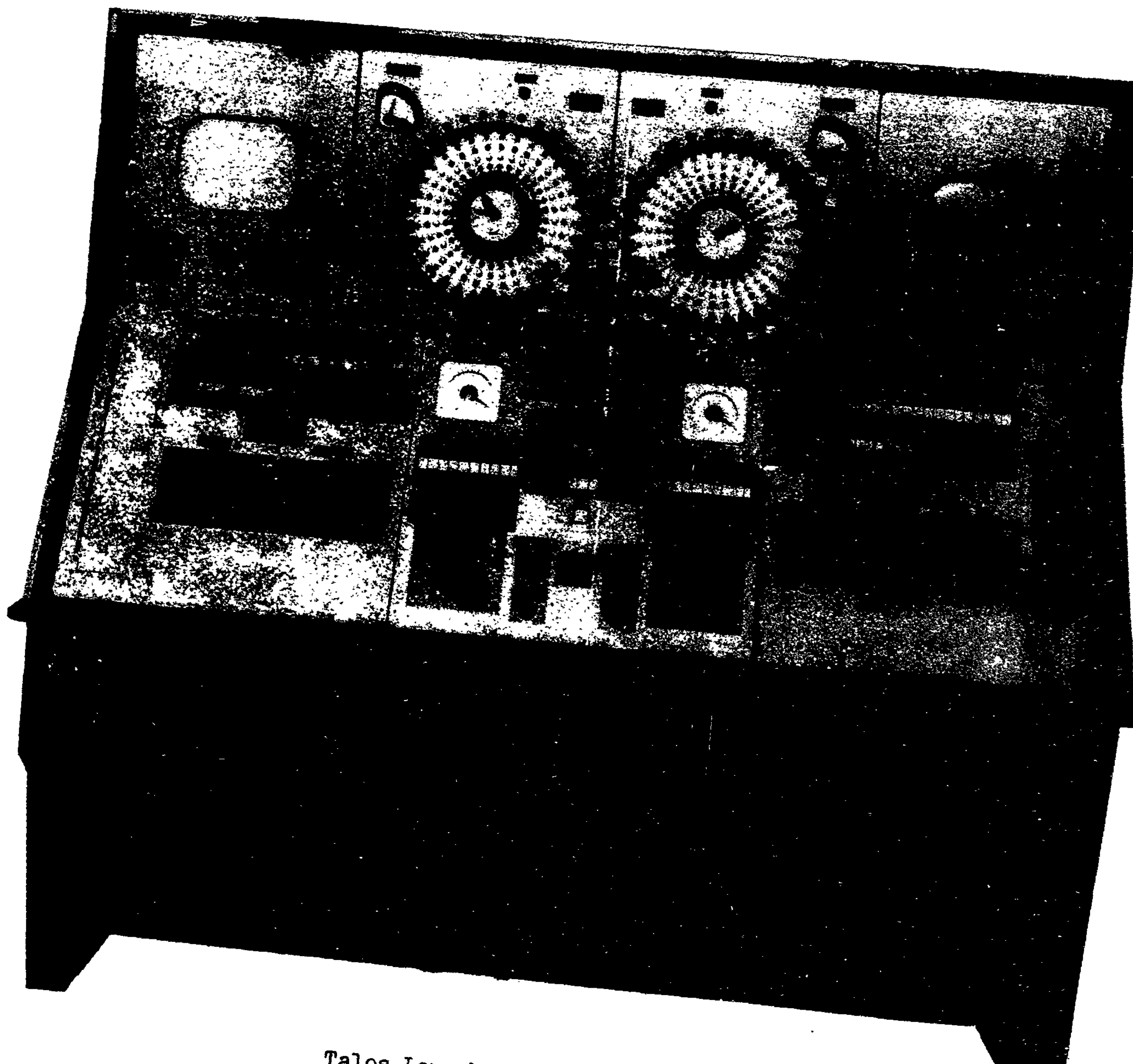



FIGURE 3-2

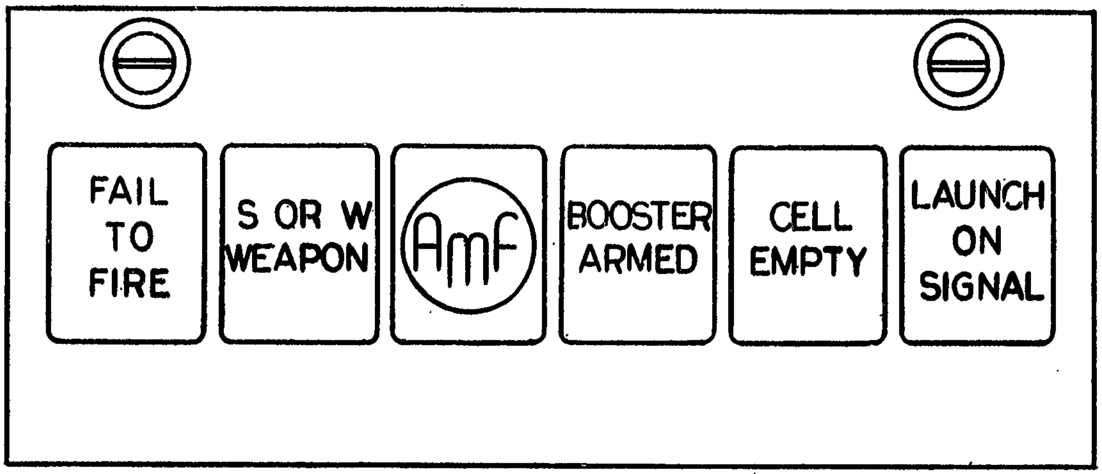


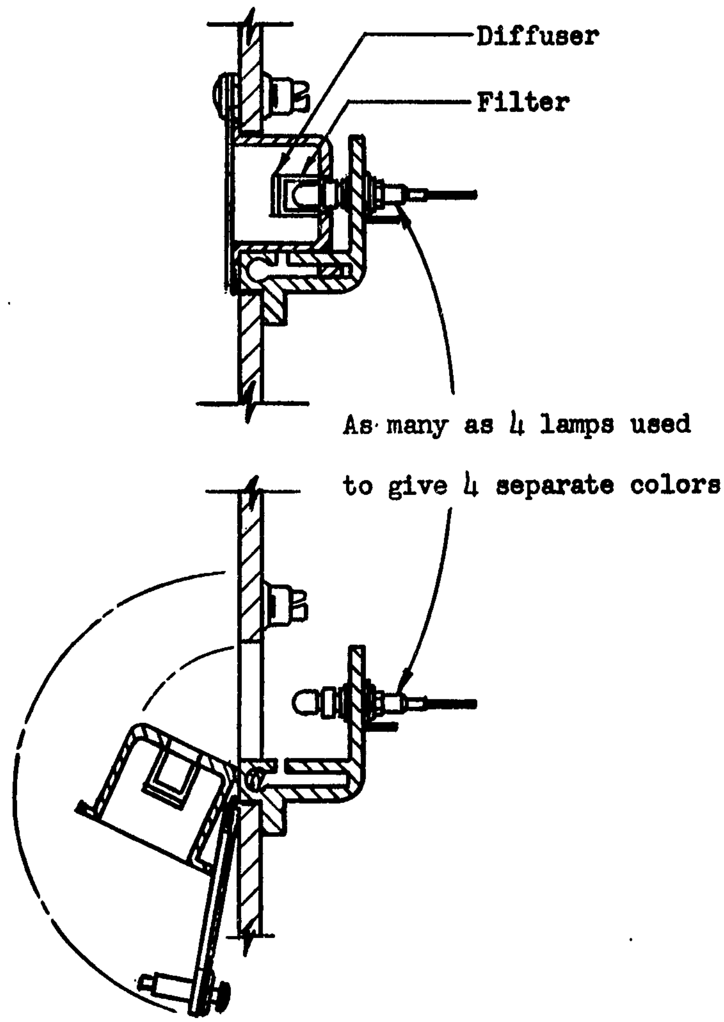
Talos Launch Control Console

FIGURE 3-3

The design requirements imposed by the human factors specifications made it imperative to use a given area for more than one bit of information. This resulted in a design wherein one indicator is illuminated with colors emanating from four light sources. Heretofore, edge lighting of a translucent panel with several colored light sources has been utilized to achieve uniform lighting of a panel indicator. Such lighting, however, requires an excessive number of component parts surrounding the panel edges and is relatively inefficient as only a small portion of the available illumination penetrates the edge of the panel. The ultimate design evolved is shown in figure 3.4. A flat sheet of transparent or translucent plastic (methyl methacrylate resin) carries the information to be displayed. The information can be painted on this sheet using an opaque or translucent or transparent material. A demonstation display panel is shown such as might be employed in a missile control console.

The illumination cells for each information area are designed as illustrated. Each cell may contain up to four lamps mounted on the bracket behind the panel. The solid filter and diffuser block assembly is removable from the front of the panel to facilitate lamp replacement. The inside surface of the heavily shaded area in the filter and diffuser block constitutes a reflecting surface which serves to direct light to the indicator sheet. The main body of the block is filled with a material having uniform light-transmitting characteristics such as transparent methyl metharcylate resin. Cylindrical color filters and diffusing elements are molded into the rear of the block. The filters are




Display Panel and Illumination Cell Design
FIGURE 3-4

cavities which surround the illuminating lamps. When mounted, the transparent portion of the block is in contact with the information-bearing sheet. The filter and diffuser block may be fabricated by any of several well-known molding techniques, the color filters being handled as inserts in the molding process so that the result is a single integral rigid assembly.

In operation, light emanating from any of the sources is directed outwardly through the color filters and diffusers into the solid clear portion of the block. Since the block is surrounded by a reflecting surface except for the front face which is in contact with the indicator sheet, substantially all of the light is conducted to the rear face of the indicator sheet. Hot spots are eliminated by the diffusers. Although the light sources are laterally spaced, the information carrying sheet is uniformly illuminated when any of the sources is activated.

This information display design provides the following advantages:

A. Three or more colors may be displayed in the same area at different times to comply with human engineering specifications on eye span.

B. Essentially all hardware is mounted behind the display area to reduce the panel and console space required.

C. Areas of information are illuminated with an even distribution of light to provide improved long distance viewing and more positive attention stimulation.

D. Nesting of color units results in reduced panel area requirements.

E. Different shapes may be displayed in the same area.

In general, the use of colors allows the operator to ignore items that are correct at the moment (green) and to concentrate on problem areas (flashing red). Other colors depict intermediate conditions such as operations about to happen (amber or yellow).

Using this approach, the design engineer can comply with the human engineering specifications of compact consoles and still display the desired information. With this type of system the operator will always find information concerning a certain device at the same spot on the console. For example: Fuel tank status; full - green, half empty - yellow, low - flashing red, filling - blue.

This information was formerly displayed by separate lights for each bit of information with resulting extra panel space and more eye space required by the operator.

## 3.2 Aerospace Operations

The Human Factors Engineering Group's participation in aerospace operations programs has ranged from concern with locally-conducted experiments in subjects which are important to human viability in space, through hardware and methods research, to concept formation and long range methodology studies on the feasibility of human participation in future, more exotic space programs.

In these contexts, the following subject matter has been studied, evaluated, experimented with, or is awaiting further experimentation:

A. Lunar Base Operations

1. Human environmental requirements - (atmosphere, temperature, sustenance, acceleration, gravity, anthropometry, physical plant, stress, noise)
2. Maintenance methodology - (space tools, weightlessness, personnel sensory perception, work-sleep cycling, team composition, team rotation, work-mating hardware)
3. Pressure suit-capsule evaluation - (vision, heat exchange methods, ease of manipulation, waste disposal, communications, psychological comfort, illumination, mechanical requirements)

B. Orbital Base Operations

1. Same as for Lunar Base
2. Same as for Lunar Base
3. Weightlessness - (Coriolis Forces Effect, physical and physiological effects, psychological effects, methods of compensation)

C. Master-Slave Manipulators - (mating procedures, remote TV methods and hardware design)

D. Space Tools - (experimental evaluation of space tool design in underwater environment to simulate space zero-g effects)

E. Weightlessness - (participation in an Air Force flight under "weightless" conditions)

F. Botanics - (evaluation of plant life development in an artificial environment)

In each of these major areas, the Human Factors Engineering Group has brought to bear a team of specialists representing diverse disciplines and backgrounds of experience. In the conduct of aerospace operational studies, the Human Factors Group has had an opportunity to display two major functions: that of original research and experimental design, and that of arranging and generating data regarding detailed requirements for the safe and efficient operations of humans in hostile environments. For these purposes, it has proven most expedient to utilize the methods of applied psychology and bio-physiological research.

## 4.0 Personnel

A description of the education and experience available within the Human Factors Engineering Group is indicated below:

A. Education

1. Bachelor's Degrees in Biology, Business Administration, Electrical Engineering, Fine Arts, Mathematics, Mechanical Engineering, Physics and Psychology.
2. Master's Degrees in Business Administration, Industrial Engineering and Psychology.
3. PhD Candidates in Management and Psychology.

B. Experience

Includes Human Factors Analysis and Evaluation on:

1. Military Equipment: Antenna Systems, Communications Equipment, Hard, Soft and Mobile Missile Launcher Systems, Mobile Equipment, Aircraft Interiors, Loran, Tanks, Command Consoles and other items.

2. Commerical Equipment: Radio, Television, Vacuum Cleaners, watches, electronic components, jacking machine, post office equipment and other items.

3. Education Field: Training and Indoctrination.

4. Research: Biodynamic and Biomedical analysis of human physical activity and locomotion relative to energy expenditure (metabolic analysis) fatigue, proprioceptive feedbacks, tactical discriminations and motor tasks.

5. Engineering and Design: Electromechanical, Hydraulic, Electrical and Mechanical equipment on Military projects as well as supervisory experience at top management level on both military and commercial equipment.

## Chapter 4

## The Titan Human Factors Program At AMF

### 1.0 The Nature of the Program

### 1.1 Introduction

It is the purpose of this chapter to present a complete yet succinct delineation of the Human Factors Program for The Titan Launcher System, as conceived, designed and developed by AMF.

### 1.2 The Scope of the Technical Directive

The Titan Human Factors program at AMF is the natural outgrowth of company efforts to implement the demands of the BMD/STL Technical Directive which defined the essentials of Human Factor engineering by:

(1) establishing requirements for Human Factors efforts in the design, development and integration of WS 107A-2 OSTF, TF, and Operational Equipment and Procedures, and by

(2) establishing Human Factor engineering design standards for the WS 107A-2 OSTF, TF, and Operational System.

Paragraph 3 of the TD specifically requires that: "AMF shall provide complete human factor engineering of that portion of system design and development for which it has responsibility." Paragraph 3 further requires that in discharging these responsibilities, AMF shall make provision for accomplishing five major functions:

(1) the integration of human factor concepts as part of design studies;

(2) the conduct of necessary and related short term research;

(3) the accomplishment of day-to-day human factor engineering applications during the design and development phase of components and sub-systems;

(4) assuring that its subcontractors have performed adequate human factor engineering; and

(5) the inclusion of pertinent human factors tests for the Launcher system.

## 1.3 Limitations of the Human Factor Program

### 1.3.1 Operational and Maintenance Equipment Limits

The AMF Human Factors program as presented herein is limited in scope to cover operational and maintenance equipment and procedures of the Titan Launching System, but it specifically excludes all aspects of initial installation procedures.

### 1.3.2 Status of Unincorporated Recommendations

Since the report covers only the history of the Human Factors effort, it follows that some results of the total effort may be pending, or may have been deleted or deferred. Subsequent addenda will give the current status of outstanding recommendations.

The results which are termed "pending," are identified as those recommendations which were made, but whose current "in or out" status is not presently determined. Incorporation of some recommendations may be deferred for a later phase, or may have been deleted due to a hardware design change which removes the necessity for the original recommendation.

It is the responsibility of the Human Factors team, however, to determine whether or not a previously submitted recommendation is still applicable.

### 1.4 Omission of Some Maintenance Requirements from the Scope of the Human Factors Program

Directive #58-4003 indicates that, in discharging its responsibilities, AMF shall provide complete human factor engineering in the design, development and integration of the equipment and procedures of the WS 107A-2 Launcher System. There are, however, certain prescribed areas of human factors engineering responsibility which were not included. AMF's Human Factors team did not participate in, or participated only minimally, in the following areas of maintenance requirements which were accomplished by other members of the AMF Titan Project:

(1) establishment of training requirements for launching system maintenance;

(2) establishment of remove & replace procedures;

(3) allocation of functions to system personnel and personnel work loads (task analysis);

(4) preparation or review of technical manuals presentations.

### 1.5 Further Studies Associated with Human Factors Effort

#### 1.5.1 The Authorization for Human Factors Research

Although additional short term research, as necessary, was recommended by BMD/STL in order to answer human factor design or developmental questions related to Launching System, AMF was not able to undertake any basic back-up research, due to the rapid growth rate of the task to be performed.

#### 1.5.2 Pushbutton Pressure vs. Frequency-of-Use Study

AMF is, however, presently conducting one research experiment entitled "Pressure versus Frequency Design Study for Functional

Variables of The Human Operation of Pushbuttons." The purpose of this study is to examine the interactive effects of the diameter of pushbuttons, the resistance of pushbuttons and the frequency of their use in order to obtain some specific and useful design variables.

The results of the study will be included in the Titan Human Factors Final Operational Report.

## 2.0 Initiation of the Program

### 2.1 Implementation of the Technical Directive

The Human Factors effort was implemented in the earliest stages by the use of a firm of outside consultants, and soon thereafter by the establishment within the AMF Titan Project organization of a Human Factors Group.

#### 2.1.1 Titan Human Factors Organization

Figure 4-1 "Human Factors Engineering Function Chart," is an illustration of the organization of the Human Factors staff, showing the interrelations of specialized personnel, according to team function. See Figure 4-1 on next page.

#### 2.1.2 BMD/STL Direction

The Technical Directive was issued as part of Contract No. AF 04(647) - 138 by the Air Force's Ballistic Missile Division (BMD) as Technical Directive Number 58-4003, and dated December 22, 1958. The established policy called for BMD direction, to be administered thru the agency of Space Technology Laboratories (STL); the AMF Human Factors Program was monitored thru the on-going direction and supervision of STL. The program was assisted immeasurably by sustained personal guidance from Dr. Jay Cohen of STL and Col. Norman Murray of BMD.

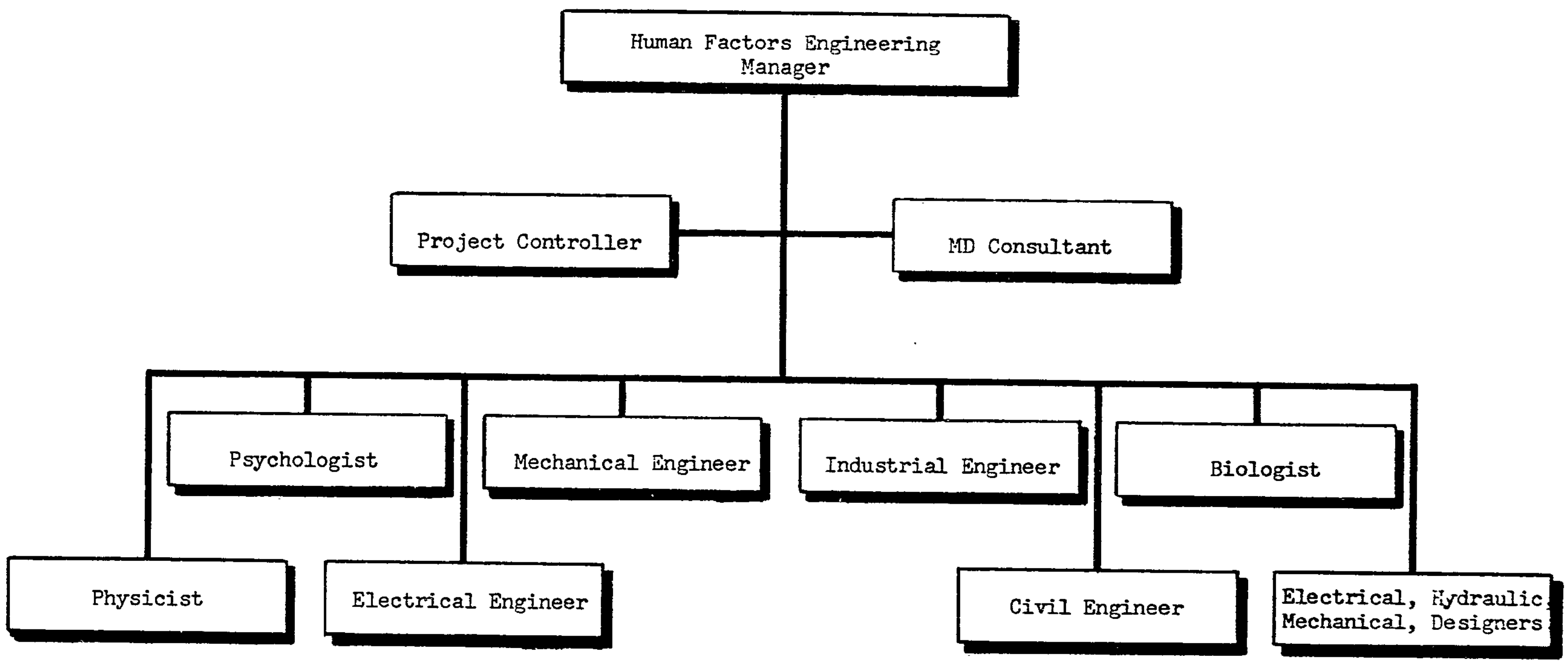



**Figure 4-1**

**Human Factors Engineering Function Chart**

### 2.1.3 The Basic Document: AFBM Exhibit 57-8A

In accordance with the requirements of TD 58-4003, the basic document to be utilized in the implementation of the Human Factor effort was WDT Exhibit 57-8 "Human Engineering Design Standards for Weapon Systems 107A-1, 107A-2 and 315A Equipment." Shortly after the TD was issued, however, supplementary correspondence was undertaken between BMD/STL and AMF which resulted in the acceptance of a more up-to-date and helpful technical reference as the basic document. By July 1959, AMF's Titan Specification AMS-1001 had been revised to reflect the fact that document WDT 57-8 had been superseded by AFBM Exhibit 57-8A, "Human Engineering Design Standards For Missile System Equipment," dated 1 November 1958.

A maximum effort was made to incorporate in the launcher system the design principles and practices which are recommended for designing equipment for maximum utilization by operator and maintenance personnel. Where it was not possible to employ ideal human engineering design principles, efforts were made to obtain optimum compromises and to establish human factor criteria for general system application.

## 2.2 Initial Efforts

The efforts during the early development of the program of necessity were quite generalized in nature and assumed the aspects of orientation reviews and investigations.

### 2.2.1 Consultants' Services

Once the need for Human Factors Engineering Requirements was acknowledged and accepted, it became apparent that additional services from experienced Human Factors consultants would be required in order to meet the prescribed objectives during that interim period while AMF developed its own full Human Factors capability.

From April 15, 1958 thru July 1958, the services of Becker and Becker Associates of New York City were acquired, to prepare a study of the human factors program on the Titan Launcher. Members of their staff participated in the earliest Human Factors conferences among the Titan Associate Contractors, as well as at AMF orientation conferences. They submitted a report on June 4, 1958 which represented their review of AMF's Human Factors Requirements for the Titan Launcher, in which they outlined a program of the specialized study which they anticipated would effectively fulfill AMF's contractual obligations to the Air Force. Becker and Becker also performed several hardware studies.

In the course of the preparation of the Becker and Becker reports, it became apparent to the AMF staff that it would be more efficient for AMF to augment and use its own staff, since it always had to perform an extensive investigation and interpretation in order to orient the consultants for their preparation of the study.

Therefore the relationship was ended on August 1, 1958, and the services of Becker and Becker were continued only on a call contract.

2.2.2 Engineering Inspections

In the summer of 1958, Ballistic Missiles Division scheduled two engineering inspections of the progress being made by AMF on the Titan Launcher System. These were designated the Preliminary Engineering Inspection (PEI) and the Development Engineering Inspection (DEI) for the WS 107A-2 Launcher System.

2.2.3 The Preliminary Engineering Inspection

The PEI, held on July 22 and 23, 1958, was a preliminary engineering inspection at the Brooklyn plant facilities of the AMF Titan Launcher System. The PEI Board, as well as representatives from cognizant Air Force activities and related contractors, inspected a 1/12 scale working model of the Launcher System, movies, models, mock-ups, displays, and exhibits representative of the OSTF Titan Launcher and related ground support equipments. The principal purpose of the PEI was to offer the Air Force board members and advisors, as well as the contractors, the opportunity to submit Requests for Alterations (RFA's) which were considered to be desirable improvements to the engineering design of the Launcher. The Requests were processed by the PEI Board, and notice of approval requests for changes or studies of Launcher System components were forwarded to AMF, followed up by technical directive meetings to authorize the change of scope.

Of the 76 RFA's submitted during the PEI, 8 were approved, 39 were disapproved, 26 were approved for further study, 1 was withdrawn and 2 were not categorized. Of the 76 requests submitted 46 were within the scope of Human Factors responsibility, and will be tabulated with a summarization of the nature of the DEI Requests in a subsequent paragraph, 2.2.5.

2.2.4 The Development Engineering Inspection

The DEI, or development engineering inspection, was held at the AMF Brooklyn plant on Sept. ber 8, 9, and 10, 1958, for the purpose of inspecting the technical, operational and logistical aspects of the equipment associated with the Titan Launcher System. The DEI was conducted by representatives of the same Air Force activities and advisors, and for continuity, 4 members of the 8 man Board were carried over to the DEI Final Review Board.

A more refined exhibit of working models and displays representative of the OSTF launcher system were examined at the DEI. Of the 28 RFA's which were presented and processed by the Final Review Board, 6 were approved, 14 were disapproved, one was approved for study, 4 were other decisions and 3 were noted for information only.

Of the 28 RFA's processed at the DEI, 22 were within the scope of Human Factors responsibility.

2.2.5 Recapitulation of Human Factors RFA's

Of the group of 104 RFA's composed of 76 FRA's from the PEI and the 28 from the DEI, a total of 68 RFA's or 66% were based on Human Factors considerations. See Figure 4-2, which shows the breakdown by areas of Human Factors considerations.

| Human Factors Basis for RFA | Number at PEI (Maximum: 76) | Number at DEI (Maximum: 28) | Combined Totals (Maximum: 104) |
|---|---|---|---|
| 1. Safety | 14 | 10 | 24 |
| 2. Maintenance and Service | 14 | 3 | 17 |
| 3. Handling | 9 | 5 | 14 |
| 4. Access | 5 | 1 | 6 |
| 5. Human Use (Procedures) | 3 | 1 | 4 |
| 6. Human Engineering Design | 1 | 1 | 2 |
| 7. Psychological | 0 | 1 | 1 |
| Totals | 46 | 22 | 68 |
| Percentage | 60% | 78% | 66% |

Figure 4-2 Breakdown of 104 RFA's Processed at PEI and DEI, Showing the Number Based on Human Factors Considerations

As might be expected, the highest specific item is Safety, with 24 or roughly 1/3 of the total of 68 requests for alterations.

In classifying the requests (RFA's) into Human Factors categories, it was occasionally noted that several general safety considerations also contained well defined as well as implied recommendations for reducing psychological or physiological stresses in order to safeguard personnel. Since the ultimate goal was increased personal safety, these were classified as safety recommendations.

The second largest category by number is Maintenance and Service with 17 total RFA's. However, if the other two functionally related categories of Handling and Access are combined with Maintenance to form a Maintainability category, this item totals 37 out of 68 or more than half of the RFA's processed. Clearly, ease-of-maintenance of a complex weapon system has a high priority with the operating activity.

## 3.0 Techniques of the Human Factors Program

The AMF Human Factors Team participated actively and extensively in all phases of the design and development of the Titan Launching System. The techniques utilized in order to implement the requirements of the technical directive ranged from broad, general outlines at the initial stages, to specific criteria at the design stage, thru to evaluation and verification stages at the completion of the project.

## 3.1 The Systems Point-of-View

Throughout the life of the project, the basic philosophy which pervaded all Human Factors efforts is that known as "the systems point-of-view." In practice, this means that all Titan Launcher System designs were reviewed with the total system in view.

The mission of The Titan Weapon System is that of launching a retaliatory weapon. In event of enemy attack, the primary importance of the mission is to get the weapon off the ground in as short a period of time as possible. Whereas other worthy considerations and improved inputs would normally be desirable, in this context, they cannot be permitted to compromise the mission objective. With this philosophy in mind constantly, each aspect of the Launcher System design was scrutinized and evaluated.

## 3.2 Progressive Phases of Titan Human Factors Effort

As the Titan program developed, opportunities for Human Factor participation multiplied. Chronologically speaking, the following sequential phases of the overall Human Factors effort were undertaken for the Titan Launcher System:

(1) Participation in the initial concept phase (DCL Review),

(2) Participation in design consultations,

(3) Generation of general human factors criteria,

(4) Generation of specific human factors criteria,

(5) Engineering design review (DAL, DDL, and EPD Review),

(6) Man-machine analyses,

(7) Human Factors verification tests,

(8) Re-design recommendations (ECP Review),

(9) Product improvement recommendations.

Identification of major problem areas, pertinent Human Factor criteria, related reports or studies and subsequent recommendations and their degree of acceptability are all recorded summarily in Chapters 8 thru 26 of this report.

## CHAPTER V

## Intergration of Human Factors Engineering for Titan Weapon System

1.0 As the Titan Human Factors program unfolded at AMF, many questions arose whose solution required that information be obtained from all or various members of the seven Titan Associate Contractors.

1.1 Coordination With The Associate Contractors

At the onset of the Titan Weapon System, the Space Technology Laboratories had been designated by the Air Force to serve as the coordinating contractor for the entire WS 107A-2 Program. In this capacity, STL organized several human factors conferences for the associate contractors in order to: a) indoctrinate all contractors, b) to unify objectives, and c) to coordinate exchange of necessary information among the associates. At the initial conferences the discussion centered on the establishment of a uniform color coding system for display lights used throughout the Titan Weapon System.

1.2 Problems Related to Interface Requirements

Aside from the expected, routine problems of interface exchange, the major problems which particularly affected AMF were concerned with interferences with facilities. The amount of flexibility permitted in locating equipment not specifically located by dimension resulted in interferences with AMF equipment that had been designed to accommodate the facility equipment per Daniel, Mann, Johnson, Mendenhall, and Associates drawings. The problems arising from overlapping interface requirements were quite serious for AMF, as they affected access to equipment, personnel safety and also impeded operation of equipment. Where possible, compromises were worked out.

Unfortunately, many of these serious interface problems have not yet been resolved at the operational bases. Objectionable interferences exist to the present day, and can only be removed by continued, persistent and arduous intergroup effort.

1.3 Coordination With Sub-Contractors

Apart from the obvious cooperation which is needed among Associate Contractors, the need also exists for each associate to coordinate Human Factor design requirements with its sub-contractors. The AMF Human Factors team did coordinate the efforts of its sub-contractors on any equipment built for us. However, if the sub-contractors parts were standard items (and most were), no inputs were required from AMF because the specifications indicated that standard parts take precedence over new design criteria.

## Chapter VI

## Human Factors Considerations in Titan Launcher System

### 1.0 Purpose: Definition of Terms

It is the purpose of this chapter to identify and define those Human Factors which are deemed to be major considerations as related to the Titan Launcher System, and to define the special terms which are used throughout this report and tabulated on the Summary Checklist.

### 1.1 The Major Human Factors Considerations

Examination of the Titan Launcher System indicates that there are seven major categories within the purview of human factors relationships:

(1) Human Engineering Design Factors

(2) Maintenance Factors

(3) Safety Factors

(4) Physiological Factors

(5) Psychological Factors

(6) Environmental Factors

(7) Human Use Factors

Within each category, there are considerations which are unique to the hard-based Titan Weapon System. These will be itemized and presented as sub-groups under each of the above category headings.

### 2.0 Human Engineering Design Factors

The aspects of engineering design which are based on good human factors principles devolve from the physical limitations of man's abilities and/or dimensions. As related to the Titan Launcher System this means that careful consideration must be given to 4 areas:

(1) Anthropometric Compatibility

(2) Controls and Displays

(3) Fail-Safe Design

(4) Malfunction Detection

## 2.1 Anthropometric Compatibility

According to the specifications of AFBM Exhibit 57-8A, it is mandatory that an anthropometric compatibility be maintained between the human operator and the equipment being operated. The system should be designed so that the 5th through the 95th percentile of Air Force personnel who will serve as operators or maintenance men will not be expected to perform at unreachable points, or to work in cramped quarters or to carry overweight burdens.

As used in this report, the expression "anthropometric compatibility" will mean that operation or maintenance activities have been evaluated in terms of the ease of use by the 5th through the 95th percentile of Air Force personnel.

## 2.2 Controls and Displays

The controls and displays should be designed so that the best human engineering design concepts are adhered to. It is necessary to design within the physical, physiological and psychological limitations of man's ability to integrate eye, mind and muscle. The design should assist, not compromise, the operator as he seeks to identify properly information shown on a display, to formulate and execute decisions, to select swiftly the proper control, and unerringly to manipulate that control with the result that the desired system function is performed.

Extreme care must also be taken to assure proper labeling, coding and panel arrangement of related controls. The penalities of poor human engineering design in this area are very severe, for errors in perception or in actuation can easily destroy expensive equipment and even operational readiness.

In this report the use of the designation "Controls and Displays" will mean that the equipment has been evaluated in terms of those related human factors considerations which will assist, not compromise, the human operator.

### 2.3 Fail-Safe Design

The term "Fail-Safe Design" can refer equally to the safeguarding of expensive equipment and of human life. In this report, the term will be limited to the achievement of a fail-safe design only in those situations where the consequences of failure of equipment would bring injury to personnel.

Fail-safe design is urgently needed in any system which involves equipment in motion, because the failure of moving parts can cause severe damage, either through the loss of actuating power or through the loss of braking power. The human engineering goal is, therefore, to design so that loss of power from whatever source will not cause inactive equipment to move to the collapsed position, nor to cause inactive equipment to become activated by power failure (such as would follow the loss of braking power). Two of the guiding principles are that powered equipment which normally holds in the ON position shall not collapse when power fails, and powered equipment which is normally collapsed in the OFF position shall not become inadvertently activated by power loss.

## 2.4 Malfunction Detection

Fault detection equipment contains the circuitry used to detect malfunction in automatically operating equipment. This equipment should enable the operator:

(1) to check out equipment prior to operation,

(2) to check out equipment during operation,

(3) to localize faults, down to single components and,

(4) to check the fault detection circuitry itself too.

Automation of fault detection equipment is desirable in order to provide maintenance crews quickly with the information which they must have regarding the exact description and location of a malfunction in this complex weapon system, the logic system has been connected to additional circuitry which detects, locates and records malfunctions.

This additional fault detection circuitry operates only during exercise of the logic system. During actual launcher operation under control of the Launch Controller, in case of a fault, the entire system will shut down, and a fault tape will be punched out. The fault tape indicates the function which failed, the type of the failure and the location of the failure, i.e., whether it concerns the launcher components or only the relay system. The fault tape punch does not, however, identify the specific component which has failed. The operator then follows a procedure for localizing the malfunction if it is within the the logic relay system.

Throughout this report, the term "Malfunction Detection" will mean the evaluation of problems related to the detection, location and registration of launcher malfunctions.

## 3.0 Maintenance Factors

Maintenance is defined by the Air Force as those orderly, timely and sequential activities which are performed to keep equipment in, or to restore it to, an operable condition.

Several areas of activity stand out as prime human factor considerations related to the Maintenance requirements of the Titan Launcher System. These cover a wide range, including:

(1) Access - this includes personnel access and vehicle access, (both to missile and to launcher, as well as to missile silo facility equipment).

(2) Handling - this covers handling requirements and limitations, of both personnel and accessories.

(3) Routine Maintenance - this includes maintenance activities related to: (a) visual inspection
(b) local repairs and replacement
(c) periodic servicing

## 3.1 Omission From Access Requirements

In this report we shall omit consideration of access space requirements for the use of crews at the initial installation of equipment. Such work will be the responsibility of the installation contracting team, which routinely utilizes extensive rigging and scaffolding. After the weapon system becomes operational, these installation aids are removed, and the Air Force's operating and maintenance crews will have available only such means of access as the associate contractors and/or the Ballistic Missile Division were able to identify in advance as necessary and contractually required.

3.2 Accessibility

The engineer's concept of "access" is a relatively recently recognized system requirement. Many hours of maintenance downtime can be eliminated by thoughtful initial design of components and installations which will permit maintenance personnel to proceed quickly with their routine assignments, without wasting precious time maneuvering intricate, awkward or complexly assembled components before they can even initiate remove-and-replace procedures. It should not be necessary to set up elaborate rigging to remove heavy, adjacent but functionally independent equipment in order to achieve physical access to a relatively small component. Nor should components be designed on the basis of a "mutually exclusive" philosophy which could permit design incongruities, a hypothetical example might be the installation of a 3' x 3' black box, with a removable access panel on one side, being dropped into a slightly oversize 3' x 3' space envelope surrounded by solid walls of other system equipment, with the net result that one has no access to the access panel, save by excessive employment of manpower, equipment and time in order to extract the component, to hold it aloft, remove fasteners, apply needed maintenance and remount the box, or by the equally infeasible method of removing and disconnecting (and thereby disabling) the adjacent equipment in order to reach the fasteners of the access panel. Or again, designers of adjacent control equipment consoles might find that each has assumed that he may step into his neighbor's space envelope in order to remove the access panel on the back of his equipment, only to discover that both designer's equipment is mounted in such a way as to make such flexibility impossible.

## 3.3 Definition of Access

The need exists for a usable definition of access, especially as it applies to the maintenance requirements of the hardened missile weapon system.

Access may be defined as the adequate space envelopes needed for the entrance, passage, withdrawal and utilization of all required personnel with all required equipment, in order to perform maintenance of hardware.

## 3.4 Access - Specific Definitions and Applications

In specialized application to a hardened missile installation, access requirements are greatly complicated and costly and trade-off studies must be performed to determine the relative value of cost versus utility. There are essential aspects of access which are peculiarly characteristic of the hardened launcher system:

a) Access space envelope for periodic visual inspection of equipment

b) Access space envelope for servicing (lubricating, testing, etc.) of equipment

c) Access space envelope for removal and replacement of equipment

### 3.4.1 Access Space Envelope - Visual Inspection

Definition: The space envelope which is required to perform visual inspection by reading gauges, checking for leaks, checking for secure wire locks, etc.

Application: The space required to perform this task includes the area necessary for safe positioning of personnel and equipment in order to accomplish the task. In order to insure the safe passage of personnel and equipment to perform this and the other maintenance tasks indicated in this chapter the following areas should be provided and conversely, equipment should not be mounted in such a manner as to interfere with the minimum access areas for at least the following situations:

1. crossing by bridge from the personnel access tunnel to the personnel elevator;
2. access into and out of the personnel elevator from every stop;
3. walking onto and across every leaf of the 5 folding work platforms and including access space all around the base of the missile on the launcher platform;
4. walking from extended work platforms or crib mounted platforms to silo mounted platforms in order to reach silo-mounted equipment;
5. walking from the work platforms or crib mounted platforms onto the personnel stairway;
6. adequate step space and personnel accessway to reach the emergency ladder which is mounted along the outside of the crib;

7. passageway to access ladders, both from the crib and from silo mounted platforms;

8. adequate access step provision to permit reaching emergency ladder or facility platforms safely;

9. passageway for reaching a special facility access stairway which extends from elevator stop No. 8 to the base of the silo, and adequate dimensions to permit human passage on the stairway;

10. and lastly a very broad category which includes at least an unhampered passageway to flat surfaces or the tops of other installations which, unofficially but effectively, serve as platforms for access to otherwise inaccessible equipment.

3.4.2 Access Space Envelope - Servicing Equipment

Definition: The space envelope required to perform routine maintenance such as lubrication, changing "O" rings, tightening connections, checking circuitry using meters, etc.

Application: The area required includes the space necessary for personnel with equipment to reach the component to be repaired.

3.4.3 Access Space Envelope - Remove and Replace

Definition: The space envelope required to remove faulty equipment and replace that equipment with a similar unit has been checked and certified.

Application: The area required not only provides for safe passage for personnel and equipment to reach the equipment and to remove the equipment, but also includes the passageways required for transporting equipment by slings through the silo toward the tunnel or top of silo. In certain instances several slings must be used together and then separately in order to provide both vertical and horizontal movement of the component being removed.

3.5 Handling - Physical Limitations

Definition: Equipment shall be provided with suitable eye hooks or other lifting accessories whenever the equipment being manually handled exceeds the weight and lifting height recommended in AFBM 57-8A.

Application: The equipment was evaluated to determine conformance with the above requirement as modified in accordance with adequate access for performing the task as well as the bulkiness of the equipment. Equipment and components were provided with handles or strongbacks as required.

3.6 Handling - Transportation

Definition: The equipment re ired to perform mechanical handling tasks were considered under this heading within the report.

Application: The use of dollies, tug trucks, trailers, etc., was recommended whenever required to accomplish a specific maintenance task. Consideration was also included for adequate space for placement and use of the mobile equipment.

3.7 Vehicle Maneuverability

Definition: The areas provided to maneuver and position equipment safely as well as to permit travel of vehicles through the tunnels and into the silos were considered under this heading.

Application: The problem of passage of vehicles going in different directions within the tunnel as well as signal warning lights and personnel passage and transportation were the main areas under consideration.

4.0 Safety Factors - From the personnel standpoint, safety is of prime consideration especially under the conditions imposed by a hardened missile launching system. The various factors that have been emphasized under this heading are:

(1) Chemical Decomtamination

(2) Escape Provisions

(3) Protection from Entanglement

(4) Protection from Falling

(5) Safety Devices

(6) Warning Devices

4.1 Chemical Decontamination - The equipment such as shower and eyewash stations required to accomplish this task was the prime consideration.

4.2 Escape Provisions - In the event of an emergency condition, such as the existence of toxic fumes, or an explosive environment, which would necessitate personnel leaving the silo quickly, escape provisions such as an emergency ladder equipped with non-slip sleeving have been provided. Additional escape provisions for attachment during climbing, passageways, and catwalks are included under this heading.

4.3 Protection from Entanglement - The equipment and/or means of preventing personnel from entanglement with rotating equipment or equipment in motion is covered under this heading. Basic protective devices such as screened guards for rotating equipment and for moving counterweights are the main protective devices used.

4.4 Protection from Falling - The requirement for austere design aggravated by the requirements for additional hardware within the silo has caused difficulties in obtaining access to certain equipment. In order to minimize the possibility of falling, resulting in injury or death, protective devices have been recommended. Among these devices are railings, safety sleeves, nets, eye hooks and safety belts, which are designed to prevent accidents.

4.5 Safety Devices - The devices considered under this category comprise all items not previously covered such as warning signs, hazard markings, interlocks, warning signals, and safety covers. These devices include not only equipment but also procedures to be followed during operation and maintenance.

5.0 Physiological Factors and Environmental Factors

Potential injury to the human body is a function of the dangers inherent in an environment and the frequency and extent to which humans are involved in activities within that environment. In the Titan silo complexes, potential injury to the human exists from the following sources:

(1) mechanical injury - moving parts

(2) chemical injury - liquid oxygen, carbon tetrachloride, etc.

(3) falling - by the human body

(4) inertial injury - moving vehicles, falling tools, bursting hardware, etc.

(5) environmental influence - acoustic energy, humidity and temperature influences, illumination, etc.

With great numbers of personnel associated with training, maintenance, and operation of a silo complex, the potential for physiological injury to the human body is relatively high. Moreover, the sources listed above do not exist separately from each other. Rather, they may work in association. For example, excessive humidity and temperature will cause more slippery surfaces and influence the chances of humans falling or being injured by moving parts. Bursting hardware cannot only be dangerous in terms of flying parts, but may also cause chemical injury and acoustic damage.

## 6.0 Psychological Factors

A Titan Missile Silo with its great depth and associated confusion of moving machinery and hardware, represents a potentially hazardous situation at best. For this reason it is important that the hazard factor not be compounded by the inclusion among missile crews, of individuals who possess personalities containing definite phobias, or unreasonable fears.

Nearly every individual has some neurotic symptoms. Moreover, the distribution of these symptoms is greater in some individuals than in others. People who possess these symptoms in greater number are operationally "normal" and cannot generally be detected from their associates as being deviates or otherwise unusual. These individuals can be called "marginal neurotics." It is only on occasions that their neurotic symptoms come to the surface.

Phobias are an important example of such neurotic symptoms. Generally, an individual does not possess a unique phobia, but rather a group of such unreasonable fears. Most individuals who are faced with a hazardous situation in which caution is indicated and in which ordinary care must be taken to avoid injury, react accordingly. The phobic individual retreats from the situation entirely, and because the phobia is generally socially unacceptable, the phobic generally attempts to conceal his unreasonable fear by an explanation, or takes great pains to prevent encountering situations in which he may find it necessary to display his phobia. The following example refers to acrophobia although it may be applied to any phobic condition.

If a group of individuals is required to ascend a long ladder to a height, the ordinary individual will do so, while taking great care to step carefully and slowly. The average individual will probably voice concern over the danger and may even display temper or hostility at a clumsy associate. The task will however be performed in the end with a modicum of tension or anxiety. On the other hand, the acrophobic individual will reject the requirement absolutely, more often than not, in defiance of retaliation by authority. If, however, the phobic individual is finally forced to defy his unreasonable fear, he will either exhibit the aforementioned reactions in an even more exaggerated sense, or will become withdrawn. In either case, performance of the phobic task by such an individual will be accompanied by some loss to his psychological well-being, if not to an explicit danger to both himself and his group as a result of extreme tension and distraction.

This example illustrates that it is extremely important that missile crews be psychiatrically screened for neurotic personality. The type of personality discussed here is not easily detected by laymen and must be uncovered by extensive psychological testing and psychiatric screening.

## 7.0 Human Use Factors

There are several aspects of total support to the Launcher System which are more closely related to personnel use and operation of equipment rather than to the best possible design of the equipment judging from the purely mechanical point of view. These were found to be:

(1) Utilization procedures

(2) Time study of maintenance operations, and

(3) Training and selection of maintenance personnel.

## 7.1 Utilization Procedures

Although equipment may be designed to achieve a particular maintenance objective, one must consider the whole task in terms of the combined results of the equipment functions plus the procedures which personnel must follow in order to accomplish the task. It may be, sometimes, that the best mechanical design may be the most difficult for personnel to utilize, and this combination will result in grossly reduced overall task proficiency.

In this report, if the abbreviated term "Procedures" is checked off, it will mean that equipment has been evaluated from the point of view of the consequences of the combined proficiency of the equipment's function objective and the procedures which must be utilized by personnel in order to accomplish this task most proficiently.

7.2 Time Study

One of the Air Force's announced weapon system objectives is Maintainability, whose definition includes a minimum of down time for maintenance and the return of the system to operational status with a minimum of delay. Complex or lengthy maintenance procedures result in excessive "down time". One means of reducing such down time would be the use of time-study of maintenance operations in order to determine where improvements of procedure or equipment should be made.

The factor "Time Study" will be used to indicate that the length of time required to accomplish maintenance operations for a particular item has been considered.

7.3 Training and Selection of Maintenance Personnel

Whereas standards already exist for the training and selection of personnel, it is anticipated that the specialized requirements for fulfilling some of the more demanding human factor criteria and/or procedures may indicate the capabilities will be required which have not been provided for. In such situations, the factor "Training/Selection" will be checked and will indicate what modifications would be or were needed in training or in personnel selection for best results.

8.0 The Human Factors Symbols

It will be observed that in every illustration and in each summary sheet which is prepared for individual launcher equipment, characteristic symbols are affixed. These symbols have been created by AMF human factors personnel, in order to help the reader in quickly identifying the main category of human factors which are under consideration. As used in the summary sheets, the symbol identifies the typical human factors category. The illustration figure depicts the equipment and also pinpoints the most important human factors inputs and recommendations. As used in the illustration, the characteristic symbol is affixed at the beginning of each statement, for easy identification of category.

It is hoped that this system of symbol coding may find acceptance and standardized application by the entire human factors profession.

## 8.1 Identification of Human Factor Symbols

Seven symbols have been selected to identify the major areas of human factor considerations. The symbol and its definition follows.

### 8.1.1 Symbol for Human Engineering Design Factors

The symbolism of a large anthropometric caliper scaling the dimensions of a silhoutted figure of a man represents the four considerations under Human Engineering Design Factors.

### 8.1.2 Symbol for Maintenance Factors

The symbol of the maintenance man's wrench crossed by a screw-driver is used to represent the 6 component aspects of characteristic Maintenance Factors.

### 8.1.3 Symbol for Safety Factors

The well known highway safety emblem with a human figure inset is used to identify six Safety Factors.

### 8.1.4 Symbol for Physiological Factors

The human figure within the conventionalized heart design is used to represent the three types of biological effects which are related to the hardened weapon system. This figure identifies Physiological Factors.

### 8.1.5 Symbol for Psychological Factors

A large Greek letter Psi, which traditionally represents Psychology, is used to identify 5 related Psychological Factors.

### 8.1.6 Symbol for Environmental Factors

The braced figure of a man within a protective enclosure is used symbolically to represent the 3 conditions which are recognized as Titan Environmental Factors.

### 8.1.7 Symbol for Human Use Factors

The outline of a man operating an elevator is used symbolically to represent the 3 types of activities which are part of Human Use Factors.

# Chapter 7

## Human Factors Engineering Evaluation of the Launcher System

### 1.1 OBJECTIVE

The purpose of this evaluation is to present a complete review of the AMF Human Factors effort on the Titan Launcher System. Each sub-system is analyzed in a separate chapter. All problem areas are listed for each sub-system and the effort in each area from initiation to installation of the end product is discussed. It should be understood that as design concepts changed during the program, certain human factors problems became less critical and in some cases were eliminated. These problems are included, however, since this evaluation is a complete documentation for the Titan Launcher System.

### 1.2 CONTENT

The content of each chapter includes the information described in the following sections.

#### 1.2.1 SUMMARY

An illustration of the sub-system is included, where possible, and indicates points at which human factors problems were involved.

A summary chart is provided in each chapter and shows the following:

a) The categories where human factors engineering effort was required.

b) The stage of the job during which the human factors engineering effort was phased in, i.e., concept, review, analysis, or field input.

c) The areas of human engineering objectives, i.e., specification compliance, safety, operational status, maintenance recommendations, or product improvement.

d) The Titan models affected by the recommendations, i.e., OSTF, TF, and OB.

1.2.2 DESCRIPTION

Section 1.0 of each chapter provides a functional description of the sub-system under consideration. The applicable human factor engineering considerations for this equipment are summarized.

1.2.3 SYNOPSIS OF HUMAN FACTORS ENGINEERING PROBLEMS

Section 2.0 of each chapter tabulates the human factors engineering problems considered for each sub-system. Included in this tabulation are the following:

a) The categories where human factors engineering effort was required (as previously indicated in Fig. 2).

b) Documentary Compliance - reference source used to determine the requirements for each human factor category.

c) Criteria for Success - the criteria established by the reference source.

d) Application of Criteria - the type of participation carried out by the AMF Human Factors Engineering Group and the type of recommendations which were made.

e) Verification - the means used to verify that recommendations had been adopted. The three possibilities for this category are systems analysis, inspection of equipment and system test.

f) Results - an indication of whether recommendations were carried out and what equipment modifications were made.

g) Relative value - a point value to identify the relative importance of each human factor problem area to a particular sub-system.

1.2.4 DISCUSSION

Section 3.0 of each chapter provides any necessary background material for the sub-system under consideration. Included in this section is information such as the following:

a) Basic assumptions made at the initiation of the effort.

b) System concept or design changes made after the initiation of effort.

c) Limitations affecting the effort such as lack of adequate data or a late phase-in period.

d) Special problems.

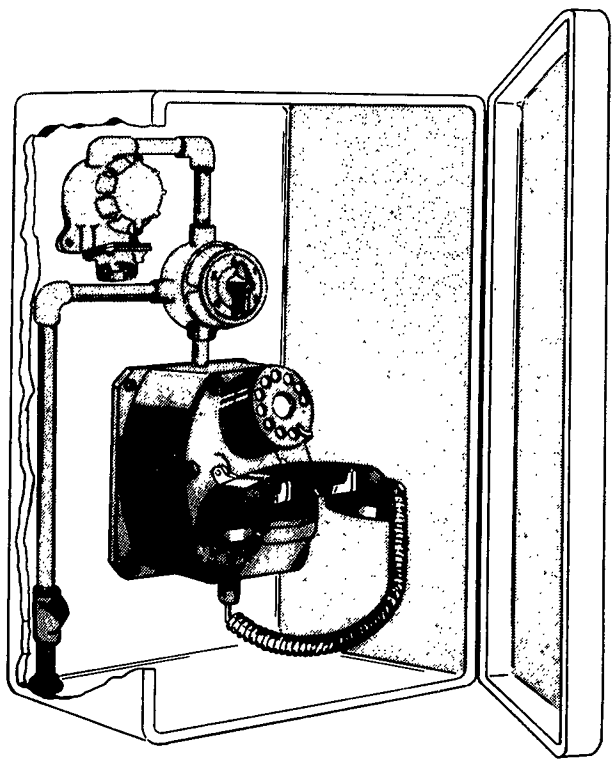
e) Special recommendations for the Operational Bases and/or future programs.

1.2.5 REFERENCES

Section 4.0 of each chapter lists in detail all reference material and documents noted within the text of the chapter.

# Chapter 8

## Human Factors Review and Evaluation of the Communications System



## CONTROL-DISPLAY HEIGHTS

The personnel elevator telephone should be located within tolerance limits with respect to operator's hand and eye heights.

## STATION LOCATIONS

Telephone stations are mounted in accessible locations recommended in AMF drawing #150-268.

## NOISE INTERFERENCE

A sound proof enclosure should be provided around the power pack room telephone to insure efficient exchange of messages while hydraulic equipment is in operation.

## CONSTANT AVAILABILITY

Telephone equipment is housed within explosion proof enclosures so that communications systems will be available in hazardous conditions

FIGURE 8-1
HUMAN FACTORS INPUTS
COMMUNICATIONS SYSTEM

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
COMMUNICATIONS:
TELEPHONE AND JACK
SYSTEM

| | | | PHASE IN STAGE | | | | HUMAN FACTORS OBJECTIVE | | | | | APPLICABLE ON MODEL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Human Factor Effort Required | Concept | Review | Analysis | Field Input | Specification Complicance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | OSTF | TF | OB | SYMBOL |
| | **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | | |
| 1.1 | Anthropometric Compatability | * | | | * | | * | | | * | * | * | * | | |
| 1.2 | Controls and Displays | * | | * | * | | * | | | * | * | * | * | * | |
| 1.3 | Fail-Safe Design | | | | | | | | | | | | | | |
| 1.4 | Malfunction Detection | | | | | | | | | | | | | | |
| | **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | | |
| 2.1 | Access, Visual | | | | | | | | | | | | | | |
| 2.2 | Access, Servicing | * | | * | * | | * | * | | * | | * | * | * | |
| 2.3 | Remove and Replace | | | | | | | | | | | | | | |
| 2.4 | Handling, Physical Limitations | | | | | | | | | | | | | | |
| 2.5 | Handling, Transportation | | | | | | | | | | | | | | |
| 2.6 | Vehicle Maneuverability | | | | | | | | | | | | | | |
| | **3.0 SAFETY FACTORS** | | | | | | | | | | | | | | |
| 3.1 | Chemical Decontamination | | | | | | | | | | | | | | |
| 3.2 | Escape Provisions | * | * | * | | | * | * | | * | | * | * | * | |
| 3.3 | Protection from Entanglement | | | | | | | | | | | | | | |
| 3.4 | Protection from Falling | | | | | | | | | | | | | | |
| 3.5 | Safety Devices (other) | | | | | | | | | | | | | | |
| 3.6 | Warning Devices | | | | | | | | | | | | | | |
| | **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | | |
| 4.1 | Biological Damage | | | | | | | | | | | | | | |
| 4.2 | Vertigo | | | | | | | | | | | | | | |
| 4.3 | Vibration Effects | | | | | | | | | | | | | | |
| | **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | | |
| 5.1 | Fear of Heights | | | | | | | | | | | | | | |
| 5.2 | Fear of Being Crushed | | | | | | | | | | | | | | |
| 5.3 | Fear of Falling | | | | | | | | | | | | | | |
| 5.4 | Fear of Isolation | * | | | * | | | * | | * | * | * | * | * | |
| 5.5 | Feeling of Insecurity | | | | | | | | | | | | | | |
| | **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | | |
| 6.1 | Acoustic Energy (noise) | * | | * | | * | * | * | | * | * | * | * | * | |
| 6.2 | Humidity & Temperature | | | | | | | | | | | | | | |
| 6.3 | Illumination | * | | | * | * | * | * | | * | * | * | * | * | |
| | **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | | |
| 7.1 | Procedure | | | | | | | | | | | | | | |
| 7.2 | Time Study | | | | | | | | | | | | | | |
| 7.3 | Training/Selection | | | | | | | | | | | | | | |

FIGURE 8-2

1.0 DESCRIPTION

1.1 The operational Communications System for the OSTF and TF models consists of the communications conduits, pull boxes, junction boxes, telephone jacks and telephone head sets which are installed on the crib for the purpose of permitting telephone communication between maintenance personnel on any of the work platform levels, outside exchanges, other silo work areas, and with personnel in the Command Control Center, the Missile Assembly Building, the Equipment Terminal and with all the control stations. Since no personnel will be in the silo during operational status, and these crib-mounted telephone facilities are intended exclusively for the use of maintenance personnel, they are located in the most active maintenance areas. Typically there are two telephone stations located on each work platform level; a wall mounted telephone with extension jack is usually installed in quadrant I-A and a telephone extension jack in quadrant III-C. In addition to the 6 Work Platform telephones there is a telephone in the Personnel Elevator, one at the Flame Deflector level, one at the bottom of the crib, one at the Tunnel Entrance Control Station, one in the Power Pack area of the Equipment Room and one in the Electrical Area of the Equipment Room.

1.2 Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to locate and use the telephones and plug-in jacks easily. The location of units should be consistant throughout the silo and each unit should be easily accessible. A telephone should be available in areas where maintenance procedures are potentially hazardous or where outside monitoring is desirable. These and other factors contributing to the successful use of the

Communication System have been itemized on the Summary Checklist (Fig. 8-2) and the progress of the design requirements relating to the Communication System has been tabulated in the following Synopsis.

ITEM: COMMUNICATIONS SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 1.0 HUMAN ENGINEERING DESIGN<br>1.2 CONTROLS AND DISPLAYS | PAR. 6.1.2.2 | | THE TELEPHONES SHOULD BE MOUNTED BETWEEN 40 TO 55 INCHES ABOVE THE STANDING SURFACE AND NOT MORE THAN 28 INCHES FROM THE OPERATOR'S EYE. | ER-TPS-204, 4/17/59. | THE TELEPHONE IN THE PERSONNEL ELEVATOR IS MOUNTED BELOW THE ELEVATOR CONTROL PANEL AND APPROXIMATELY 20 INCHES ABOVE THE FLOOR LEVEL. IT WAS RECOMMENDED THAT BOTH THE CONTROL PANEL AND TELEPHONE BE RAISED AN ADDITIONAL 20 INCHES TO BRING THE TELEPHONE WITHIN THE MINIMUM HEIGHT REQUIREMENT. THE TOP OF THE PANEL WOULD THEN BE 73 INCHES FROM THE FLOOR AND THE CONTROLS WOULD STILL BE WITHIN ACCEPTABLE LIMITS. RELOCATION OF THE PERSONNEL ELEVATOR TELEPHONE WAS ALSO RECOMMENDED TO BRING IT UP TO AN OPTIMUM HEIGHT. | X | X | | THE PERSONNEL ELEVATOR TELEPHONE HAS BEEN RAISED BUT IT IS STILL NOT WITHIN TOLERANCE LIMITS. | 5 |
| 2.0 MAINTENANCE<br>2.2 ACCESS, SERVICING | PAR. 1.1<br>4.3.2.8 | | ARRANGEMENT SCHEMES AND LAYOUTS FOR EQUIPMENT SHALL BE STANDARDIZED FOR ALL MISSILE SYSTEM EQUIPMENT, SIMILAR COMPONENTS SHOULD BE MOUNTED WITH A STANDARD ORIENTATION THROUGHOUT. WALL MOUNTED TELEPHONES AND EXTENSION JACKS SHOULD BE INSTALLED IN THE SAME LOCATION ON EACH WORK PLATFORM. | MR-TPS-247, 12/2/59. | DRAWING REVIEW OF THE FACILITY CONTRACTORS DRAWINGS DISCLOSED THAT SOME TELEPHONE STATIONS WERE BEING LOCATED IN INACCESS-IBLE AREAS. RECOMMENDATIONS WERE MADE TO INSTALL THESE STATIONS IN THE LOCATIONS DESIGNATED BY AMF AS SHOWN ON AMF DRAWING #150-268 "TB COMMUNICATIONS STATIONS". | X | | | THE TELEPHONE STATIONS WERE INSTALLED AT THE LOCATION DESIGNATED BY AMF.<br>ADOPTED | 10 |

ITEM: COMMUNICATIONS SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 3.0 SAFETY<br>3.2 ESCAPE PROVISIONS | PAR. 7.15 | | SPECIAL PROTECTIVE DEVICES SHALL BE MADE AVAILABLE IN HAZARDOUS AREAS OF OPERATION OR MAINTENANCE. MEANS OF COMMUNICATION SHOULD BE AVAILABLE FOR MEN PERFORMING EMERGENCY REPAIRS IN A POTENTIALLY EXPLOSIVE SILO WHERE OUTSIDE MONITORING MAY BE ADVANTAGEOUS TO CLARIFY PROCEDURES AND BRING EMERGENCY HELP IF REQUIRED. | ER-TPS-130, 10/22/58.<br>ER-TPS-163, 12/30/58. | IT WAS FELT THAT THE MULTIPLE FLEXIBILITY FOR COMMUNICATION NEEDS ARISING FROM ROUTINE AND EMERGENCY MAINTENANCE COULD BEST BE MET BY THE USE OF STANDARD DIAL TYPE PHONES WITH NORMAL RINGING METHODS AND STATION-TO-STATION OPERATION. IT WAS ALSO CONSIDERED MANDATORY THAT PROVISION BE MADE FOR MAINTAINING CONSTANT TELEPHONE COMMUNICATION THROUGHOUT THE LAUNCHER SYSTEM DURING HAZARDOUS CONDITIONS. | X | | | ADOPTED<br>STATION-TO-STATION DIALING WITH NORMAL RINGING TELEPHONES INCORPORATED IN TF. EXPLOSION PROOF TELEPHONES AND JACKS HAVE BEEN INCORPORATED. | 40 |
| 5.0 PSYCHOLOGICAL<br>5.4 FEAR OF ISOLATION | PAR. 7.15 | | SEE ABOVE (3.2) | ER-TPS-163, 12/30/58. | AS AN ADDITIONAL SAFETY ITEM THE PERSONNEL ELEVATOR TELEPHONE SHOULD BE RETAINED ALONG WITH THE WORK LEVEL TELEPHONES. THIS WOULD GIVE PERSONNEL TRAPPED BETWEEN STOPS A MEANS OF COMMUNICATION AND ALSO BE AN AUXILIARY MEANS OF COMMUNICATION FROM THE WORK PLATFORMS. | X | | | THE PERSONNEL ELEVATOR TELEPHONE HAS BEEN RETAINED.<br>ADOPTED | 10 |

ITEM: COMMUNICATIONS SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 6.1 ACOUSTIC ENERGY (NOISE) | PAR. 5.1.1 | | GENERATION OF NOISE CONTAINING INTENSE PURE-TONE COMPONENTS SHOULD BE AVOIDED. THE NOISE LEVEL IN AREAS NEAR TELEPHONES SHOULD BE SUCH THAT NORMAL COMMUNICATION IS NOT IMPAIRED. | ER-TPS-130, 10/15/58. TEST REPORT ADTP-V-6025 ADDENDUM A - 2/27/60. | THE TELEPHONE LOCATED NEAR THE HYDRAULIC EQUIPMENT IN THE POWER PACK ROOM LOCATED IN AMF'S EQUIPMENT TERMINAL IS REQUIRED FOR MAINTENANCE. THE TEST REPORT STATES "THERE IS TOO BACKGROUND NOISE FOR AUDIBLE DISCERNMENT." (CAUSED BY THE HYDRAULIC PUMPS). THE HUMAN FACTOR TEAM RECOMMENDED THAT ADDITIONAL PROTECTION BE PROVIDED TO PREVENT OPERATOR LOSS OF EFFICIENCY OR ERROR IN UNDERSTANDING VERBAL INSTRUCTIONS DUE TO EXCESSIVE NOISE. A SOUND BARRIER, PREFERABLY AN ACOUSTIC CHAMBER IS RECOMMENDED FOR INSTALLATION AROUND THE TELEPHONE STATION IN THE POWER PACK ROOM ON OB. | X | | X | NOT ADOPTED | 30 |
| 6.3 ILLUMINATION | PAR. 5.5.3 | ASA A11.1-1952 TABLE I PG. 10 TABLE II PG. 15 | THE ILLUMINATION REQUIRED FOR TELEPHONE DIALING AND TO PLUG IN THE JACKS IS 10 FOOT CANDLES (CASUAL SEEING TASK). | ER-V-55, 1/11/61. | A PRELIMINARY FIELD INVESTIGATION INDICATED THAT THE EXISTING ILLUMINATION ON ALL WORK PLATFORMS WAS LESS THAN ONE-FOOT CANDLE. IT WAS THEREFORE RECOMMENDED THAT THE ILLUMINATION BE INCREASED TO 10 FOOT CANDLES. | X | | X | PARTIALLY ADOPTED | 5 |
| | | | | | | | | | | 100 |

2.0 SYNOPSIS

## 3.0 DISCUSSION

The location of the telephone in the elevator, although rearranged from the original layout, does not bring the equipment within tolerance limits with respect to operator eye and hand heights. In the act of dialing it is necessary for personnel either to stoop or bend to bring the phone into the range necessary for reaching and viewing.

The telephone in the Power Pack room cannot be relocated because it is required at that location during maintenance procedures. In view of this requirement and considering the high noise level created by the hydraulic pumps, the necessity of some type of sound barrier or phone booth still exists. Until this situation is resolved the use of the telephone will be restricted and the expected efficiency of the maintenance procedures will be lost. Human errors with resulting accidents can occur if commands to and from this station are lost or misunderstood.

## 4.0 REFERENCES


1. AFBM Exhibit 57-8A, Human Engineering Design for Missile System Equipment.

2. ASA - A11.1-1952 American Standard Practice for Industrial Lighting, Sponsor: Illuminating Engineering Society, Table I, P. 10 and Table II, P. 15.

3. Air Force Manual No. 160-30, Physiology of Flight, Department of The Air Force, Revised July 1953, Chapter 10, Effects of Noise and Altitude on Communication.

4. ADTP-V-6025 Addendum A, 27 February 1960, Human Factors Test Procedure for Evaluation of the Cycling Control Station in Conjunction with the Hydraulic Power Pack. Group I, Test Plan 1B.

5. AMF Report, ER-V-55, Crib Lighting - TF and OB, 1/11/61.

6. AMF Report, ER-TPS-204, Evaluation of Personnel Elevator from WS 107A-2 Launcher System for TB and OB, 4/17/59, Par. 3.1, 3.1.3, 4.3 and 5.2.

7. AMF Report ER-TPS-163, Telephone Communication's Equipment for WS 107A-2 Launcher System, Constant Need For, 12/30/58.

8. AMF Report, ER-TPS-130, Communication Facilities for OSTF Launcher System, 10/22/58.

9. AMF Report, MR-TPS-247, Telephone Communications - TF-1, Par. 4.7, 12/2/59.

10. AMF Report, MR-TPS-149, Information Interchange on Communications, Par. 4.1.1 thru 4.1.3, 10/29/59.

11. AMF Drawing No. HF-T-1093 - Telephone Installation Study.

12. AMF Drawing No. HF-T-1095 - C-H ETW Dial Telephone Station.

13. AMF Drawing No. Cert. 150-268 - TB Communications Stations.

# Chapter 9

## Human Factors Review and Evaluation of the Crib Locking System

### HANDLING

Eye hooks have been provided on the underside of the silo cap and door for use in the removal and replacement of the crib lock components.

Lifting eyes have been provided on all crib lock components weighing in excess of 50 lbs.

### HAZARD MARKING

Low overhead areas have been hazard marked.

Upturned angles on the catwalks should be hazard marked to prevent tripping.

### REACH REQUIREMENT

The platforms provided to service the horizontal locks should be located at the proper height for servicing the locks.

### ACCESS TO SWITCH

Access to the elevator drive switch should be provided. The drive mechanism should be capable of being shut down by men working in the area to prevent entanglement.

### SAFETY BELT SUPPORTS

Safety belt eye supports should be field located and installed.

FIGURE 9-1
HUMAN FACTORS INPUTS
CRIB LOCKING
SYSTEM

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
CRIB LOCKING SYSTEM

| No. | Item | Human Factor Effort Required | Phase in Stage: Concept | Phase in Stage: Review | Phase in Stage: Analysis | Phase in Stage: Field Input | Human Factors Objective: Specification Compliance | Human Factors Objective: Safety | Human Factors Objective: Operational Status | Human Factors Objective: Maintenance Recommendation | Human Factors Objective: Product Improvement | Applicable on Model: OSTF | Applicable on Model: TF | Applicable on Model: OB | Symbol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | |  |
| 1.1 | Anthropometric Compatability | * | * | * | * | | * | * | | * | * | * | * | * | |
| 1.2 | Controls and Displays | | | | | | | | | | | | | | |
| 1.3 | Fail-Safe Design | | | | | | | | | | | | | | |
| 1.4 | Malfunction Detection | | | | | | | | | | | | | | |
| | **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | |  |
| 2.1 | Access, Visual | * | * | * | * | | * | | | * | | * | * | * | |
| 2.2 | Access, Servicing | * | * | * | * | | * | | | * | * | * | * | * | |
| 2.3 | Remove and Replace | * | * | * | * | | * | * | | * | * | * | * | * | |
| 2.4 | Handling, Physical Limitations | * | * | * | * | | * | * | | * | * | * | * | * | |
| 2.5 | Handling, Transportation | | | | | | | | | | | | | | |
| 2.6 | Vehicle Maneuverability | | | | | | | | | | | | | | |
| | **3.0 SAFETY FACTORS** | | | | | | | | | | | | | |  |
| 3.1 | Chemical Decontamination | | | | | | | | | | | | | | |
| 3.2 | Escape Provisions | | | | | | | | | | | | | | |
| 3.3 | Protection from Entanglement | | | | | | | | | | | | | | |
| 3.4 | Protection from Falling | * | * | * | * | | * | * | | * | * | * | * | * | |
| 3.5 | Safety Devices (other) | * | | | * | | * | | | | | * | * | * | |
| 3.6 | Warning Devices | * | | | | * | * | * | | | | * | * | * | |
| | **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 4.1 | Biological Damage | | | | | | | | | | | | | | |
| 4.2 | Vertigo | | | | | | | | | | | | | | |
| 4.3 | Vibration Effects | | | | | | | | | | | | | | |
| | **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 5.1 | Fear of Heights | | | | | | | | | | | | | | |
| 5.2 | Fear of Being Crushed | | | | | | | | | | | | | | |
| 5.3 | Fear of Falling | * | * | | | | * | * | | * | * | * | * | * | |
| 5.4 | Fear of Isolation | | | | | | | | | | | | | | |
| 5.5 | Feeling of Insecurity | | | | | | | | | | | | | | |
| | **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | |  |
| 6.1 | Acoustic Energy (noise) | | | | | | | | | | | | | | |
| 6.2 | Humidity & Temperature | | | | | | | | | | | | | | |
| 6.3 | Illumination | | | | | | | | | | | | | | |
| | **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | |  |
| 7.1 | Procedure | | | | | | | | | | | | | | |
| 7.2 | Time Study | | | | | | | | | | | | | | |
| 7.3 | Training/Selection | | | | | | | | | | | | | | |

FIGURE 9-2

1.0 DESCRIPTION

1.1 The Crib Locking System, located at the top of the crib, consists of jacks at each of the four corners of the crib. When the missile silo is in the "soft" condition preparatory to raising the launcher platform, these corner jacks lock and level the crib rigidly into a predetermined position in order to provide a constant and stable above-ground platform for missile launching activities or for missile emplacement. When the missile is underground in the "hardened" condition the jacks remain unlocked allowing the crib suspension system to provide shock-mounting for everything mounted on or within the crib envelope, including the launching system of the missile itself.

1.2 Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to perform the required maintenance on the Crib Locking Mechanism. The platforms must provide adequate access and safety to personnel in the performance of their duties. The design of the removable parts of the Crib Locks should be such that they can be handled easily and efficiently. All efforts to make this hazardous area of maintenance as safe as possible should be incorporated. These and other factors contributing to the successful maintenance of the Crib Locking System have been itemized on the Summary Checklist (fig. 9-3) and the progress of design requirements relating to the Maintenance Dolly has been tabulated in the following Synopsis..

ITEM: CRIB LOCKING SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 1.0 HUMAN ENGINEERING DESIGN<br>1.1 ANTHROPOMETRIC COMPATABILITY | PAR. 6.1.1 | | MINIMUM PASSING BODY WIDTH = 13 INCHES.<br>MAXIMUM OVERHEAD REACH = 76 INCHES. | HUMAN FACTORS ACCESS LAYOUTS:<br># HF-T-1065<br># HF-T-1072<br># HF-T-1076 | A COMPLETE SYSTEM OF FIXED PLATFORMS & LADDERS ALL AROUND THE UPPER SILO WITH AUXILIARY PLATFORMS TO BRING THE CRIB LOCKS WITHIN THE REACH SPECIFICATIONS WAS PROPOSED, PER DRAWING # HF-T-1065. HUMAN FACTORS EVALUATION OF THE ALTERNATE OR "AUSTERE" PLATFORM ARRANGEMENT (DWG. # HF-T-1072 & HF-T-1076), REVEALED THAT PLATFORMS WERE PROVIDED ONLY LOCALLY AT THE CRIB LOCKS AND REQUIRED THE USE OF A PORTABLE LADDER TO REACH THE CRIB LOCKS. THE HORIZONTAL LOCK PLATFORM WAS 7'-11" BELOW THE HORIZONTAL LOCK. THIS ARRANGEMENT USES THE CRIB LEDGE AT EL. 389'-0", AS A WALKWAY. HYDRAULIC MANIFOLDS OBSTRUCT THIS WALKWAY IN SEVERAL PLACES AND MAKE PASSING VERY DIFFICULT. THE DRIVE CONTROL PLATFORM ALLOWS A PASSING WIDTH OF ONLY 8" AND REQUIRES PERSONNEL TO WALK ALL AROUND THE SILO TO REACH THE OTHER SIDE. | X | X | | THE ALTERNATE OR "AUSTERE" ARRANGEMENT WAS INSTALLED. | 35 |

2.0 SYNOPSIS

ITEM: CRIB LOCKING SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 2.0 MAINTENANCE<br>2.1 ACCESS, VISUAL | 4.3.3.9.1.4 | | PROVISION FOR PERIODIC VISUAL INSPECTION OF THE CRIB LOCKS (FOR LEAKS OR DAMAGE) IS REQUIRED. | SAME AS ABOVE. | THE PLATFORM ARRANGEMENT SHOWN ON HF-T-1065 WOULD ALLOW BETTER VISUAL ACCESS FROM MORE VANTAGE POINTS THAN THE ADOPTED ARRANGEMENT WHICH LIMITS VISUAL ACCESS BY REDUCING THE NUMBER AND SIZE OF THE PLATFORMS. | X | X | | VISUAL ACCESS REQUIREMENT IS NOT FULLY SATISFIED. | 10 |
| 2.2 ACCESS, SERVICING | 4.3.3.9.4 | | UNITS SHALL BE SO LOCATED AND MOUNTED THAT ACCESS TO THEM MAY BE ACHIEVED WITHOUT DANGER TO PERSONNEL FROM ELECTRICAL CHARGE, HEAT, SHARP EDGES AND POINTS, MOVING PARTS, CHEMICAL CONTAMINATION AND OTHER SOURCES. | SAME AS ABOVE. | THE HUMAN FACTORS ACCESS PLAN (HF-T-1065) INCLUDED A PLATFORM AROUND THE ELEVATOR DRIVE UNIT WHICH WAS ACCESSIBLE FROM THE UPPER SILO PLATFORM IMMEDIATELY ABOVE. PERSONNEL WORKING IN THE AREA WOULD HAVE ACCESS TO THE KEY SWITCH WHICH LOCKS OUT THE ELEVATOR DRIVE.. THE ACCESS PLATFORM PLAN WHICH WAS INSTALLED (HF-T-1076) PROVIDES NO MEANS OF ACCESS TO THIS SWITCH, AND PERSONNEL WORKING IN THE AREA ARE EXPOSED TO REVOLVING SHEAVES AND MOVING CABLES AS A RESULT. | X | X | | CRITERIA NOT SATISFIED. | 10 |

2.0 SYNOPSIS

ITEM: CRIB LOCKING SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 2.3 REMOVE-REPLACE | 4.3.3.3 | | ALL UNITS DESIGNED TO BE REMOVED AND REPLACED, IN ACCORDANCE WITH A FULL AND REPLACE PHILOSOPHY, SHALL BE PROVIDED WITH HANDLES OR OTHER SUITABLE PROVISION MADE FOR GRASPING, HANDLING, OR CARRYING. | | EYE HOOKS SHOULD BE PROVIDED AT STRATEGIC LOCATIONS IN THE DOOR FOUNDATIONS FOR REMOVAL AND REPLACEMENT OF THE VARIOUS COMPONENTS.<br>BECAUSE OF THE INADEQUACY OF THE INSERT LOCATIONS PROVIDED BY DMJM & A FOR AMF EQUIPMENT REMOVAL, A LAYOUT OF THE INSERTS REQUIRED FOR AMF MAINTENANCE WAS SUBMITTED. THE DMJM & A INSERT PLAN WAS CONSIDERED IMPRACTICAL AND HAZARDOUS AND COULD CAUSE DAMAGE TO THE MISSILE AND/OR OTHER EQUIPMENT. | X | | | CRITERIA PARTIALLY SATISFIED. | 10 |
| | | | | | THE END CAP OF THE WORM GEAR JACK ASSEMBLY WAS PINNED TO THE SHAFT. IT WAS RECOMMENDED THAT THESE PINS BE REPLACED WITH SET SCREWS FOR EASE OF REMOVAL.<br>TWO OF THE SUPPORTING BRACKETS FOR THE HORIZONTAL JACKS HAD LIFTING EYES ON THE UNDERSIDE WHEN INSTALLED. IT WAS RECOMMENDED THAT THESE EYES BE RELOCATED TO BE ON THE UPPER SIDE. | | | | CRITERIA SATISFIED. | |

2.0 SYNOPSIS

ITEM: CRIB LOCKING SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 2.4 HANDLING, PHYSICAL LIMITATIONS | 4.3.3.1 | | A LIFTING FITTING IS REQUIRED ON ALL HARDWARE IN EXCESS OF 50 LBS. | | IT WAS RECOMMENDED THAT ALL EQUIPMENT IN EXCESS OF 50 LBS. BE PROVIDED WITH LIFTING EYES FOR HANDLING. | X | | | CRITERIA SATISFIED. | 5 |
| 3.0 SAFETY<br>3.4 PROTECTION FROM FALLING | 7.8, 7.9 | | PROVIDE HANDRAILS ON PLATFORMS, STAIRS AND AROUND FLOOR OPENINGS OR WHEREVER PERSONNEL MAY FALL FROM AN ELEVATION. ATTACH A SAFETY BAR OR CHAIN ACROSS STAIR OR STEP OPENINGS ON A PLATFORM TO PREVENT FALLING. | HUMAN FACTORS ACCESS LAYOUTS:<br>HF-T-1065<br>HF-T-1072<br>HF-T-1076 | HANDRAILS AND CHAINS WHERE REQUIRED ARE LOCATED ON LAYOUT HF-T-1065. LAYOUT HF-T-1072 AND HF-T-1076 WHICH SHOW THE PLATFORM LAYOUT WHICH WAS INSTALLED ALSO INDICATE HANDRAILS AND CHAINS ON THE PLATFORM AND WALKWAY PERIMETERS. HOWEVER, THESE SMALL PLATFORMS REQUIRE THE USE OF UNPROTECTED PORTABLE LADDERS AND ALSO REQUIRE THAT PERSONNEL CLIMB OVER EQUIPMENT AND REACH FAR FROM THE PROTECTED AREAS IN THE PERFORMANCE OF MAINTENANCE DUTIES. | X | X | | CRITERIA NOT COMPLETELY SATISFIED. | 10 |
| 3.5 SAFETY DEVICES (OTHER) | 7.15 | | SAFETY BELTS SHOULD BE PROVIDED FOR HAZARDOUS MAINTENANCE TASKS. | HUMAN FACTORS ACCESS LAYOUTS:<br>HF-T-1072<br>HF-T-1076 | SAFETY BELTS ARE REQUIRED ON THE AUSTERE UPPER SILO PLATFORM LAYOUTS BECAUSE OF THE PROPOSED SMALL PLATFORMS. THESE SAFETY BELT ATTACHMENT HOOKS ARE SPECIFIED FOR FIELD LOCATION AND INSTALLATION. | X | | | CRITERIA NOT SATISFIED. | 10 |

2.0 SYNOPSIS

ITEM: CRIB LOCKING SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 3.6 WARNING DEVICES | 7.3 | | AREAS OF HAZARDOUS CONDITIONS SHOULD BE CAUTION MARKED TO MINIMIZE ACCIDENTS. | | IT WAS RECOMMENDED THAT THE ANGLES ON THE CATWALKS BE HAZARD MARKED TO INDICATE A TRIPPING POSSIBILITY. | | X | | RECOMMENDATION NOT INCORPORATED. | 10 |
| 5.0 PSYCHOLOGICAL<br>5.3 FEAR OF FALLING | 7.8 | | PERSONNEL SHOULD BE ABLE TO PERFORM THEIR DUTIES WITHOUT THE ADDED STRAIN OF WORKING IN AREAS WHERE THE DANGER OF FALLING IS EXCESSIVE. | HUMAN FACTORS ACCESS LAYOUTS:<br>HF-T-1065<br>HF-T-1072<br>HF-T-1076 | THE PLATFORM LAYOUT PER HF-T-1065 WAS RECOMMENDED BECAUSE THE PRESENCE OF COMPLETE PLATFORMS ALL AROUND IN ADDITION TO ALLOWING MORE COMPLETE ACCESS ALSO HAD FEW GAPS OR EXPOSED OPENINGS THROUGH WHICH PERSONNEL MIGHT FALL. THIS WOULD ALLOW THE MAXIMUM FEELING OF SECURITY TO PERSONNEL AND INCREASE THE EFFICIENCY OF PERFORMANCE OF UPPER SILO MAINTENANCE. | X | | | THIS PLATFORM ARRANGEMENT WAS NOT INSTALLED. | |

## 3.0 DISCUSSION

The Upper Silo work platforms which have been installed do not provide either optimum access nor optimum safety. It is most probable that Crib-Lock removal operations will necessarily have to be performed by special rigging crews. Field observation of this operation, conducted by professional riggers with scaffolding, revealed that the workers had to crawl on the hammerhead beams and in general expose themselves to many hazards which cannot be expected of Air Force Personnel without this special training. The hazards are compounded by the great number of operations (switching of cables between eye-bolts and on the crib-lock components). A simplified method for crib lock removal and adequate access ladders, catwalks and platforms would eliminate much of the problem.

## 4.0 REFERENCES


1. AFBM Exhibit 57-8A, Human Engineering Design Standards for Missile System Equipment.

2. AMF Document, TS 7.2.27, Lifting Eyes in Door Foundation, 5/25/59.

3. AMF Document, TS 7.2.28, Transmittal of Removal Study Drawings, 6/5/59.

4. AMF Document TS 7.2.29, Handling Requirements for Horizontal & Vertical Jacks-OSTF, TB & OB, 6/18/59.

5. AMF Document TS 7.2.30, OSTF Lift Inserts on Door Foundation, 7/20/59.

6. AMF Report, ER-TPS-280, Field Evaluation VAFB, 5/4/60.

7. AMF Drawing No. HF-T-1034, Emergency Ladder (Quad. IV) to Bridge (Crib-to-Silo) OB.

8. AMF Drawing No. HF-T-1036, Platform, Top Crib Access Face A.

9. AMF Drawing No. HF-T-1037, Top of Silo (Quad. IV) TF & OB.

10. AMF Drawing No. HF-T-1042, Emergency Catwalk & Ladder Face C & D OB.

11. AMF Drawing No. HF-T-1055, Platforms - Silo Upper Access.

12. AMF Drawing No. HF-T-1065, Upper Silo Access Layout.

13. AMF Drawing No. HF-T-1072, Alternate Upper Silo Access Layout OSTF.

14. AMF Drawing No. HF-T-1073, Access Ladders & Work Platform #1 to Drive Base TF & OB.

15. AMF Drawing No. HF-T-1153, Handling for Maintenance - Torque Motor & Lock Jack - Inclined Jack.

16. AMF Drawing No. HF-T-1076, Upper Silo Access Layout TF.

# Chapter 10

## Human Factors Review and Evaluation of the Crib Mounted Equipment (Non-AMF)

TOXICITY HAZARDS

Highly toxic fluids require the use of protective clothing and gas masks with independent air supply.
OPTIMUM SAFETY CONDITIONS CAN NOT BE EXPECTED WITH IN-SILO DEGREASING.

PROTECTIVE CLOTHING

Protective clothing must not interfere with personnel performance.

TOXICITY SENSORS

Personnel should be provided with toxicity sensors which indicate visually and audibly when dangerous limits have been exceeded.

HOSE CONNECTIONS

Design hose connections so that inadvertent interchanging is impossible.

HANDLING

Winches and hoists must be used to handle heavy solvents and degreaser units.

COMMUNICATIONS

Throat microphones are recommended connected to the communications system for contacting other crew members and to allow outside monitoring of procedures.

ACCESS

Auxiliary platform and steps are needed to provide access to service connections.

FIGURE 10-1
HUMAN FACTORS INPUTS
IN-SILO DEGREASING

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
DEGREASER UNIT
(NON-AMF)

| | | Human Factor Effort Required | Concept | Review | Analysis | Field Input | Specification Compliance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | OSTF | TF | OB | SYMBOL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PHASE IN STAGE | | | | HUMAN FACTORS OBJECTIVE | | | | | APPLICABLE ON MODEL | | | |
| | **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | |  |
| 1.1 | Anthropometric Compatability | * | | | * | * | * | * | | * | | * | * | * | |
| 1.2 | Controls and Displays | | | | | | | | | | | | | | |
| 1.3 | Fail-Safe Design | | | | | | | | | | | | | | |
| 1.4 | Malfunction Detection | | | | | | | | | | | | | | |
| | **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | |  |
| 2.1 | Access, Visual | | | | | | | | | | | | | | |
| 2.2 | Access, Servicing | * | | | * | * | * | * | | * | | * | * | * | |
| 2.3 | Remove and Replace | * | | | * | * | * | * | | * | | * | * | * | |
| 2.4 | Handling, Physical Limitations | * | | | * | * | * | * | | * | | * | * | * | |
| 2.5 | Handling, Transportation | | | | | | | | | | | | | | |
| 2.6 | Vehicle Maneuverability | * | | | * | * | * | * | | * | | * | * | * | |
| | **3.0 SAFETY FACTORS** | | | | | | | | | | | | | |  |
| 3.1 | Chemical Decontamination | | | | | | | | | * | | | | | |
| 3.2 | Escape Provisions | * | | | * | * | * | * | | | | * | * | * | |
| 3.3 | Protection from Entanglement | | | | | | | | | * | | | | | |
| 3.4 | Protection from Falling | | | | | | | | | * | | | | | |
| 3.5 | Safety Devices (other) | * | | | * | * | * | * | | * | | * | * | * | |
| 3.6 | Warning Devices | * | | | * | * | * | * | | * | | * | * | * | |
| | **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 4.1 | Biological Damage | * | | | * | * | * | * | | * | | * | * | * | |
| 4.2 | Vertigo | | | | | | | | | | | | | | |
| 4.3 | Vibration Effects | | | | | | | | | | | | | | |
| | **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 5.1 | Fear of Heights | | | | | | | | | | | | | | |
| 5.2 | Fear of Being Crushed | | | | | | | | | | | | | | |
| 5.3 | Fear of Falling | | | | | | | | | | | | | | |
| 5.4 | Fear of Isolation | | | | | | | | | | | | | | |
| 5.5 | Feeling of Insecurity | * | | | * | * | * | * | | * | | * | * | * | |
| | **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | |  |
| 6.1 | Acoustic Energy (noise) | | | | | | | | | | | | | | |
| 6.2 | Humidity & Temperature | | | | | | | | | | | | | | |
| 6.3 | Illumination | * | | | * | * | * | * | | * | | * | * | * | |
| | **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | |  |
| 7.1 | Procedure | * | | | * | * | * | * | | * | | * | * | * | |
| 7.2 | Time Study | | | | | | | | | | | | | | |
| 7.3 | Training/Selection | | | | | | | | | | | | | | |

FIGURE 10-2

## 1.0 DESCRIPTION OF THE DEGREASER EQUIPMENT

1.1 The Degreaser consists of two units: the decontaminating unit and the solvent fill unit. The decontaminating unit includes the following: (1) tank and reel unit or liquid solvent recovery (hereinafter termed the solvent disposal unit.), (2) portable solvent recovery platform, (3) hydraulic test console or gas generator valve opening kit, (4) a set of electrical power cables, (5) two flexible hoses, (6) bellows restrainers, (7) blank flanges, (8) a pressure gauge, (9) a metal stemmed thermometer, (10) new crush washers and, (11) hand tools for operating. The solvent fill unit is composed of: two barrel stands, two flex hose assemblies, two globe valves and associated piping, and three solvent transfer containers. These units are used in degreasing a missile after a captive or aborted firing and an accidental contamination of the liquid oxygen manifold or injector.

1.2 Applicable Human Factors Considerations

Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to operate and transport the Degreaser unit efficiently throughout the tunnels and within the Missile Silo without causing damage to equipment or injury to personnel. These vehicular units must be designed to provide adequate access to all parts that may require constant service, and where maintenance tasks require removal of components heavier than a man can safely lift, special handling devices must be provided. Factors contributing to the successful use of the Degreasing units have been itemized on the summary checklist (Figure 10-2) and the progress of the Degreaser design has been tabulated in detail in the following synopsis.

ITEM: DEGREASER UNIT (NON AMF)

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 1.0 HUMAN ENGINEERING DESIGN | | | | | | | | | | |
| 1.1 ANTHROPOMETRIC COMPATABILITY | 6.1.1 & 6.1.2 | | MUST BE CAPABLE OF OPERATION BY 5TH TO 95TH PERCENTILE PROTECTIVE CLOTHING SHOULD NOT INTERFERE WITH OPERATION. | DEGREASING PROCEDURE 27M9320009 TS 7.2.16 | | | | | ACCEPTABLE | 5 |
| 2.0 MAINTENANCE | | | | | | | | | | |
| 2.2 ACCESS, SERVICING | 4.3.3.9.1 TO 4.3.3.9.4 | | CONNECTION POINTS SHOULD BE ACCESSIBLE. | HF-T-1028, 1029, 1030, 1031, AND 1131 (SK 194-11951) ER-T/S-5101 | PIPING CONNECTIONS ARE 4'-0" TO 8'-0" ABOVE MAINTENANCE PLATFORM. THEREFORE AN AUXILIARY PLATFORM AND STEPS ARE NEEDED FOR ACCESS. HYDRAULIC LINES, CRIB BEAM, AND A TELEPHONE CABINET INTERFERE WITH SERVICE CONNECTIONS. | X | | | TO BE USED ON WORK PLATFORM NO. 5 AND WORK PLATFORM NO. 3. RECOMMENDATIONS TRANSMITTED. | 5 |
| 2.3 REMOVE & REPLACE | 4.3.3.8.8 | | DESIGN OF CONNECTORS SHOULD MAKE INADVERTENT INTERCHANGING IMPOSSIBLE. | REVIEW OF EQUIPMENT SPEC TMC - 039 TMC - 040 | DESIGN HOSE CONNECTIONS ON DEGREASER SO THEY CAN NOT BE INADVERTENTLY INTERCHANGED. | X | | | APPROVED HANDLING EQUIPMENT. | 10 |
| 2.4 HANDLING, PHYSICAL LIMITATIONS | 4.3 | ADS - 1003C 4.15 | PROVISIONS SHOULD BE MADE FOR LIFTING WEIGHTS (HANDLES, SLINGS ADAPTERS, ETC.) | EQUIPMENT SPEC SR-TPS-225, TS 7.2.15 AND FTR-TPS-297 | DRUM TO BE DESIGNED FOR HANDLING BY 2 OR 3 MEN. NEED FOR A SOLVENT FILLING METHOD. | X | | | WINCHES MUST BE EMPLOYED TO MOVE VEHICLE. | 5 |
| 2.6 VEHICLE MANEUVERABILITY | | | PROVISION SHOULD BE MADE FOR EQUIPMENT HANDLING ON WORK PLATFORMS, PERSONNEL ELEVATOR & WITHIN TUNNELS. | FTR-TPS-297 | RECOMMEND USING DEGREASER ON PLATFORM 5 INSTEAD OF PLATFORM 6. (PLATFORM 6 - TOP OF LAUNCHER PLATFORM TOO SMALL TO ACCOMMODATE DEGREASER UNIT.) | X | | | SIZE OF DEGREASER L. 50" X W.30" X H.54" ESTIMATED WT. 1800 LBS. SOLVENT WT. 11.1 LBS/GAL. SOLVENT REQUIRED 24 GALS. SOLVENT TOTAL WT. 266.4 LBS. 10 GAL. CONTAINER = 111. + LBS. APPROVED | 5 |

2.0 SYNOPSIS

ITEM: DEGREASER UNIT (NON AHF)

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 3.0 SAFETY<br>3.2 ESCAPE PROVISIONS | 7.12 | | DO NOT OPERATE PERSONNEL ELEVATOR OR OTHER POWER EQUIPMENT IF HAZARDOUS. | ER-TPS-219 | DO NOT OPERATE ELECTRICAL EQUIPMENT IF SOLVENT VAPORS ARE PREVALENT. | X | | | NOT OPTIMUM BELOW GROUND. RECOMMENDATIONS TRANSMITTED. | 5 |
| 3.5 SAFETY DEVICES | 7.1, 7.2, 7.3, 7.10, 7.11, 7.15, AND 7.20 | ADS-1003C 6.5.1, 6.5.3, 6.5.4, 6.5.7, 6.5.8, 6.5.9, AND 6.5.10 | SAFETY EQUIPMENT SHOULD BE EASY AND NATURAL TO USE. | TMC-039<br>TMC-040<br>FTR-TPS-297<br>ER-T/S-5101 | PERSONNEL MUST WEAR A GAS MASK WITH INDEPENDENT AIR SUPPLY PROTECTIVE CLOTHING AND GOGGLES. | X | | | NOT OPTIMUM BELOW GROUND RECOMMENDATIONS TRANSMITTED. | 15 |
| 3.6 WARNING DEVICES | 7.1, 7.3, 7.17, AND 7.20 | ADS-1003C 3.24 | THE MEANING OF EACH DEVICE SHOULD BE OBVIOUS. | TMC-039<br>TMC-040<br>ER-T/S-5101 | RECOMMEND RELIANCE UPON TMC WARNING DEVICES. | X | | | (APPROVED) - BUT NOT OPTIMUM BELOW GROUND. | 20 |
| 4.0 PHYSIOLOGICAL<br>4.1 BIOLOGICAL DAMAGE | 7.0 | E. I. DUPONT BULLETINS: S24-659 S29-258 S18-259 S10-459 | PROTECTIVE MASKS AND CLOTHING MUST BE PROVIDED. | TMC-039<br>TMC-040<br>TMC-ECO-2719 TS 7.2.17<br>SOLVENT IS HIGHLY TOXIC AND CAN BE FATAL, ALSO CORRODES ALUMINUM. WHEN HEATED, IT BECOMES EXPLOSIVE. | IN USING TOXIC SOLVENTS AVOID DIRECT CONTACT WITH BODY. PERSONNEL SHOULD CARRY SENSORS WITH AUDIBLE AND VISUAL ALARM DEVICES. | X | | | RECOMMENDATIONS TRANSMITTED. | 10 |
| 5.0 PSYCHOLOGICAL<br>5.5 FEELING OF INSECURITY | 7.0, 7.3, 7.10, 7.11, 7.15, 7.20 | | SYSTEM MUST IMPART CONFIDENCE THROUGH THE ELIMINATION OF HAZARDS. | | THROAT MIKE FOR CONTACT BETWEEN CREW MEMBERS. | X | | | NOT OPTIMUM BELOW GROUND. RECOMMENDATIONS TRANSMITTED. | 10 |
| 6.0 ENVIRONMENTAL<br>6.1 ILLUMINATION | 5.5.0 THRU 5.5.3 | ADS-1003C 6.4.1 H | MOST WORK AREAS REQUIRE AT LEAST 25 FOOT CANDLES. | | 25 FOOT TO 100 FOOT CANDLES ARE REQUIRED. | X | | | TMC PROJECT. | 10 |
| | | | | | | | | | | 100 |

2.0 SYNOPSIS

## 3.0 DISCUSSION

The task originated when TMC through STL requested that AMF make specific technical inputs to ECP-M-45. The basic data used in this evaluation of the degreaser problem comes from various projected procedures, vendor data sheets and drawings all provided by others (non-AMF).

A definite problem in handling will arise when large, heavy degreaser units must be moved from storage, through tunnels, down the personnel elevator and finally onto the work platforms. Levels #6 and #7 around the stage I engines provide minimum surface for handling any piece of equipment. The Human Factors Engineering Group has recommended the following safety considerations: protective clothing, gas masks with independent air supply, goggles, throat microphones for audible contact, connections designed so they cannot be inadvertently interchanged, sensors with audible and visual warning devices. Many handling and safety problems would be minimized or eliminated by above ground degreasing of the missile.

## 4.0 REFERENCES


1. AFBM 57-8A, Human Engineering Design Standards for Missile System Equipment.

2. ADS-1003C, Personnel Safety for WS 107A-2 Launcher System.

3. The Martin Company - TMC-039 and TMC-040, Facility Modification for Use of Engine Degreasing Equipment in Hard Condition.

4. The Martin Company - Degreasing Procedure No. 327M9320009-1 thru 21.

5. E. I. DuPont Bulletins: S24-659, 518-259, S29-258, and S10-459.

6. AMF Report, ER-T/S 5101, 11/3/60.

7. AMF Report, ER-TPS-225, 8/26/59.

8. AMF Report, FTR-TPS-297, 12/1/60.

9. AMF Document, TS 7.2.15, 12/27/60, Degreaser.

10. AMF Document, TS 7.2.16, 10/13/60, AMF ECP-M-45.

11. AMF Document, TS 7.2.17, 7/30/59, Liquid Oxygen Manifold Degreaser.

12. AMF Drawing No. HF-T-1028, Extension - #7 Platform @ 289'-1" for TF & OB.

13. AMF Drawing No. HF-T-1029, Degreaser - Connection Access Platform (TF & OB).

14. AMF Drawing No. HF-T-1031, Degreaser Platform - Flame Deflector Area (TF).

15. AMF Drawing No. HF-T-1131, Degreaser Facility (TF & OB).

# Chapter 11

## Human Factors Review and Evaluation of the Crib-to-Silo Bridge

MANEUVERABILITY

The bridge dimensions provide adequate area for the movement of the men and equipment to be transported from the Personnel Tunnel to the Personnel Elevator.

SAFETY GATE

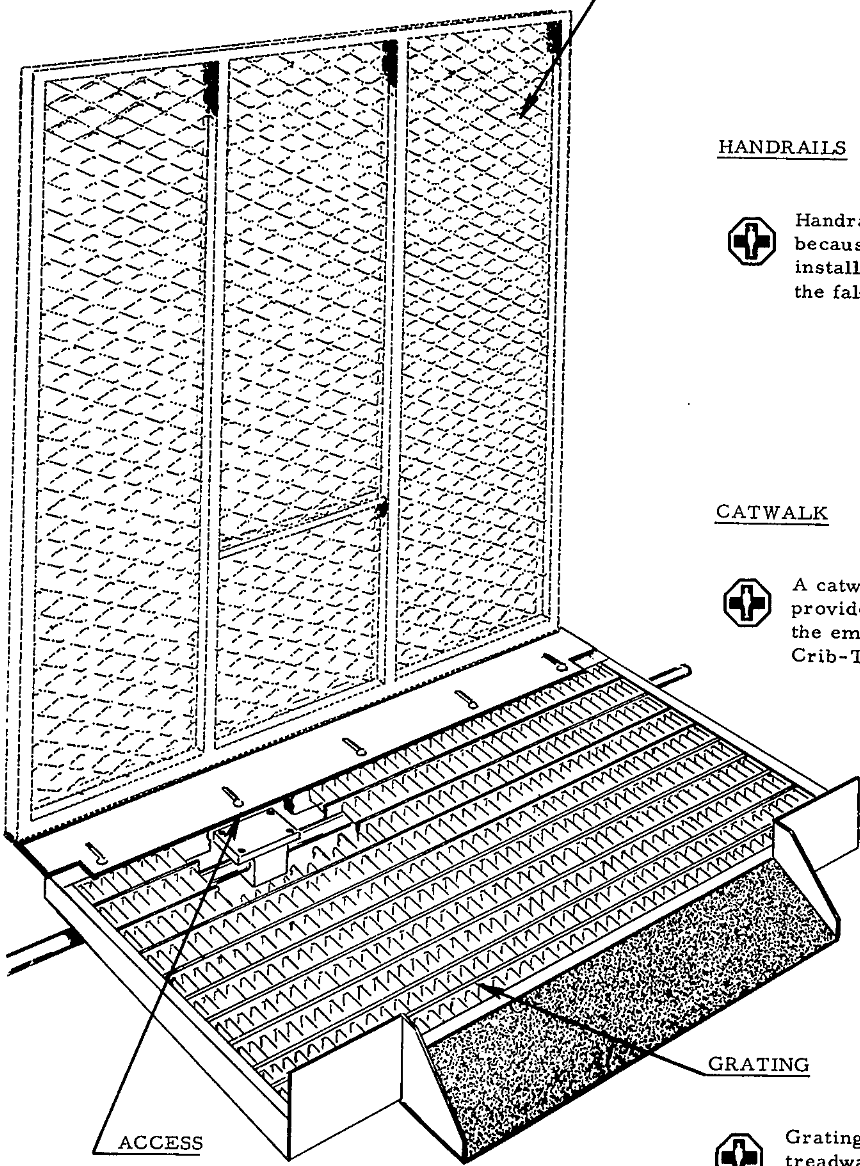
A gate has been added to protect personnel from the danger of the open elevator shaftway.

HANDRAILS

Handrails have been removed because associate contractor installations have eliminated the falling hazard.

CATWALK

A catwalk has been added to provide safe passage between the emergency ladder and the Crib-To-Silo Bridge.




GRATING

Grating on the bridge treadway prevents slipping while maneuvering equipment across the bridge.

ACCESS

Sliding Plate provides access to the bridge pivot bushings for servicing.

FIGURE 11-1
HUMAN FACTORS INPUTS
CRIB-TO-SILO BRIDGE

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
CRIB-TO-SILO BRIDGE

| | | | Phase in Stage | | | | Human Factors Objective | | | | | Applicable on Model | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Human Factor Effort Required | Concept | Review | Analysis | Field Input | Specification Complicance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | OSTF | TF | OB | Symbol |
| | **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | |  |
| 1.1 | **Anthropometric Compatability** | * | * | * | | | * | * | | | | * | * | * | |
| 1.2 | **Controls and Displays** | | | | | | | | | | | | | | |
| 1.3 | **Fail-Safe Design** | | | | | | | | | | | | | | |
| 1.4 | **Malfunction Detection** | | | | | | | | | | | | | | |
| | **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | |  |
| 2.1 | **Access, Visual** | | | | | | | | | | | | | | |
| 2.2 | **Access, Servicing** | * | * | * | | | * | | | * | * | * | * | * | |
| 2.3 | **Remove and Replace** | | | | | | | | | | | | | | |
| 2.4 | **Handling, Physical Limitations** | | | | | | | | | | | | | | |
| 2.5 | **Handling, Transportation** | | | | | | | | | | | | | | |
| 2.6 | **Vehicle Maneuverability** | * | * | * | | | * | | | | * | * | * | * | |
| | **3.0 SAFETY FACTORS** | | | | | | | | | | | | | |  |
| 3.1 | **Chemical Decontamination** | | | | | | | | | | | | | | |
| 3.2 | **Escape Provisions** | * | * | | | * | * | * | | | | * | * | * | |
| 3.3 | **Protection from Entanglement** | | | | | | | | | | | | | | |
| 3.4 | **Protection from Falling** | * | * | * | * | * | * | * | | | | * | * | * | |
| 3.5 | **Safety Devices (other)** | | | | | | | | | | | | | | |
| 3.6 | **Warning Devices** | | | | | | | | | | | | | | |
| | **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 4.1 | **Biological Damage** | | | | | | | | | | | | | | |
| 4.2 | **Vertigo** | | | | | | | | | | | | | | |
| 4.3 | **Vibration Effects** | | | | | | | | | | | | | | |
| | **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 5.1 | **Fear of Heights** | | | | | | | | | | | | | | |
| 5.2 | **Fear of Being Crushed** | | | | | | | | | | | | | | |
| 5.3 | **Fear of Falling** | * | * | | * | | | * | | | * | * | * | * | |
| 5.4 | **Fear of Isolation** | | | | | | | | | | | | | | |
| 5.5 | **Feeling of Insecurity** | | | | | | | | | | | | | | |
| | **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | |  |
| 6.1 | **Acoustic Energy (noise)** | | | | | | | | | | | | | | |
| 6.2 | **Humidity & Temperature** | | | | | | | | | | | | | | |
| 6.3 | **Illumination** | * | * | * | * | * | * | * | | * | | * | * | * | |
| | **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | |  |
| 7.1 | **Procedure** | | | | | | | | | | | | | | |
| 7.2 | **Time Study** | | | | | | | | | | | | | | |
| 7.3 | **Training/Selection** | | | | | | | | | | | | | | |

FIGURE 11-2

## 1.0 DESCRIPTION

1.1 The Crib-to-Silo Bridge spans the gap between the mouth of the personnel tunnel and the personnel elevator. The bridge provides the only means of gaining man and equipment access to the missile silo when entering through the personnel tunnel. The bridge is a structural platform with a grating on the tread surface. It is hinged from the crib and rests on the tunnel entrance. The design allows the bridge either to pivot about its hinge pin or to slide laterally along the hinge pin while the tunnel side of the bridge remains free. This design prevents damage to the bridge, crib and surrounding equipment during ground-shock.

1.2 Applicable Human Factors Considerations

Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to maneuver vehicles across the bridge efficiently without causing damage to equipment or injury to personnel. Any parts of the bridge which require servicing must be readily accessible and easily serviced. The bridge design should incorporate all necessary safety features to prevent falling or the fear of falling. Factors contributing to the successful use of the Crib-to-Silo Bridge have been itemized on the Summary Checklist (Fig. 11-2) and the progress of the design requirements relating to the Crib-to-Silo Bridge have been tabulated in the following synopsis.

ITEM: CRIB-TO-SILO BRIDGE

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE: CONTRACTUAL AFBM 57-8A | DOCUMENTARY COMPLIANCE: TECH. REF. | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA: PARTICIPATION | APPLICATION OF CRITERIA: RECOMMENDATIONS | VERIFICATION: ANAL | VERIFICATION: EQUIP | VERIFICATION: TEST | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 HUMAN ENGINEERING DESIGN FACTORS<br>1.1 ANTHROPOMETRIC COMPATABILITY | PAR. 6.1.1<br>6.1.7.1 | | THE CLEAR VERTICAL DISTANCE BETWEEN ANY PART OF THE BRIDGE WALKING SURFACE AND ANY INSTALLATION OR ENCUMBERANCE MUST BE AT LEAST 73". | REVIEW OF DMJMM LAYOUTS AND AMF DDL'S. | IT WAS DETERMINED THAT THE CLEAR PASSAGE AREA WAS SUFFICIENT. | X | | | ADOPTED | 10 |
| 2.0 MAINTENANCE FACTORS<br>2.2 ACCESS, SERVICING | PAR. 4.3.3.<br>7.1 | | THE BUSHINGS USED IN THE PIVOTING AND HORIZONTAL SLIDING ACTION BETWEEN THE BRIDGE AND CRIB REQUIRE LUBRICATION AND MUST BE EASILY ACCESSIBLE. | | THE BUSHINGS ARE ACCESSIBLE THROUGH AN OPENING MADE BY LOOSENING THE FIVE SCREWS WHICH MOUNT THE ADJUSTABLE PLATE ON TO THE ELEVATOR FRAME AND SLIDING IT TOWARD THE BRIDGE. | X | | | ADOPTED | 5 |
| 2.6 VEHICLE MANEUVERABILITY | PAR. 4.3.3.<br>9.2 | | OPENINGS AND WORK SPACES PROVIDED FOR ADJUSTING AND HANDLING UNITS SHALL BE AMPLE TO PERMIT THE REQUIRED ACTIVITY AND WHERE POSSIBLE TO PERMIT ADEQUATE VIEW OF THE COMPONENTS BEING MANIPULATED. | REVIEW OF DMJMM LAYOUTS AND AMF DDL'S. | REVIEW OF THE BRIDGE DIMENSIONS, VEHICLE DIMENSIONS AND THE PROBABLE MANEUVERING METHODS SHOWED THAT THE BRIDGE DIMENSIONS WERE ADEQUATE. | X | | | ADOPTED | 30 |
| 3.0 SAFETY FACTORS<br>3.2 ESCAPE PROVISIONS | PAR. 7.12 | | EMERGENCY ESCAPE DEVICES SHOULD BE CONSTRUCTED SO THAT THEY ARE READILY ACCESSIBLE, UNOBSTRUCTED AND QUICK OPENING. | HUMAN FACTORS ASSISTED IN THE CATWALK DESIGN WHEN THE NECESSITY FOR THE CATWALK WAS OBSERVED IN THE FIELD. | A CATWALK WAS RECOMMENDED TO PROVIDE A SAFE METHOD OF PASSAGE BETWEEN THE EMERGENCY LADDER AND CRIB-TO-SILO BRIDGE. | X | | | ADOPTED | 20 |

2.0 SYNOPSIS

ITEM: CRIB-TO-SILO BRIDGE

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 3.4 PROTECTION FROM FALLING | PAR. 7.8 | ASA #A12-1932 PAR. 7.1, 7.3 | HANDRAILS SHOULD BE PROVIDED WHEREVER PERSONNEL MAY FALL FROM AN ELEVATION. STANDARD RAILING SHALL CONSIST OF A SMOOTH TOP RAIL, AN INTERMEDIATE RAIL HALFWAY DOWN THE POSTS, A KICKPLATE AND ITS HEIGHT SHALL BE 42" FROM THE TOP OF THE PLATFORM. THE POSTS AND TOP RAILS SHALL BE AT LEAST 1¼" INSIDE DIAMETER, THE INTERMEDIATE RAIL AT LEAST 1" INSIDE DIAMETER AND THE KICKPLATE 3" HIGH AND SECURELY FASTENED. THE DISTANCE BETWEEN POSTS SHALL NOT EXCEED 8". | DDL REVIEW | RECOMMENDATIONS PER THE AMERICAN STANDARD SAFETY CODE REQUIREMENTS, (AS DESCRIBED IN THE CRITERIA FOR SUCCESS COLUMN) WERE MADE. | X | | | ADOPTED. DURING INSTALLATION VARIOUS ANTICIPATED PROBLEMS SUCH AS FALLING FROM THE CRIB-TO-SILO BRIDGE HAVE BEEN DELETED BECAUSE THE DESIGN OF ASSOCIATE CONTRACTOR EQUIPMENT SURROUNDING THE AREA HAS ELIMINATED ALMOST ALL OF THE FALLING HAZARD. THE RAILINGS AND KICKPLATE HAVE, AS A RESULT, BEEN REMOVED EXCEPT FROM THE CATWALKS. | 10 |
| | PAR. 7.2 7.9 | | THE CRIB SIDE OF THE CRIB-TO-SILO BRIDGE MUST HAVE A GATE TO PROTECT PERSONNEL FROM THE ELEVATOR SHAFTWAY. THIS GATE MUST BE INTERLOCKED TO PREVENT ITS OPENING EXCEPT WHEN THE ELEVATOR IS AT THE LANDING. | MEETING REPORT TS 7.2.21 10/1/58. DRAWING REVIEWS | A SAFETY GATE INTERLOCKED PER CRITERIA WAS RECOMMENDED. | X | | | ADOPTED. A SAFETY GATE BETWEEN THE BRIDGE AND SHAFTWAY WAS ADDED WITH THE NECESSARY INTERLOCKS. | 10 |
| | PAR. 7.22 | | SKID PROOF, SPARK PREVENTIVE FLOORING MUST BE PROVIDED. | | GRATING WITH A DEXOTEX COATING WAS RECOMMENDED FOR THE CRIB-TO-SILO BRIDGE. THIS WOULD PREVENT SLIPPING AND SPARKING. | X | | | ADOPTED. THE CRIB-TO-SILO BRIDGE FLOOR IS GRATING. BECAUSE OF ITS HIGH COST DEXOTEX WAS NOT EMPLOYED. THE ALTERNATIVE WAS TO HAVE NON-SPARKING WHEELS ON ALL SILO VEHICLES. | 5 |

ITEM: CRIB-TO-SILO BRIDGE

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 5.0 PSYCHOLOGICAL FACTORS<br>5.3 FEAR OF FALLING | | | THE DESIGN OF THE CRIB-TO-SILO BRIDGE SHOULD BE SUCH THAT PERSONNEL WHEN WORKING ON OR CROSSING IT WILL NOT BE SUBJECTED TO EXCESSIVE NERVOUS STRAIN DUE TO FEAR OF FALLING. | ENGINEERING REPORT ER-TPS-106 9/12/58. | IN ADDITION TO THE RAILING, AN OPAQUE FIBRE GLASS CLOTH, COATED WITH TEFLON AND ATTACHED TO THE RAILING WAS RECOMMENDED. THIS WOULD PREVENT PERSONNEL FROM FALLING THROUGH THE RAILING AND ALSO REDUCE THE VISUAL AWARENESS OF HEIGHT. | X | X | | ADOPTED<br>THE RECOMMENDED FIBRE GLASS CURTAINS WERE INSTALLED AND LATER REMOVED ALONG WITH THE RAILINGS AND OTHER ITEMS. (SEE RESULTS ITEM 3.4) | 5 |
| 6.0 ENVIRONMENTAL FACTORS<br>6.3 ILLUMINATION | PAR. 5.5, 7.21 | | THE TYPE AND DEGREE OF ILLUMINATION REQUIRED IS DETERMINED BY THE NATURE OF THE TASK TO BE PERFORMED. THE TASKS ON THE BRIDGE ARE THE MANEUVERING OF THE VARIOUS VEHICLES AND THE OPERATION OF THE TUNNEL ENTRANCE CONTROL STATION. THE ILLUMINATION LEVEL THEREFORE SHOULD BE APPROXIMATELY 10-25 FOOT CANDLES. | | THE ILLUMINATION OF THIS AREA HAS BEEN OBSERVED BY HUMAN FACTORS PERSONNEL. ALTHOUGH THE LEVEL OF ILLUMINATION WAS ACCEPTABLE THE MERCURY VAPOR LAMPS PRODUCED AN UNCOMFORTABLE GLARE. THIS SITUATION WOULD BE EASED BY THE USE OF MORE LIGHT SOURCES OF LESSER INTENSITY. | X | X | | THE CRITERIA ARE SATISFIED BUT THE TYPE OF ILLUMINATION IS NOT OPTIMUM. | 5 |
| | | | | | | | | | | 100 |

## 3.0 DISCUSSION

Human Factors Evaluation of the Crib-to-Silo Bridge was based on the consideration of the bridge as an independent unit because human factors problems depended upon interfaces with many other items which were in some cases not in the scope of AMF Design. On this basis human factors recommended the use of railings, toe boards and opaque curtains to prevent falling from the bridge, dropping tools from the bridge and to minimize the visual awareness of height. Associate contractor drawings were reviewed to monitor space envelopes surrounding the bridge. As the design of the installations in this area progressed, it became apparent that the need for railings, toe boards and opaque curtains did not exist and therefore they were subsequently deleted as design requirements.

## 4.0 REFERENCES


1. AFBM 57-8A, Human Engineering Design Standards for Missile System Equipment.

2. ASA A12-1932 - American Standard Safety Code for Floor and Wall Openings, Railings and Toe Boards.

3. Daniel, Mann, Johnson & Mendenhall and Associates, WS 107A-2 Technical Facilities Mountain Home Air Force Base, Mt. Home, Idaho, Vol. I, sheet #92-E-1; Vol. II, sheets #93-E-1, 2; Vol. III sheets #93-E-1, 2.

4. AMF Report ER-TPS-106, Crib-to-Silo Bridge, 9/12/58.

5. AMF Report MR-TS 7.2.21, Crib-to-Silo Bridge and Safety Gate, 10/1/58.

6. AMF Document TS 7.2.20, Lighting System in Missile Silo, 6/24/59.

7. AMF Drawing No. HF-T-1067 - Catwalk Stairway to Bridge OSTF - TB.

8. AMF Drawing No. HF T 1070 - Proposed Platform to Personnel Tunnel OSTF.

9. AMF Drawing No. HF-T-1082 - Crib to Silo Bridge Study for TB & OB.

10. AMF Drawing No. HF-T-1104 - Bridge & Catwalk Guard Rail Modifications (OSTF & TF-1).

11. AMF Drawing No. HF-T-1138 - Catwalk & Bridge Handrail Study.

12. AMF Drawing No. HF-T-1157 - Crib to Silo Bridge Safety Study.

# Chapter 12

## Human Factors Review and Evaluation of the Lifting & Handling Equipment

PROCEDURE

Detailed procedures are recommended for safe and efficient removal and replacement of heavy components.

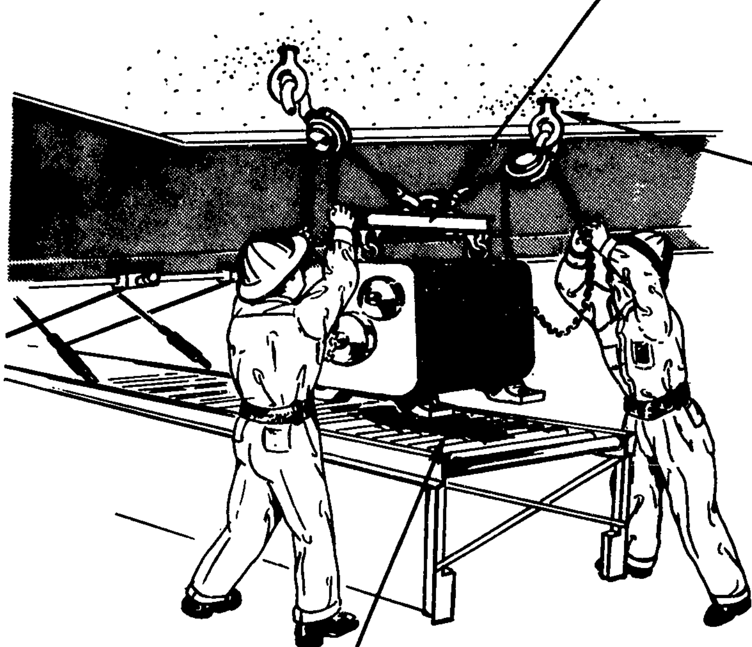
COMPONENT WEIGHTS

Strongbacks have been recommended to distribute heavy loads evenly.

All components which are above the safe limit for a man to lift must be provided with some special handling means.

LIFTING POINTS

Eyebolts have been specified to provide correct lifting points for hoists.



SPECIAL EQUIPMENT

Roller bed conveyors, multiple hoists, monorails and other pieces of special handling equipment have been recommended to solve specific problems.

FIGURE 12-1
HUMAN FACTORS INPUTS
LIFTING AND HANDLING DEVICES

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
LIFTING AND HANDLING DEVICES

| | Human Factor Effort Required | PHASE IN STAGE: Concept | Review | Analysis | Field Input | HUMAN FACTORS OBJECTIVE: Specification Complicance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | APPLICABLE ON MODEL: OSTF | TF | OB | SYMBOL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | | |
| **1.1 Anthropometric Compatability** | * | * | * | * | | * | * | | | * | * | * | * | |
| **1.2 Controls and Displays** | * | | | * | | * | * | | * | * | * | * | * | |
| **1.3 Fail-Safe Design** | | | | | | | | | | | | | | |
| **1.4 Malfunction Detection** | | | | | | | | | | | | | | |
| **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | | |
| **2.1 Access, Visual** | | | | | | | | | | | | | | |
| **2.2 Access, Servicing** | | | | | | | | | | | | | | |
| **2.3 Remove and Replace** | * | * | * | * | | * | * | | * | | * | * | * | |
| **2.4 Handling, Physical Limitations** | * | * | * | * | | * | * | | * | | * | * | * | |
| **2.5 Handling, Transportation** | * | * | * | * | | * | * | | * | | * | * | * | |
| **2.6 Vehicle Maneuverability** | | | | | | | | | | | | | | |
| **3.0 SAFETY FACTORS** | | | | | | | | | | | | | | |
| **3.1 Chemical Decontamination** | | | | | | | | | | | | | | |
| **3.2 Escape Provisions** | | | | | | | | | | | | | | |
| **3.3 Protection from Entanglement** | | | | | | | | | | | | | | |
| **3.4 Protection from Falling** | * | * | * | * | * | * | | | | | * | * | * | |
| **3.5 Safety Devices (other)** | | | | | | | | | | | | | | |
| **3.6 Warning Devices** | | | | | | | | | | | | | | |
| **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | | |
| **4.1 Biological Damage** | | | | | | | | | | | | | | |
| **4.2 Vertigo** | | | | | | | | | | | | | | |
| **4.3 Vibration Effects** | | | | | | | | | | | | | | |
| **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | | |
| **5.1 Fear of Heights** | | | | | | | | | | | | | | |
| **5.2 Fear of Being Crushed** | | | | | | | | | | | | | | |
| **5.3 Fear of Falling** | | | | | | | | | | | | | | |
| **5.4 Fear of Isolation** | | | | | | | | | | | | | | |
| **5.5 Feeling of Insecurity** | | | | | | | | | | | | | | |
| **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | | |
| **6.1 Acoustic Energy (noise)** | | | | | | | | | | | | | | |
| **6.2 Humidity & Temperature** | | | | | | | | | | | | | | |
| **6.3 Illumination** | * | * | * | | | * | * | | | * | * | * | * | |
| **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | | |
| **7.1 Procedure** | * | | * | * | * | | * | | | | * | * | * | |
| **7.2 Time Study** | | | | | | | | | | | | | | |
| **7.3 Training/Selection** | | | | | | | | | | | | | | |

FIGURE 12-2

## 1.0 DESCRIPTION

1.1 Various lifting and handling devices are required throughout the silo to assist in the removal and replacement of heavy components. At the top of the silo, in the door cap, there are approximately forty-one inserts. These inserts are prime in importance when handling most of the equipment to be replaced. Much of the equipment requires simultaneous use of two, three, or more of the handling devices available. In some cases it is necessary to use a strongback, when moving equipment, in order to distribute a load more evenly. At other times the weight of a component to be replaced may require the use of a roller bed conveyor so that it can be guided through tight clearances. Hoists are sometimes used in series in order that components pass laterally to where they can be removed from the silo. Most areas in the silo are confining and many different methods with their special devices are required if any replacement of equipment is to be realized.

1.2 Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to use these lifting and handling devices efficiently without causing damage to equipment or injury to personnel.

Factors affecting the successful use of this equipment have been itemized on the Summary Checklist (Fig. 12-2). There have been numerous studies made to determine handling methods to be used and the equipment to accommodate. The following are just a few: Removal of Door Actuator, Method for Replacement of Counterweight Cylinders, Method for Replacement of Power Drive Motor, Handling for Maintenance-Torque Motor and Lock Jack-Inclined Jack, and Handling for Maintenance-Idler Sheave and Water Connection.

## 2.0 SYNOPSIS

The synopsis sheets have been deleted from this chapter because each item requiring special handling devices has been analyzed completely on the basis of those human factors considerations specified on the Summary Checklist. These analyses which are in drawing form can be found listed in section 4.0 of this chapter.

## 3.0 DISCUSSION

The need for maintenance procedures requiring removal and replacement of components may extend to those items which are above the safe weight for a man or a team of men to handle. When this occurs, special lifting and handling devices must be provided so that various rigging techniques can be applied to the operation. Down time and hazards are minimized by: A. Accurate preliminary planning, B. Installation of eye bolts, monorails, hoists and other necessary equipment as specified, and C. Complete adherence to the procedure in every detail while removing the heavy components.

Several eye bolt patterns have been submitted by AMF to provide the lifting points required in carefully planned removal and replacement procedures. Not all of these inserts have been approved by associate contractors and installed, however, and design modifications have rendered others obsolete.

Procedures which could have been followed safely by Air Force personnel may have become too hazardous for anyone but a trained crew of rigging specialists. With the present conditions a special rigging crew for each squadron is a reasonable solution to the problem, but new studies and modified lifting and handling devices could provide the means whereby missile silo crews may be able to remove and replace the heavy components.

## 4.0 REFERENCES


1. AFBM 57-8A, "Human Engineering Design Standards for Missile System Equipment".

2. AMF Design Specification, ADS-1003C "Personnel Safety for WS 107A-2 Launcher System".

3. AMF Drawing No. HF-T-1097, Winch Anchoring Location (OSTF & Up).

4. AMF Drawing No. HF-T-1105, Removal of Door Actuator.

5. AMF Drawing No. HF-T-1106, Misc. Handling Portable Trolley (OSTF).

6. AMF Drawing No. HF-T-1107, Actuator Maintenance Door Closure (OSTF & TF).

7. AMF Drawing No. HF-T-1108, Method for Replacement of Counterweight Cylinders.

8. AMF Drawing No. HF-T-1109, Method for Replacement of C'W'T Cylinders (OSTF & TF).

9. AMF Drawing No. HF-T-1117, Handling for Maintenance - Idler Sheave & Water Connection (OSTF).

10. AMF Drawing No. HF-T-1126, Proposed Lift Insert Location - Door Foundation.

11. AMF Drawing No. HF-T-1127, Proposed Lift Inserts Location - Underside of Missile Silo Cap.

12. AMF Drawing No. HF-T-1133, Method for Replacement of Power Drive Motor (OSTF & TF).

13. AMF Drawing No. HF-T-1136, Door Seal Removal (OSTF, TF & OB).

14. AMF Drawing No. HF-T-1143, Handling for Maintenance - Winch Block at Personnel Tunnel.

15. AMF Drawing No. HF-T-1153, (8Sh.), Handling for Maintenance - Torque Motor & Lock Jack - Inclined Jack.

16. AMF Drawing No. HF-T-1098 - Door Configuration Eye Bolt Req.

17. AMF Drawing No. HF-T-1118 - Equipment Passage, Door Foundation.

18. AMF Drawing No. HF-T-1134 - Method for Replacement of Power Drive Motor (OSTF & TB).

19. AMF Drawing No. HF-T-1135 - Door Seal Removal.

20. AMF Drawing No. HF-T-1137 - Installation Fittings, Door Foundation.

21. AMF Drawing No. HF-T-1147 - Closure Door Study #1.

22. AMF Drawing No. HF-T-1148 - Closure Door Study #2.

23. AMF Drawing No. HF-T-1149 - Closure Door Study #3.

# Chapter 13

## Human Factors Review and Evaluation of the Maintenance Dolly

MANEUVERABILITY

Equipment must be easily moved from its storage location and into position on work platform in order to satisfy functional requirements.

CONTROL - REACTION MOTIONS

Control direction of movement must be consistent with that direction of reactive movement desired of the piece of powered equipment.

CONTROL DISTRIBUTION

Distribute controls for optimum human performance.

CONTROL HEIGHT

Pitch boom control lever should be at least 30 inches above standing surface.

VISUAL REQUIREMENTS

Labels should follow controls into optimum areas of reaching and seeing.

BATTERY CHARGING

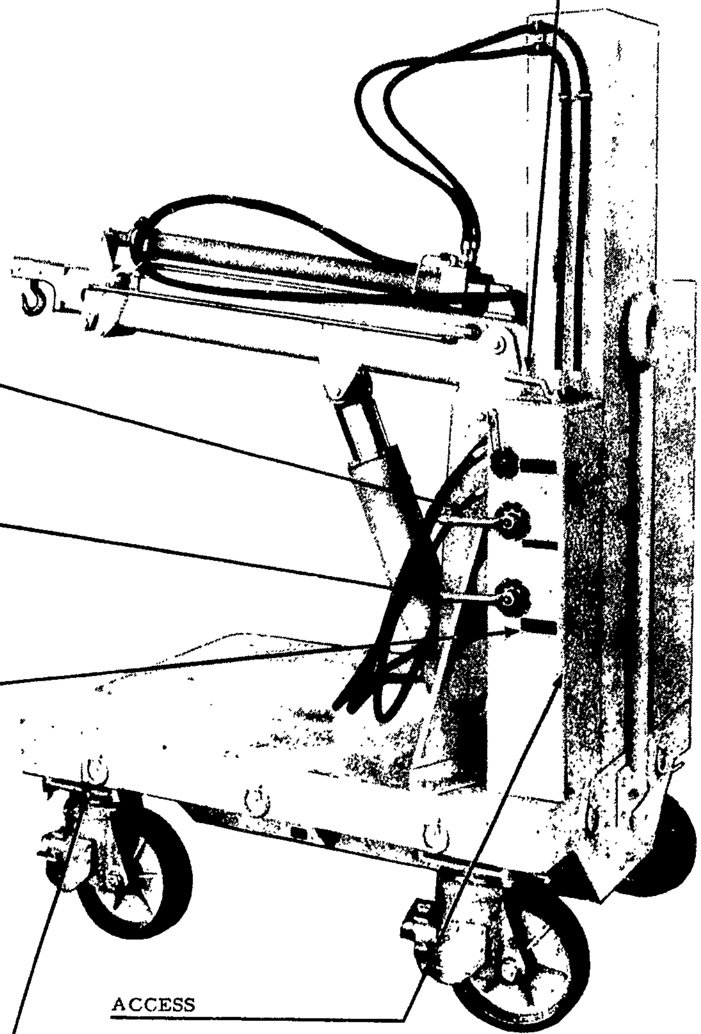
An outlet should be provided to allow charging of batteries without their removal from the equipment.

STABILITY

Tie-down straps have been provided for added stability.

HAND CLEARANCE

Allow adequate hand clearance for safe control of equipment.



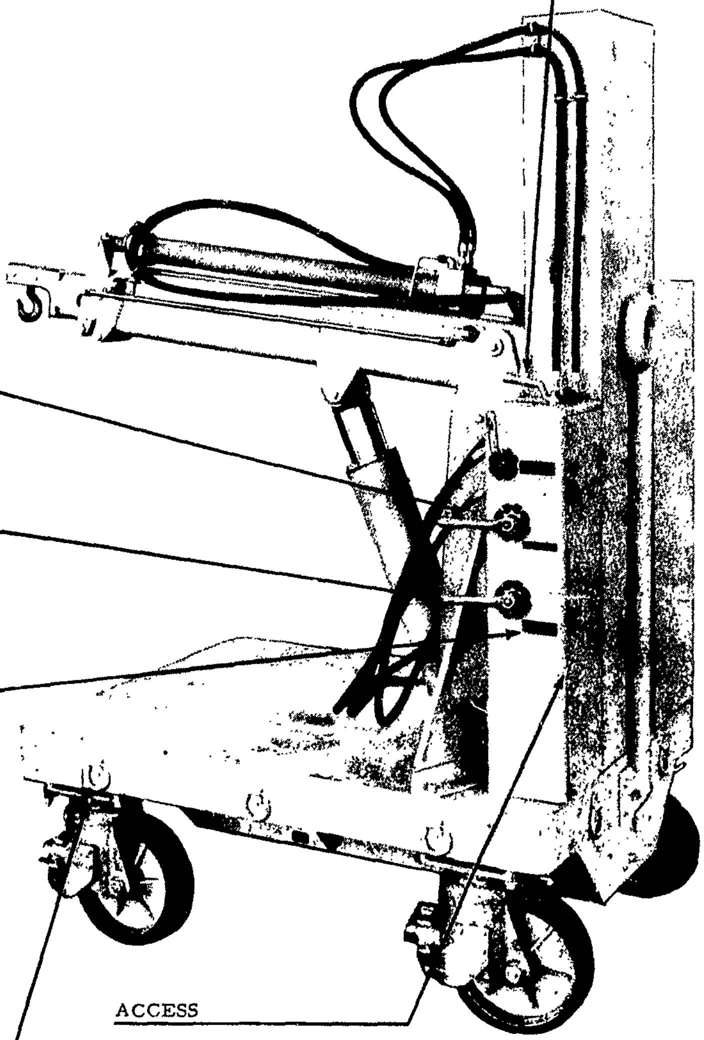
ACCESS

Access openings for maintenance have been provided.

CAPACITY

Warning signs shall indicate load capacities and proper hydraulic fluids.

FIGURE 13-1
HUMAN FACTORS INPUTS
TRAILER, LIFT & MAINTENANCE DOLLY



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ACCESS

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CAPACITY

Warning signs shall indicate load capacities and proper hydraulic fluids.

FIGURE 13-1
HUMAN FACTORS INPUTS
TRAILER, LIFT & MAINTENANCE
DOLLY

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
TRAILER, LIFT AND MAINTENANCE DOLLY

| | | Phase in Stage | | | | Human Factors Objective | | | | | Applicable on Model | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Human Factor Effort Required | Concept | Review | Analysis | Field Input | Specification Compliance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | OSTF | TF | OB | SYMBOL |
| **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | |  |
| **1.1 Anthropometric Compatability** | * | * | * | | | * | * | | * | * | * | * | * | |
| **1.2 Controls and Displays** | * | | * | | | * | | | | * | * | * | * | |
| **1.3 Fail-Safe Design** | | | | | | | | | | | | | | |
| **1.4 Malfunction Detection** | | | | | | | | | | | | | | |
| **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | |  |
| **2.1 Access, Visual** | | | | | | | | | | | | | | |
| **2.2 Access, Servicing** | * | | * | | | * | | | * | * | * | * | * | |
| **2.3 Remove and Replace** | | | | | | | | | | | | | | |
| **2.4 Handling, Physical Limitations** | | | | | | | | | | | | | | |
| **2.5 Handling, Transportation** | | | | | | | | | | | | | | |
| **2.6 Vehicle Maneuverability** | * | | * | | * | * | * | | | | * | * | * | |
| **3.0 SAFETY FACTORS** | | | | | | | | | | | | | |  |
| **3.1 Chemical Decontamination** | | | | | | | | | | | | | | |
| **3.2 Escape Provisions** | | | | | | | | | | | | | | |
| **3.3 Protection from Entanglement** | | | | | | | | | | | | | | |
| **3.4 Protection from Falling** | | | | | | | | | | | | | | |
| **3.5 Safety Devices (other)** | * | | * | | * | * | * | | * | * | * | * | * | |
| **3.6 Warning Devices** | | | | | | | | | | | | | | |
| **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| **4.1 Biological Damage** | | | | | | | | | | | | | | |
| **4.2 Vertigo** | | | | | | | | | | | | | | |
| **4.3 Vibration Effects** | | | | | | | | | | | | | | |
| **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| **5.1 Fear of Heights** | | | | | | | | | | | | | | |
| **5.2 Fear of Being Crushed** | | | | | | | | | | | | | | |
| **5.3 Fear of Falling** | | | | | | | | | | | | | | |
| **5.4 Fear of Isolation** | | | | | | | | | | | | | | |
| **5.5 Feeling of Insecurity** | | | | | | | | | | | | | | |
| **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | |  |
| **6.1 Acoustic Energy (noise)** | | | | | | | | | | | | | | |
| **6.2 Humidity & Temperature** | | | | | | | | | | | | | | |
| **6.3 Illumination** | * | * | | | | * | * | | | * | * | * | * | |
| **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | |  |
| **7.1 Procedure** | | | | | | | | | | | | | | |
| **7.2 Time Study** | | | | | | | | | | | | | | |
| **7.3 Training/Selection** | | | | | | | | | | | | | | |

FIGURE 13-2

## 1.0 DESCRIPTION

1.1 The Maintenance Dolly is a handling and transportation device used primarily for replacement of "black box equipment" in the missile. Its design features a battery powered, hydraulically operated boom with controls for vertical height, pitch, traverse and extension. Handling adaptors are provided to facilitate removal and replacement of various missile components known as "black boxes". The dolly is coupled to the tug truck for movement between the launcher storage area and the silo (via the access tunnel).

1.2 Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to operate the Maintenance Dolly controls easily and maneuver the Dolly on work platforms. The vehicle design must provide adequate access to the self-contained batteries and other units requiring frequent service. Caution signs indicating operating loads, maximum capacity and operating instructions must be affixed to prevent injury to personnel and damage to equipment. Factors contributing to the successful use of the Maintenance Dolly have been itemized on the Summary Checklist (Fig. 13-2) and the progress of design requirements relating to the Maintenance Dolly have been tabulated in the following Synopsis.

ITEM: TRAILER, LIFT AND MAINTENANCE DOLLY

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 1.0 HUMAN ENGINEERING DESIGN<br>1.1 ANTHROPOMETRIC COMPATABILITY | PAR. 6.1.1 & 6.1.2.2 | | CONTROLS ON VERTICAL PANEL TO BE NO LOWER THAN 30" ABOVE STANDING SURFACE. | ER-V-59 | THE PITCH BOOM LEVER IS APPROX. 24" FROM THE FLOOR. THIS LOCATION IS TOO LOW FOR COMFORTABLE OPERATION AND MAY AFFECT THE OPERATOR'S COORDINATION WHILE MANIPULATING THE BOOM. IT SHOULD BE RAISED. | X | X | | NOT ADOPTED | 5 |
| | | WADC TR 56-171 (REF. #2) PAR. 2.1.2-A | FOR INSTRUMENTS WHOSE DISPLAYS ARE LOCATED CLOSE TO THEIR CONTROLS, VIEWING DISTANCE IS LIMITED BY REACH DISTANCE AND SHOULD NOT EXCEED 28". | ER-V-59 | THE LOCATION OF THE CONTROL LEVERS GOVERNS THE LOCATION OF THE INSTRUCTION PLATES. IF THE CONTROLS ARE PROPERLY PLACED, FOR EXAMPLE, RAISING THE PITCH BOOM LEVER, THE VISUAL REQUIREMENTS WILL ALSO BE MET. | X | X | | NOT ADOPTED | 5 |
| 1.2 CONTROLS AND DISPLAYS | PAR. 3.1.1.1 | | CONTROLS SHOULD BE DISTRIBUTED SO THAT NO ONE LIMB IS OVERBURDENED. | ER-V-59 | THE LOCATION OF THE BOOM CONTROLS DESIGNATE ONE CONTROL FOR OPERATION BY THE RIGHT HAND AND THREE FOR THE LEFT. THE OPTIMUM CONDITION WOULD BE TO EVENLY DISTRIBUTE THE CONTROLS. IF EVEN DISTRIBUTION IS NOT POSSIBLE, IT IS PREFERABLE TO OVERLOAD THE RIGHT HAND. | X | X | | NOT ADOPTED | 10 |
| | PAR. 3.1.1.2 | WADC TR 56 - 171 PAR. 4.1-E (REF. #2) | CONTROL MOVEMENT SHOULD CONFORM WITH EQUIPMENT COMPONENT MOVEMENT. | ER-V-59 | THE SLEW BOOM CONTROL LEVER IS INCONSISTANT WITH THE DIRECTION OF MOTION OF THE BOOM. THE CONTROLS SHOULD BE REORIENTED TO ESTABLISH THE FOLLOWING RELATIONSHIP: | X | X | | NOT ADOPTED | 10 |

ITEM: TRAILER LIFT AND MAINTENANCE DOLLY

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE: CONTRACTUAL AFBM 57-8A | DOCUMENTARY COMPLIANCE: TECH. REF. | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA: PARTICIPATION | APPLICATION OF CRITERIA: RECOMMENDATIONS | VERIFICATION: ANAL | VERIFICATION: EQUIP | VERIFICATION: TEST | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | LEVER FORWARD-STOP POSITION<br>LEVER RIGHT-BOOM MOVES RIGHT<br>LEVER LEFT-BOOM MOVES LEFT<br>THE INSTRUCTION PLATE SHOULD READ "RIGHT" AND "LEFT" RATHER THAN "CLOCKWISE" AND "COUNTER-CLOCKWISE". | | | | | |
| | PAR. 6.1.5.1 | | SUFFICIENT ROOM TO ACCOMODATE THE HAND SHALL BE PROVIDED IN THE GRASPING OF ALL HANDLES. | ER-V-59 | TO ALLOW A FIRM GRIP THE DISTANCE BETWEEN THE SLEW BOOM CONTROL LEVER AND THE PANEL SHOULD BE INCREASED TO 4" (MEASURED FROM THE LEVER CENTERLINE TO THE PANEL). | X | X | X | NOT ADOPTED | 5 |
| 2.0 MAINTENANCE<br>2.2 ACCESS, SERVICING | PAR. 4.3.3.<br>9.1.3 | | HINGED DOORS OR COVERS WITH CAPTIVE QUICK-OPENING FASTENERS SHALL BE PROVIDED WHEREVER POSSIBLE. | EQUIPMENT DESIGN REVIEW | THE COVERS ON THE VALVE HOUSING PUMP MOTOR AND HYDRAULIC HOUSING ARE HINGED, HAVE QUICK OPENING FASTENERS, AND ALLOW SUFFICIENT ACCESS. | X | X | | CRITERIA SATISFIED. | 5 |
| | PAR. 4.3.3.<br>9.3.1 | ADS 5008B<br>PAR. 3.11<br>(REF. #3) | REMOVAL OF ANY REPLACEABLE UNIT SHALL REQUIRE OPENING OR REMOVAL OF A MINIMUM NUMBER OF COVERS OR PANELS (PREFERABLY ONE). | | REMOVAL OF THE BATTERY REQUIRES REMOVAL OF SIX SCREWS AND ONE PANEL WHICH MIGHT BE UNDER SOME HEAVY ITEM THE DOLLY IS CARRYING AT THE TIME. AN ELECTRICAL OUTLET FOR BATTERY RECHARGING WAS RECOMMENDED. THIS WOULD ELIMINATE THE NEED FOR REMOVING THE BATTERY CASE COVER FOR THIS PURPOSE. | X | X | | NOT ADOPTED | 5 |
| 2.6 VEHICLE MANEUVERABILITY | PAR. 6.1.1 | ADS 5008B<br>PAR. 3.12, 3.13B<br>(REF. #3) | THE LOCATION AND SIZE OF EQUIPMENT SHALL BE SUCH THAT THE EQUIPMENT WILL BE EASILY OPERATED AND MAINTAINED BY AT LEAST THE | ER-V-59 | WHERE THE AREA IS CONFINED AND THE DOLLY WHEELS ARE ON GRATING, (WORK PLATFORMS) THE DOLLY IS EXTREMELY DIFFICULT TO MANEUVER EITHER LOADED OR UNLOADED. | X | X | X | NOT ADOPTED | 10 |

ITEM: TRAILER LIFT AND MAINTENANCE DOLLY

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| | | | 5TH TO 95TH PERCENTILE GROUP OF THE AIR FORCE POPULATION. | | IT REQUIRES EXTREME PHYSICAL EXERTION AND MANY PERSONNEL TO GET THE DOLLY INTO THE POSITION DESIRED.<br>ADDITIONAL STEERING AIDS FOR TURNING THE WHEELS SEPARATLY UNDER LOAD AND POSSIBLY FRONT AND REAR STEERING CONTROLS SHOULD BE CONSIDERED. | | | | | |
| 3.0 SAFETY<br>3.5 SAFETY DEVICES | PAR. 7.17 | | WEIGHT CAPACITY SHOULD BE INDICATED ON DOLLY. | ER-V-59 | ADD A STENCIL (½" HIGH LETTERS PER MIL STD 130) "CAPACITY 2,000 POUNDS MAXIMUM".<br>THE MAXIMUM OPERATING LOAD WITH BOOM EXTENDED SHOULD BE ADDED TO THE CHARACTERISTIC BLOCK AS FOLLOWS:<br>MAX. LOAD WITH BOOM EXTENDED TO 8'-1,000 LBS. SECURE ALL TIE-DOWN STRAPS BEFORE OPERATING BOOM. | X | X | | NOT ADOPTED | 10 |
| | PAR. 7.20 | | INSURE THAT ALL PIPE LINES ARE CLEARLY AND UNAMBIGUOUSLY LABELED OR CODED AS TO CONTENT, PRESSURE, HEAT OR COLD AND ANY SPECIFIC HAZARD PROPERTIES. | ER-V-59 | ADD A STENCIL (½" HIGH LETTERS PER MIL STD 130) "USE WATER-GLYCOL HYDRAULIC FLUID ONLY--DO NOT USE OILS". ALSO, ADD STENCILS TO INDICATE THE FOLLOWING OPERATING REQUIREMENTS:<br>1. "LOCK REAR CASTERS FOR TOWING"<br>2. "LOCK ALL BRAKES WHEN OPERATING"<br>3. "UNLOCK FRONT CASTERS FOR TOWING"<br>STEEL STAMP BATTERY POLARITY IN BATTERY CASE. | X | X | | NOT ADOPTED | 10 |

ITEM: TRAILER LIFT AND MAINTENANCE DOLLY

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE: CONTRACTUAL AFBM 57-8A | DOCUMENTARY COMPLIANCE: TECH. REF. | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA: PARTICIPATION | APPLICATION OF CRITERIA: RECOMMENDATIONS | VERIFICATION: ANAL | VERIFICATION: EQUIP | VERIFICATION: TEST | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ADS 5008B PAR. 3.12C (REF. #3) ADS 1003C PAR. 6.4.19 (REF. #4) | THE MAINTENANCE DOLLY OPERATES IN OR NEAR AREAS WHERE SPARKING IS NOT TOLERABLE. TO REDUCE THE POSSIBILITY OF BUILDUP OF STATIC CHARGE, THE DOLLY SHOULD HAVE CONDUCTING WHEELS. | | ADD NAME PLATE INCLUDING BATTERY IDENTIFICATION, HOOK-UP INSTRUCTIONS AND BATTERY MAINTENANCE INSTRUCTIONS (WATER, ETC.). THE MAINTENANCE DOLLY IS EQUIPPED WITH CONDUCTING TIRES. | | | | | |
| SAFETY DEVICES (CONT'D) | PAR. 7.6 | | SOME FORM OF ANCHOR OR OUTRIGGERS SHOULD BE EMPLOYED ON THE DOLLY TO PREVENT TIPPING WHEN HANDLING LOADS WITH THE BOOM EXTENDED. | | THE DOLLY HAS FOUR TIE-DOWN STRAPS WHICH ARE TO BE USED DURING ALL OPERATIONS AND NOT TO BE REMOVED UNTIL THE LOAD HAS BEEN CENTERED OVER THE DOLLY'S BED. | X | X | X | CRITERIA SATISFIED | 15 |
| 6.0 ENVIRONMENTAL<br>6.3 ILLUMINATION (NON AMF TASK) | PAR. 5.5 THRU 5.5.3 | | BLACK BOX REMOVAL IS A DIFFICULT AND PROLONGED VISUAL TASK AND REQUIRES 100 OR MORE FOOT CANDLES OF ILLUMINATION. | AMF DOCUMENT TS 7.2.34 | THE LIGHTING PROVIDED IN THE SILO WORK PLATFORM AREAS WHERE THE DOLLY IS USED IS AT THE MAXIMUM, 5FOOT-CANDLES. TO SUPPLEMENT THIS LIGHTING, A LIGHT SHOULD BE AFFIXED TO THE END OF THE BOOM. THIS LIGHT WOULD ILLUMINATE THE DARK "BLACK BOX" COMPARTMENTS AND FACILITATE THE ATTACHMENT OF THE ADAPTER, REMOVING AND REPLACING MOUNTING HARDWARE, AND PREVENT POSSIBLE EQUIPMENT DAMAGE WHEN [illegible] | X | | | SHOULD BE FURTHER EVALUATED | 10 |
| | | | | | | | | | | 100 |

## 3.0 DISCUSSION

The layout and design of the Maintenance Dolly controls may not permit optimum operator performance. A handling device of this nature demands that full operator attention be given to the boom and the equipment being handled by the boom. The boom controls, therefore, should be designed and laid out so that their manipulation does not require excessive visual attention or body movement other than arms and hands. The present control layout even with training may not permit the operator to control the boom easily. If redesign of this unit, or design of a similar unit is contemplated, the control panel design should be afforded primary consideration to insure optimum man-machine performance.

## 4.0 REFERENCES


1. AFBM Exhibit 57-8A, Human Engineering Design Standards for Missile System Equipment.

2. WADC TR 56-171, Layout of Workspace, September 1956.

3. ADS 5008B, Maintenance Dolly for WS 107A-2 Launcher System.

4. ADS 1003C, Personnel Safety for WS 107A-2 Launcher System.

5. AMF Report ER-V-59, Maintenance Dolly 59-202-9014 Proposed Change Effort, 1/14/61.

6. AMF Report ER-T/S-5102, Trailer Lift & Maintenance Dolly - Stage Separation Control Box - Coles Crane Remote Control Box, 11/3/60.

7. AMF Report FTR-D-198, Maintenance Dolly Evaluation Joint Report, 12/17/58.

8. AMF Document TS 7.2.35, DDL Review 5053 Maintenance Dolly, 2/2/59.

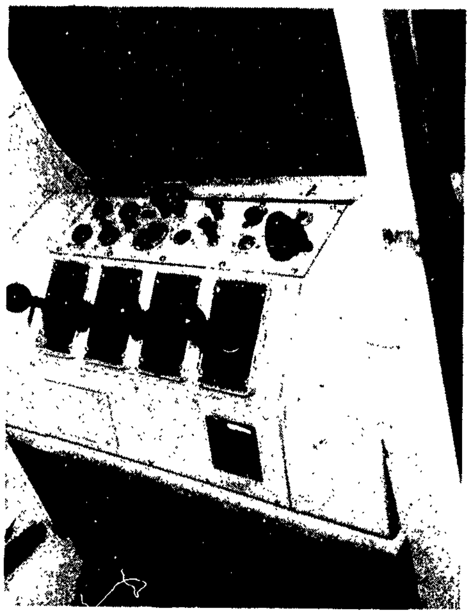
9. AMF Document TS 7.2.34, General Illumination Requirements Silo and Environs, 6/8/58.

10. AMF Document TS 7.2.37, Advance Transmittal of Handling Dolly Evaluation Report, 12/16/58.

Chapter 14

# Human Factors Review and Evaluation of the Missile Emplacement System

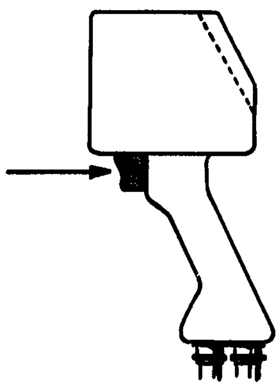
FIGURE 14-1
HUMAN FACTORS INPUTS
MISSILE EMPLACEMENT



CONTROLS

Arrangement of controls should be consistent from application to application.

Direction of control movement should be identical in cab and on remote controller.



DEAD-MAN CONTROL

A dead-man trigger switch has been provided to insure fail safe conditions.

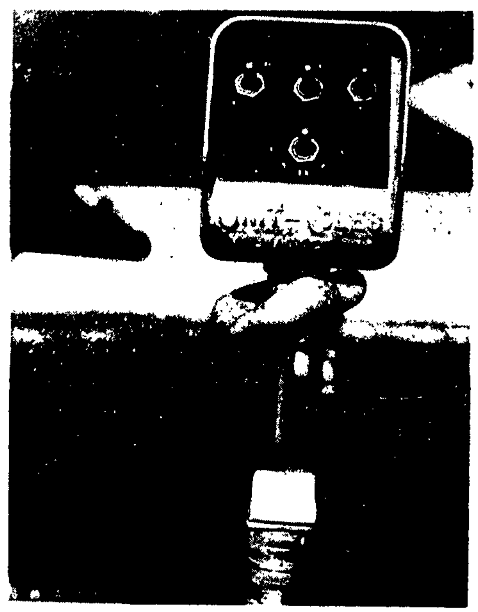
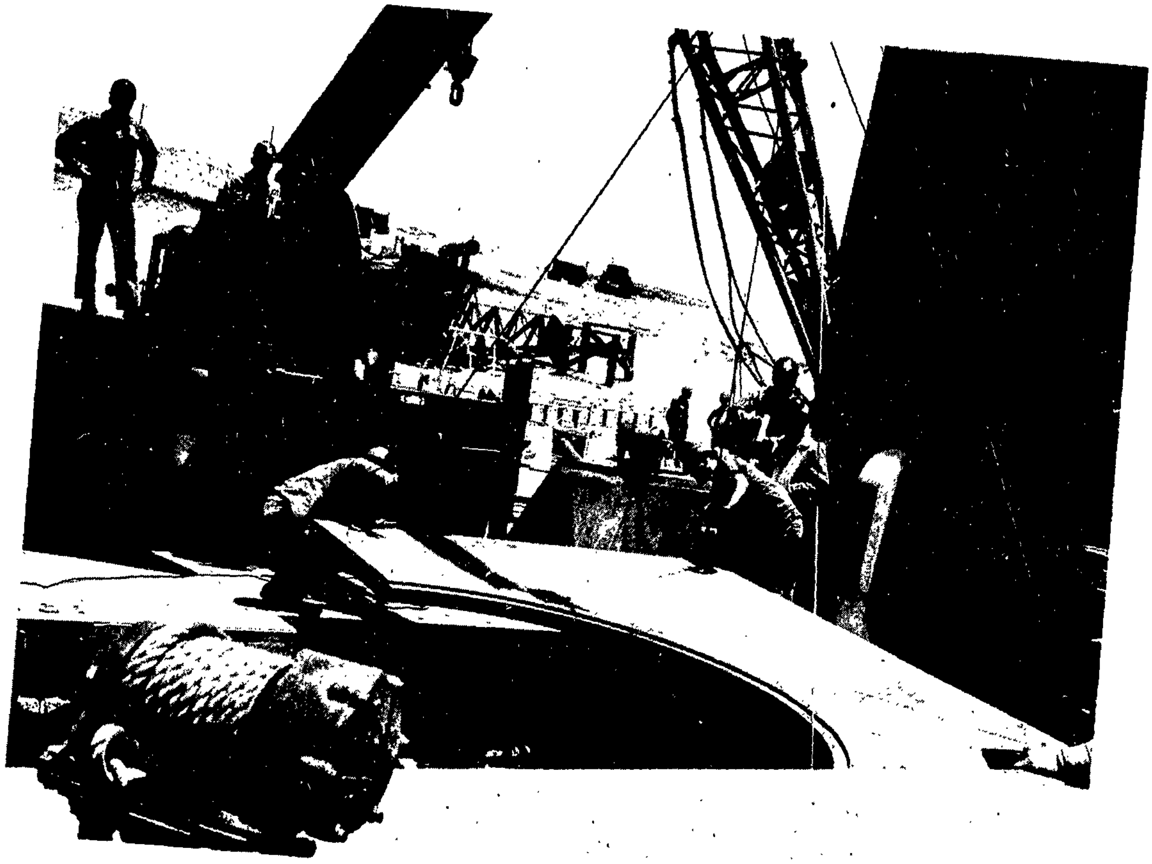


FIGURE 14-2
HUMAN FACTORS INPUTS
COLES CRANE



WINCHES

Tag line winches should be located for optimum standing operation of the crank.

PLATFORMS

Silo mouth platforms have been provided for safe access to missile during emplacement.

FIGURE 14-3
HUMAN FACTORS INPUTS
SILO MOUTH PLATFORMS
AND
TAG LINE WINCHES

**SUMMARY CHECKLIST OF HUMAN FACTORS PROGRAM IN RELATION TO:**
GSE MISSILE EMPLACEMENT SYSTEM

| | Human Factor Effort Required | Phase in Stage: Concept | Review | Analysis | Field Input | Human Factors Objective: Specification Compliance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | Applicable on Model: OSTF | TF | OB | Symbol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.0 HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | |  |
| **1.1 Anthropometric Compatability** | * | | * | | | * | | | * | * | * | * | * | |
| **1.2 Controls and Displays** | * | | * | | | * | * | | * | * | * | * | * | |
| **1.3 Fail-Safe Design** | | | | | | | | | | | | | | |
| **1.4 Malfunction Detection** | | | | | | | | | | | | | | |
| **2.0 MAINTENANCE FACTORS** | | | | | | | | | | | | | |  |
| **2.1 Access, Visual** | * | | * | | | * | | | * | * | * | * | * | |
| **2.2 Access, Servicing** | * | | * | | | * | | | * | * | * | * | * | |
| **2.3 Remove and Replace** | | | | | | | | | * | | | | | |
| **2.4 Handling, Physical Limitations** | * | | * | | | * | | | * | * | * | * | * | |
| **2.5 Handling, Transportation** | | | | | | | | | * | | | | | |
| **2.6 Vehicle Maneuverability** | | | | | | | | | * | | | | | |
| **3.0 SAFETY FACTORS** | | | | | | | | | | | | | |  |
| **3.1 Chemical Decontamination** | | | | | | | | | | | | | | |
| **3.2 Escape Provisions** | | | | | | | | | | | | | | |
| **3.3 Protection from Entanglement** | | | | | | | | | | | | | | |
| **3.4 Protection from Falling** | | | | | | | | | | | | | | |
| **3.5 Safety Devices (other)** | * | | * | | | * | * | | * | * | * | * | * | |
| **3.6 Warning Devices** | | | | | | | | | | | | | | |
| **4.0 PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| **4.1 Biological Damage** | | | | | | | | | | | | | | |
| **4.2 Vertigo** | | | | | | | | | | | | | | |
| **4.3 Vibration Effects** | | | | | | | | | | | | | | |
| **5.0 PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| **5.1 Fear of Heights** | | | | | | | | | | | | | | |
| **5.2 Fear of Being Crushed** | * | | * | | | * | * | | * | * | * | * | * | |
| **5.3 Fear of Falling** | * | | * | | | * | * | | * | * | * | * | * | |
| **5.4 Fear of Isolation** | | | | | | | | | | | | | | |
| **5.5 Feeling of Insecurity** | | | | | | | | | | | | | | |
| **6.0 ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | |  |
| **6.1 Acoustic Energy (noise)** | | | | | | | | | | | | | | |
| **6.2 Humidity & Temperature** | * | | * | | | * | | | * | * | * | * | * | |
| **6.3 Illumination** | * | | * | | | * | * | | * | * | * | * | * | |
| **7.0 HUMAN USE FACTORS** | | | | | | | | | | | | | |  |
| **7.1 Procedure** | * | | * | | | * | * | | * | * | * | * | * | |
| **7.2 Time Study** | | | | | | | | | | | | | | |
| **7.3 Training/Selection** | | | | | | | | | | | | | | |

FIGURE 14-4

1.0 DESCRIPTION

1.1 The Missile Emplacement System consists of the methods, procedures and equipment which are used to mate the three stages of the missile on the missile support mechanisms. The system equipment consists of a crane containing a primary and secondary hoist as well as a remote control unit, the MC-1 crane for emplacing the silo mouth platforms, a mobile maintenance platform and relevant hardware, adaptors and tag lines. The emplacement procedure provides a means by which the stages and reentry-vehicle of the missile may be connected successively, as well as methods by which pertinent maintenance may be applied.

1.2 Applicable Human Factors Considerations

Men of the Air Force population who represent body sizes between the 5th and 95th percentile must be able to conduct the required operations of missile emplacement efficiently without causing damage to equipment or injury to personnel. The individual procedures which comprise the system must be designed to provide for simplicity and efficiency so that men can execute the requirements of the emplacement system effectively with a minimum of training and a minimum of time and expenditure of effort.

Factors contributing to the successful conduct of the Missile Emplacement System have been itemized on the summary checklist (Figure 14-4) and the progress of missile emplacement design has been tabulated in detail in the following synopsis.

ITEM: GSE MISSILE EMPLACEMENT SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 1.0 HUMAN ENGINEERING DESIGN<br>1.1 ANTHROPOMETRIC COMPATABILITY | 6.1.1 -<br>6.1.2.2 | WADC TR56-30 | PASSING BODY THICKNESS MINIMUM 13"<br>PASSING BODY WIDTH MINIMUM 20" | ACCESS STUDY, ER-TPS-238 CITES THAT CREW CANNOT CLIMB OVER BASE OF UMBILICAL TOWER DUE TO OBSTRUCTION BY UMBILICAL LINES ATTACHED TO FAIRLEAD GUIDE. | THAT ALTERNATE METHOD FOR ROTATING MISSILE BE PROVIDED, OR ALTERNATE PASSAGEWAY. ONE POSSIBLE METHOD IS TO ATTACH TAGLINES TO A POLE & PASS THE POLE END TO MEN ON THE OTHER SIDE OF THE TOWER. | X | X | | ALTERNATE METHOD ADOPTED FOR PASSING TAG LINES. | 10 |
| | | WADC TR52-321 | ELBOW HEIGHT (5TH PERCENTILE) 41" | AMF DDL REVIEW #290, APRIL 14, 1959 | THAT OPERATOR CANNOT REACH WINCH IN QUADRANT II, HENCE, OPTIMUM OF WINCH SHOULD BE 43" FROM THE CENTER LINE OF THE WINCH SHAFT TO LEVEL SURFACE WHERE OPERATOR CAN STAND TO CONTROL TAG LINES. | X | X | | NOT ADOPTED | 5 |
| 1.2 CONTROLS AND DISPLAYS (COLES CRANE) | 2.1 | WADC TR54-160<br>WADC TR56-172<br>WADC TR56-171 | NON-REFLECTION OF LIGHT<br>ADEQUATE WARNING LIGHTS AND DEVICES; INDICATOR LIGHTS<br>ADEQUATE CONTROL FEEDBACK<br>CONTROL ACTUATION FORCE 10-40 OUNCES<br>CONTROL DISPLACEMENT .125 - 1.5 INCHES<br>FOOT PEDAL<br>MIN. DIMENSION 1 X 3 INS.<br>ACTUATION FORCE MIN. 4 LBS. MAX. 20LBS.<br>DISPLACEMENT ½ INCH<br>MAX. ANKLE FLEXION 2½ INS.<br>MAX. LEG MOVEMENT 7 INS. | HUMAN FACTORS TEST PROCEDURE FOR EVALUATION OF THE MISSILE HANDLING CRANE IN CONJUNCTION WITH GROUP I: TEST PLAN 1K ADVP-V-1083, ADDENDUM B<br>13 JULY 1960 | SEE CRITERIA FOR SUCCESS. | X | X | X | RECOMMENDATION NOT COMPLETELY ADOPTED | 20 |

2.0 SYNOPSIS

ITEM: OSE MISSILE EMPLACEMENT SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE: CONTRACTUAL AFBM 57-8A | DOCUMENTARY COMPLIANCE: TECH. REF. | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA: PARTICIPATION | APPLICATION OF CRITERIA: RECOMMENDATIONS | VERIFICATION: ANAL | VERIFICATION: EQUIP | VERIFICATION: TEST | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.2 CONTROLS & DISPLAYS (COLES CRANE) (CONT'D) | | | TOGGLE SWITCH<br>TIP DIAMETER 1/8 - 1 INCH<br>LEVER ARM LENGTH ½- 2 INS.<br>DISPLACEMENT 30°-120°<br>ACTUATION FORCE 10-40 OZS. | | | | | | | |
| REMOTE CONTROL | 3.1.4-3.1 | WADC TR56-172 | TOGGLE SWITCHES<br>RESISTANCE 10-40 OUNCES<br>CONTROL TIP DIAM. 1/8-1 INCH<br>LEVER ARM LENGTH ½-2 INCHES<br>DISPLACEMENT 40°-120°<br>SPACING 1" MINIMUM | AMF DOCUMENT TS 7.2.18, MARCH 23, 1960, REVIEW OF SKETCHES OF SUGGESTED VERSION OF CRANE REMOTE CONTROLLER. | REVISION OF REMOTE CONTROL FEATURES: SIMPLIFIED CONSTRUCTION, LIGHTWEIGHT, COMPACT, INTEGRATED GRIP, RAIN PROTECTION, ETC. | | | | | |
| | | | DIR. OF MOVEMENT - ATTEMPT TO MAKE DIRECTION OF MOVEMENT IDENTICAL OR SIMILAR TO ACTUAL MOVEMENT OF RESPONSE | ENGINEERING REPORT ER-TPS-109, SEPT. 16, 1958, HUMAN ENGINEERING STUDY OF STAGE HANDLING CRANE | "DEADMAN" TRIGGER SWITCH IN REMOTE CONTROL; DIRECTION OF SWITCH MOVEMENT IDENTICAL TO CAB CONTROL MOVEMENTS. | X | X | | ECP-AMF-113P, MODIFICATION OF MISSILE HANDLING CRANE REMOTE CONTROL CONSOLE. | 20 |
| 2.0 MAINTENANCE<br>2.1 VISUAL ACCESS | 4.3.3.9.10<br>5.5.1-5.5.3 | WADC TR54-160 | OPTIMUM VIEWING RANGE 40-70 INS. IN VERTICAL PLANE; MAX. 30 INS. FROM OPERATING PERSONNEL<br>VIEWING ANGLE OPTIMUMS<br>LATERAL 15°<br>VERTICAL 30° | PHYSICAL EVALUATION OF MISSILE SITE EMPLACEMENT PROCEDURES. | THAT CONSIDERATION BE GIVEN TO AVOIDING EXCESSIVE GLARE (DIFFERENCE BETWEEN DETAIL AND ITS BACKGROUND) BY DAY, AND TO PROPER ILLUMINATION BY NIGHT. | | X | | | 10 |
| 2.2 SERVICING ACCESS | 4.3.3.9 | | SEE AFBM 57-8A REFERENCE | EVALUATION OF MISSILE SITE EMPLACEMENT PROCEDURES | THAT SILO MOUTH PLATFORMS BE MADE AVAILABLE TO FACILITATE ACCESS TO MISSILE IN SILO MOUTH. | X | X | | RECOMMENDATION ADOPTED | 10 |

ITEM: GSE MISSILE EMPLACEMENT SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 2.4 HANDLING, PHYSICAL LIMITATIONS | 4.3.3.3 | WADC TR56-171 | 5TH PERCENTILE MAN DATA (MAX)<br>HEIGHT 65"<br>EYE HEIGHT 61"<br>OVERHEAD REACH 77"<br>ONE ARM REACH FORWARD<br>MAX. 35"<br>FUNCTIONAL 30"<br>TWO ARM SPAN 66" | AMF DDL REVIEW #290, APRIL 14, 1959 | SEE ABOVE | X | X | | | |
| 3.0 SAFETY<br>3.5 SAFETY DEVICES | 7 - 7.25 | | SEE CONTROLS AND DISPLAYS | HUMAN FACTORS TEST PROCEDURE FOR EVALUATION OF THE MISSILE HANDLING CRANE IN CONJUNCTION WITH GROUP I: TEST PLAN 1K ADVP-V-1083, ADDENDUM B 13 JULY 1960 | SEE APPENDIX | | X | X | | |
| 5.0 PSYCHOLOGICAL<br>5.2 FEAR OF BEING CRUSHED<br>5.3 FEAR OF FALLING | 1.4, 7.8, 7.9, 7.22 | | SEE REFERENCE | EVALUATION OF MISSILE SITE EMPLACEMENT PROCEDURE | THAT AUXILIARY PLATFORMS BE INSTALLED IN ADDITION TO SILO MOUTH PLATFORMS, IN ORDER TO PROVIDE FLOOR AREA BETWEEN OPEN JOINTS OF THE SILO MOUTH PLATFORM. IN ADDITION, THAT THE GROUND LEVEL PORTABLE CONTROL STATION CONNECTOR CABLE BE EXTENDED SOME 50 FT. TO REMOVE THE STATION FROM BEING UNDER THE SLEWING COLES CRANE BOOM. | X | X | | RECOMMENDATIONS ADOPTED | 10 |

2.0 SYNOPSIS

ITEM: OSE MISSILE EMPLACEMENT SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 6.0 ENVIRONMENTAL<br>6.2 HUMIDITY AND TEMPERATURE | 5.3 - 5.4.1 | | ACCEPTABLE LIMITS; WIND CHILL EFFECTS (see below) | EVALUATION OF MISSILE SITE EMPLACEMENT PROCEDURES AND EXAMINATION OF METEROLOGICAL DATA FOR MISSILE SITES. | THAT CONSIDERATION BE GIVEN TO AMBIENT WEATHER CONDITIONS AT TIME OF MISSILE EMPLACEMENT TO INSURE THAT PERSONNEL ARE ADEQUATELY PROTECTED. | X | | | NOT ADOPTED BECAUSE REQUIREMENT IS NOT IN THE MODEL SPECIFICATION. | 10 |

**ACCEPTABLE LIMITS**

| REL. HUMIDITY (%) | DRY BULB TEMP (F) DIFFICULT | DRY BULB TEMP (F) EASY |
|---|---|---|
| 100 | 94 | 92 |
| 90 | 96 | 94 |
| 80 | 99 | 96 |
| 70 | 103 | 101 |
| 60 | 106 | 104 |
| 50 | 111 | 107 |
| 40 | 115 | 113 |
| 30 | 120 | 120 |

**WIND CHILL EFFECTS**

| WIND VELOCITY | AMBIENT TEMP. | EQUIV TEMP. |
|---|---|---|
| 45 | 90 | 83 |
| 45 | 72 | 23 |
| 45 | 51 | -27 |
| 25 | 89 | 83 |
| 25 | 71 | 23 |
| 25 | 39 | -38 |
| 15 | 79 | 60 |
| 15 | 67 | 23 |
| 15 | 42 | -27 |
| 5 | 76 | 60 |
| 5 | 60 | 23 |
| 5 | 44 | -11 |
| 2 | 86 | 83 |
| 2 | 57 | 23 |
| 2 | 44 | -11 |

ITEM: GSE MISSILE EMPLACEMENT SYSTEM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 6.3 ILLUMINATION | 5.5.1-5.5.3 | | ILLUMINATION INDICES — FT. CAND.<br>VERY DIFFICULT SEEING TASKS — 100<br>DIFFICULT & CRITICAL SEEING TASKS — 50<br>ORDINARY SEEING TASKS — 30<br>CASUAL SEEING TASKS — 10<br>ROUGH SEEING TASKS — 5 | EVALUATION OF MISSILE SITE EMPLACEMENT PROCEDURES. | THAT NO WORKING AREA HAVE LESS THAN 10 FT./CANDLES/SQ. FT. ILLUMINATION, AND THAT INCREASED LEVELS OF ILLUMINATION BE USED AS INDICATED IN THE REFERENCE, DURING MISSILE EMPLACEMENT ON CLOUDY DAYS OR AT NIGHT. | X | | | NOT ADOPTED BECAUSE REQUIREMENT IS NOT IN THE MODEL SPECIFICATION. | 5 |
| | | | | | | | | | | 100 |

## 3.0 DISCUSSION

3.1 The missile emplacement system was never formally evaluated as an entity from the standpoint of human factors engineering. Rather, evaluations were made of sub-systems and techniques from DDL's and EPD's, through review and procedural examination.

3.2 The success of any given missile emplacement effort will depend upon three general conditions: the efficiency of the team, the degree of smoothness and reliability which the system affords, and the effect of the ambient environmental conditions. Team training and team dynamics are generally not within the scope of human factors engineering concern. It must be noted, however, that an efficient missile emplacement team will most generally be composed of men who have worked together over a considerable period of time and who have a complete understanding of their tasks as integrated functions in an overall system.

3.3 Although it is possible that missiles will have to be emplaced in environmental conditions which are not always optimal, many precautions and preparations can be adopted which will minimize the effects and permit satisfactory emplacement procedures. Although menta' rk does not deteriorate as rapidly as humidity and temperature rise, the rate of physical work drops off and accidents increase. It is generally conceded that men can tolerate a much hotter temperature if the air is relatively dry. In a similar fashion, the wind which exists in an operational area must be considered as a serious factor in work efficiency. Wind chill can cause effects on exposed skin which is equivalent to a considerable reduction in temperature, and for this reason wind chill must be considered in protecting operating crews and in avoiding accidents as a result of stiff fingers, etc.

3.4 Considerations should also be given to ambient illumination and artificial illumination at a missile emplacement site. During daylight the general earth light on a clear day is 300 candles/sq.ft., (enough for the finest precision work), and therefore, the problem is not that of inadequate light, but of brightness and glare. The ability to see detail depends upon the brightness difference between the detail and its background. The greater the difference in brightness, the more readily the seeing task is performed. In general, the brightness ratio of the visual task to its immediate surroundings should be no greater than three. Glare can be reduced by the application of dull surface coverings where applicable, and by attempting to reduce angles of operation to exclude the open sky as a background for a given task.

3.5 Consideration of the above conditions indicates that there are many emplacement variables which cannot be wholly controlled. For this reason, and reasons which are contained in the emplacement procedure itself, future attention should be directed toward a re-design of the missile emplacement system which will contain a more automated methodology, less dependent upon human judgments and skills.

## 4.0 REFERENCES


1. AFBM Exhibit 57-8A, Human Engineering Design Standards for Missile System Equipment.

2. WADC Technical Report 56-30, Annotated Bibliography of Applied Physical Anthropology in Human Engineering, May 1958.

3. WADC Technical Report 52-321, Anthropometry of Flying Personnel, September 1954.

4. WADC Technical Report 54-160, Visual Presentation of Information, August 1954.

5. WADC Technical Report 56-172, Design of Controls, Chapt. VI of the Joint Services Human Engineering Guide to Equipment Design, November 1956.

6. WADC Technical Report 56-171, Layout of Workplaces, Chapt. V of the Joint Services Human Guide to Equipment Design, September 1956.

7. Journal of Industrial Hygiene and Toxicology, The Upper Limits of Environmental Heat and Humidity Tolerated by Acclimatized Men Working in Hot Environments, Vol. 27, 1945, p. 59-84.

8. Air Conditioning, Heating and Ventilating, Army Develops Wind Chill Table, March 1959, p. 88.

9. AMF Report, ER-TPS-238, Access-Missile Emplacement (OSTF), 10/19/59.

10. AMF Report, ER-TPS-109, Human Engineering Study of Stage Handling Crane, 9/16/58.

11. AMF DDL Review #290, 4/14/59.

12. AMF Test Plan 1K, ADTP-V-1083, Addendum B, Human Factors Test Procedure for Evaluation of the Missile Handling Crane in Conjunction with Group I, 13 July 1960.

13. AMF Document TS 7.2.18, Review of Sketches of Suggested Versions of Crane Remote Controller, 3/23/60.

14. Engineering Change Proposal, AMF-113P; Subject, Modification of Missile Handling Crane Remote Control Console, 3/23/61.

# Chapter 15

## Human Factors Review and Evaluation of the Mobile Work Platform

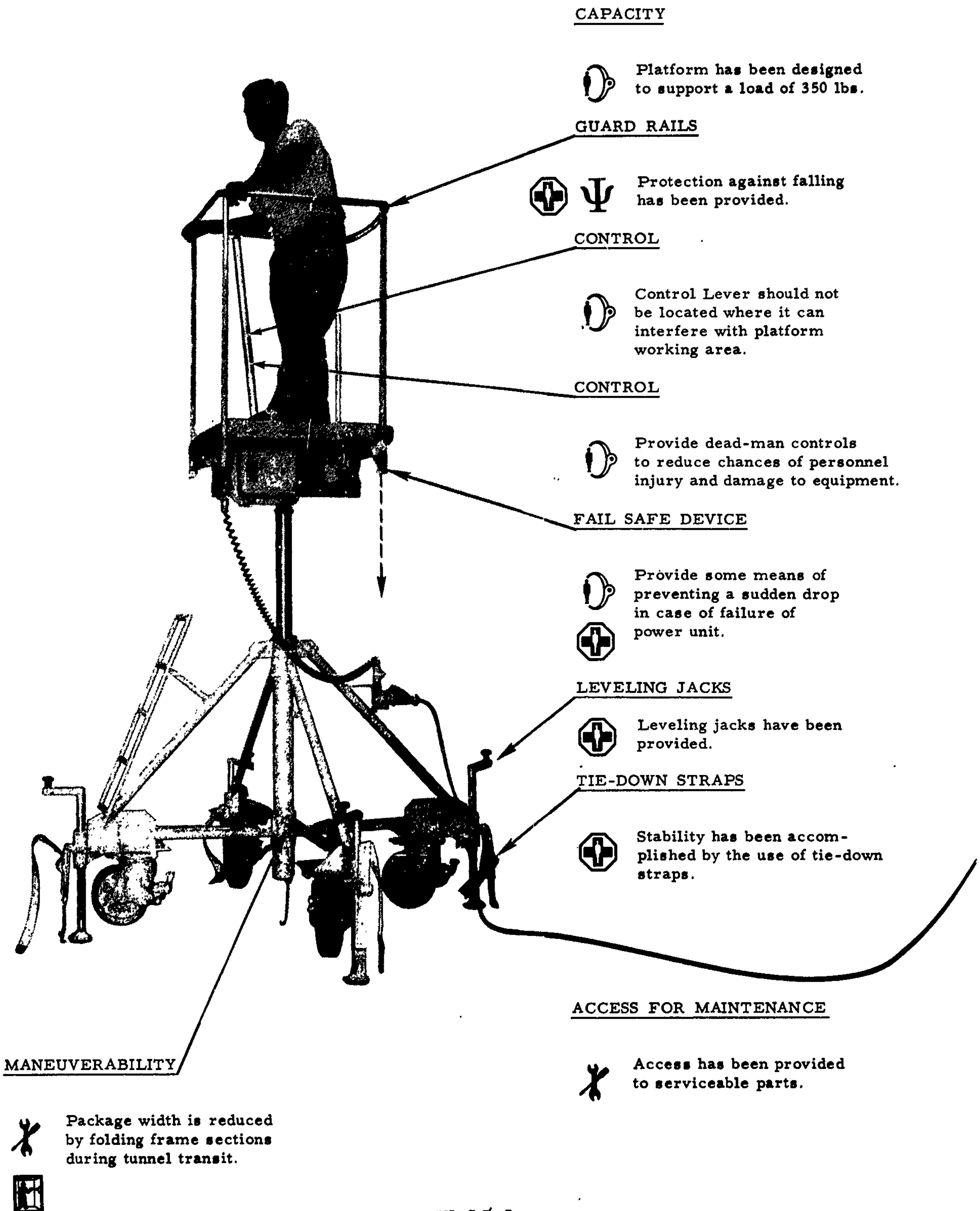



FIGURE 15-1
HUMAN FACTORS INPUTS
MOBILE WORK
PLATFORM

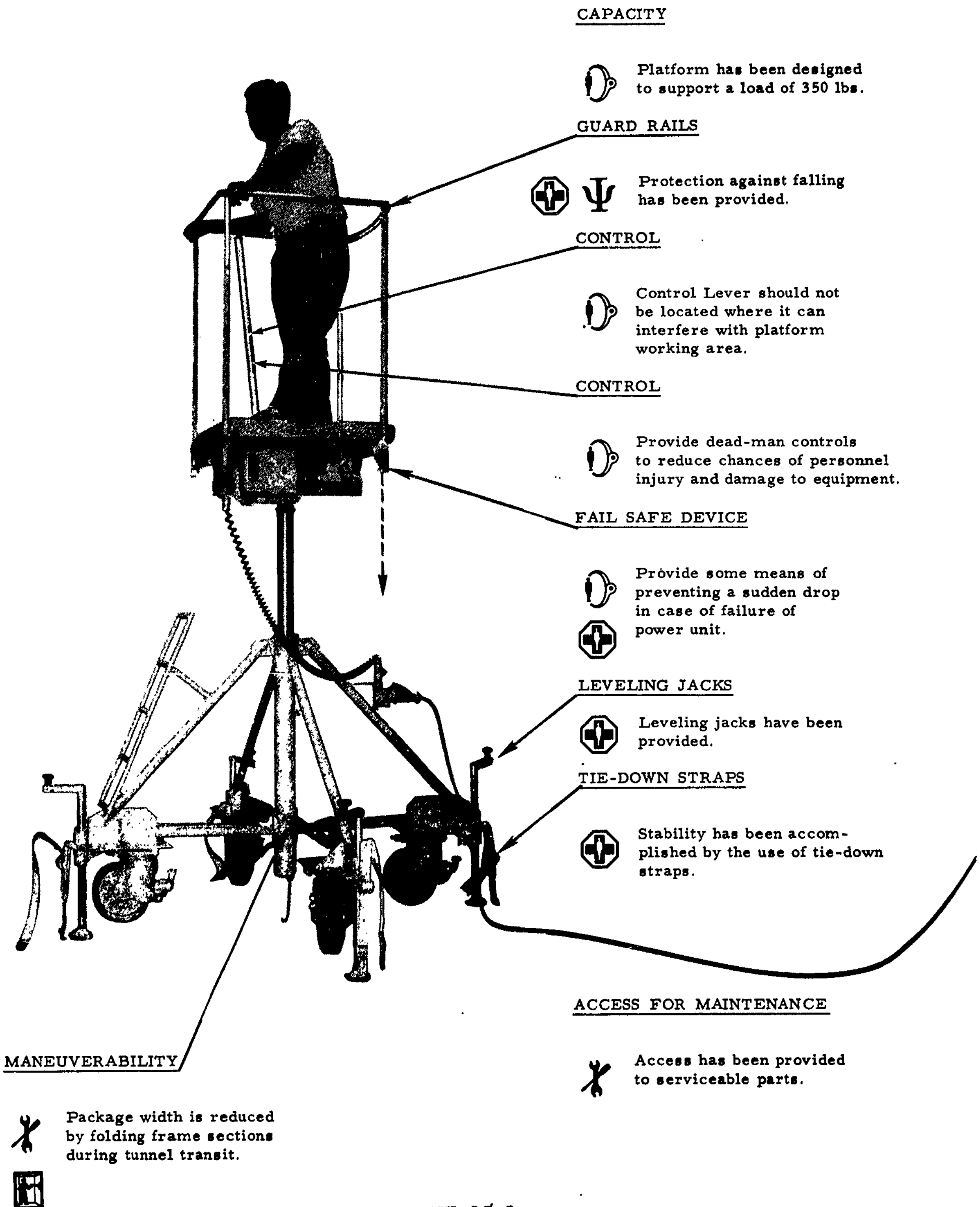



FIGURE 15-1
HUMAN FACTORS INPUTS
MOBILE WORK
PLATFORM

SUMMARY CHECKLIST OF
HUMAN FACTORS PROGRAM
IN RELATION TO:
MOBILE WORK PLATFORM

| | | Human Factor Effort Required | PHASE IN STAGE: Concept | Review | Analysis | Field Input | HUMAN FACTORS OBJECTIVE: Specification Compliance | Safety | Operational Status | Maintenance Recommendation | Product Improvement | APPLICABLE ON MODEL: OSTF | TF | OB | SYMBOL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.0** | **HUMAN ENGINEERING DESIGN FACTORS** | | | | | | | | | | | | | |  |
| 1.1 | Anthropometric Compatability | * | * | * | * | | * | * | | | * | * | * | * | |
| 1.2 | Controls and Displays | * | * | * | * | | * | * | | | * | * | * | * | |
| 1.3 | Fail-Safe Design | * | * | * | * | | * | * | | | * | * | * | * | |
| 1.4 | Malfunction Detection | | | | | | | | | | | | | | |
| **2.0** | **MAINTENANCE FACTORS** | | | | | | | | | | | | | |  |
| 2.1 | Access, Visual | | | | | | | | | | | | | | |
| 2.2 | Access, Servicing | * | * | * | * | | * | * | | | | * | * | * | |
| 2.3 | Remove and Replace | | | | | | | | | | | | | | |
| 2.4 | Handling, Physical Limitations | | | | | | | | | | | | | | |
| 2.5 | Handling, Transportation | | | | | | | | | | | | | | |
| 2.6 | Vehicle Maneuverability | * | * | * | * | | * | * | | | | * | * | * | |
| **3.0** | **SAFETY FACTORS** | | | | | | | | | | | | | |  |
| 3.1 | Chemical Decontamination | | | | | | | | | | | | | | |
| 3.2 | Escape Provisions | | | | | | | | | | | | | | |
| 3.3 | Protection from Entanglement | | | | | | | | | | | | | | |
| 3.4 | Protection from Falling | * | * | * | * | * | * | * | | | | * | * | * | |
| 3.5 | Safety Devices (other) | * | * | * | * | | * | * | | | * | * | * | * | |
| 3.6 | Warning Devices | | | | | | | | | | | | | | |
| **4.0** | **PHYSIOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 4.1 | Biological Damage | | | | | | | | | | | | | | |
| 4.2 | Vertigo | | | | | | | | | | | | | | |
| 4.3 | Vibration Effects | | | | | | | | | | | | | | |
| **5.0** | **PSYCHOLOGICAL FACTORS** | | | | | | | | | | | | | |  |
| 5.1 | Fear of Heights | * | * | * | * | | | | | | | * | * | * | |
| 5.2 | Fear of Being Crushed | | | | | | | | | | | | | | |
| 5.3 | Fear of Falling | * | * | * | * | | | * | | | | * | * | * | |
| 5.4 | Fear of Isolation | | | | | | | | | | | | | | |
| 5.5 | Feeling of Insecurity | * | * | * | * | | | | | | | * | * | * | |
| **6.0** | **ENVIRONMENTAL FACTORS** | | | | | | | | | | | | | |  |
| 6.1 | Acoustic Energy (noise) | | | | | | | | | | | | | | |
| 6.2 | Humidity & Temperature | | | | | | | | | | | | | | |
| 6.3 | Illumination | | | | | | | | | | | | | | |
| **7.0** | **HUMAN USE FACTORS** | * | | | | | | | | | | * | * | * |  |
| 7.1 | Procedure | | | | | | | | | | | | | | |
| 7.2 | Time Study | | | | | | | | | | | | | | |
| 7.3 | Training/Selection | | | | | | | | | | | | | | |

FIGURE 15-2

1.0 DESCRIPTION

1.1 The Mobile Work Platform is a power elevated and manually rotated auxiliary working level designed basically to provide access to the missile compartment and skin areas located out of reach of the crib mounted work platforms. The unit has a telescoped height of 5'-6 3/4" and it can be raised an additional 6'-7¼", controlled by a person standing on the platform.

The platform surface measures 27" square with a protruding 12" segment on one side which mates with the missile openings to provide improved access into the missile in those areas just above the stage I and II mating line. The platform can be rotated 360° and locked into any one of thirteen positions without moving the vehicle on its wheels.

The unit is powered hydraulically through an electrically driven pump which is energized by plugging the extension cord into a 110 Volt A.C. utility box.

A ladder has been permanently attached to one supporting leg to provide access to the platform while in its lowest position. Leveling jacks and tie down straps have been provided to stabilize the fully extended unit in high level operations. A guard rail can be raised manually from its stored position to a height of 42" to keep personnel from falling. All four wheels can be locked against swivel action and are provided with static brakes to hold the vehicle in its stored location.

The supporting leg sections rotate, from their position of maximum stability, closer together to reduce the width of the vehicle while it passes through doorways and tunnels from the Ready Maintenance Room to the Missile Silo. With the unit at its narrowest width a two bar can be attached which allows it to be towed by the Tug Truck.

1.2 Air Force personnel who represent body sizes between the 5th and 95th percentile must be able to handle the Mobile Work Platform efficiently in transit and on the work platform levels without causing damage to equipment or injury to personnel. The device must be designed to provide adequate access to those components of the system which are not within reach of the work platforms but require frequent maintenance attention. Factors contributing to the successful use of the Mobile Work Platform have been itemized on the Summary Checklist (Fig. 15-2) and the progress of the Mobile Work Platform design has been tabulated in detail in the following Synopsis.

ITEM: MOBILE WORK PLATFORM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE | | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA | | VERIFICATION | | | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| | CONTRACTUAL AFBM 57-8A | TECH. REF. | | PARTICIPATION | RECOMMENDATIONS | ANAL | EQUIP | TEST | | |
| 1.0 HUMAN ENGINEERING DESIGN FACTORS.<br>1.1 ANTHROPOMETRIC COMPATABILITY | 6.1.1, 6.1.2 AND 6.1.5.1 | ASA-A14.2 AND A14.3, ADS-1003C 4.9.1 AND 4.9.2 ADS-5003B | MUST BE CAPABLE OF OPERATION BY MEN OF THE AIR FORCE IN THE 5TH TO THE 95TH PERCENTILE GROUPS. | REVIEWED E.P.D. | MUST SUPPORT MINIMUM LOAD OF 350 LBS. | X | X | | SPECIFICATIONS COMPLIED WITH. | 5 |
| 1.2 CONTROLS AND DISPLAYS | 3.1 | ADS-5003B | LOCATION OF CONTROLS SHOULD NOT INTERFERE WITH PLATFORM USE. PLATFORM SHOULD ELEVATE BETWEEN 5'-3" AND 12'-0" MEASURED FROM FLOOR SWIVEL 360° AND LOCK IN 13 DIFFERENT POSITIONS OF ROTATION. PLATFORM AREA SHALL BE CAPABLE OF RISING TO MAXIMUM STROKE IN 50 SEC. AND TO RETURN IN 30 SEC. | REVIEWED E.P.D. | HAND PUMP HANDLE (LEVER) SHOULD NOT INTERFERE WITH FLOOR SPACE. DRIVE UNIT SHOULD BE MOUNTED ON BASE FRAME. | X | X | | NOT ADOPTED | 10 |
| 1.3 FAIL SAFE DESIGN | 1.4 | | EQUIPMENT SHOULD RETURN TO STOP, OFF, OR BRAKING POSITION TO PREVENT INJURY TO MEN AND DAMAGE TO EQUIPMENT. | REVIEWED E.P.D. | RECOMMEND "DEAD MAN" TYPE CONTROL ON PUMP HANDLE. RECOMMEND BRAKE OR LOCKING PIN OF SOME TYPE ON CYLINDER TO PREVENT SUDDEN DROP OF PLATFORM. | X | X | | NOT ADOPTED | 20 |
| 2.0 MAINTENANCE FACTORS<br>2.2 ACCESS SERVICING | 4.3.1.2, 4.3.2.3, 4.3.3.6.8, 4.3.3.7.1, & 4.3.3.9.4 | | SERVICEABLE PARTS SHOULD NOT BE BLOCKED OR HIDDEN. | REVIEWED E.P.D. | | X | X | | SPECIFICATIONS COMPLIED WITH | 5 |

2.0 SYNOPSIS

ITEM: MOBILE WORK PLATFORM

| HUMAN FACTORS | DOCUMENTARY COMPLIANCE: CONTRACTUAL AFBM 57-8A | DOCUMENTARY COMPLIANCE: TECH. REF. | CRITERIA FOR SUCCESS | APPLICATION OF CRITERIA: PARTICIPATION | APPLICATION OF CRITERIA: RECOMMENDATIONS | VERIFICATION: ANAL | VERIFICATION: EQUIP | VERIFICATION: TEST | RESULTS | % RELATIVE VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.6 VEHICLE MANEUVERABILITY | | ADS-5003B | MODEL SPEC. REQUIRES THAT HANDLING METHODS BE SIMPLE. SHOULD BE TRANSPORTABLE WITHIN THE SILO, TUNNEL AND PERSONNEL ELEVATOR. MUST HAVE TOW BAR (LUNETTE COMBINATION FOR TOWING) 10" FROM GROUND. TOW BAR SHOULD BE QUICKLY REMOVABLE TYPE AND STORED ON MOBILE WORK PLATFORM. | REVIEWED E.P.D. | NEED METHOD TO KEEP MINIMUM PACKAGE SIZE WHEN ENROUTE TO AND FROM WORK POINT. | X | X | | MAXIMUM SIZE: (WHEN TOWING) 40" X 73" X68 3/4" HIGH APPROXIMATE WEIGHT: 700 LBS. | 15 |
| 3.0 SAFETY FACTORS<br>3.4 PROTECTION FROM FALLING | 7.5, 7.8, AND 7.9 | ADS-1003C 4.10 AND 4.11 | GUARD RAILS SHOULD BE 42 INS. IN HEIGHT | REVIEWED E.P.D. | | X | X | | INSTALLED GUARD RAILS AND SAFETY CHAINS. | 20 |
| 3.5 SAFETY DEVICES (OTHER) | 7.6, 7.7, 7.15, AND 7.22 | ADS-1003C 3.2, 4.14, AND 5.0 | MUST BE SIMPLE TO USE AND/OR EASY TO UNDERSTAND, SHOULD HAVE TIE DOWN SAFETY STRAPS AND LEVELING JACKS. GROUNDING STRAP. | REVIEWED E.P.D. | | X | X | | SPECIFICATIONS COMPLIED WITH. | 15 |
| 5.0 PSYCHOLOGICAL<br>5.3 FEAR OF FALLING | SEE 3.4 ADS-1003C 4.10 AND 4.11 | | EFFECTIVE USE OF GUARDRAILS. GUARDRAILS SHALL BE MANUALLY RAISED AND LOWERED, BUT MUST BE LOCKED IN THE RAISED POSITION. | REVIEWED E.P.D. | | X | X | | SPECIFICATIONS COMPLIED WITH. | 5 |
| 5.5 FEELING OF INSECURITY | 7.0, 7.5, AND 7.6 | ADS-1003C 6.4B AND D | PLATFORM SHOULD BE RIGID. (WITHOUT WOBBLE WHEN EXTENDED) | REVIEWED E.P.D. | RECOMMENDED MODIFICATION TO PLATFORM-TO-SHAFT CONNECTION | X | X | | MODIFICATION WAS MADE & CONDITION IMPROVED. | 5 |
| 7.0 HUMAN USE FACTORS<br>7.1 PROCEDURE | | | | AMFP-V-5225 (H.F. TEST PROCEDURE FOR EVALUATION OF MOBILE MAINTENANCE EQUIPMENT.) | | X | X | | NOT AVAILABLE | |
| | | | | | | | | | | 100 |



2.0 SYNOPSIS

## 3.0 DISCUSSION

Original design criteria for the Mobile Work Platform called for a unit which provided access to the missile skin area and to the missile doors. TMC then established the requirement that missile crews must be able to gain access into the missile compartments from this auxiliary platform and requested changes to accomplishing this end. A rubber covered, curved segment was recommended by Human Factors Engineering and incorporated into a modification of the hardware. A study of TMC drawings revealed that no missile opening exceeded the 42" guard rail height on the Mobile Work Platform; the railing was therefore kept as a rigid box form for added strength and rigidity, and the removable chain originally recommended for that side was deleted. Several additional recommendations were made by Human Factors Engineering as a result of drawing reviews and equipment inspections. Of these, the following remain as suggestions for OB equipment and should be considered in any future devices of this type:

The controls should be packaged in one easily accessible box containing dead-man features to keep personnel from being crushed or the missile equipment from being damaged. The present control stick in a position which interferes with complete use of platform area while the unit is being operated and could be dropped accidentally while being stowed, with injury or damage as a result.

The entire power unit should be part of the static lower section. This would lower the center of gravity and improve stability while personnel are using the platform in high level maintenance tasks.

Fail safe features such as an anti-drop device and some means of manually lowering the platform are needed to improve personnel safety.

## 4.0 REFERENCES

1. AFBM Exhibit 57-8A, Human Engineering Design Standards for Missile System Equipment.

2. ADS-1003C, Design Specification Personnel Safety for WS 107A-2 Launcher System.

3. ADS-5003B, Design Specification Mobile Work Platform for WS 107A-2 Launcher System.

4. ASA-A14.2, Safety Code for Portable Metal Ladders.

5. AHFP-V-5225, Human Factors Test Procedure for Evaluation of Mobile Maintenance Equipment.

6. AMF Drawing No. HF-T-1002 - Mobile Work Platform Modification.

7. AMF Drawing No. HF-T-1004 - Basic Data-Access Areas via Hand Reach, Ladder and Mobile Platform.

8. AMF Drawing No. HF-T-1013 - Layout Showing the Use of Maintenance Dolly and Adjustable Work Platform.

9. AMF Drawing No. HF-T-1103 - Work Platform Mobile Rework.

10. AMF Drawing No. HF-T-1033 - Stabilizer Mobile Work Platform.

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HUMAN FACTORS ENGINEERING REVIEW AND EVALUATION OF TITAN WEAPON SYSTEM 107A-2 LAUNCHER, OSTF & TF-1: FINAL REPORT, by Lewis W. Bennett, Leo Bricker and Rona F. Malhenzie. 1 Jan 62. 3 vol, 516 p. incl. illus. (TS 7.2.36)

Contract AF 04(647)-138 Unclassified report

The purpose of this report is to document the AMF Human Factors Engineering effort covering the overall system review and evaluation of the AMF Launcher System for the 107A-2 Titan Weapon System, OSTF & TF-1. The report has been designed to present summarized human factor data and discussion concerning 30 selected items of launcher equipment. A Summary Checklist of human factors considerations and an illustrated Summary of Inputs was originated and prepared for each item, as well as a tabulated Synopsis which identifies pertinent human factors considerations, type of documentary compliance, human factors (over)

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1. Human engineering--Launcher systems
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3. Human engineering--Guided missiles
4. Human engineering--Maintenance
5. Guided Missiles--Handling & Launching
6. Guided Missiles--Guidance & Control
7. Guided Missiles--Ground Support Operations

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1. an Introduction which discusses background information and the format of the report (Chap. 1-7);
2. a major section which contains 30 evaluations of and sets of human factors recommendations for AMF launcher equipment (Chap. 8-26); and 3. an Appendix which reproduces 3 typical human factors man-machine analyses for the Titan Launcher. It is expected that this report will be helpful to the Air Force and to all missile manufacturers in future weapon system programs, as it pin-points the type and scope of problems met in systems design of missile hardware. The results are: several hundred human factors recommendations were made and adopted; only 273 of these were documented, since many were incorporated directly into the design during the early, informal concept phase. Of the 273 recommendations, 55% were adopted completely, 13% partially, and 32% were not adopted.

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