Integration and Implementation of an Advanced Measurement System into The Assembly Process in Support of “NEAT” Hull Block Construction and Erection

U. S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION, NAVAL SURFACE WARFARE CENTER

in cooperation with

Newport News Shipbuilding

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1993**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Integration and Implementation of an Advanced Measurement System into The Assembly Process in Support of "NEAT" Hull Block Construction and Erection**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230-Design Integration Tools Bldg 192, Room 128 9500 MacArthur Blvd, Bethesda, MD 20817-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**119**	

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THE NATIONAL SHIPBUILDING
RESEARCH PROGRAM

PROJECT REPORT

INTEGRATION AND IMPLEMENTATION OF AN ADVANCED MEASUREMENT SYSTEM INTO THE ASSEMBLY PROCESS IN SUPPORT OF "NEAT" HULL BLOCK CONSTRUCTION AND ERECTION

SUBMITTED TO:

SHIP PRODUTION COMMITIEE
DESIGN/PRODUCTION INTEGRATION PANEL

BY

NATIONAL STEEL AND SHIPBUILDING COMPANY
HARBOR DRIVE AND 28TH STREET
SAN DIEGO, CALIFORNIA

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FOREWORD:

This report is the product of the National Shipbuilding and Research Program (NSRP) Project "Integration and Implementation of an Advanced Measurement System into the Assembly Process in support of Neat HullBlock Construction and Erection" developed and cost shared by National Steel and Shipbuilding Company (NASSCO) under a David Taylor Research Center contract. The program is a cooperative effort of the U. S. Navy and the United States Shipbuilding Industry. Industry direction was provided by the Society of Naval Architects and Marine Engineers (SNAME), Ship Production Committee on Design/ Production Integration Panel (SP-4). The Program Manager is W. G. Becker of Newport News Shipbuilding.

The purpose of this study is to demonstrate practical strategies for integration and implementation of an advanced laser based Optical Coordinate Measuring System (ACMAN) into selected processes supporting "neat" hull block construction and erection.

This study was performed by David L. Malmquist, Production Engineer, Steel Department and assisted by Paul Downs, Supervisor, Accuracy Control, Dan Sfiligoi, Accuracy Control Analyst, Wayne Stevenson, General Foreman Shipwrights, Gerry Flynn, Production Engineer, Frank Sanders, Shipwright, and Ken Smith, Engineering Liaison, all members of the NASSCO AC MAN Implementation team.

ACKNOWLEDGEMENTS:

The author would like to thank the following people for their assistance in the development of this project:

1) Len Schneider, retired Manager of Steel Planning at NASSCO, who had the vision to recognize the potential of the ACMAN System.

2) Jarl Jaatinen of Optec International and Dr. Markku Manninen of Prometrics Oy for their assistance in arranging visits to European Shipyards utiliziig the ACMAN System, for the excellent training sessions, and for their continued support throughout the project.

3) Mr. Timo Kaskinen, Head of Hull Section, Finnyards and Mr. J. S. MacDougall, Director of Engineering, Swan Hunter Shipyard for the Shipyard tours, ACMAN demonstrations, and their gracious hospitality shown to NASSCO's evaluation team.

4) The production supervision, engineers, and loftsmen who supported the ACMAN implementation and contributed to it's success.

1.0 ABSTRACT:

In the NSRP study “Advanced Measurement Techniques for U.S. Shipbuilding”, Report 0300, issued in March of 1990, state of the-art advanced measurement techniques were identified and tested in-yard on various processes supporting “neat” hull block construction and erection. Those techniques which were found to be effective tools for measuring within the shipyard environment were evaluated and their usefulness extrapolated to the remaining processes of fabrication, sub-assembly, assembly and erection.

Although the per measurement cost of each of the advanced measurement techniques were evaluated, the overall potential cost savings attributable to each system in a particular stage of construction could not be estimated due to the limited time frame and scope of the field tests.

Therefore, this study proposes to extensively demonstrate practical strategies for integration and implementation of an advanced laser based Optical Coordinate Measuring System (ACMAN) into selected processes supporting "neat" hull block construction and erection. In addition, the implementation of the integration strategies will be evaluated and analyzed for actual labor costs and cost savings achieved per measured unit. Finally, overall cost savings potential of an advanced measurement system will be estimated.

2.0 BACKGROUND:

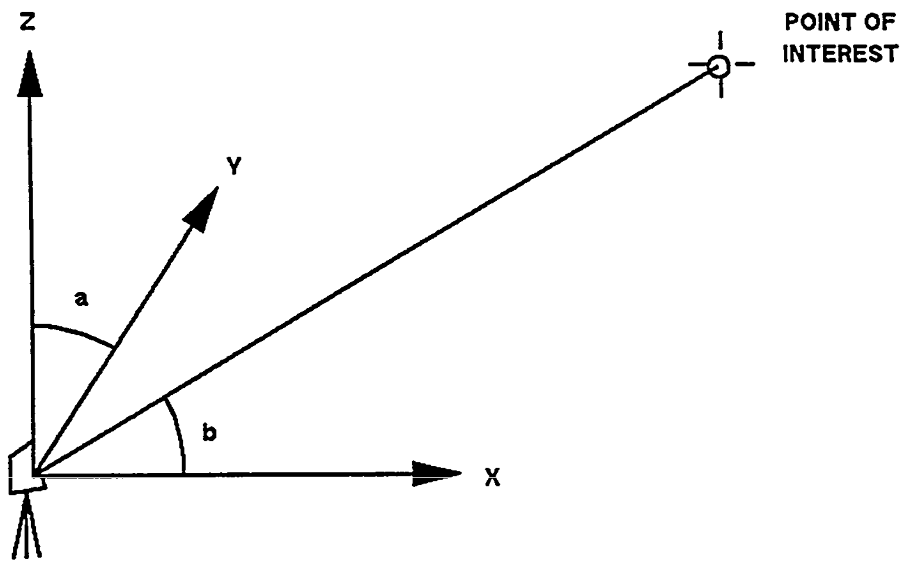
Development of the ACMAN System began in late 1986 in Oulu, Finland by Prometrics Oy. A unique opto electronic scanning laser distance meter was constructed to measure large three-dimensional structures. Developed in conjunction with major Finnish Shipyards, the system was designed as a complete, integrated measurement and control system covering the requirements of hull block construction from manufacturing of the parts through erection of the blocks.

The system was first introduced in 1988 at the Rauma Shipyard (now called Finnyards) in Finland, and has been in continuous operation there. In addition, the Turku New Shipyard (formerly Wartsila) has cooperated for several years with Prometrics Oy in the development of a block measurement and control system and a CAD based shape measurement and control system. Swan Hunter Shipyard, Newcastle Upon Tyne, United Kingdom, recently completed a one year evaluation of the ACMAN System. Following evaluation, they plan to have integrated the ACMAN System into a total process control system.

The ACMAN System was introduced in the United States through the NSRP study "Advanced Measurement Techniques for U.S. Shipbuilding", Report 0300, March 1990.

3.0 TECHNOLOGY DESCRIPTION:

The Optical/Laser based coordinate measuring device is a hybrid combination Theodolite/Laser that uses the common navigational principle of bearing and range in a predetermined 3 dimensional coordinate system to locate points in space. The angles (bearings), between the line of sight fRom the measuring device to the target and the X and Y axes of the coordinate system, are determined by the optics (much like a theodolite). The distances (range) to the targets, along the line of sight, are measured by a laser. A pulsating laser emits short bursts of laser light at the point of interest and a small fraction of the light is reflected back to a sensor. The distance is then computed from the time interval between the transmitted and the received pulses. Developed by Prometrics Oy of Oulu, Finland, this pulsating laser technique is called the 'time-of-flight" principle and represents an improvement in accuracy over conventional laser based distance meters.

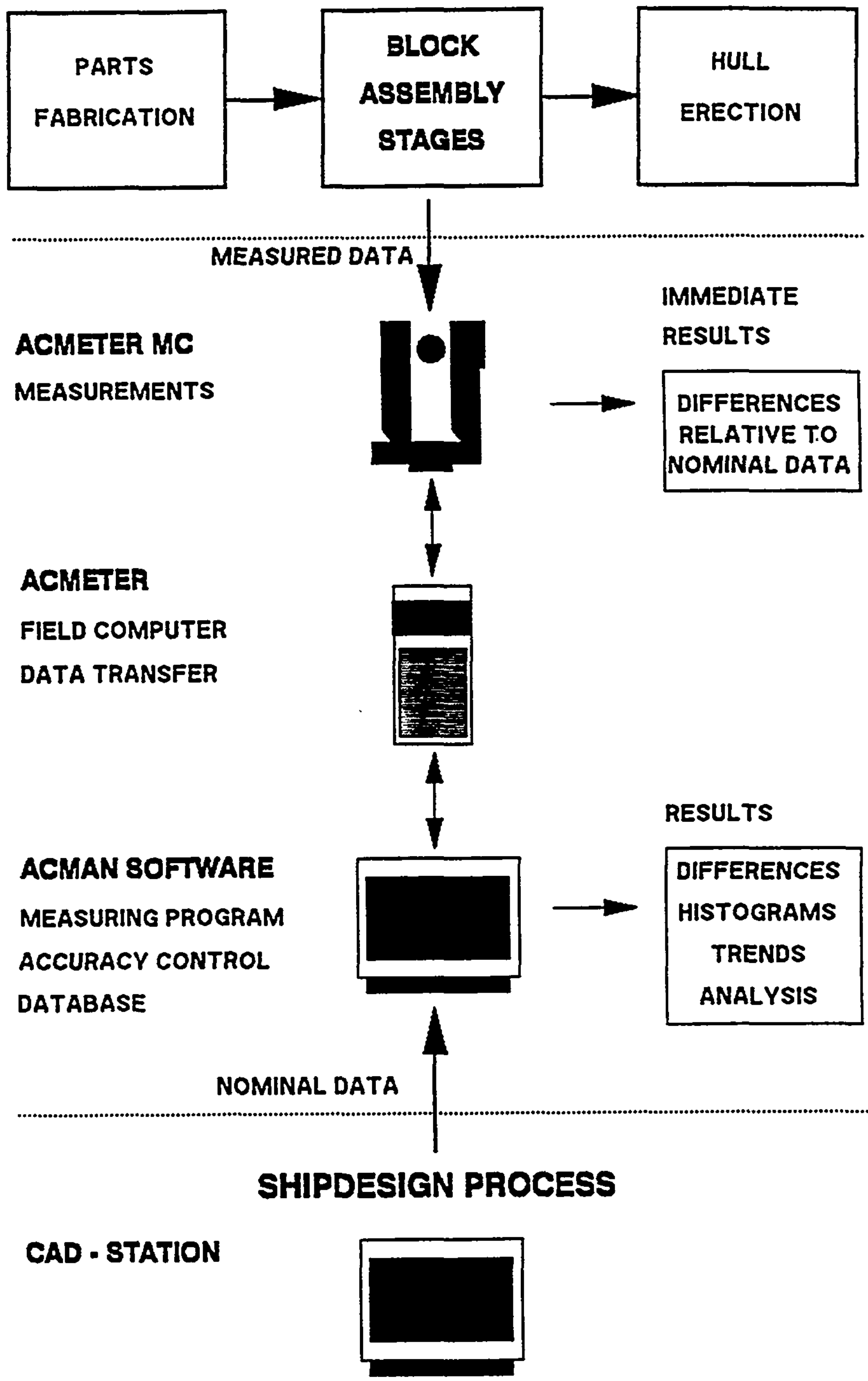


ACMAN
MEASUREMENT GEOMETRY

- Figure 3-1 -

4.0 THE ACMAN SYSTEM:

The ACMAN System consists of the ACMETER Measuring Device, a set of easily attachable hardware options, and PC-based manufacturing accuracy software programs. The combination of the ACMETER coordinate meter with ACMAN software allows computer supported planning and execution of all accuracy control phases. This comprises of direct coordinate measurements, storage of design and measurement data, processing of the results, and automatic calculation of accuracy statistics.


PARTS
FABRICATION
BLOCK
ASSEMBLY
STAGES
HULL
ERECTION
MEASURED DATA
ACMETER MC
MEASUREMENTS
IMMEDIATE
RESULTS
DIFFERENCES
RELATIVE TO
NOMINAL DATA
ACMETER
FIELD COMPUTER
DATA TRANSFER
RESULTS
ACMAN SOFTWARE
MEASURING PROGRAM
ACCURACY CONTROL
DATABASE
DIFFERENCES
HISTOGRAMS
TRENDS
ANALYSIS
NOMINAL DATA
SHIPDESIGN PROCESS
CAD - STATION

<u>**- FIGURE 4-1 -**</u>

SYSTEM COMPONENTS DESCRIPTION:

The ACMETER is a compact coordinate meter with the following features:

•Laser based microprocessor controlled coordinate meter
•User friendly, menu controlled console
ŽAccuracy within +/- 1 millimeter
•Measurement up to 30 meters direct off the surface
ŽInstant display of measurement results.

Based on distance and angular measurements, the coordinate value of a control point is calculated by the ACMETER and shown on the console display. The distance is measured by a unique time-of-flight principle using a succession of short laser pulses. At the same time the tilt and pan angles of the measuring head are registered on optical incremental sensors. The measurements can (with some restrictions) be taken from the natural surfaces of the object. This requires a sufficient reflection of the transmitted light pulse The reflection from a light colored and diffuse surface is thereby the optimum case. Restricting obstacles for direct measurements are:

•Dark or glossy surfaces
ŽGreat measurement distances
ŽMeasurement angles approaching 90 degrees
•Corner point or edge measurements

For these cases, standard ACMAN marking tapes with reflecting surface and aiming figure are attached to the control points. The aiming figure of the tape defines exactly the location of the point and the tape will adhere to the object surface. For easy location of control points on the object, the corresponding measuring point numbers or codes can be written on the marking tapes.

The obtainable measurement accuracy is:

Direct Measurement	+/- lmm at 30m and at +/- 60 degrees
ACMAN tapes	+/- lmm at 30m and at +/- 60 degrees
ACMAN tapes	+/- 2mm at 50m and at +/- 45 degrees

For measurements of distances above 50m, use of specfic ACMAN high reflecting tapes, or alternatively, reflecting prisms used in geodesic measurements should be considered.

One of the unique features of the ACMETER is to take measurements up to right angles of the object surface. This is facilitated by bending the marking tape along its centerline to allow exact location of the control point.

The ACMETER coordinate meter is used for shop floor coordinate measurements. The portable ACMETER is brought to the measuring site and is ready for measuring in a few minutes. For transportation convenience, the ACMETER is mounted on the ACCART and wheeled to the work site.

The ACMETER measuring head is attached to its tripod by an arresting screw. The hand-held ACMETER operators console is connected to the control unit. The ACMETER control unit is connected to a supply voltage of 220V 50H^{z} (optionally 11OV 60H^{z}). Alternatively the optional ACBAT 8-hour accumulator unit can be used. Observing a warming up time of some 10 minutes ensures a stable functioning of the ACMETER

All basic functions, including alignment to the object coordinate system and taking coordinate, distance or angle measurements, are selected on the ACMETER console. After aiming the objective towards a control point and taking the measurement, the coordinate value of the control point is shown on the console display.

Measurements are taken by aiming the objective towards the point to be measured. The objective can be manually focused by pressing the red ‘Mannual” key on the console and then focusing by the “Up” and “Down” cursor keys.

When the objective is aimed exactly at the point, the blue “Trigger" key is pressed to activate the measurement. The measurement includes an autofocus sequence after which the results i.e. the three coordinate values (x, y, z) are shown on the display. The measurement can be instantly repeated by pressing the “Trigger” key again. The result is stored in the Field Computer.

MEASUREMENT SOFTWARE:

The ACMETER basic software handles normal measurement tasks of the meter, including measurement of coordinates, distances and angles. The measurement data is stored in the ACMETER memory and the results are shown on the console display.

ACMETER measurement values are transferred to a PC-computer for later application oriented processing of the data by ACCALC software modules.

ACCALC - is a combination of basic information processing tasks and application/user oriented software modules. The program is run on an IBM compatible PC-computer with MS-Windows operative system. For most applications the system also uses a printer device:

- IBM PC/AT or compatible computer
- Matrix or laser printer

The external connections of the PC-computer are

ACMETER: Serial port COM1
Mouse: Serial port COM2
Printer: Parallel port LPTl

The ACCALC basic program includes display and printing of measurement value lists and coordinate transformations.

Examples of ACCALC application oriented software modules are:

- •Printouts of measurement lists.
- ŽFlatness checks of surface structures
- ŽCoordinate transformations
- •Matching of structures to be joined.
- ŽHistograms
- •Graphical Results

To handle the transfer of measuring data between the ACMETER and external devices, a communication feature is included in the ACMETER. This way ACMETER data can be processed on PC-computer by ACCALC software.

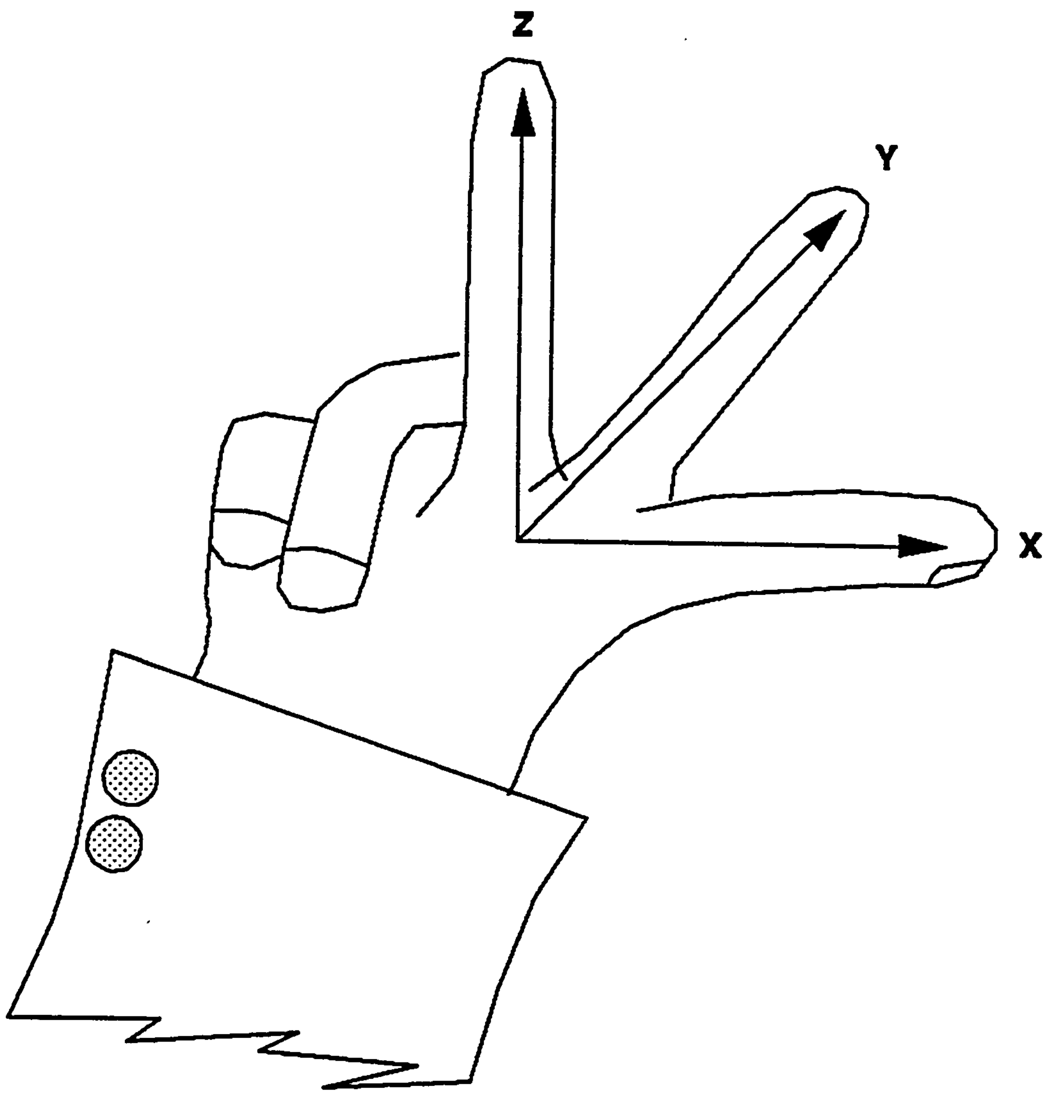
ACBASE - The ACBASE program encompasses the main software functions of an integrated ACMAN accuracy control system. It is used as a means to gain understanding of the accuracy factors influencing the manufacturing process and to build a database of accuracy information. This enables a statistical analysis of the manufacturing process and is the starting point for the development of this process.

The dimensional values are presented as measurement sheets on the computer screen. The program calculates the difference of the nominal and actual measurement values for each control point. It also calculates statistical variables defining the manufacturing accuracy of the measured object.

The nominal coordinate values for each control point can be typed into the measurement sheet by the PC-keyboard. A more convenient way is to import that information from a CAD system as a text file on a 3.5” diskette

5.0 COORDINATE MEASURING:

A right handed coordinate system, illustrated below, is used for all mathematical calculations and when defining object points. The picture shows the direction of the positive coordinate axes when a human's right hand is used.

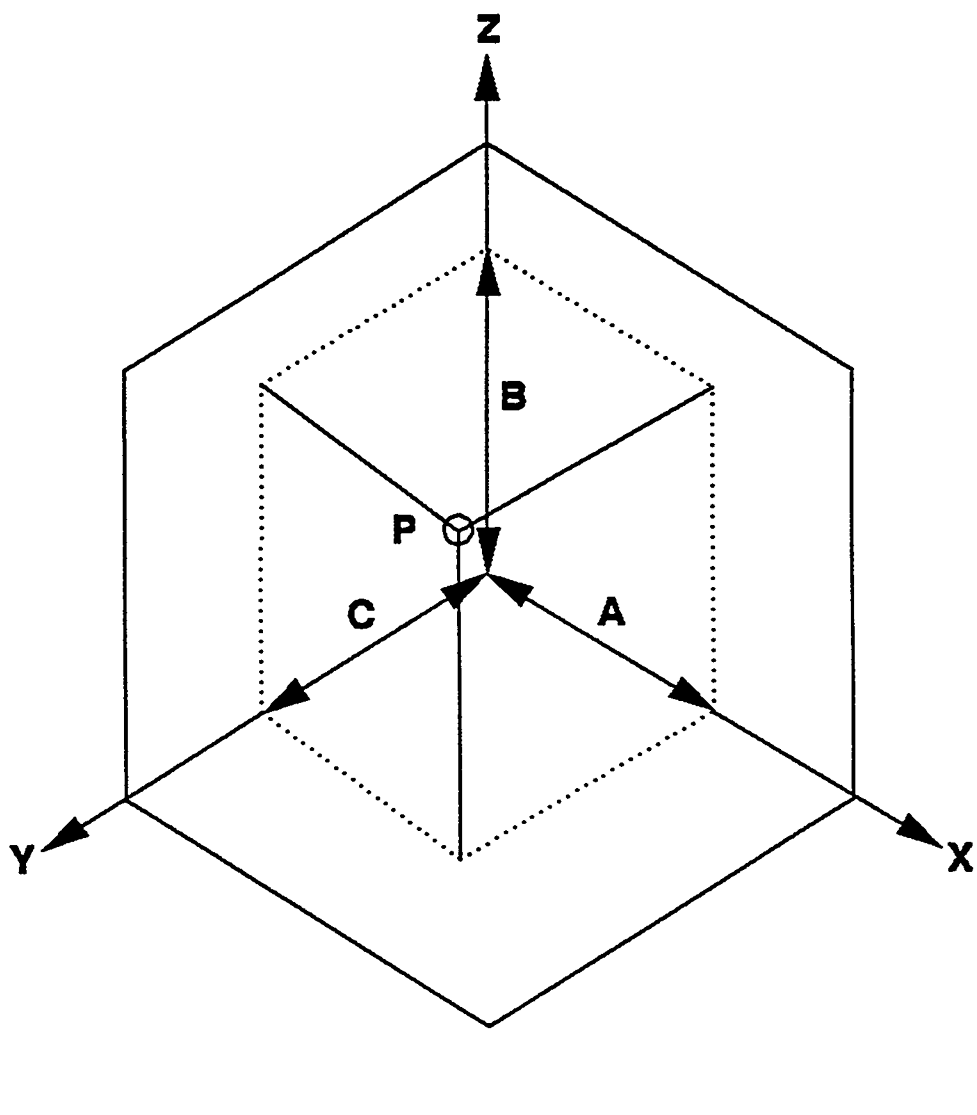


HUMAN RIGHT HAND

- FIGURE 5-1 -

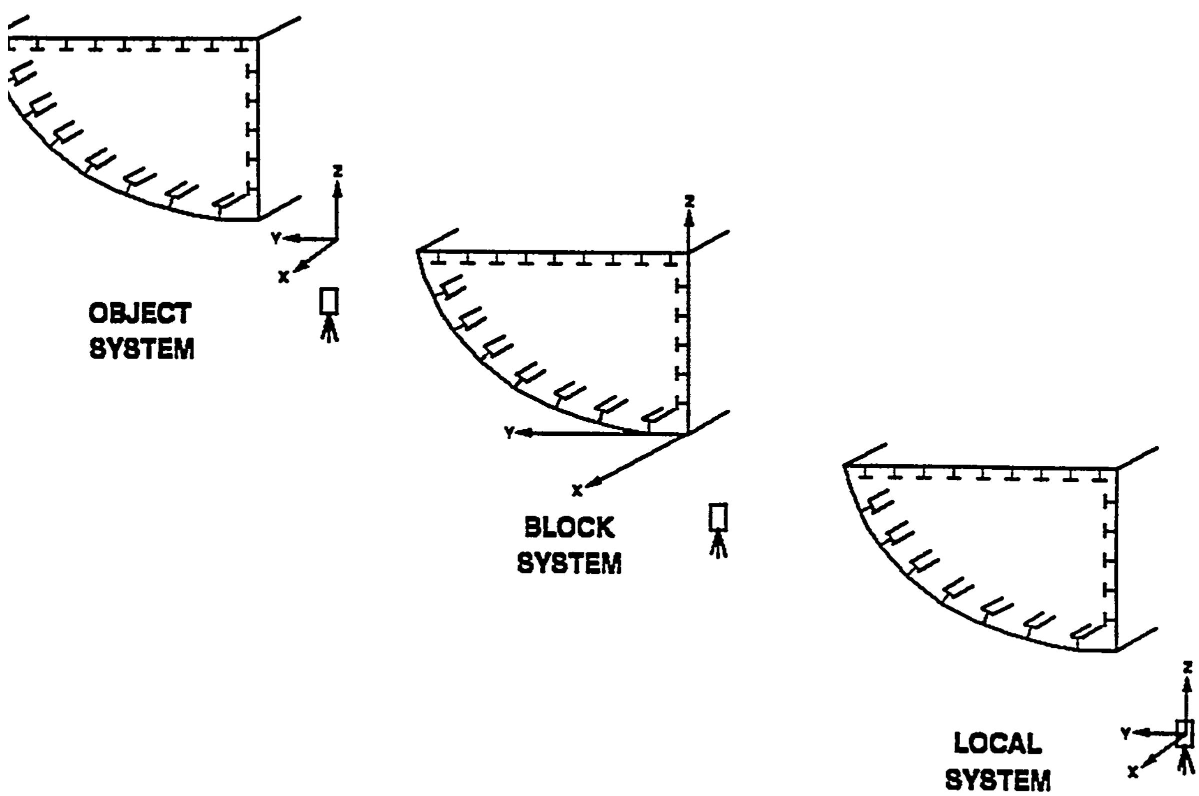
CARTESIAN COORDINATE SYSTEM

The spatial position of points, planes, and three-dimensional objects are defined relative to three mutually perpendicular planes of reference. These planes meet at a point, termed the origin, and produce three mutually perpendicular lines of intersection (“x”, “y”, “z”), to which all coordinate dimensions are referred. The spatial location of an object point (“P”) is specified relative to the origin in terms of three ordered numbers (A, B, C) measured along, and projected from, the mutually perpendicular axes.



- FIGURE 5-2 -

As with Theodolites, the ACMAN system is capable of measuring points of interest in either local or object coordinate systems. The ACMETER may also utilize a block coordinate system. A local coordinate system produces x, y, and z coordinates relative to the ACMETER. The block coordinate system produces coordinates relative to the coordinate system of the block with the origin at any pre-specified location. The object coordinate system produces measurements relative to the ship's coordinate system and requires one point from that system to transform the coordinates.



OBJECT COORDINATE SYSTEM
VS
BLOCK COORDINATE SYSTEM
VS
LOCAL COORDINATE SYSTEM

- FIGURE 5-3 -

6.0 ACMAN SYSTEM EVALUATION:

In conjunction with this study, and prior to the purchase of the ACMAN System by NASSCO, a visit to European Shipyards currently using the ACMAN System was undertaken. The purpose of visiting these shipyards was to assess the integration and implementation of the ACMAN System into the shipyards hull block construction processes. This trip was necessary for the following reasons:

1) At the beginning of this study, the only shipyards using the ACMAN System were located in Europe.

2) During the initial testing at NASSCO for the NSRP study "Advanced Measurement Techniques for U.S. Shipbuilding", the ACMAN Systems accuracy and per measurement and acquisition costs were evaluated. However, due to the limited time time and scope of the field tests, the entire system could not be evaluated.

3) The ACMAN system purchase price (approximately $180,000), represents a large capital cost for a shipyard. NASSCO Senior Management required that a thorough evaluation of the ACMAN System be performed prior to system purchase.

An evaluation team was formed consisting of the Manager of Steel Planning, the Supervisor of Accuracy, and the author of this report. The following report details the findings and recommendations of the evaluation team.

FINNYARDS:

The first shipyard visited currently using the ACMAN Measurement system was Finnyards (formerly Rauma Shipyard) in the town of Rauma in Finland. They have been using the equipment for approximately four years. Mr. Timo Kaskinen, Head of Hull Section, stated that after the development and introduction stage they have been very satisfied with the system itself and especially with the measurement accuracy.

Mr. Kaskinen stated that two persons are required in their normal production to operate the system. In addition, about one hour's work per section is required in the design office for defining points to be measured, extracting the nominal coordinate values of the points, making a measurement sketch of the block showing the locations of the measurement points, and transferring the nominal and design data to the measurement and control system. Finnyards normal production consists of about 40 measured blocks per year with an average block size of 20 to 25 meters by 10 to 15 meters.

The ACMAN operators normally measure the block ends, which takes about one day (8 hour shift). The most time consuming task is targeting the points of interest to be measured. One end of a block would typically have about 25 targeted points of interest, with a total of approximately 50 targeted points of interest for both ends of the block. A practical minimum measuring distance is about 3 meters, and accuracies of +/- 1 millimeter are obtainable in distances up to 30 meters.

Some improvements were noted in the AC MAN Measurement System since the initial system tests for the NSRP Project “Advanced Measurement Techniques for U. S. Shipbuilding” performed at NASSCO in 1990.

The ACCART had been totally redesigned, with large wheels making it easier for one man to transport the equipment to the measurement site. The cart has a compartment for the ACMETER case, the operators console transport fixture, a shelf to mount a new rechargeable battery unit, and straps to attach the tripod and alignment base. The ACBAT (new), is a rechargeable battery unit that provides a power source for the system at the measurement site The battery unit provides power uP to 8 hours. The power source had previously been a problem at the measurement site. A new hand-held storage device had replaced the old lap-top computer for field work. The new field computer shortened the on-site set up time for the measurement task. In addition, some new software programs were also available.

The operators were asked if the equipment had experienced any breakdowns during operation. They stated that no equipment problems had occurred in the four years of operation. The only time the equipment had been out of service was during the recommended yearly maintenance by Optec.

SWAN HUNTER SHIPYARD:

Swan Hunter Shipyard, located in Newcastle Upon me in the United Kingdom, has been using the ACMAN measuring equipment since April of 1991 following preliminary evaluation. They have been assisting Prometrics Oy in evaluating the practical field applications of the ACMAN System, and Prometrics Oy have been responding in a positive way to Swan Hunter's development suggestions. In fact) many of the improvements in the ACMAN System previously noted, were a result of suggestions from the Swan Hunter evaluation team. Implementation of the system at Swan Hunter is not yet complete but is progressing satisfactorily. The period of evaluation will be complete in the Spring of 1992 by which time they plan to have integrated the ACMAN equipment (subject to satisfactory evaluation) into a total process control system aimed at reducing the unnecessary cost elements of the steel manufacturing and assembly operations as part of a total quality initiative.

The NASSCO team was greeted by Mr. J. S. McDougall, Director of Engineering, who presented a short video on the history of shipbuilding at Swan Hunter. Following the video, Mr. MacDougall introduced Mr. R Simpson, Section Leader Mold Loft, and Mr. J. Downey, Loftsman, two members of the Swan Hunter ACMAN measurement team. Discussions focused on Swan Hunter's experience in the implementation of the ACMAN Measurement System.

Six (6) people are involved on a part time basis on the ACMAN implementation program. One (1) person from Production Engineering, two (2) people from the Mold Loft, two (2) from Quality Assurance, and one (1) from the Design Office.

Swan Hunter's findings to date on implementation of the ACMAN Measurement System are as follows:

1) Nominal Coordinates - It can be time consuming collecting the nominal coordinates and inputting the data into the measuring reports. Swan Hunter has made inquiries to their software support people who say a link to their CADAM System is possible to collect the data using point generator software.

2) Power Supply - The current version of the system Swan Hunter is evaluating is operated from a 240 volt power supply. Swan Hunter's policy is to use a 110 volt power supply throughout their Production Areas. This problem was overcome by using a transformer on site to boost the power from 110V to 240v. In January 1992, Optec introduced a rechargeable battery unit (ACBAT), that operates the system independent of a power supply up to 4 hours of operation.

3) Weather - It is not possible to use the ACMAN equipment in bad weather (rain, snow, and strong winds) when the measurement site is outdoors. The sun can also cause problems when measuring in the direction of the sun, the ACMETER is unable to "see" the targets when the sun's ray shine directly into the lens. The equipment's accuracy is limited to a temperature range of 32° F to 95°F.

4) Personal Computer - It proved difficult to view the personal computer display screen in the early stages of implementation. Swan Hunter overcame this problem by changing to a Sharp 5500 personal computer.

<u>NOTE:</u> Optec now offers a portable computer (type Telxon PTC 730), firmwired with ACCOM Software to communicate with the ACMETER measuring instrument and the ACMAN computer.

5) Target Positioning - Difficulty was experienced in attaching targets to the steel when the steel was wet. Swan Hunter overcame this problem by using an additional adhesive substance to hold the targets in position. Close positioning of units/blocks can restrict the measurement task. Staging can also obstruct the line of sight to targets. The targets can be dislodged when the unit/block is under construction and in many cases some type of access is required for positioning of targets.

6) Calibration - It is a policy at Swan Hunter to calibrate all measuring equipment on a six month basis. They are unable at present to calibrate the ACMAN equipment and it is necessary to have the calibration carried out by Prometrics Oy in Finland. Calibrated equipment is also a requirement of AQAP 1-3, a contractual requirement for United Kingdom Defense Projects. This problem is currently under discussion with Prometrics Oy.

NOTE: Optec offers a number of maintenance and service options upon request.

7) Measurement Time - Total estimated time from gathering the nominal coordinate values from the CADAM System to placing the targets and performing the measurements, takes the Swan Hunter team approximately six (6) hours. They expect to reduce this time to around two (2) hours when they introduce the software Iii to extract the nominal coordinates from the CAD System.

RECOMMENDATIONS:

The NASSCO ACMAN evaluation team recommends purchase of the ACMAN Integrated Accuracy Control System based on findings from the evaluation team investigating the integration and implementation of the ACMAN measurement system in European shipyards. Listed below are some of the reasons for recommending purchase of the ACMAN system:

1) The ACMAN System has been developed in conjunction with shipyards, under actual shipyard conditions, to measure and support the construction and process improvement of hull block assembly and erection.

2) The system is designed to interface the shipyards design database and CAD systems with the control system for instant on-line coordinate measurement.

3) A distinct added bonus is the ACMAN systems capabilities for data manipulation and statistical process control.

4) The ACMAN System is accurate to shipbuilding tolerances (+/-lmm in 100').

3 The measurement equipment is applicable to many processes.

6) The equipment is rugged and reliable.

7) A high skill level is not required for the measurement task, the equipment was found to be very user friendly.

8) The measurement task requires only one person and the equipment is easily transported on it's own cart.

9) Immediate on-site feedback of measurement results can reduce costly errors and decrease rework.

10) The measuring system is flexible with fewer measurement geometry restrictions than theodolites.

11) Measurement reports and graphics give fast feedback of information and they are easy to understand.

7.0 SYSTEM PURCHASE:

Immediately following the evaluation of the ACMAN System by NASSCO's team, a meeting was set-up with NASSCO Senior Management to review the evaluation team's recommendations, and approve the request for Capital Expenditure. After a lengthy discussion in which the evaluation team answered many questions, the request for Capital Expenditure was signed by NASSCO's President Richard Vortmann.

The next step in the process was placing the Purchase Order for the ACMAN System with Optec International. NASSCO's Purchasing Department began negotiations with Optec International and an order was placed May 27, 1992. The negotiations proved to be difficult and time consuming for a number of reasons. First, the price quotations for the ACMAN System and Training were in Finnish Marks. At the time of negotiations the Finish Mark exchange rate for U. S. Dollars was fluctuating. This problem was overcome by having Optec International provide a firm freed quote in U. S. Dollars. Secondly, all correspondence was either by FAX or a pre-determined time for telephone calls, due to the time difference between San Diego, California and Helsinki, Finland. The last issue was Optec's terms and delivery conditions which were based on the "General Conditions for the Supply of Plant and Machinery for Export" ECE 188, by the United Nations Economic Commission for Europe. NASSCO's buyer was unfamiliar with these conditions and needed to study the conditions prior to acceptance.

Any large purchase order requires negotiation time. The buyer attempts to negotiate a lower price the seller attempts to maintain their quoted price, and usually the purchase price is somewhere in-between. It is important to note that Optec International cooperated quickly and efficiently in the negotiation process.

The ACMAN System offer from Optec Comprised of the following:

- ACMETER MC 100 including the ACLASER
- ACCART and ACBAT units
- ACMAN System Software
- ACMAN Field Computer
- Tripod
- Personal Computer
- Training Session I and II
- Training Session III and IV
- Traveling Expenses

8.0 IMPLEMENTATION TEAM:

Selection of the Implementation Team members is the most important task to be accomplished to assure successful system implementation! They will be responsible for their individual portions of the overall implementation plan, and ultimately, for the success or failure of the shipyard's plan.

Careful thought must be given to the selection of team members. Each member will possess unique skills that will contribute to the success of the implementation plan.

Selection of NASSCO's ACMAN Implementation Team was tasked to two (2) members of the ACMAN System Evaluation Team. Detailed below is a description of the NASSCO ACMAN Implementation Team positions, position responsibilities and individual member skills.

PROJECT LEADER:

Assisted in the selection of Implementation Team Members and the development of NASSCO's integration strategies. Will be responsible for the integration and implementation of the ACMAN System into the hull block construction process. Unique skills include, over 30 years experience in shipbuilding, extensive experience in Shipwrighting and Accuracy Control, is computer literate, and possesses excellent skills in organizing and directing work.

PROJECT COORDINATOIN:

Assisted in the selection of Implementation Team Members and the development of NASSCO's integration strategies. Will be responsible for the development of NASSCO's Integration and Implementation Strategies, coordination of the ACMAN System Training, and will be the point of contact between NASSCO and the Optec International. Unique skills include, over 20 years experience in shipbuilding, extensive experience in Accuracy Control and Steel Planning, computer literate, and has previous knowledge of the ACMAN System through involvement in the NSRP Study "Advanced Measurement Techniques for U.S. Shipbuilding.

PROJECT ENGINEER:

Responsible for development of ACMAN measuring procedures, design of measurement forms, data manipulation using the ACMAN software, assisting in the download of design nominal data, maintenance of the accuracy database, and in-yard system training. The Project Engineer is a young degreed Naval Architect assigned to the Accuracy Control Department. Unique skills include, strong background in the use of personal computers and computer programming, knowledgeable about Accuracy Control and Statistical Analysis, Engineering background, and has worked in production for the past 2 1/2 years.

MEASUREMENT FOREMAN:

Responsible for planning and scheduling the measurement tasks, supervising the measuring operators, and notifying the appropriate Steel Managers when defects are found. Also assists in the in-yard system training. Unique skills include, over 20 years experience in shipbuilding, extensive experience in shipwrighting and block erection, computer literate, and possesses good supervisory skills.

MEASUREMENT OPERATOR:

Responsible for targeting the points of interest, measurement tasks, and care of the equipment. The Measurement Operator is an hourly production worker assigned to the Shipwright Department. Unique skills include, strong background in Lofting and Shipwrighting, computer literate, and over 20 years experience in shipbuilding.

ENGINEERING LIAISON:

Responsible for extracting design nominal values from the SPADES Database for downloading into the ACMAN System. Unique skills include, over 25 years experience in Lofting, Design Engineering, and Maintenance of hull load database

TEAM MEMBER:

Responsible for incorporation of the ACMAN measuring into the Steel Planning process. Unique skills include, strong background in Lofting, Production Engineering, and Steel Planning.

9.0 SYSTEM TRAINING:

System Training was scheduled to coincide with the delivery of the ACMAN System which arrived on-schedule August 28, 1992. The equipment was carefully repacked in the presence of the Optec Representative, examined and found to be in good shape and fully operational.

The training course offered to NASSCO by Optec comprised of the following:

TCI - HOW TO TAKE COORDINATE MEASUREMENTS

Five (5) days training course at the yard including:

- Team establishment
- Basic topics of accuracy control and the ACMAN System.
- Two days introduction course, how to take coordinate measurements.
- Three days experimental guided use of the ACMETER MC coordinate meter and ACMETER Field Computer (ACCOM program).
- Learning by doing period of the yard ACMAN Team.

TC II- HOW TO USE THE MEASURING SOFTWARE

Three (3) days training course at the yard including:

- One (1) day introduction course, how to use the ACCALC program.
- Two (2) days experimental and guided course.
- Learning by doing period of the yard ACMAN Team.

TC III - HOW TO USE THE ACCURACY MANAGEMENT SOFTWARE

Three (3) days training course at the yard including

- •One (1) day introduction course, how to use the ACBASE and ŽACREPORTER programs.
- •Two (2) days experimental and guided use.
- •"Learning by doing" period of the yard ACMAN Team.

TC IV- HOW TO IMPLEMENT THE ACMAN

Three (3) days planning course at the yard including:

- ŽHow to integrate the ACMAN System to customers CAD.
- •How to implement the coordinate measurements on shop floor.

TIME TABLE

The start of the project would be within two (2) months from receiving the order. The duration of the implementation process is six (6) months from the introduction meeting. The duration of the single steps is as follows:

- •1st step: TC I + two (2) weeks use
- •2nd step: TC II + three (3) weeks use
- •3rd step: TC III + three (3) weeks use
- •4th step: **TC IV**

The payment schedule for the consulting cost is:

Consulting and training fees will be charged per 14 days net upon each course. Normal traveling costs, daily allowances for USA and accommodation costs will be added to the consulting fees.

Discussions were held between the Project Coordinator and NASSCO's Purchasing Department concerning the training courses, training time table, and the consulting fees. A decision was made to combine training sessions I and II offered by Optec into NASSCO's Training Session Number I, and Training Session III and IV into Training Session Number II. A three week duration would be provided between the two training sessions for improving the skill in measuring with the ACMETER

Combining the training sessions achieved the following objectives:

1) Reduced the overall training schedule from 12 weeks to 5 weeks.

2) Reduced the consulting fee's by eliminating two (2) trips from Finland to San Diego, California and associated accomodation/per diem costs.

Training Session Number I, commenced on schedule August 31,1992. The training instructors were Jarl Jaatinen, Managing Director of Optec International, and Dr. Markku Manninen, Managing Director of Prometrics Oy. This training session focused on coordinate measuring and how to take measurements with the ACMAN System. The training classes ran from 8:00 a.m. to 3:30 p.m. on August 31, Septemer 1,2,3, and 4, 1992. In general, the training class was excellent! At the conclusion of the training class, all members of the NASSCO ACMAN Implementation Team understood how to take measurements with the ACMAN System, and three (3) memebers of the team were very proficient in measuring with the ACMAN System.

Following Training Session Number I, a period of three (3) weeks hands-on use was scheduled prior to the start of Training Session Number 2. This time was used to improve the skill in measuring and analyze the system for any problems.

Training Session Number 2 commenced on September 28, 1992 and ran from 8:00 a.m. to 3:30 p.m. through October 2, 1992. This training session focused on using the ACCALC.BL and ACBASE.BL software and reviewing the measured block data. The instructor for Training Session Number 2 was Jarl Jaatinen of Optec. Again, the training session was good, and the implementation team understood how the ACCALC.BL and ACBASE.BL software works.

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10.0 NASSCO ACMAN IMPLEMENTATION GOALS:

SHORT TERM GOALS:

I. Establishment and Maintenance of Master Reference Lines

IL Development of the ACMAN Measurement Procedures.

III. Integration of ACMAN Measuring into the Production Cycle.

IV. "Neat” cut of Hull Blocks to the Erection Area.

V. Distribution and Acceptance of ACMAN results.

VI. Train Additional People in the use of the ACMAN System

VII. Reduce ACMAN System Checking Time

VIII. Research and Development of ACMAN System uses for outfitting, ship checks, conversion and repair.

LONG TERM GOALS:

I. Collection, organization and analysis of dimensional data in development of NASSCO’s Accuracy Control Database.

IL Elimination of excess material.

III. Improvement of the ACMAN System.

10.0 NASSCO ACMAN IMPLEMENTATION GOALS:

Integration and Implementation of the ACMAN Measuring and Accuracy Control System into NASSCO's steel production cycle has been designed as a number of short term and long term goals by the ACMAN Implementation Team. Short term goals are those goals that can be accomplished within the first year of use, and long term goals are the goals that will take from one (1) to five (5) years to accomplish. Listed below are the short and long term goals, a description of each goal, an explanation of how each goal will be measured, and a time frame for completion of the goal.

SHORT TERM GOALS:

I Establishment and Maintenance of Master Reference Lines.

Key datum lines have been established for each hull block in the form of centerline, buttock lines, frame lines, and water lines. Establishment (marking) and maintenance of these Master Reference Lines are critical tasks relating to coordinate based measurement systems. Not only must the marking be accurate, but care must be taken to ensure the sub-blocks and hull blocks are assembled and erected utilizing the Master Reference Lines. Accurate and clearly marked reference lines will improve both block construction and the ACMAN measurement process. Accomplishment of this goal will be measured by the following criteria:

1) Development of procedures for establishing and maintaining Master Reference Lines.

2) Acceptance and adherence of these procedures by production workforce.

The time frame for completion of this goal is April 2, 1993 (6 months).

Evaluation of Goal:

Most shipyards utilize key datum lines in the form of centerline, buttock lines, frame lines, and water lines for erecting hull blocks. These lines establish a relationship between the ship coordinate system and the hull block. In order for these lines to be meaningful, the same lines must be used from the fabrication of parts to the assembly and erection of the block Use of these lines as key building reference points will improve the accuracy of the interim processes and will facilitate the coordinate measuring with the ACMAN System.

Common problem encountered in the past include:

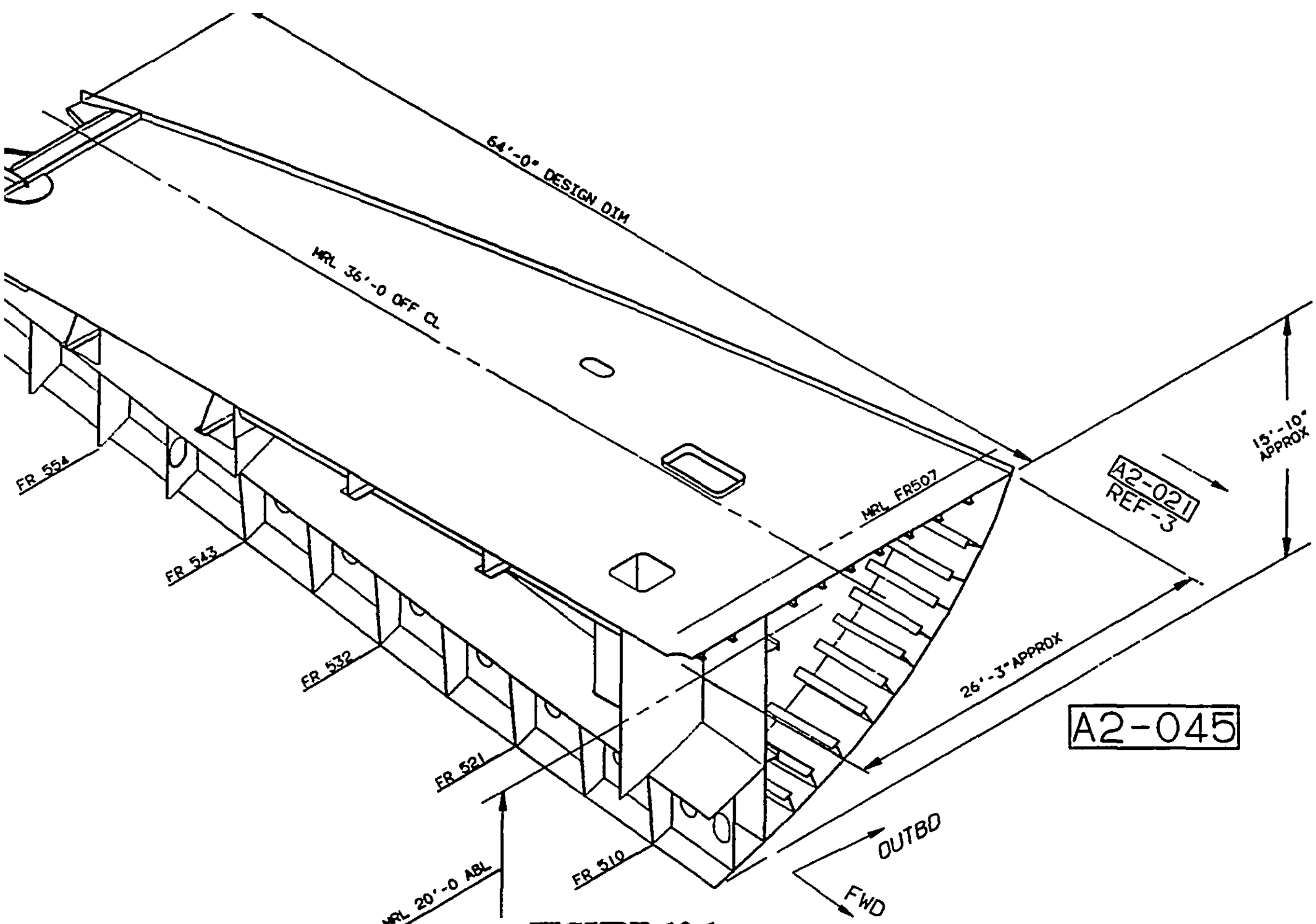
- Inaccurate marking of reference lines by both the N/C marking on the burning machines and manual layout. Because common reference lines were not used between fabrication and assembly, many of these errors went undetected, causing considerable rework at the block assembly and erection stages. In addition, the necessary feedback to correct the base cause of the error did not occur, creating more rework

- Block assembly errors from layout, burning, fitting and welding were not discovered because the reference lines used to assemble the blocks were in some cases different from the reference lines used to erect the blocks. This problem is compounded when the assembly reference lines are lost in the blasting and painting process after block assembly. When this occurs new Lines are established for block alignment to erect the block from erection vital points and the existing block configuration. Past experience has shown that rework as a result of mis-alignment of structure increases dramatically in these cases.

- Improper blocking and shoring of hull blocks during the on-block outfitting stage of construction. This causes out-of-level conditions to be permanently locked into the block during installation of piping and other outfitting items. The end result is rework to either cut the oufitting loose or modify the block.

- The errors resulting from a poor scribe or burn of the excess material, errors in setting previous blocks, and undetected rack or twist in the erected blocks.

In order to overcome these problems, improve accuracy and reduce rework, and facilitate measuring with the ACMAN System, procedures were established and implemented for marking and maintaining Master Reference Lines. An example of NASSCO's Master Reference Lines is shown in Figure 10-1.



- FIGURE 10-1 -

II. Development of the ACMAN Measurement Procedures.

In order to realize the full benefits of the ACMAN System it will be necessary to develop measuring procedures to ensure that measurements are taken in a consistent and cost effective manner. These measurement procedures will address the following:

1) Development of vital points by block type.

2) Efficient downloading of design nominal values.

3) Procedures for establishing reference planes.

4) Development of Sub-Assembly, Assembly, On-Block, and Erection Measuring Procedures.

Accomplishment of this goal will be measured by the completion of a NASSCO manual title “ACMAN Measurement Procedures”.

The time frame for completion of this goal April 2, 1993 (6 months).

Evaluation of Goal:

Incorporation of any new equipment into the hull block construction process should be accompanied by the development of procedures for the use of that equipment. This will ensure that the equipment is used properly, in a consistent and cost effective manner. In addition, when it comes time to train new people in the use of the equipment, established work methods and operating instructions will decrease the training time required.

The ACMAN Implementation Team initially decided to develop procedures for the following:

ŽDevelopment of vital points.
•Downloading of design nominal values.
ŽEstablishing reference planes.
•Measuring procedures.

These procedures would be developed by members of the Implementation Team and compiled in a manual titled “NASSCO ACMAN Procedures Manual”. As development of the procedures progressd, it became apparent that additional procedures would be required in the future, as application of the ACMAN Measurement System is expanded. Examples of ACMAN Measurement Procedures are provided in Appendix "A” of this report.

III. Integration of ACMAN Measuring into the Production Cycle.

Effective use of the ACMAN System will require some changes to current methods of planning and executing work at the Sub-Assembly, Assembly, On-B1ock, and Erection work sites. In addition, production supervision needs to understand the planned use of the ACMAN System to support the implementation plan.

Accomplishment of this goal will be measured by the following criteria:

1) Completion of a series of ACMAN Implementation Plan meetings with production supervision in the Sub-Assembly, Assembly, On-Block, and Erection Areas.

2) Effective integration of ACMAN Measuring Tasks into the steel production cycle.

The time frame for completion of this goal is January 1, 1993 (3 months).

Evaluation of Goal:

Careful thought must be given to this item by the Implementation Team. The following issues should be considered:

1) Downloading of design nominal values - The ideal situation would be to implement the ACMAN System in support of a new shipbuilding contract. Then as the new ships coordinate values were loaded into the hull's database a system could be established to flag vital coordinate values for later extraction into the ACMAN System.

   This was not possible for the NASSCO ACMAN Implementation Team since the hull database had been established for several years and NASSCO was currently building the third ship in a series of AOE-6 Class Fast Combat Support Ships. The design nominal values had to be extracted manually from the ship file and downloaded into the field computer. Fortunately, the cost for manual extraction of design nominal values can be spread over two ships, because NASSCO has recently been awarded the fourth ship in this class, the AOE-1O.

2) Establishing a time frame for measuring blocks - Effective use of the ACMAN System will require some changes to the planning and executing of work at the Assembly, On-Block Outfitting, and Erection work sites. A time frame or "window" needs to be established for measurements with the ACMAN System. This issue proved to be relatively simple to incorporate in the Assembly area. In most cases, the measurement task was accomplished while the work was in progress, requiring no additional duration. In a few cases, where the measurement task required removal of staging for targeting or measuring, a window of time was allocated (usually 2 to 4 hours) by the Assembly Supervision. In these cases, the manpower was temporarily transferred to another block to accommodate the measuring task.

Establishing the window of time for measuring at the On-Block Outfitting Stage of Construction was accomplished by utilizing a one-week period of time designated as “float” between On-Block Outfitting and Block Erection.

The erection time frame for measuring was established using some of the “float” between On-Block Outfitting and Erection and absorbing the rest of the time out of the erection duration. The first problem to overcome was the volume of measurements that needed to be taken to determine the accuracy of the erected hull. In an ideal scenario, measurements are taken of the erected hull form as the blocks complete, establishing the hull envelope for the incoming hull blocks. The erection measurements can then be compared to the measurements of the block on the ground to determine if any adjustments are necessary or to scribe and cut excess material prior to erection. This issue was resolved by accelerating measurements aboard the ship to determine the erected hull form.

3) Support of the production supervision in the planned use of the ACMAN System - The production supervision needs to understand how the ACMAN System works, what the goals are for implementation, and how their support will help achieve these goals. The ACMAN Implementation Team held a series of meetings and demonstrations with key production supervision to show the power of the measurement system, it’s intended use, and solicit their support in achieving the implementation goals. The success of the implementation plan has been a result of the cooperation and support of the production supervisors and management of the Assembly, On-Block Outfitting and Erection Areas.

IV. "NEAT" cut of Hull Blocks to the Erection Area.

NASSCO's Steel Department has been erecting selected hull blocks "neat", that is without the traditional excess material, since the Exxon Tankers were built in the mid 1980's. Some of these "neat" hull blocks have required substantial rework at the erection site due to errors during block assembly. Many of these errors are difficult to detect in complicated three dimensional blocks with standard block assembly checking methods.

The ACMAN System can easily detect these types of errors in a fraction of the standard block assembly checking time. Errors such as mis-alignment of structure, twist, and deviations from the ships absolute coordinate system are quickly discovered. Utilizing the AC MAN System, it is now possible to neat cut many of the blocks that previously would not have been considered as candidates for neat cutting, particularly curved shell blocks with compound curvature.

Accomplishment of this goal will be measured by the following criteria:

1) Gaining Confidence - Measuring the erected blocks, measuring the adjoining block on the ground, scribing the adjoining block prior to erection, and then erecting the adjoining block and verifying the scribe.

2) Cutting prior to Erection - Measuring the erected block, measuring the adjoining block on the ground, scribing/burning/beveling the adjoining block prior to erecting.

3) Reduction in erection cycle time as a result of erecting neat hull blocks.

4) Reduction in manhours per ton at erection measured by block type categories.

Evaluation of Goal:

This integration strategy has been given the highest priority and is currently proceeding as planned. Detailed below is a report generated by the ACMAN Measurement Team and the Project Engineer describing their efforts to date on this integration strategy.

NEAT CUT REPORT:

The purpose of this report is to give a brief overview of the process involved in using the AC MAN System to neat cut units prior to erection. It will give insight into the problems encountered and accomplishments achieved, and finally, will attempt to describe the direction in which the project is heading.

One of the key goals of the ACMAN System during its implementation over the past six months has been to utilize the equipment to load units at the Erection Stage with no excess material. Removing all excess material on the ground before erection will save manpower and reduce costs aboard the ship. As a general rule of thumb each hour of work on the ground translates to three hours aboard the ship. Using the simplistic formula, it is easy to see how removing excess material prior to erection can truly benefit cost savings.

The ACMAN System accomplishes this goal by discerning the existing condition aboard the ship and then superimposing this condition onto the unit to be erected. The unit is then scribed and cut to match the existing condition aboard the ship. Then when erected, the unit can be placed into its final location on the first try.

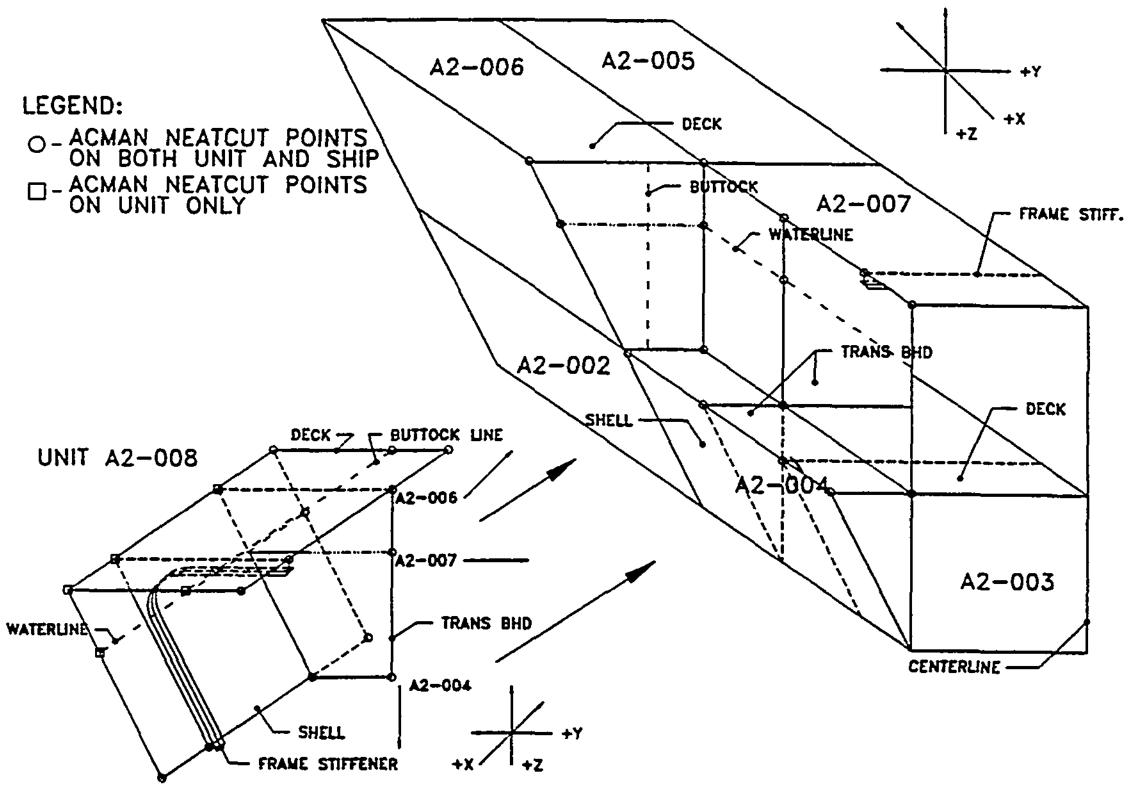
ACMA NEAT CUT PROCEDURE

To date no procedure has been set in concrete as to how the units should be prepared for neat cutting. Each unit tends to have its own individual characteristics and circumstances which dictate the step by step instruction to follow. Along with that, as experience is obtained with the ACMAN System and with this procedure in particular, new and often better methods to approach this procedure are discovered and incorporated into the routine.
As it stands today the procedure is as follows:

1) Once the units have been identified for neat cutting, time must be scheduled for the actual ACMAN checking phases. This often proves to be quite difficult to manage. First of all the area to be checked aboard the ship cannot be checked until all units surrounding this area have been erected and set in their final ship coordinate positions. This can and will prove to be a problem especially when the schedule is tight or accelerated leaving little time between erections to accomplish the required checks. Second, the unit must be scheduled and checked allowing a minimum of two to three days before erection to allow for the burning of the unit This must also be organized around the final outfit, blast and paint schedules.

   The current AOE-8 schedule has allowed sufficient time for accomplishing these tasks. Most of the problems experienced have been with the unit being scheduled for blast or paint during the checking phases.

2) In general, the unit to be erected was checked first. The unit was checked to the nominal design values provided by Engineering. Then the area into which the unit would be erected aboard ship was checked. This area would also be checked to the nominal design values. This permits a verification of the overall ship condition.



- FIGURE 10-2 -

3) Both sets of measured data would then be compared to one another. Through this comparison, an analysis would be performed determining which areas need to be cut and to what extent. During this process it is often necessary to take into account other factors which would govern the ship alignment.

4) Once a scribe is determined, the unit and/or ship is marked and burned. Often a scribe is required on both areas, the unit and the ship, since excess to come down is usually located on the ship. (Cutting excess on the ship prior to erection still saves time, in that the unit when erected does not need to be reset. It should only take the crane one lift to erect and set the unit in it final position.)

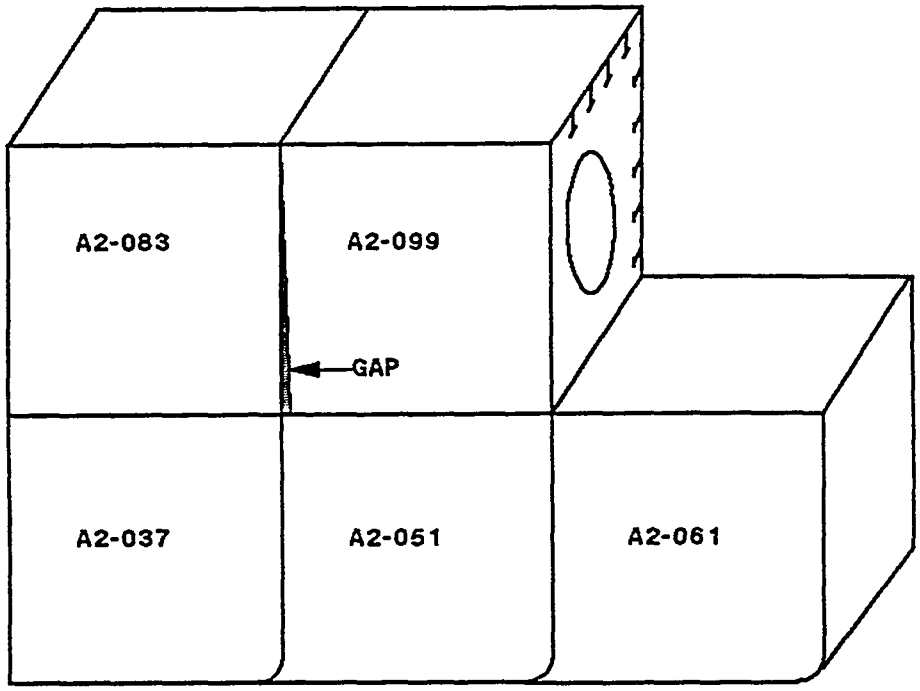
The following is a list of all the units which were scheduled for neat cutting by the ACMAN System and brief description of the results obtained.

A2-163

This unit was the first unit scheduled for neat cutting. It was done as a trial run. Both areas were checked and compared and a scribe determined. No actual burning was done prior to erection. However, the results of the ACMAN scribe matched the conditions of the final set within allowable tolerances.

A2-099 and A2-100

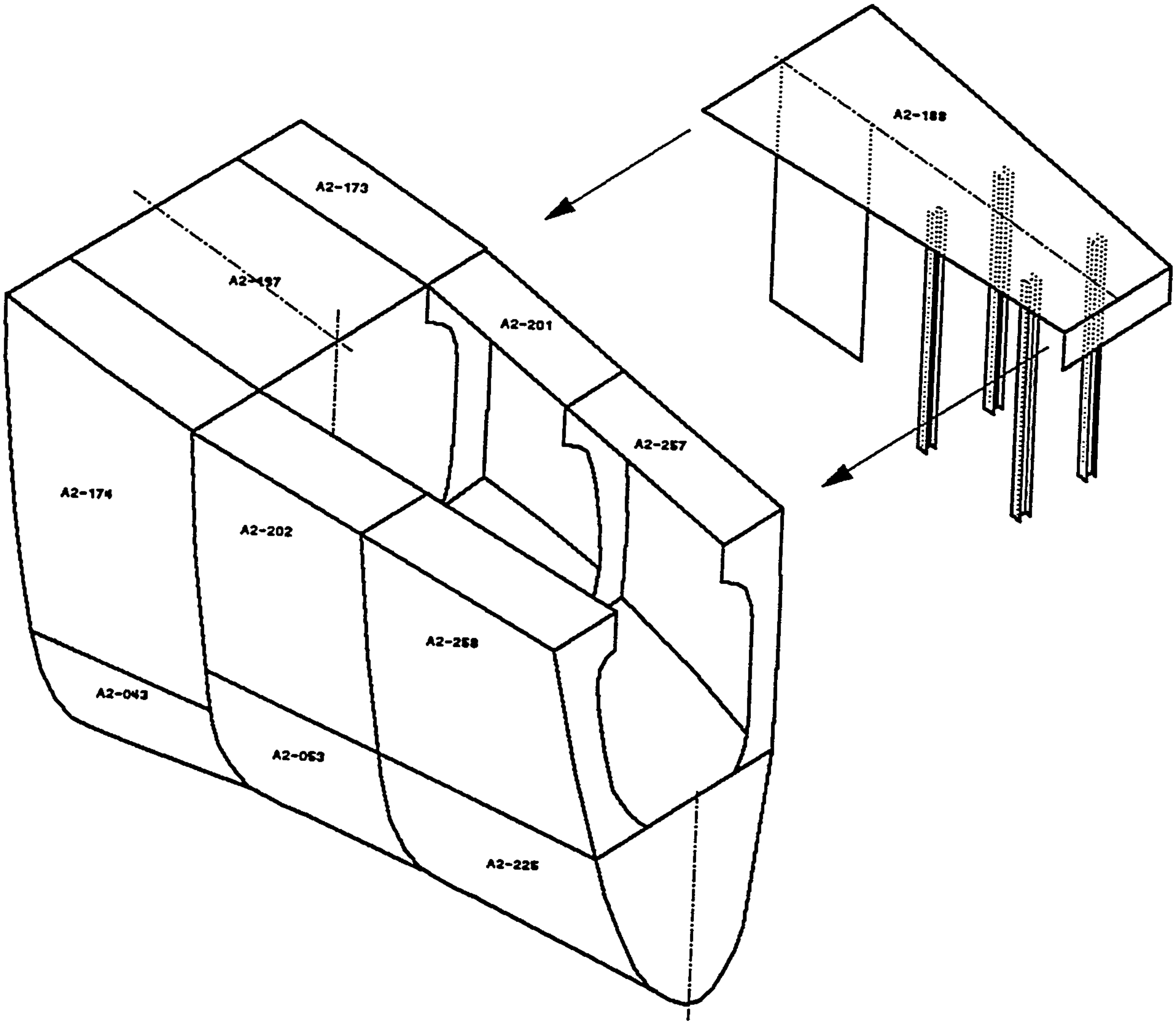
A2-099 and A2-1OO were both scheduled for ACMAN neat cut. However, due to a schedule change only A2-099 was completed. The final set for A2-099 showed a large gap in the shell on the side where the unit was checked with the ACMAN. The problem with this unit dealt with the condition of the unit on the ground. Sometimes a small twist of the units on the ground is indiscernible Apparently A2-099 was twisted and the scribe was determined not accounting for this twist. What this caused was a wedge shaped scribe to be cut on the unit. Then when the unit was erected, the twist came out of the unit. The scribe which was plumb on the ground now caused a reverse wedge shaped gap aboard the ship. This forced an additional scribe aboard ship to remove this wedge which then caused a large gap in the shell. This problem may have been avoided had the overall position of the unit been taken into account by the ACMAN checks (especially in relation to half-breadths). Had the upper open most corners been checked, instead of just the mating surfaces, large deviations on the overall position of the mating unit may have been pointed out and brought to the attention of the team in order to compensate. The overall position of the unit, and especially the position of the open end, was given priority on future units.



- FIGURE 10-3 -

A2-188

A2-188 was a complicated unit which mated into nine other units aboard ship. This meant the potential for nine different problem areas. Since the unit was wedge shaped it was important that all areas fit into their proper location with no overlap. Any excess on the aft end would push the wide aft end forward and cause an interference as the unit was erected. The scribe was cut and the unit fit into it's fired location with no trouble.



- FIGURE 10-4 -

A2-243 and A2-244

Both these units were checked on the ground and almost no excess was found on these units to scribe, therefore, nothing was done to them prior to erection.

A2-119 and A2-120

These units mate onto units A2-099 and A2-1OO respectively. Both of these units were checked and scribed. No scribe was determined for A2-119 since it mated to A2-099 and this unit was already short (see description above). On AZ-120, the scribe was determined and cut, however, the bevel was put on backwards which caused a small gap on the shell. Overall though, the ACMAN portion of the procedure proved to be accurate. A new problem discovered with these units was the determination of the six point coordinate system. It was decided in order to avoid any possible problems that the same six points used to orientate the unit on the ground would be used to orientate the unit aboard the ship. The most important of all of the six points, would be to ensure that the same origin was used on both checks.

A2-169 and A2-170

These two units were scheduled but due to inclement weather a reasonable window of opportunity could not be found prior to erection and therefore the neat cut for these units was never completed.

Al-554

When this grandblock was checked, very little scribe was found to cut. So little it was deemed unnecessary to cut prior to erection.

Each experience points out a new issue in which close attention must be paid when following this procedure. For all future attempts to neat cut units prior to erection the following guidelines will be adhered to closely.

1) Pre-planning of all ACMAN neat cuts is essential. Time must be allotted in the schedule for the ACMAN checks. The unit must be prepared for the check and the area aboard the ship must be in its final orientation before the ACMAN checks can begin.

2) The schedule must be maintained. Changing the schedule or missing a date by anyone can cause an entire day's worth of work to be lost.

3) It would be beneficial to check the area aboard the ship first. However, accounting for a much more accelerated schedule on future ships, this would be unreasonable It would be best to check the unit on the ground as early as possible, then when the area aboard ship is ready, check that.

4) The points chosen to define the neat cut must contain enough information so that the final position of the entire unit can be determined after the scribe. The points will tend to differ from the typical ACMAN points. In particular, it is best to check as many hard points as possible (Note: This must also not be too excessive). Every area that requires a scribe must be accounted for by a sufficient number of points to insure that interferences are avoided and that enough information has been provided to instill confidence in the procedure.

5) The same six points coordinate system must be used on both checks. This requires that the persons determining the coordinate system take into account all areas of interferences on both the ship and on the unit. It also means taking into account transfer points and any of the other various intricacies involved with using the ACMAN System.

6) In order to insure that the units do not have a twist, the units should be leveled prior to checking with the ACMAN. The units generally should be level in order to allow for outfitting work, however, transporting the units and outfit welding sometimes causes the unit to shift and twist. Therefore, re-leveling, and verifying that the unit is level, prior to checking should eliminate some problems.

7) Both sets of checks should be done at nearly the same time of day and temperature. This should reduce the variations associated with changes in steel due to the temperature

8) No points should be transferred during the actual check to facilitate the line of sight. While this method of transferring points while checking a unit for overall dimensions may be ok, for the purposes of neat cut this can introduce errors which could result in shortages of material.

9) AU points checked should include any excess material still located in that area. This will not match the nominal values since the nominal values are molded offsets to the neat edge.

10) Once the checks are completed, each individual check should be compared to the nominal hull values. A check against the nominal values should point out blatant errors in the checking procedure or problems such as twist or rotated coordinates systems. These problems can then be fixed prior to mating the surfaces.

11) Once both checks are determined to be accurate then the surfaces can be mated using the program provided by the ACCALC Software. This program will give the deviations for each individual mating point. These deviations can then be translated into either gaps or excess material.

12) The data provided from the mated surfaces will generally be the scribe of the excess material. However, the existing condition of the ship must be taken into account prior to determining the final scribe. If the unit below the unit to be erected is 1/2" too far inboard it is not necessarily the best decision to cut the unit to match. Ideally the unit should be cut to remove some of this deviation. Therefore, the scribe may be matched at the bottom but only scribed a 1/4" at the top in order to alleviate this error.

A unit may match the surrounding units, but by doing so, cause an error in overall ship dimensions which is unacceptable. When determining the final scribe of the mating surfaces, the ships design nominal values and the existing condition of the ship must be taken into account. Sometimes the best scribe to match the overall ship condition will necessitate throwing off the opposition of other important areas.

All areas of erection must be weighed before determining the scribe.

13) When the unit is erected, the team responsible for the scribe, or at least a team who has been briefed on the ACMAN neat cut should be responsible for setting the unit. This team would be the most knowledgeable about the units current situation and therefore should be able to set the unit in its final position rather quickly.

RECOMMENDATIONS:

1) It would be beneficial to have an area set aside specifically for checking with the AC MAN (sort of a pre-erection/ACMAN). The area could also be used by the burners after the scribe is completed. This area would help to eliminate the following problems.

   a) The unit being level. The unit could be leveled and verified specifically for the ACMAN check whale set in this area.

b) Obstructions - Space between stored units is tight. Sometimes checks in certain areas of the unit are impossible due to an obstructed view by surrounding units. This area would be clear all around to accommodate the ACMAN Measurement Task.

c) No scaffolding - One of the key problems is the ability to get around the unit for checking. Scaffolding could be provided in the area without any fear of obstruction. Perhaps rolling staging which could be utilized by both the ACMAN operator and the burners.

d) Having a pre-determined area would allow the use of a general coordinate system which would not differ from unit to unit. Establishing the six point coordinate system is a time consuming task. Any method to shorten the time span and eliminate doubt would be welcomed.

2) A number of difficulties have surfaced from the irregular edge of the units being checked. This suggestion comes in two parts:

a) All irregular mating edges aboard the ship should be cut into straight lines prior to checking with the ACMAN. The unit edges can then be checked to these straight edges and a much neater scribe determined.

b) However, to accommodate this future, all the excess must be relocated to the unit to be erected NASSCO's current policies put some of the excess on the unit to be erected and some aboard the ship. To make this procedure work it would be necessary to have all the excess on either the unit or the ship.

As you can see from thereport, problems were encountered, lessons were learned, and adjustments to procedures and work methods were required. In addition, recommendations were made to improve the process on future blocks scheduled for “neat” cutting. The important point is that the erection crew has gained confidence in “neat” cutting erection units with the ACMAN System and they plan to continue the process.

V. Discribution and Acceptance of ACMAN Results.

The ACMAN System will generate a large volume of data and statistical analysis of that data. The distribution and acceptance of this data will lead to improvements in design, planning, procedures, processes, and work methods. To fully realize the benefits of the data analysis, the production workforce must agree with the data results, and be confident that changes in procedures, processes, and work methods will result in improved production. Accomplishment of this goal will be measured by the following criteria:

1) Acceptance of ACMAN results by the production workforce.

2) Changes in design, planning, procedures, processes, and work methods as a result of ACMAN Data Analysis.

3) Documentation of production improvement resulting from the above changes.

The time frame for partial accomplishment of this goal is October 1, 1993 (1 year). It should be noted that this will be an on-going goal leading to the accomplishment of many of the long term goals.

Evaluation of Goal:

Acceptance of ACMAN measurement results by the production workforce is relatively easy to accomplish. A simple demonstration of the equipment measuring a block will prove the accuracy of the system. If someone questions the system's accuracy, have them manually measure the points and compare the measurements.

It is recommended that no results of a block measurement in progress be given to anyone until the data has been examined on the ACMAN PC. The reason behind this is that there is a great deal of information taken during a measurement and the full overview of the measurement task is not clearly visible whale on-sits Errors in the coordinate system are usually not discovered until the PC Data is examined.

Changes in design as a result of ACMAN data analysis have not occurred yet, however, the following changes are anticipated:

- Changes to shrinkage allowances - NASSCO currently adds material allowances to plates and shapes for weld shrinkage during block assembly and erection. Preliminary data indicates that in many cases these allowances are too small.

- Changes to Master Reference Lines - As measuring with the ACMAN System has progressed, difficulty in sighting some of the Master Reference lines (MRL's) has occurred. In order to overcome these problems in the future the MRL's must be located clear of structure to facilitate the measurement task A simulation of the block measurement prior to establishing the MRL will eliminate these sighting obstruction problems.

Changes in planning resulting from ACMAN data analysis have already occurred. Time frames for block measuring at the Assembly, On-Block Outfitting, and Erection stages have been established. Further refinement of these time frames is on-going and future new construction contracts will have adequate durations established in the Master Schedule.

The most significant changes have occurred in work procedures, processes, and methods. In the Assembly area, when there is doubt about the blocks accuracy, both pre-weld and post-weld checks are undertaken. Pre-weld checks are done to verify the accuracy of structure prior to welding. Post-weld checks are done when distortion from welding is suspected. Not all of the Assembly Blocks are checked on the platens with the ACMAN System. In process checks by the fitters building the blocks and by the accuracy control checkers identify most errors in construction. Usually, the complicated three-dimensional crowed shell blocks are requested to be checked for accuracy with the ACMAN System. At the On-Block Outfitting and Erection areas, procedures and work methods have changed to support trimming of excess material from the blocks prior to erection.

VI. Train Additional People in the use of the ACMAN System.

The quick pace of the initial training classes allowed three (3) members of the ACMAN Implementation Team to become proficient in measuring with the ACMAN System. In addition, only one member of the team became proficient in the use of the software and data analysis. In house training is currently underway to increase the number of people proficient in measuring and data analysis. Accomplishment of this goal will be measured by the successful training and proficiency of six (6) people in measuring and three (3) people in data analysis.

The time frame for accomplishment of this goal is January 1, 1993 (3 months).

Evaluation of Goal:

Accomplishment of this goal proved to be elusive for a number of reasons. Our intention was to train three (3) more people to become proficient in measuring with the ACMAN, and two (2) more people in the data analysis using the ACMAN software To date, the training in measuring has been accomplished, however, only one additional person has been trained in the data analysis. Dedication of ACMAN System time to accomplish the training was the major reason for falling behind schedule on this goal. The ACMAN System has been in continuous operation since the original training sessions held by Optec International. At this time, the Project Engineer is preparing procedures for training in the use of the ACCALC.BL and ACBASE.BL software programs on the personal computer.

It is important to note that ACMAN System time must be set aside if an accelerated training program is chosen. Training in measuring is not difficult because the ACMAN System is very user friendly. Experience has shown that even people with no previous exposure to computers can quickly learn how to measure with the ACMAN System. Training in the use of the ACCALC.BL and ACBASE.BL accuracy software is a different story. Computer literacy is a must! A knowledge of accuracy control, statistics, and alignment principles is strongly recommended.

VII. Reduce ACMAN System Checking Time.

In learning to use the ACMAN System, the total time required for checking will initially be higher. As proficiency increases and lessons are learned the total time required for checking will decrease Included in the total time for checking are the following tasks:

a) Determination of block vital points.
b) Downloading of design nominal values.
c) Targeting of block vital points.
d) Measuring time, including set-up and breakdown.
e) Extracting data from the field computer and data analysis.

Accomplishment of this goal will be measured by the following criteria:

1) Documentation of the total time required for checking by block type category.

2) Monthly monitoring of total checking time by block type for reduction in total time.

The time frame for accomplishment of this goal is April 2, 1993 (6 months).

Evaluation of Goal:

Five factors were chosen to determine the total time required for checking a block with the ACMAN System.

a) Determination of block vital points
b) Downloading of design nominal values
c) Targeting of Block Vital Points.
d) Measuring time, including set-up and breakdown
e) Extracting data from the field computer

For analysis purposes two (2) of these factors will be grouped together as measurement tasks and three (3) factors will be grouped as computer data tasks. The measurement tasks are targeting of block vital points and measuring time including set-up and breakdown. The computer data tasks are determination of block vital points, downloading of design nominal values, and extracting data from the field computer and data analysis. The table below compares the times for measurement tasks, computer data tasks, and total checking time.

DATE	MESUREMENT TASKS	COMPUTER DATE TASKS	TOTAL CHECKING TIME
10/01/92	2 MEN X 8 HOURS = 16 HOURS	2 MEN X 2 HOURS = 4 HOURS	20 HOURS
03/01/93	2 MEN X 3 HOURS = 6 HOURS	1 MAN X 2 HOURS = 2 HOURS	8 HOURS

The times shown are average times which can vary depending on the complexity of the blocks measured. Overall, the total time for checking blocks has reduced by 60% from system start-up.

VIII. Research and Development of ACMAN System uses for Outiftting, Ship Checks, Conversion, and Repair.

Following the integration and implementation of the ACMAN System into the Steel Production Cycle, other potential uses of the ACMAN System will be investigated. Examples of potential uses are:

a) Measuring large outfitting components (pipes, vents, foundations, etc.) and predicting join-up at erection.

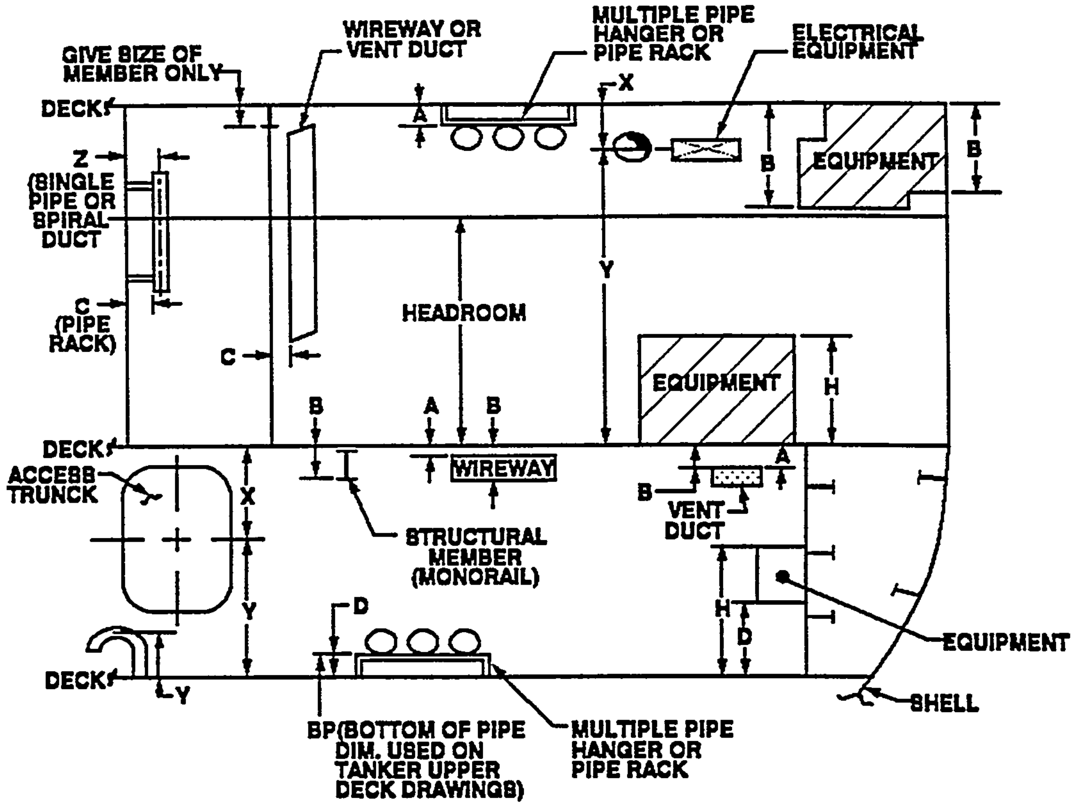
b) Measurement of existing ship structure for repair and conversion work.

Accomplishment of this goal will be measured by the successful use of the ACMAN System in a research and development project.

The time frame for accomplishment of this goal is October 1, 1993 (1 year).

Evaluation of Goal:

Progress to date on this goal has been limited to planning how this task would be accomplished. The first major hurdle to overcome would be to translate the dimensioning of outfitting components to coordinate values. Currently outfitting components are dimensioned off of ships structure. (See Figure 10-5)



- FIGURE 10-5 -

In order to check these components with the ACMAN System, coordinate values would have to be developed, and a database established, by the Engineering Department. Then the coordinate values could be downloaded into the ACMAN System and measurements would be taken in a similar manner to checking hull blocks.

Another issue is how the component would be measured. On piping, dimensions are given to the center of the pipe. How would this point be targeted? Perhaps, an adjustable targeting fixture could be designed to overcome this problem. Or as an alternative, the coordinate values could be established at the top or bottom of the pipe. These are issues that would have to be worked out with the Engineers and the production supervision.

It is easy to visualize the potential savings of assuring the mating of major outfitting components. Having the ability to tie the coordinate systems of the ship, to the hull block, to the outfitting components can make mating of components a reality.

LONG TERM GOALS:

I. Collection, organization and anaiysis of dimensional data in development of NASSCO's Accuracy Control Database.

Development of an accuracy database is a long term commitment to process improvement. After this database has been established, the normal accuracy performances can be identified, and then the accuracy can be regulated as a tool for constantly improving productivity.

Accomplishment of this goal will be measured by the following criteria:

1) Establishment of construction tolerances for interim processes of Sub-assembly, Assembly, On-Block and Erection.

2) Development of standard fitting and welding sequences by block category.

3) Monthly reports indicating accuracy performances for interim processes.

The time frame for completion of this goal is October 3, 1997 (5 years).

Evaluation of Goal:

Collection and organization of dimensional data from measurements with the ACMAN System has been on-going since system start-up. Part of the original strategy for implementation of the system was to categorize block types by NASSCO's management system block identification code. This allows sorting of measurement data established by NASSCO block types. In addition, performance reporting of manhours per ton and weld footage per hour can be analyzed manually, along with accuracy trends, using the same block categorization.

Analysis of dimensional data by block is also on-going, however, analysis of accuracy trends by block type will require more data, and is not included within the scope of this project. Neither is establishment of construction tolerances for the interim processes of Assembly, On-Block Outfitting and Erection.

A feature of the ACMAN System that has not been discussed is that once the measurement has been taken, a permanent record of that measurement is established in the system. If you need to review the measurement a year from today for a specific accuracy study, the measurement could be brought up on the system for analysis.

Development of the Accuracy Control Database is currently progressing ahead of schedule. We anticipate completing this goal within three (3) years.

II. Elimination of Excess Material.

Careful monitoring of construction processes and weld shrinkage will lead to the development of new added material factors, designed into interim processes of block construction. The goal is to fabricate parts neat, and eliminate the commitment to rework that excess material represents.

Accomplishment of the goal will be measured by the following criteria:

1) Development of new added material factors for interim processes of Sub-Assembly, Assembly and Erection.

2) Neat fabrication of hull blocks.

The time frame for accomplishment of this goal is October 3, 1997 (5 years).

Evaluation of Goal:

Accomplishment of this goal will require close monitoring of the interim processes of block Fabrication, Assembly, On-B1ock Outfitting and Erection. A total accuracy control effort in all areas of hull block construction is necessary. Data from measurements with the ACMAN System will help in establishing added material factors for assembly and erection processes, however, additional data is needed. Accuracy control checks of fabrication and sub-assembly processes verifying these processes are performing to tolerances, and are in statistical control, must occur. Programs have been established in support of this objective.

Current progress on this goal has been in the area of pre-planning. The ACBASE.BL program has been set-up to accept manual input of fabrication and sub-assembly data. As the data is gathered, it can be input into the ACBASE.BL program, and statistics can be generated indicating accuracy performance.

Much more needs to be done to realize "neat" fabrication of hull blocks. The first steps have been taken, now a long term commitment to data gathering and tightening of construction tolerances will make this goal a reality.

NASSCO has been building selected hull blocks "neat" since the mid-1980's with limited success. We have seen tremendous savings when the process works properly. We will accomplish this goal!!!

III. Improvement of the ACMAN System.

Development of the current ACMAN System has evolved from use in shipyards in Finland and England. Many improvements in the system design and software are a result of recommendations from the shipyards using the ACMAN System. Members of NASSCO's ACMAN Implementation Team anticipate further design and software improvements from recommendations by the team. An ACMAN System Log has been established to document recommendations. Accomplishment of this goal will be measured by the number of recommendations implemented from NASSCO's ACMAN LOG.

The time frame for completion of this goal is October 5, 1995 (3 years).

Evaluation of Goal:

AS previously mentioned, many of the improvements in the ACMAN System design and software have been a result of recommendations from the shipyards using the ACMAN System. Optec International and Prometrics Oy are very open to suggestions for improvement of their current system. An ACMAN System Log has been established to document all recommendations from NASSCO's ACMAN Implementation Team. The ACMAN System Log was designed to address Information Requests (IR), Action Request (AR), and Improvement Proposals (IP). Information requests are items that require more information from Optec International or Prometrics Oy to resolve. Action requests are either system hardware or software items that require correction by Prometrics Oy to resolve. Improvement proposals are recommendations from NASSCO's ACMAN Implementation Team on future improvements to the AC W System.

The ACMAN System Log design was suggested by Jarl Jaatinen of Optec International and has proved to be an extremely useful tool in resolving issues concerning the ACMAN System. Shown below is an excerpt from NASSCO's ACMAN System Log to illustrate how the requests are handled.

ACMAN OPERATION LOG:

Measuring Tape Input into ACMAN Programs - IR #3 - Resolved

We are now familiar with and have used several methods to input manual measuring information into the ACMAN programs.

Additional Telxon Cable - IP #14 - Resolved

We have received the new transfer cable and it has made using the field computer significantly simpler. Thank you.

Interference from Targets in Close proximity - IR #8 - Open

By selecting better positions for the ACMETER and with a better selection of points we have been able to avoid most of our problems with interfferences of target in close proximity. However, we still encounter problems with interferences from structures, outfitting, staging, etc. in the line of site of the scope We are awaiting any more information you may provide in helping to avoid such problems.

ACMETER Cable - IP #10 - Open

As a further suggestion to the lengthening of the cables, we have observed that the cables tends to develop twists from the rolling and unrolling necessary to store the cable in the ACMETER case These twists cause two (2) problems;

1) It makes the cable difficult to store

2) It tends to unscrew and spin the connector on the bottom of the ACMETER optical head.

To alleviate this problem we recommend that some type of quick release or snap on connection be placed on one of the ends of the cable. This would allow the cable to be disconnected for storage, allowing the free end to spin and untwist itself while being rolled up. It would also provide a way to attach extensions to lengthen the cable for those instances where a longer cable is needed.

ACCART Wheel Improvements - AR #11 - Resolved

The new wheels had been received and installed They are much better suited to the uneven terrain here at NASSCO.

ACMETER Display of Millimeters - IR #18 - Resolved

We have attempted the conversion to millimeters and the system operates as explained. This should prove to be extremely useful with our expected upcoming contracts. Thank you.

11.0 LESSONS LEARNED:

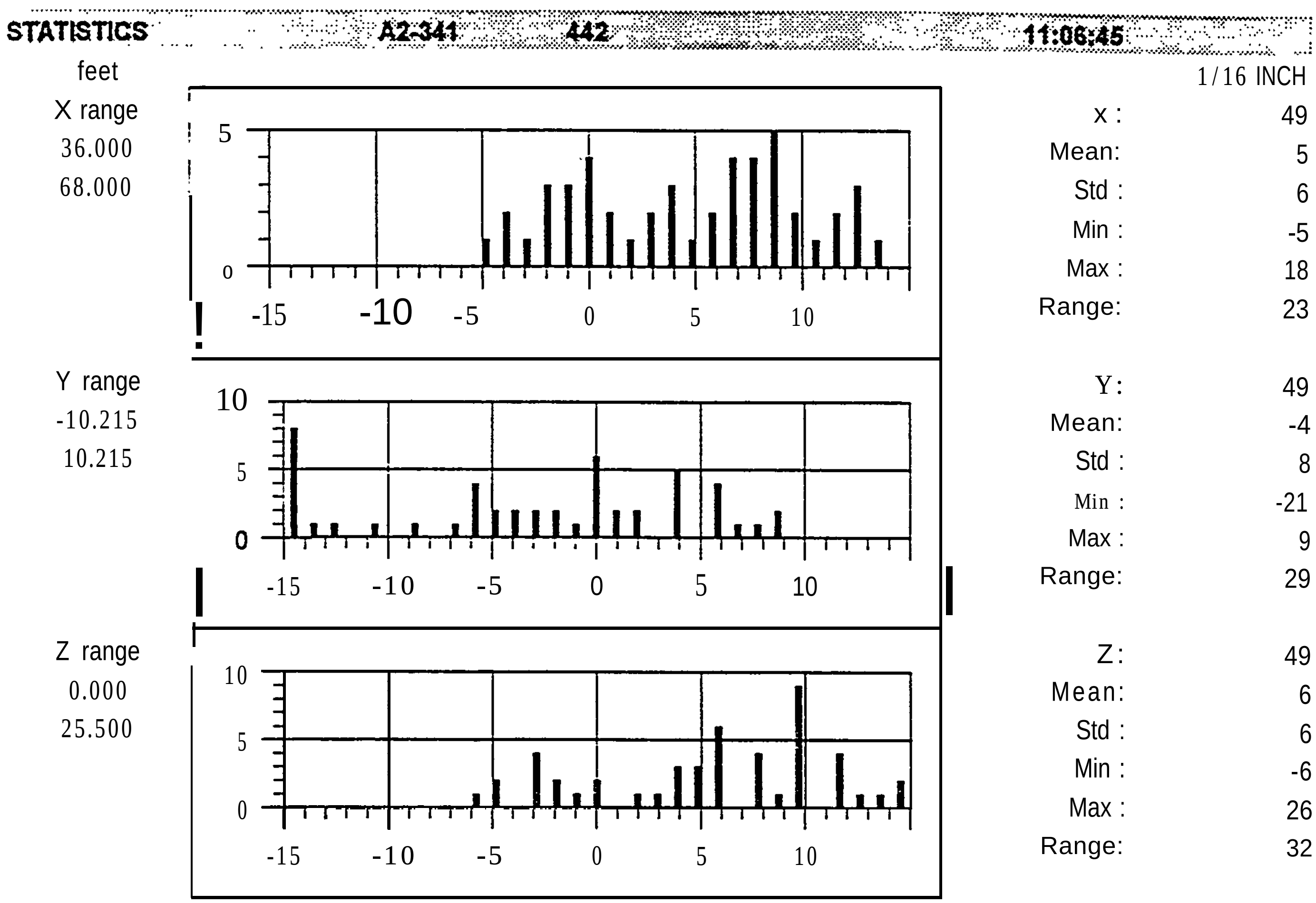
Projects involving integration and implementation of equipment should address the unique problems encountered in the implementation process so that other shipyards will not make the same mistakes. Listed below are some of the lessons learned from this project.

1) Time - Realize that the cycle time from the request for capital expenditure to the actual delivery of the equipment will take from four to six months if not longer. Many times, capital items are tied into the next new construction ship contract for a shipyard. In those cases the cycle time is typically longer. The manufacturer will also need time to process your order.

2) Training - As previously mentioned, NASSCO opted to consolidate the training courses offered by Optec International. The reasons for the decision were sound based on the known facts at that time. In retrospect, an extended training program could have speeded up the implementation of the system. Some of the trial and error in learning to use the system could be overcome from having the experts in-yard to answer questions and demonstrate with the equipment. In addition, the problems we experienced in attempting to train additional people while fully utilizing the system would not have occurred. The full training program is recommended.

3) Downloading of design nominal values - NASSCO's SPADES Database does not lend itself to efficient downloading of design nominal values. At best, the desired nominal values could be flagged during hull load for later extraction in the ACMAN System. The problem encountered here is the exact vital points must be known for the flag to operate efficiently. Any points not flagged would have to be manually extracted later. The preferred method for downloading design nominal values would be a graphical interface with a 3-D CAD System. The selection of vital points would be only a matter of point and click with a mouse. The CAD's own database could save these selected points into a file which could easily be converted into the ACMAN format.

4) Development of the shipyards accuracy control database - The ACBASE.BL program calculates the difference of the nominal and actual measurement values for each measured point. It also calculates statistical variables defining the accuracy of the measured object. These statistical figures are shown as coordinate deviations in “X”, “T", and “Z” dimensions. The program lumps all dimensions taken along the “X” Axes together, the same is true for “Y" and “Z” dimensions. This works well when examining blocks for trends. However, if you wished to study just the main block dimensions (i.e., 2 lengths, 2 widths, etc.) to determine overall shrinkage, the program is not designed to accomplish this. Naturally, programs can be written to overcome this issue and provide the desired results. An example of ACMAN statistics is shown in Figure 11-1 below.



- FIGURE 11-1 -

12.0 CONCLUSION:

Acquisition of the ACMAN Measurement and Accuracy Control System has been a good investment for NASSCO. Although the system has only been in active use for the past six months, projections of cost savings resulting from defects found, indicate the system will pay for itself within the first year of use.

Be warned. It is not a magical instrument that will solve all your accuracy problems. Implementation and integration will involve a lot of hard work and proper planning. Proficiency comes with use over time We are still learning. The real potential of the ACMAN System is yet to be realized by NASSCO. There are a tremendous amount of manhours that can be saved in rework.

Of course, the definition of what constitutes rework can have totally different meanings depending on the shipyard surveyed. A U. S. Shipyard may consider excess material trimmed at the erection stage as planned work, where as, a Japanese shipyard would consider the trimming as rework. No matter what the definition of rework is, one common problem exists that all shipyards can agree upon. That problem is additional manhours required for fitting and welding work to adjust components at the erection stage due to inaccuracies in the manufacturing processes.

Japanese and European shipyards have been successful in reducing both the manhours and the durations for erecting ships by eliminating some of this costly rework. Production work has been organized so that the accuracy of interim products is checked automatically at every stage in the manufacturing process. The processes need to be understood, analyzed, monitored, and refined on a continual basis. Process improvement will enhance accuracy and improve productivity.

For many years after the introduction of accuracy control concepts, the accuracy of assembled hull blocks were checked with standard measuring tapes. As the hull blocks became more complex more precision in measuring was required, and distortion of three-dimensional blocks could not be accurately checked. Therefore, rework continued to be a problem. In a recent paper presented to the Society of Naval Architects and Marine Engineers by Masaaki Yuuzaki and Yasuhisa Okumato of Ishikawajima-Harima Heavy Industries Company Ltd., Japan, an excellent analysis of the current situation was described. The author's stated “Since the latter half of the 1950’s when the idea of quality control concepts was introduced in Japan, Hull Accuracy Control concepts have been developed and widely used in each stage of hull work and with this a remarkable productivity improvement has resulted. However, looking at the final goal of having assembled blocks fitted and welded at the erection site without any remedial adjustment, it must be said that the present situation is far from ideal”.

The paper goes onto illustrate that nearly 1/2 of the fitting manhours and 1/3 of the welding manhours at erection are consumed by adjustment work. The authors indicate that extensive manhour savings can be realized by eliminating rework. These are statements by a “premier" Japanese Shipbuilding Company that currently builds ships for 1/3 of the manhours of most U. S. Shipyards. How do they propose to eliminate this unnecessary rework? By reduction of variations throught mechanization or automation, heat deformation analysis, and The Development and App1ication of a Three-Dimensional Analysis System for the Assembly and Erection Stages.

Finally! Measurement systems have been designed that will accurately measure the complex three-dimensional hull blocks we have been expected to build. The challenge is to control variations in the building process and build ships to an absolute coordinate system.

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[1] Author's Note: This description from an article presented by Masaaki Yuusaki, Visitor and Yasuhisa Okumato, Visitor, Ishikawajima-Harim Heavy Industries Compmy Ltd. "An Approach to a New Ship Production System based on Advanced Accuracy Control. Paper presented to the NSRP Ship Production Symposium, New Orleans, Lousiana, 1992.

The ACMAN System is a tool to assist in controlling the dimensional accuracy of the hull block construction process. In order to succeed, all of the tools must be used. Every member of NASSCO's Steel Team is committed to improving processes, accuracy, and quality at each stage of construction. Dramatic improvements in productivity and significant reductions in rework have already occurred. More needs to be done if we are to survive in this competitive business of shipbuilding.

The ACMAN System will help NASSCO's Steel Department in taking the next "Quantum" leap to improve the hull block construction methods and to further reduce steel manhours.

APPENDIX “A”

ACMAN PROCEDURES

ACMAN PROCEDURE MANUAL

INDEX

HEADER DEFINITIONS FOR ACCALC.BL AND ACBASE.BL PROGRAMS:

NASSCO -03.11.92

1) Block Number
   - Defines A2 number of Block/Unit

2) Project Number
   - NASSCO Hull Number

3) Project Name
   - Ship/Project Name

4) Note a
   - Starting Time of Measuring Check

5) Block Type
   - Management System Block Identification Code

6) Assembly Method
   - Unit Orientation

7) Assembled by
   - Table or Area Location of Unit

8) Note B
   - Weather Conditions at Time of Measurement

9) Checking Stage
   - Stage of Construction

10) Measuring Data

11) Measured by
    - Operators initials

12) Note C
    - Currently used to Denote Grandblock Number of units for entire ship checks.

POINT NAMING CONVENTION:

The purpose of this procedure is to aid in the naming of selected points for checking with the ACMAN System. There are two (2) main reasons why the naming of points are important.

1) To organize points into select groups for analysis and special study cases in order to establish trends in the production methods and eliminate the cause of problems.

2) To help with the analysis of points by describing the location and nature of the point location. By identifying where a point is located in the point name it will be easier to organize and sort points so that special areas of production can be studied.

To this end the following point naming conventions should be followed:

1) The point name can not exceed six (6) characters in length.

2) The point name will be broken up into three (3) distinct sections:

   2a) The first section (1 letter) shall describe the type of point and the nature of the analysis to be done on this point. The choices for this section shall be taken from Table 1 (See below).

TABLE 1	
POINT TYPE	POINT TYPE SELECTION SECTION 2a
v	Vital point
w	Weld Study Point
P	Additional Points
	Etc.

   2b) The Second Section (2 numbers) shall be in direct relation to the ACMETER counter. Therefore, the third point of study shall be the third point on the ACMETER counter. NOTE Number from 1 through 9 shall be prefixed with a 0 (Zero) i.e. 01, 02, 03, etc..

2C) The Third Section (3 Letters) shall describe the point intersection location on a given unit. The choices for this section shall be taken from Table 2 (see below). For example, a point located on the shell at the intersection of deck could be named V02SD.

TABLE 2	
POINT TYPE	POINT TYPE SELECTION SECTION 2C
s	Point on Shell
D	Point on Deck
L	Point on Longitudinal Bulkhead
T	Point on Transverse Bukhead
MB	Master Buttock line for Unit
MW	Master Waterline for Unit
L##[1]	Stiffener on Deck or Buikhead
s##[1]	Stiffener on Shell

[1] -## Signifies the actual stiffener number - S36

3) *The* first point shall always be the origin and shall be named 001. the location of this will be given so as to simplify the establishment of the six (6) point coordinate system.

FIELD CHECK PROCEDURE:

The purpose of this procedure is to outline the key steps to follow in the field when checking a unit with the ACMAN System in order to insure accurate, timely results under safe conditions.

O Safety:

A) Remember to follow all safety rules and regulations when operating this equipment.

B) Remember to look out for other peoples safety as well. Since the equipment often requires the movement of ladders, handrails, etc. remember to keep other workers away from unsafe areas until they have been made safe again.

1) Prior to Leaving the Office

A) Make sure the measuring form has been downloaded into the field computer for all units to be checked that day.

To do this follow these steps:

1) Double-Click on ACMAN icon.
2) click on ACALC.BL Button
3) Open the Programs Menu
4) Select ACCOMM
5) Select Receive
6) Make sure unit numbers appear on the list

B) Make sure you have a copy of the measuring sheets and drawings that outline the point locations.

C) If possible before taking the field computer out to the site, target as many points as possible and establish the points necessary for the 6-point coordinate system.

2) Initial on site set-up:

A) Choose your vantage point carefully. Make sure you can see as many critical points on the unit as possible. In addition, remember to set-up in a location where the conditions for work are safe for the operator and the equipment. (i.e., the middle of a roadway is not a safe location).

B) Prior to turning the equipment on, fill out the header of the measuring sheet. Please remember to fill in:

1) The time (Note A)

2) The temperature (Note B). This temperature should be taken on the steel of the unit being checked. A second temperature reading should then be taken after the transformation on the second side of the unit being checked.

3) The date (Measuring Date).

4) The person operating the equipment (Measured by)

5) The orientation of the Unit (Assembly Method) (i.e Right Side Up, Upside Down, etc.).

6) The location including grid number if applicable (Assembled by) (i.e., if the unit is located on Table 6 please also note the grid such as Table 6-3).

3) Operation:

A) Set up Equipment

B) Turn on Equipment. Make sure the battery or power line is connected to the ACMETER.

C) Initialize the ACMETER by finding the Pan and Tilt Zero pulses.

D) Go to the 6-point Calibration Mode Please be sure that the ACMETER has properly targeted the points. Trigger the ACMETER several times to be sure that the results are repeatable

1) Shoot in the 3-points for X-Y Plane. Circle the approximate locations of these points on the drawing.

2) Shoot in the 2-points for X-Axis. Mark the approximate location of these points on the drawing.

3) Shoot in the origin. Then enter the values of the origin. Write down these values next to point 001 on the measuring data sheet.

4) Save the calibration.

E) Go to the measure point function. Select 3 to 5 points on the unit for which you know the design coordinates and which have targets. Shoot these points to make sure the 6-point calibration has functioned properly. At least one of the points checked should be on the far end of the unit.

F) Go to the measure form function.

1) Select the proper measuring form from the field computer.

2) Begin shooting the points.

3) For every point checked place a number in the dX column of the measuring form. The number to use should signify the location of the ACMETER A number 1 indicates the first set-up location (station 1) for the ACMETER A number 2 will indicate the second set-up location (Station 2) for the ACMETER after the 3-point transformation has been accomplished A number 3 would indicate the third station, Station 3 after another transformation has been done and so on.

G) Accuracy is the key goal. Follow these rules when moving targets from their original positions.

1) Although it is unavoidable at times due to obstruction in the line of sight, targets should not be moved from their original locations. When a target must be moved, move it as little as possible.

2) Remember to move the ship's coordinate plane, not simply 90 degrees to the surface the target is OIL For instance moving 1 inch outboard 90 degrees to the shell will actually consist of a movement of less than 1 inch in the Y direction and additionally a movement of less than 1 inch in the Z direction. The only way to accurately calculate this new location is to know the angle of the shell to the centerline plane.

3) Whenever a target is moved, the amount of movement in each direction (X, Y, and Z) must be marked on the measurement sheet.

4) Transformations:

A) 3-Point Transformation (Recommended)

1) Once all the points which could be seen from Station 1, have been shot in three points must be chosen for the transformation to Station 2.

2) Select three points which can be seen from both stations clearly and with as little interferences as possible.

3) The three points should be chosen so as to encompass an area larger than the unit being checked.

4) The points should also be at varying heights above the ground. If possible (though highly unlikely) at least one point should be set-up higher than the highest point on the unit being checked.

5) Remember to set-up the point within the ACMETERS distance restrictions. No point should be over 150 feet from both Station 1 and Station 2. Remember to account for the second station as well.

6) Shoot the 3-points under the P#-Obj selections. Remember to check for repeatabtity in the results and also be sure that the results make sense.

7) It is not necessary and not recommended that this data be saved prior to turning off the equipment. However, if save is accidentally pressed the 3-point transformation can still be accomplished.

8) Be sure to note the order in which the points were shot. (This order must be repeated at the second station). If possible mark on the drawing the approximate location of the three points chosen for the transformation.

9) At the second station set-up and start the equipment as usual, but instead of using the 6-point Calibration mode go to the 3-Point. Re-shoot the same three points in the same order under the P#_Dev selections. Then save the transformation and check several points to be sure the transformation was successful.

B) 6-Point Transformation

1) To be filled in later.

5) Second Station and Tear Down

A) After the transformation from the previous station has been successfully accomplished, several points (3 to 5) should be checked to insure accurate readings.

B) Remember to mark the new points checked with the correct number of the new station location.

C) Before turning off the ACMETER power be absolutely sure that all the points that could possibly rechecked have been checked. Once the power is off and no new transformation has been prepared, the reference plane data will be lost. The only way to check any additional points would be to start over or establish a new 6-point reference plane.

D) In tearing down the equipment be extra careful while storing the cables.

1) The main cable has the tendency to develop a twist. It is a good idea to remove any twists prior to rolling up this cable. If this is not done the connection to the optical head tends to spin and may eventually unscrew.

2) The console cable is very fragile. Be sure not to catch this cable between the lid and the case when closing. This wire could easily be cut.

E) Be sure to remove any magnetic targets that have been used to check the unil.

F) Return all ladders, scaffolding, etc. that have been moved throughout the check back to their original locations when done. This is not only common courtesy but a good safety practice.

6) Important Reminders:

A) The battery for the field computer and the ACMETER itself have demonstrated an approximate time span 5-7 hours. The best suggestion is to plug the battery in for charging during the lunch period. This should also allow the PC operator to download the data already collected to insure that all systems are operating correctly.

B) Remember that the ACMAN works in three dimensions. Therefore you can set up the transfer points and reference points in this three dimensional plane.

C) Whenever it is getting close to lunch or quitting time a decision must be made to easier work through or to establish a three point transformation. The best bet is to work through. This will account for less errors in the data.

D) In some low light situations the ACMETER has difficulty picking up the contrast in the target. In this situation shining a flashlight on the target may alleviate the problem. (Therefore it is a good thing to carry a flashlight with you at all times.)

E) Remember the ACMETER and Telxon are computers. Computers and magnets just do not get along. Keep all magnets away from the field computer.

F) During the actual check attempt to keep the area clear of other workers. Remember two (2) things:

1) While using this equipment it is often necessary to move ladders, handrails, etc.. By keeping people away you could be preventing accidents. Safety first.

2) You have a job to do!! Other workers tend to get in the way and cause delays. Make sure they respect your right to do your job.

ESTABLISHING THE OBJECT COORDINATE SYSTEM:

The purpose of this procedure is to outline the methods used at NASSCO to establish the 6-point coordinate system for the ACMAN unit checks. This system converts the ACMETER's device orientated coordinate system into a reference system identical to the ship's coordinate system.

At NASSCO, the ship's reference plane is defied as follows. The horizontal plane is parallel to the baseline of the ship. The origin (0,0,0) is considered to be a point at the FP on the baseline at centerline. The positive X direction (X-Axis) run aft from the FP along the frame numbering system. The positive Z direction (Z-Axis) run up from the molded baseline or bottom of the ship. The positive Y direction (Y-Axis) runs starboard from the ship's centerline This makes all values on the starboard side positive and all values on the port side negative. NOTE: These three (3) Axes represent a right handed coordinate system which is used exclusively with the ACMAN System.

Since only a small portion of the ship is checked with ACMAN at any one time (i.e., a Unit-Block), it is necessary to explain to the ACMETER the relationship between the unit and the ship's overall coordinate system. This is accomplished by creating a 6-point coordinate system which orientates the unit in relation to the ship.

The NASSCO ACMETER operators have established a system by which this procedure is accomplished. The following is a breakdown of what points are chosen to determine the coordinate system.

The X-Y Plane:

Three (3) points are used to determine the X-Y Plane. This plane must be parallel to the baseline (bottom) plane of the ship. This is easily accomplished by shooting three (3) points on the unit which all fall on the same waterline. All waterline planes should be parallel to the baseline plane. This can usually be accomplished by shooting two (2) points on the shell waterlines and one (1) point on a bulkhead waterline located further inboard on the unit. All units at NASSCO are required to have not only waterlines but also buttock, and frame master reference lines from which all critical dimension should be taken. Therefore, using the waterline at three points at the far ends of the unit should create an adequate X-Y plane.

Note also that the three (3) points must be shot in a specific order so as to orient the positive Z-Axis in the correct direction. For instance, if a unit were upside down, the positive Z-Axis would be pointing into the ground. Therefore, the three (3) points would have to be shot clockwise. This is also a right hand rule of sorts. Take your right thumb and point it in the direction of the positive Z-Axis. Cup your remaining fingers. Notice the direction your fingers are pointing. If your thumb is pointing up your fingers are creed in a counter clockwise fashion. This is the direction/order you must shoot the three (3) points on the *X-Y* plane.

The X-Axis

Two (2) points are used to determine the X-Axis. The Axis must be parallel to the centerline of the ship. The two (2) points must be shot in an increasingly positive direction. For NASSCO this translates from forward to aft. Since all units must have master buttock lines marked on them, These buttock lines which run parallel to the centerline make a good choice for the X-Axis. Therefore, at each end of the unit a point is shot indicating the X-Axis along the master buttock line.

If one of these points is obstructed then the points are transferred equally to a location where both points can be seen.

The O Point (Origin):

Clearly it would be impossible to have the ship's origin on every unit built. Therefore the origin or O point referred to here is a point who's coordinates are generally assured due to the limited change of distortion in the area of this point. Generally the O point is a point that can be seen from the starting ACMETER position, it should be on the molded sides of any structure present and should be defined by two solid structures, such as where a deck and shell meet. It is also helpful to choose a point for which the nominal values have already been provided. The nominal values speed the checking of units by utilizing the orientation mode of the ACMETER. In essence what this does is pre-focus the ACMETER lens to the design distance from the ACMETER position. This eliminates the time consuming tediousness of forcing the operator to focus the ACMETER on each individual point.

Required Accuracy:

It is imperative that when any points are transferred to facilitate a clear line of sight that the final location of these points is verified 100%. Improperly locating just one of the three X-Y plane points can cause a twist of all the points in relation to the entire unit. The same is true for one of the X-Axis points. An error in locating the O point or entering incorrect values would manifest itself on the output form by showing all the points of the unit shifted in the same direction. While each one of these problems is recognizable on its own, a combination of any of them can cause a situation where the data appears to be incorrect but without any discernible pattern.

When a pattern of deviation is detected it is possible to take the data in the ACCALC program and then rotate and translate the points to account for the errors. For instance if the forward X-Axis point where incorrectly located by six (6) inches, this would show deviations in the transverse dimensions of all the points, However, this deviation would be smallest at the aft end and would increase up to six (6) inches at the forward. This pattern when detected could be fixed by selecting a point to rotate the unit about. The most logical point selection would be to select two points on the master buttock line, one forward and one aft. The entire unit would then be rotated about the after point until the forward point showed no deviations in the Y dimension. After the rotation the measured values of all points would then be changed to reflect the new orientation.

FIELD COMPUTER TRANSFERS PROCEDURE:

The purpose of this procedure is to outline the steps necessary to follow in order to download measurement files to the Telxon field computer and to retrieve these files back into the ACMAN PC.

O. Preliminaries:

A) A basic understanding of computers, windows and the mouse is necessary to successfully understand this procedure

B) If required the windows tutorial can be run to give a basic understanding of how to use the mouse and windows. To run the tutorial:

1) Press the <Alt> key
2) Press the “H” key
3) Press the “W” key
4) Follow the Tutorial Instructions.

1) Starting the ACMAN Program:

A) Double click on the ACMAN.B icon in the main windows screen. The screen should change to the ACMAN for window screen.

B) Be sure the proper directory is displayed in the directory button. The default directory should be C:\ACMAN\DATA _BL\AOE-8. If this directory is not shown or if you wish to select another directory (such as for neat cut data) then follow these steps:

1) Click once on the Directory button.

2) Scroll through the directory list until you see the directory you wish to use.

3) Click once on this directory. It should then become highlighted (black).

4) Click once on the OK button.

The directory button should now display this new directory.

c) Click once on the ACCALC.BL button. An A2-Unit list should now appear on the screen.

D) Click once on the Programs menu selection at the top of the screen. A pull down menu should appear under the programs.

E) Click once on the ACCOMM menu selection in the pull down menu. An ACCOMM window should appear in the middle of the screen.

2) Using the ACCOM Window:

A) To download files into the Telxon field computer use the following procedure.

1) Click once on the Command menu selection.

2) Click once on the Transmit menu selection.

3) Scroll through the file list until you see the A2-Unit you want to download.

4) Click once on this file name This file should become highlighted and the name on the tile should appear in the box near the top of the ACCOMM window.

5) Click once on the Receive button.

6) A new window may appear asking if you wish to Replace Existing File A2-NUN.MNF. Click once on the OK button. This window should disappear and the screen should then show the percentage of data transferred to the ACMAN PC. This process should take some time.

7) Once the screen reads 1 File Received 100% Error Free you may then either select another file to receive (Repeat steps 3 to 6 for the file) or you may click once on the Quit button to exit the retrieve mode.

8) Optional: Before quitting the receive mode you may choose to delete the files on the Telxon which have already been transferred back into the ACMAN PC To delete a file from the Telxon, follow 3 steps and 4 above for this file, then click once on the Delete it button. Remember do not delete the files from the Telxon until the data has been transferred back into the ACMAN PC (Steps 1 through 7).

B) To exit from ACCOMM window use the following procedure:

1) Click once on the Command menu selection.

2) Click once on the Exit menu selection.

This should return you to the A2-Unit List screen.

3) <u>Printout of Measurement Form Sheets:</u>

A) In addition to transferring the data into the Telxon, this is also a good time to printout a copy of the data measurement forms for the units to be checked if there is not a copy available already in the Units to be checked file located above the ACMAN PC.

B) A printout of the measurement form sheets is a necessary accompaniment to the data in the field computer. It is used to record deviations from the designed point location due to line of sight interferences and also to record the weather and unit conditions during the ACMAN check.

C) If a copy of the form is needed use the following procedure:

1) While in the A2-Unit list screen, of the ACMAN programs scroll through the list to find the A2-Number of the unit for which you need the measurement form.

2) When you can seethe A2-Unit you need, Click once on the A2-Unit number. A box should appear around this unit.

3) Click once on the File menu selection at the top right hand corner of the screen. A pull down menu should appear below this.

4) Click once on the Open menu selection. The screen should now change to the block information screen.

5) Click once on the Points menu selection at the top of the screen. A pull down menu should appear below this word.

6) Click once on the Show Points menu selection. The screen should then display the nominal value of the points.

7) Be sure the printer has been turned on and that the Ready lights is on and not blinking.

8) Click on the Points menu selection again. The pull down menu should reappear.

9) This time click once on the Print Points menu selection. A small window should appear telliig you the number of pages sent to the printer. Simply wait until this window disappears.

10) Once the forms have been printed you may now exit. Click one on the Exit menu selection. A pull down menu should appear below this.

11) Click once on the Exit menu selection in the pull down menu to return to the A2-Unit List screen.

4) Exiting the Program:

A) To exit from the A2-Unit List Screen:

1) Click once on the Exit menu selection on the menu at the top of the

screen. A pull down menu with the choice Exit should appear below the word exit.

2) Click once on this new Exit menu selection.

This should return you to the ACMAN for Window screen.

B) To exit the ACMAN program, now click once on the Exit button in the middle of the screen. This should return you to the main Window screen.

5) <u>Troubleshooting</u>:

A) Strange creatures and spaceships have taken over the screen, HELP!!!

1) Don't worry one of two things has happened:

a) You've been away from the computer so long that the screen saver has turned itself on, or.

b) You accidentally moved the mouse into the lower left hand corner of the screen which automatically turn the screen saver program on.

2) All your hard work and data are still intact, they are just hidden behind this protective screen.

3) Simply move the mouse around over the mouse pad and your screen will return good as new.

B) I was working in the ACCOMM window when POOF!! it just disappeared, HELP!!!

1) Chances are you've accidentally clicked the mouse on the wrong screen.

2) To fix this problem follow these instruction:

   a) Begin by clicking the Minimize button. The minimize button appears as one small triangle pointing down in the upper right hand corner of the screen. Once you've done this the ACMAN program will disappear and a small WINGZ icon will appear in the bottom left hand corner of the screen. You should also be able to see the ACCOMM window now in the middle of the screen.

   b) Being very careful so as not to repeat your mistake, click once on the Command menu selection in the ACCOMM window. A pull down menu should appear directly below this word.

   c) Click once on the Exit menu selection. The ACCOMM window should now disappear.,

   d) To restart your program double click on the WINGZ icon at the bottom of the screen. The A2-Unit list screen should now reappear.

   e) To get the ACCOMM program up and running again, begin from Step 1D.

3) Make sure you follow this procedure. Simply trying to restart the ACCOMM program will not allow you access to the Telxon, because a link will not be established.

c) I can't find my A2-Unit file in the lists, HELP!!!

1) First go back and make sure you are in the right directory.

2) If you are in the wrong directory follow the procedure in the lB to get to the right directory.

3) If you are in the right directory and still can't find the files you are looking for, chances are the file just doesn't exist.

4) You should now get on the PC Operator's back to get his job done on time.

Remember normal ACMAN data files can be found the C:\ACMAN\DATA_BL\AOE_8\ directory. Data files for checking neat cut units can be found in the C:\ACMAN\DATA_BL\NEATCUT\ directory.

D) I deleted a file by mistake before I could upload the data to the ACMAN PC, HELP!!!

1) First call the PC operator, maybe he can help.

2) If can’t help or he’s not around then CRY!!!

Therefore be very careful before deciding to delete files. Be absolutely sure they have been saved.

E) No matter how hard I try I just can’t get the file onto the Telxon, HELP!!!

1) Chances are the Telxon’s memory is full.

2) Follow the procedures in 2B to see just how many files are in the Telxon’s memory.

3) If it’s a lot then you are just going to have to bite the bullet and delete some files, but before you do read 5C.

DEVELOPMENT OF VITAL POINTS:

The purpose of this procedure is to outline the rationale used in determining which of the thousands of available data points associated with the hull design are to be used as nominal data for the ACMAN System.

The SPADES data system contains three (3) dimensional information in relation to the ships coordinates for the following.

1) All Master Reference Waterlines.

2) All Master Reference Buttock Lines.

3) All decks, platforms and breasthooks at the ship's centerline and at the shell molded line.

4) AU vertical longitudinal stiffeners located on bulkheads.

5) All longitudinal stringers located on the underside off decks.

6) All plating seams along the molded shell lines. This usually does not correspond to deck heights since a 5 to 6 inch lip of plating is usually left above the deck height on each individual unit.

7) All control lines

AND

8) All shell stiffeners to the molded shell line.

All the information is organized by frame location from the forward perpendicular. The internal between frame location varies but does include every web frame location, generally every transverse bulkhead location as well as all the unit breaks.

What the ACMAN PC and the SPADES users must do is sort through these points to obtain the short list which will accurately define the unit to be checked and which will provide sufficient amounts of data for statistical analysis. TOO many points is as bad as too few. The more points, the greater chance for fatigue and error.

To assist in the selection of vital points the following guidelines have been created. Assuming a typical number of points to be checked is 30 per block, the following guidelines will give an average number of each type of point to check.

1) **The unit or block break data is of the utmost importance. These unit edges can be checked to determine how close to the tolerance the units are being built, and if possible, to reduce the amount of excess material. Of the average 30 points checked usually 15-20 points are on the edges of unit breaks.**

2) **Most units breaks do not fall on a transverse frame. Therefore, the edges of the unit tend to be loose plate which can generally be distorted easily.**

3) **All units must have a Master Reference Waterline, and a Master Reference Buttock Line marked on them. These lines should be checked in as many areas of the unit as possible. They are key in orienting the unit to the 6-point coordinate system and later for insuring that the unit has been checked properly. Of the 30 points a minimum of 4 points shall be MRL's. Generally these points are located on the unit breaks for ease of visibility.**

4) **Another source of data points can be any major structures other than decks and shells, such as longitudinal and transverse bulkheads. These structures are usually checked at the edges making sure to check the open most corner and the waterline at both ends of the bulkheads. Of the 30 points on the unit with bulkheads 6 to 12 points may be associated with these checks.**

5) **Finally since each unit has its own individual characteristics certain vital points can be assigned to accommodate these special areas. For instance trunks or elevator openings, which are both areas of concern during construction, can be selected for checking. Of the 30 points a maximum of 6 points may be associated with this type of point.**

The current vital point selection process is done manually. By establishing criteria or flagging data points this process can be sped up to free up the PC operator's time. However, on complex units such as those defined for the current AOE contract an automated process would not work.

A graphical interface would make the vital point selection easier. Using a CAD System the section of points would be only a matter of point and click with a mouse. The CAD's own database could save these selected points onto a file which could easily be converted into the ACMAN format.

DATA DOWNLOAD FROM THE NASSCO SPADES SYSTEM LOCATED ON THE MAINFRAME COMPUTER TO THE ACMAN SYSTEM.

The following procedure briefly outlines the steps currently followed to transfer data from the SPADES database used by NASSCO to identifyl in ships design, to the ACMAN PC System. It will also include the steps used to edit and sort the data in ACMAN PC format. Finally, a collection of suggestions to improve the process.

Step 1 A unit is identified by production.

Step 2 Data is incorporated into the SPADES data system on the NASSCO mainframe computer.

Step 3 A three (3) dimensional area surrounting the block to be checked is identified using programs on the mainiframe. This area identifies all the points corresponding to the unit to be checked, from all different hull databases. (i.e. Longitudinal, Decks and Platforms, Waterlines, Shell Traces, etc..)

Step 4 This mass of data points is edited removing all duplicates and any extraneous bits of information that appear on the SPADES database files. In this process any points deemed unnecessary for download to the ACMAN are deleted.

Step 5 The cropped mass of points is then transferred (downloaded) from the mainframe computer onto a PC floppy disk. This disk is then delivered to the ACMAN PC operator.

Step 6 The ACMAN PC operator must then sort through the data using the vital point selection process to determine which points will actually be used in the AC W forms. Any points which have been accidentally deleted or points needed for special studies must be manually entered into the PC at this time from the Table of Offsets and/or the Steel Production drawings.

Step 7 The final set of points must then be named (as per the Naming Procedure) and put into a format which the ACMAN Software can interpret. The nominal data file can then be read in the ACMAN ACCALC program.

Step 8 The nominal data is then saved to a measurement form which can be downloaded into the ACMAN Field Computer for checking. Also, lines must be added to the data in the ACCALC program to better represent the unit on the computer screen. Finally, a hard copy print out of the data points to be checked must be made in order to better instruct the ACMETER operators as to the location of the required check points.

Steps to speed up the process at NASSCO.

Step I A specific database identifying all blocks by the block breaks can be set up for the ACMAN PC. This database would also prove to be easier to understand for all the workers who utilize the table of offsets yet only work with units, as opposed to the entire ship. (Why waste time looking through the entire ship offsets when you could just look through the unit offsets.)

This procedure would help to eliminate Step 2 through Step 4. Which are currently done manually. This database would be the only piece of information that would need to be downloaded. It would be organized by block, therefore, less chances of missing data would occur.

Step II If the work done on the mainframe were limited to only eliminating duplicate points and deleting non-ACMAN related information, this would eliminate the number of times the data is sorted and cut. Since the ACMAN PC operator must select the vital points anyway, allow him to select these points from the entire selection as opposed to just those points chosen by the mainframe operator.

ADVANTAGE

This would eliminate the need to manually enter data from the table of offsets.

DISADVANTAGE

The number of points to sort through would be greater and more PC storage (Floppy disk) space would be required.

NOTE:

The sorting of the data would be most efficiently done as up front in the process as possible. However, the selection of vital points must be done by someone who has intimate knowledge of the field checking procedure and the times the units will be checked. For instance, selecting a vital point for a deck long mid-way along the length of a unit may work if the unit is checked at the assembly area, but if there is any outfitting in the way, this point could not be checked.

Step III Programs can be written to automate several of the procedures used to select, sort, download, and edit the data points into what is finally used as ACMAN PC data. Several macros have been written currently to expedite the process on the PC.

Step IV Eliminate the number of people involved. Data download (until automated) is a job for one man.

Step V If all data were downloaded to the PC any changes needed to accommodate interferences and special studies could be quickly made by the PC operator. With only portions of the data downloaded changes require that the data be manually entered.

Step VI A direct link to CADAM or CALMA from mainfame to PC would definitely speed the process.

Step VII Pre-planning - Allowing time ahead of schedule to prepare, download and organize the data into usable formats.

APPENDIX "B"

MARKETING INFORMATION

MARKETING INFORMATION

OPTEC INTERNATIONAL
LAIVALAHDENKATU 4 A
SF-OO81O HELSINKI, FINLAND

PHONE: +358-0-755-5122
TELEFAX: +358-0-755-5611

MANAGING DIRECTOR: JARL JAATINEN

PROMETRICS LTD.
TECNOLOGIANTIE 690570
OULU, FINLAND

PHONE: +358-81-551=4361/4162 (DIRECT)
TELEFAX: +358-81-551-4160

MANAGING DIRECTOR MARKKU MANNINEN

APPENDIX "C"

MEASUREMENT FORMS

ACMAN/ACCALC.BL A1-554S 06-28-93

Block n .	Project no.	Project name	Note A
A1-554	442	AOE-8	
Block ty e	Assembly method	Assembiled by	Note B
GRAND BLOCK	RIGHT SIDE UP	WAYS 4	
Checkin stage	Measuring date	Measured by	Note C
ON BO RD	02-11-93	SH,FS	A2-269,270,293,294

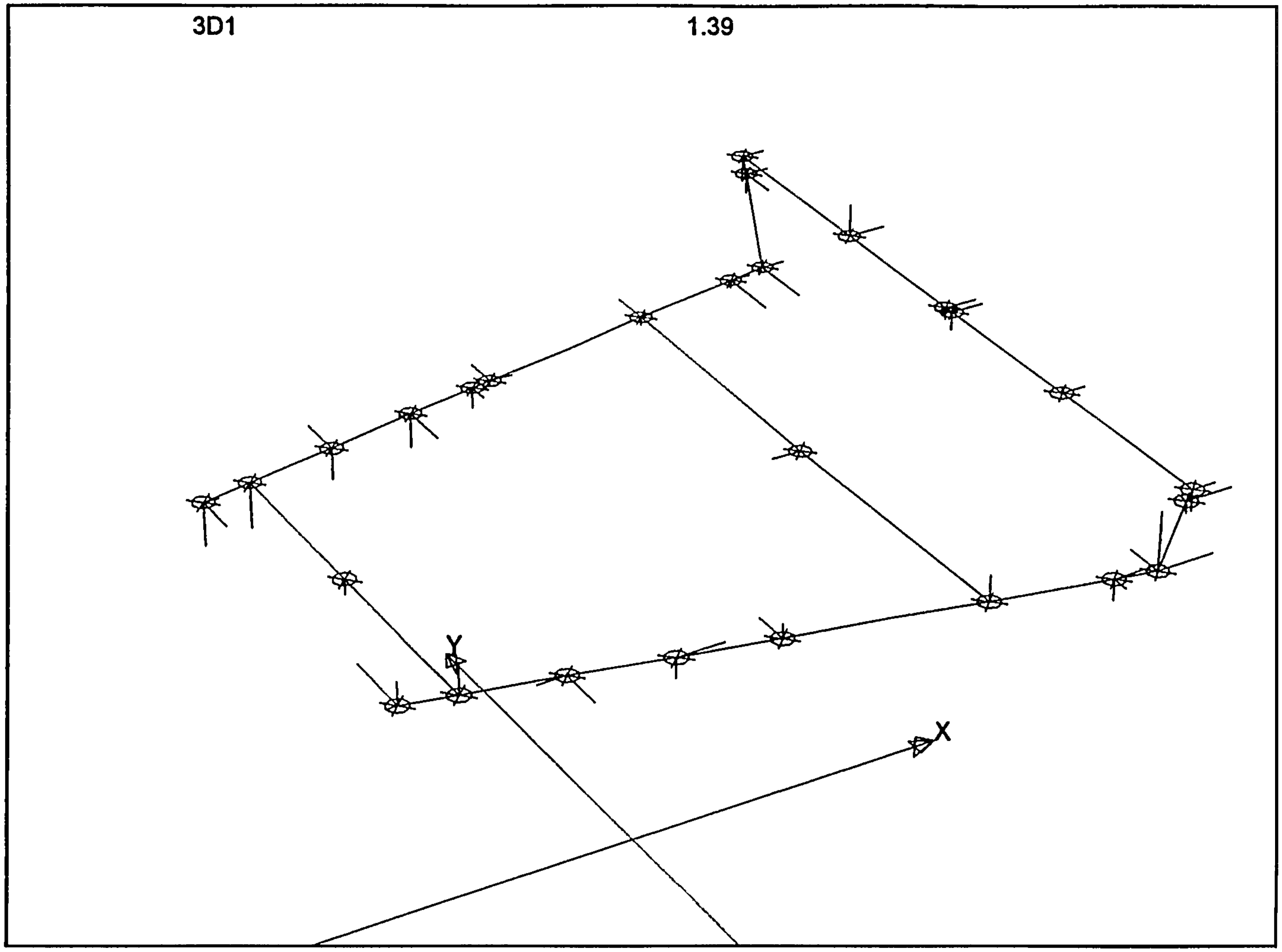
POINT	X_nom	Y_nom	Z_nom	X_mea	Y_mea	Z_mea	dX	dY	dZ	NOTE
O01	0.000	0.000	0.000	0.042	0.021	-0.042				
P02S	100.000	-18.443	35.500	99.984	-18.313	35.542	-0.016	0.130	0.042	
P03MW	100.000	-21.469	44.000	100.083	-21.380	44.000				
P04SD	100.000	-22.286	45.500	100.063	-22.240	45.536				
P05L7	100.000	-17.083	45.500	100.068	-17.042	45.438				
P06MC	100.000	0.000	45.500	100.063	0.052	45.490				
P07D	100.000	1.000	45.500	100.068	1.063	45.479				
P08L7	100.000	17.083	45.500	100.063	17.115	45.448				
P09SD	100.000	22.286	45.500	100.052	22.307	45.464				
P10MW	100.000	21.469	44.000	100.073	21.474	43.974				
P11S	100.000	18.443	35.500	100.026	18.359	35.422	0.026	-0.083	-0.078	
P12ST	105.000	-19.521	35.500	104.995	-19.443	35.557	-0.005	0.078	0.057	
P13SD	105.000	-23.438	45.500	105.047	-23.448	45.427				
P14DT	105.000	1.000	45.500	0.042	0.021	-0.042				
P15SD	105.000	23.438	45.500	105.057	23.500	45.438				
P16ST	105.000	19.521	35.500	105.010	19.432	35.417	0.010	-0.089	-0.083	
P17T	105.000	1.000	35.500	104.995	0.974	35.474	-0.005	-0.026	-0.026	
P18S	114.000	-21.302	35.500	113.948	-21.385	35.505	-0.052	-0.083	0.005	
P19SD	114.000	-25.510	45.500	114.109	-25.521	45.417				
P20SD	114.000	25.510	45.500	114.047	25.568	45.438				
P21S	114.000	21.302	35.500	114.005	21.385	35.443	0.005	0.083	-0.057	
P22S	123.000	-23.380	35.500	123.083	-23.385	35.464	0.083	-0.005	-0.036	
P23SD	123.000	-27.531	45.500	123.078	-27.536	45.432				
P24SD	123.000	27.531	45.500	123.057	27.573	45.427				
P25S	123.000	23.380	35.500	122.979	23.286	35.438	-0.021	-0.094	-0.063	
P26S	130.000	-24.865	35.500	0.042	0.021	-0.042				
P27SD	130.000	-29.078	45.500	130.073	-29.099	45.417				
P28SD	130.000	29.078	45.500	130.021	29.125	45.432				
P29S	130.000	24.865	35.500	129.990	24.828	35.464	-0.010	-0.036	-0.036	
P30S	132.000	-25.286	35.500	132.021	-25.219	35.526	0.021	0.068	0.026	
P31SD	132.000	-29.510	45.500	132.089	-29.349	45.125				
P32SD	132.000	29.510	45.500	0.042	0.021	-0.042				

ACMAN/ACCALC.BL AI-554S 06-28-93

Block n	Project no.	Project name	Note A
A1-554	442	AOE-8	
Block ty e	**Assembly method**	**Assembled by**	**Note B**
GRAND BLOCK	RIGHT SIDE UP	WAYS 4	
Checkin stage	**Measuring date**	**Measured by**	**Note C**
ON BO RD	02-11-93	SH,FS	A2-269,270,293,294

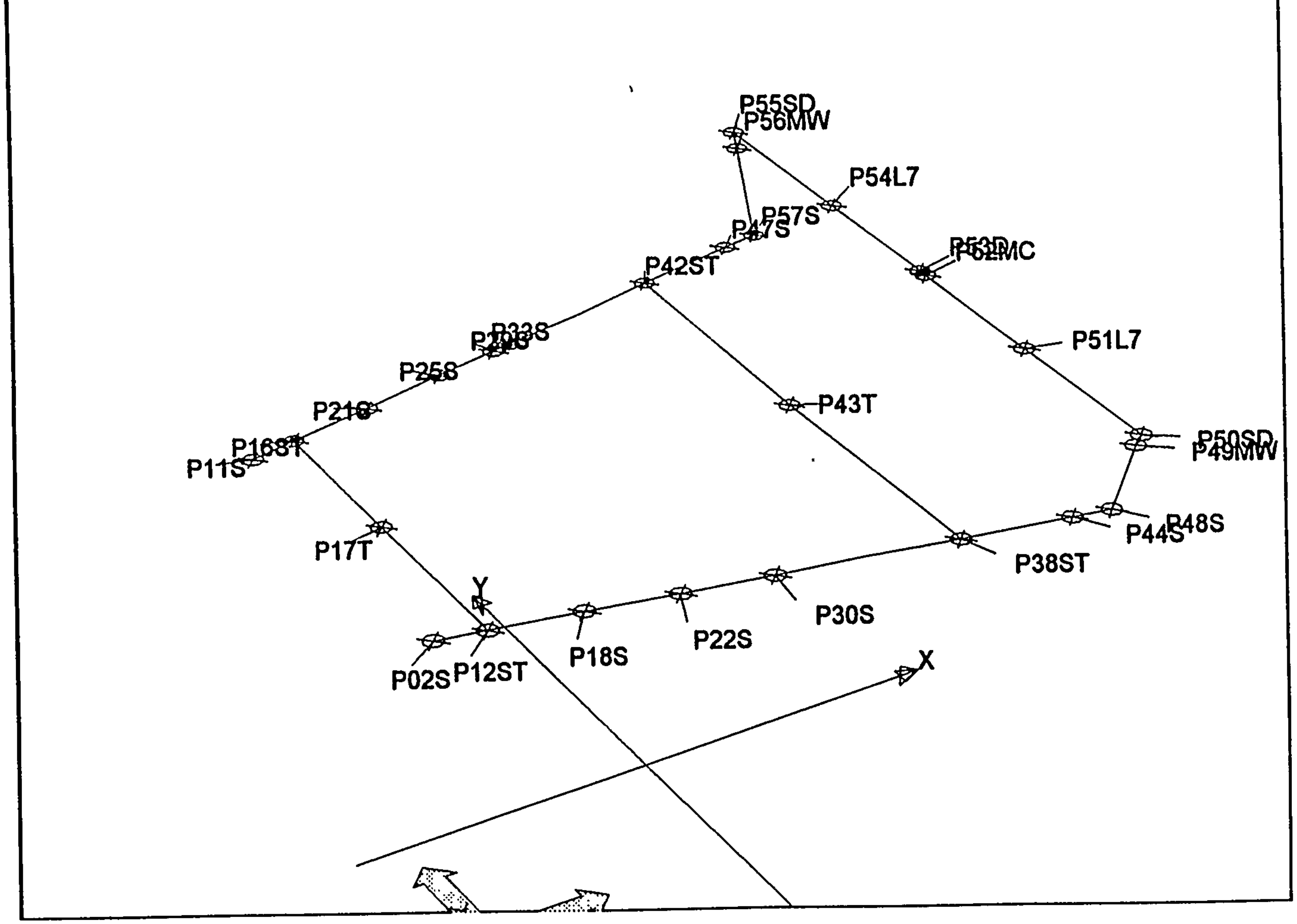
POINT	X_nom	Y_nom	Z_nom	X_mea	Y_mea	Z_mea	dX	dY	dZ	NOTE
P33S	132.000	25.286	35.500	132.042	25.349	35.490	0.042	0.063	-0.010	
P34S	141.000	-26.911	35.500	141.031	-27.094	35.542				
P35SD	141.000	-31.083	45.500	141.073	-31.438	45.396				
P36SD	141.000	31.083	45.500	141.010	31.526	45.411				
P37S	141.000	26.911	35.500	140.984	27.089	35.615				
P38ST	150.000	-29.052	35.500	150.010	-28.974	35.547	0.010	0.078	0.047	
P39SD	150.000	-33.271	45.500	150.073	-33.286	45.370				
P40DT	150.000	1.000	45.500	0.042	0.021	-0.042				
P41 SD	150.000	33.271	45.500	150.010	33.323	45.417				
P42ST	150.000	29.052	35.500	150.021	29.125	35.484	0.021	0.073	-0.016	
P43T	150.000	1.000	35.000	149.948	0.979	35.000	-0.052	-0.021	0.000	
P44S	161.000	-31.307	35.500	161.078	-31.339	35.464	0.078	-0.031	-0.036	
P45SD	161.000	-35.385	45.500	161.052	-35.411	45.401				
P46SD	161.000	35.385	45.500	160.755	35.385	45.422				
P47S	161.000	31.307	35.500	161.036	31.193	35.484	0.036	-0.115	-0.016	
P48S	165.000	-32.109	35.500	165.104	-32.036	35.604	0.104	0.073	0.104	
P49MW	165.000	-35.354	44.000	165.083	-35.333	43.979	0.083	0.021	-0.021	
P50SD	165.000	-36.109	45.500	165.042	-36.089	45.464	0.042	0.021	-0.036	
P51L7	165.000	-17.083	45.500	165.042	-17.089	45.510	0.042	-0.005	0.010	
P52MC	165.000	0.000	45.500	165.057	-0.021	45.469	0.057	-0.021	-0.031	
P53D	165.000	1.000	45.500	165.057	0.984	45.479	0.057	-0.016	-0.021	
P54L7	165.000	17.083	45.500	165.068	17.068	45.557	0.068	-0.016	0.057	
P55SD	165.000	36.109	45.500	165.042	36.089	45.453	0.042	-0.021	-0.047	
P56MW	165.000	35.354	44.000	165.042	35.281	43.964	0.042	-0.073	-0.036	
P57S	165.000	32.109	35.500	165.042	31.990	35.516	0.042	-0.120	0.016	

ACMAN/ACCALC.BL A1-554S 06-28-93



ACMAN/ACCALC.BL A1-554S 06-28-93

3DP 1.39



ACMAN/ACCALC.BL AI-554S 06-28-93

STATISTICS A1-554S 442 07:31:39

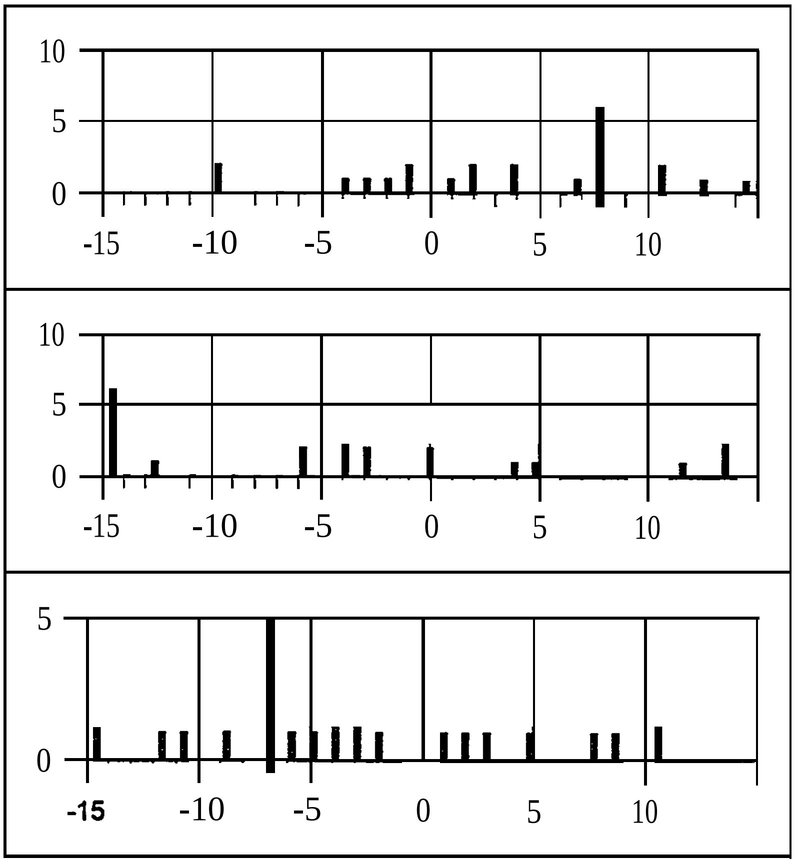
feet

1/16 INCH

X range
100.000
165.000

Y range
-36.110
36.110

Z range
35.000
45.500



x :	27
Mean:	5
Std :	7
Min:	-10
Max :	20
Range:	30
Y:	27
Mean:	-1
Std :	13
Min :	-23
Max :	25
Range:	48
z :	27
Mean:	-2
Std :	8
Min :	-16
Max :	20
Range:	36

ACMAN/ACCALC.BL A1-554U 06-28-93

Block n .	Project no.	Project name	Note A
A1-554	442	AOE-8	12:30 PM
Block ty e	Assembly method	Assemblied by	Note B
GRAND BLOCK	RIGHT SIDE UP	A6,A7	72
Checkin stage	Measuring date	Measured by	Note C
ON BL CK	02-09-93	SH,FS	A2-269,270,293,294

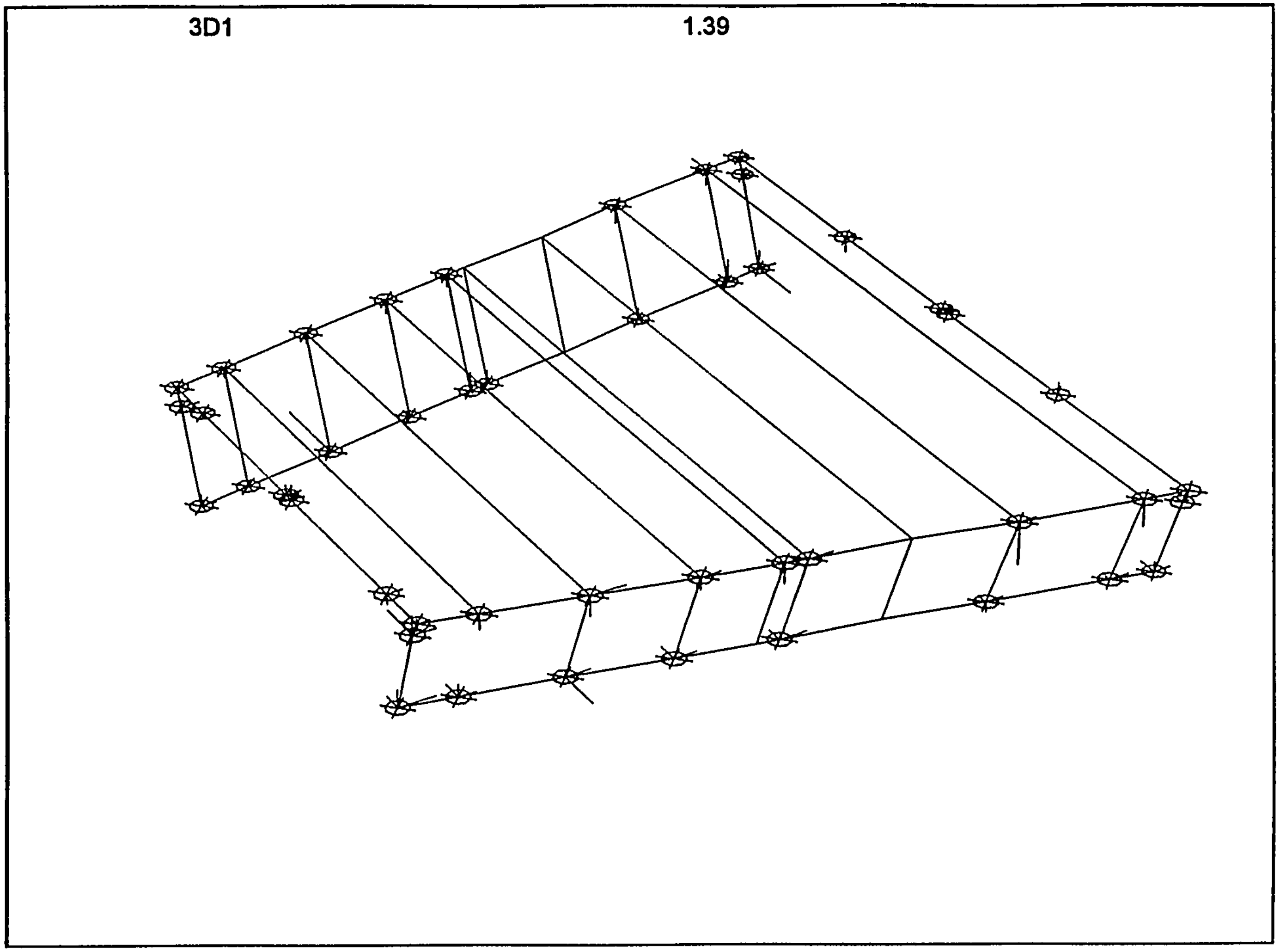
POINT	X_nom	Y_nom	Z_nom	X_mea	Y_mea	Z_mea	dX	dY	dZ	NOTE
O01	0.000	0.000	0.000	0.005	0.021	0.000				
P02S	100.000	-18.443	35.500	100.078	-18.401	35.536	0.078	0.042	0.036	
P03MW	100.000	-21.469	44.000	100.047	-21.375	44.042	0.047	0.094	0.042	
P04SD	100.000	-22.286	45.500	100.026	-22.240	45.510	0.026	0.047	0.010	
P05L7	100.000	-17.083	45.500	100.031	-17.042	45.479	0.031	0.042	-0.021	
P06MC	100.000	0.000	45.500	100.026	0.057	45.531	0.026	0.057	0.031	
P07D	100.000	1.000	45.500	100.031	1.063	45.521	0.031	0.063	0.021	
P08L7	100.000	17.083	45.500	100.021	17.115	45.490	0.021	0.031	-0.010	
P09SD	100.000	22.286	45.500	100.016	22.307	45.505	0.016	0.021	0.005	
P10MW	100.000	21.469	44.000	100.036	21.479	44.016	0.036	0.010	0.016	
P11S	100.000	18.443	35.500	100.031	18.422	35.526	0.031	-0.021	0.026	
P12ST	105.000	-19.521	35.500	105.036	-19.474	35.526	0.036	0.047	0.026	
P13SD	105.000	-23.438	45.500	105.010	-23.417	45.469	0.010	0.021	-0.031	
P14DT	105.000	1.000	45.500	0.005	0.021	0.000				
P15SD	105.000	23.438	45.500	105.021	23.448	45.479	0.021	0.010	-0.021	
P16ST	105.000	19.521	35.500	104.995	19.500	35.510	-0.005	-0.021	0.010	
P17T	105.000	1.000	35.000	150.380	1.042	35.542				
P18S	114.000	-21.302	35.500	114.052	-21.401	35.510	0.052	-0.099	0.010	
P19SD	114.000	-25.510	45.500	114.073	-25.469	45.458	0.073	0.042	-0.042	
P20SD	114.000	25.510	45.500	114.010	25.516	45.479	0.010	0.005	-0.021	
P21S	114.000	21.302	35.500	114.010	21.484	35.495	0.010	0.182	-0.005	
P22S	123.000	-23.380	35.500	123.047	-23.333	35.505	0.047	0.047	0.005	
P23SD	123.000	-27.531	45.500	123.042	-27.479	45.474	0.042	0.052	-0.026	
P24SD	123.000	27.531	45.500	123.021	27.526	45.469	0.021	-0.005	-0.031	
P25S	123.000	23.380	35.500	123.005	23.406	35.495	0.005	0.026	-0.005	
P26S	130.000	-24.865	35.500	0.005	0.021	0.000				
P27SD	130.000	-29.078	45.500	130.036	-29.036	45.458	0.036	0.042	-0.042	
P28SD	130.000	29.078	45.500	129.984	29.078	45.474	-0.016	0.000	-0.026	
P29S	130.000	24.865	35.500	130.005	24.854	35.542	0.005	-0.010	0.042	
P30S	132.000	-25.286	35.500	132.057	-25.250	35.510	0.057	0.036	0.010	
P31SD	132.000	-29.510	45.500	132.052	-29.396	45.500	0.052	0.115	0.000	
P32SD	132.000	29.510	45.500	0.005	0.021	0.000				

ACMAN/ACCALC.BL A1-554U 06-28-93

Block n	Project no.	Project name	Note A
A1-554	442	AOE-8	12:30 PM
Block ty e	Assembly method	Assembled by	Note B
GRAND BLOCK	RIGHT SIDE UP	A6,A7	72
Checkin stage	Measuring date	Measured by	Note C
ON BL CK	02-09-93	SH,FS	A2-269,270,293,294

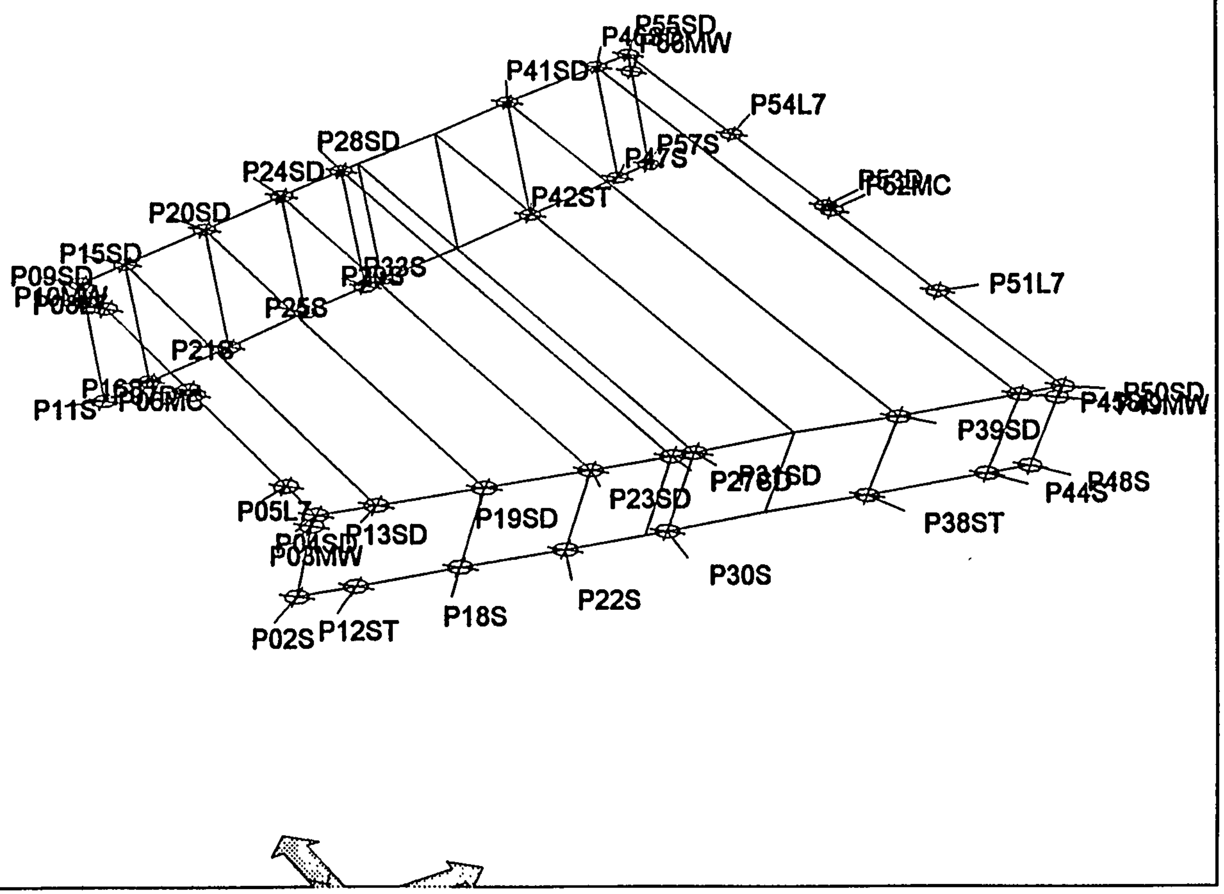
POINT	X_nom	Y_nom	Z_nom	X_mea	Y_mea	Z_mea	dX	dY	dZ	NOTE
P33S	132.000	25.286	35.500	132.005	25.297	35.531	0.005	0.010	0.031	
P34S	141.000	-26.911	35.500	141.104	-27.172	35.490				
P35SD	141.000	-31.083	45.500	141.036	-31.380	45.438				
P36SD	141.000	31.083	45.500	140.974	31.438	45.453				
P37S	141.000	26.911	35.500	140.995	27.182	35.510				
P38ST	150.000	-29.052	35.500	150.036	-29.031	35.479	0.036	0.021	-0.021	
P39SD	150.000	-33.271	45.500	150.036	-33.234	45.411	0.036	0.036	-0.089	
P40DT	150.000	1.000	45.500	0.005	0.021	0.000				
P41SD	150.000	33.271	45.500	149.969	33.276	45.458	-0.031	0.005	-0.042	
P42ST	150.000	29.052	35.500	149.984	29.031	35.526	-0.016	-0.021	0.026	
P43T	150.000	1.000	35.000	0.005	0.021	0.000				
P44S	161.000	-31.307	35.500	161.042	-31.292	35.500	0.042	0.016	0.000	
P45SD	161.000	-35.385	45.500	161.016	-35.359	45.443	0.016	0.026	-0.057	
P46SD	161.000	35.385	45.500	160.969	35.443	45.464	-0.031	0.057	-0.036	
P47S	161.000	31.307	35.500	161.021	31.344	35.552	0.021	0.036	0.052	
P48S	165.000	-32.109	35.500	165.036	-32.068	35.521	0.036	0.042	0.021	
P49MW	165.000	-35.354	44.000	165.016	-35.328	44.005	0.016	0.026	0.005	
P50SD	165.000	-36.109	45.500	165.000	-36.089	45.500	0.000	0.021	0.000	
P51L7	165.000	-17.083	45.500	165.005	-17.099	45.526	0.005	-0.016	0.026	
P52MC	165.000	0.000	45.500	165.016	-0.005	45.516	0.016	-0.005	0.016	
P53D	165.000	1.000	45.500	165.010	1.000	45.500	0.010	0.000	0.000	
P54L7	165.000	17.083	45.500	165.021	17.094	45.469	0.021	0.010	-0.031	
P55SD	165.000	36.109	45.500	165.021	36.089	45.490	0.021	-0.021	-0.010	
P56MW	165.000	35.354	44.000	165.021	35.333	44.000	0.021	-0.021	0.000	
P57S	165.000	32.109	35.500	165.042	31.984	35.542	0.042	-0.125	0.042	

ACMAN/ACCALC.BL A1-554U 06-28-93



ACMAN/ACCALC.BL A1-554U 06-28-93

3DP 1.39



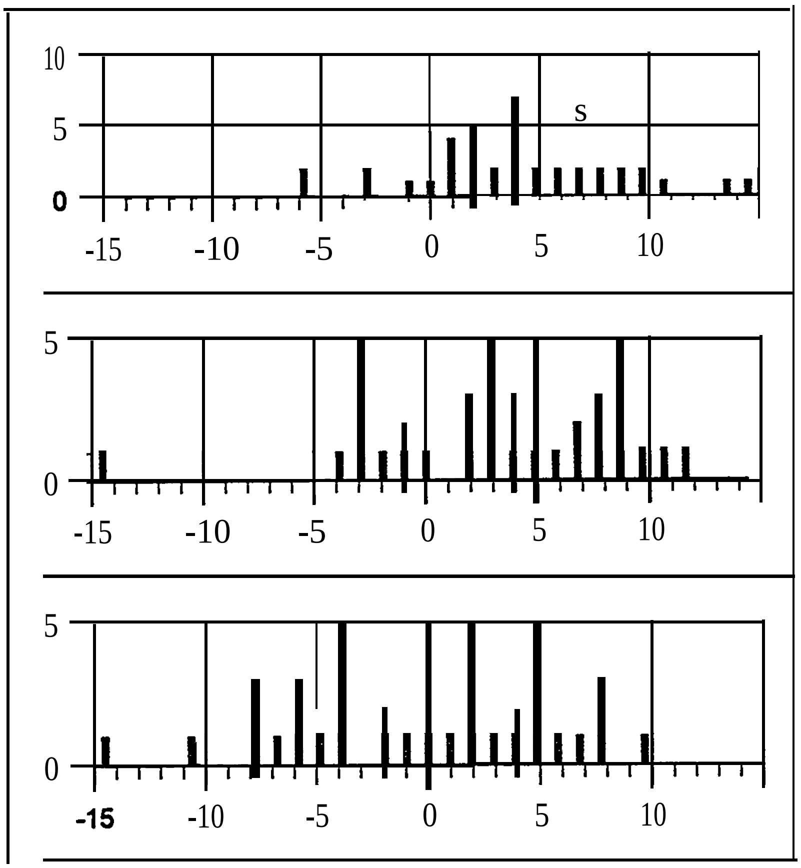
ACMAN/ACCALC.BL AI-554U 06-28-93

A1-554U 442 07:40:10

STATISTICS
feet

1/16 INCH

X range
100.000
165.000



x :	46
Mean:	4
Std :	4
Min :	-6
Max :	15
Range:	21

Y range
-36.110
36.110

Y:	46
Mean:	4
Std :	9
Min :	-24
Max :	35
Range:	59

Z range
35.500
45.500

Z:	46
Mean:	0
Std :	6
Min :	-17
Max :	10
Range:	27

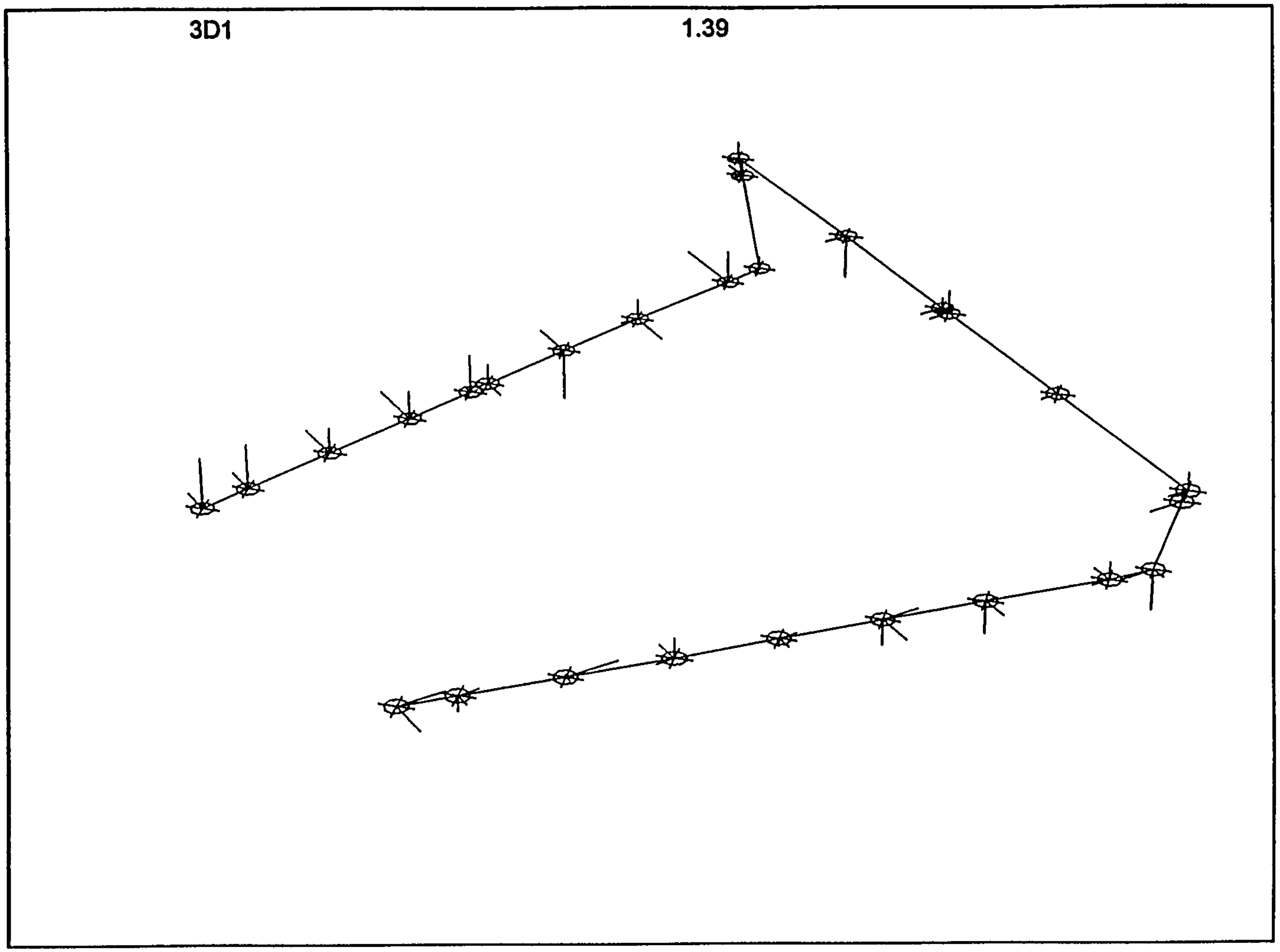
Block n	Project no.	Project name	Note A
A2-554 /A2-554U	442	AOE-8	
Block ty e	Assembly method	Assemblied by	Note B
GRAND BLOCK	MERGED	WAYS 4	
Checkin stage	Measuring date	Measured by	Note C
ON BO RD	02-12-93	SH,FS	A2-269,270,293,294

POINT	X_mea1	Y_mea1	Z_mea1	X_mea2	Y_mea2	Z_mea2	dX	dY	dZ	NOTE
O01-01	0.042	0.021	-0.042	0.005	0.021	0.000				
P02-02	99.984	-18.313	35.542	100.078	-18.401	35.536	0.094	-0.089	-0.005	
P03-03	100.083	-21.380	44.000	100.047	-21.375	44.042				
P04-04	100.063	-22.240	45.536	100.026	-22.240	45.510				
P05-05	100.068	-17.042	45.438	100.031	-17.042	45.479				
P06-06	100.063	0.052	45.490	100.026	0.057	45.531				
P07-07	100.068	1.063	45.479	100.031	1.063	45.521				
P08-08	100.063	17.115	45.448	100.021	17.115	45.490				
P09-09	100.052	22.307	45.464	100.016	22.307	45.505				
P10-10	100.073	21.474	43.974	100.036	21.479	44.016				
P11-11	100.026	18.359	35.422	100.031	18.422	35.526	0.005	0.063	0.104	
P12-12	104.995	-19.443	35.557	105.036	-19.474	35.526	0.042	-0.031	-0.031	
P13-13	105.047	-23.448	45.427	105.010	-23.417	45.469				
P14-14	0.042	0.021	-0.042	0.005	0.021	0.000				
P15-15	105.057	23.500	45.438	105.021	23.448	45.479				
P16-16	105.010	19.432	35.417	104.995	19.500	35.510	-0.016	0.068	0.094	
P18-18	113.948	-21.385	35.505	114.052	-21.401	35.510	0.104	-0.016	0.005	
P19-19	114.109	-25.521	45.417	114.073	-25.469	45.458				
P20-20	114.047	25.568	45.438	114.010	25.516	45.479				
P21-21	114.005	21.385	35.443	114.010	21.484	35.495	0.005	0.099	0.052	
P22-22	123.083	-23.385	35.464	123.047	-23.333	35.505	-0.036	0.052	0.042	
P23-23	123.078	-27.536	45.432	123.042	-27.479	45.474				
P24-24	123.057	27.573	45.427	123.021	27.526	45.469				
P25-25	122.979	23.286	35.438	123.005	23.406	35.495	0.026	0.120	0.057	
P26-26	0.042	0.021	-0.042	0.005	0.021	0.000				
P27-27	130.073	-29.099	45.417	130.036	-29.036	45.458				
P28-28	130.021	29.125	45.432	129.984	29.078	45.474				
P29-29	129.990	24.828	35.464	130.005	24.854	35.542	0.016	0.026	0.078	
P30-30	132.021	-25.219	35.526	132.057	-25.250	35.510	0.036	-0.031	-0.016	
P31-31	132.089	-29.349	45.125	132.052	-29.396	45.500				
P32-32	0.042	0.021	-0.042	0.005	0.021	0.000				
P33-33	132.042	25.349	35.490	132.005	25.297	35.531	-0.036	-0.052	0.042	

Block n	Project no.	Project name	Note A
A2-554 /A2-554U	442	AOE-8	
Block ty e	Assembly method	Assembled by	Note B
GRAND BLOCK	MERGED	WAYS 4	
Checkin stage	Measuring date	Measured by	Note C
ON BO RD	02-12-93	SH,FS	A2-269,270,293,294

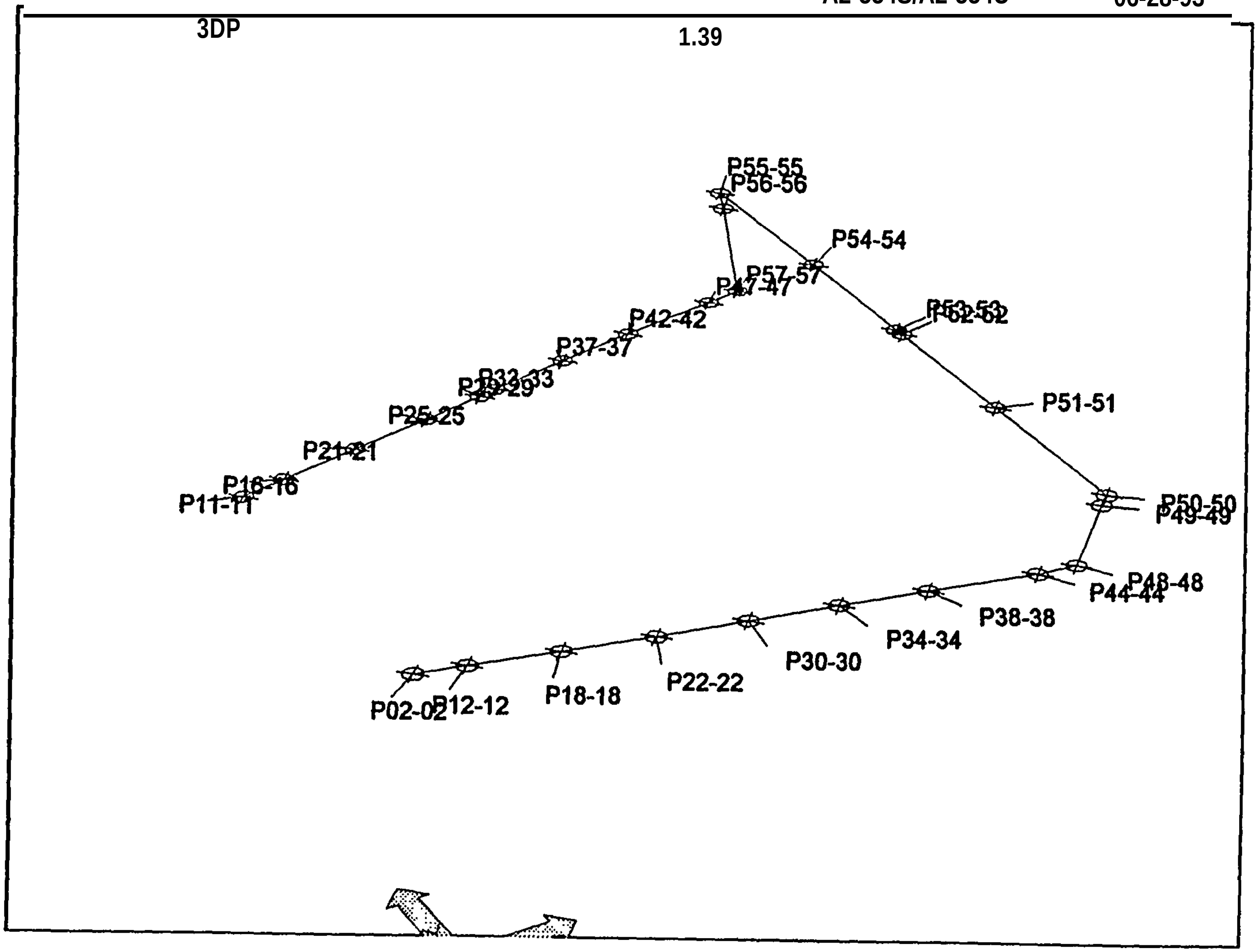
POINT	X_mea1	Y_mea1	Z_mea1	X_mea2	Y_mea2	Z_mea2	dX	dY	dZ	NOTE
P34-34	141.031	-27.094	35.542	141.104	-27.172	35.490	0.073	-0.078	-0.052	
P35-35	141.073	-31.438	45.396	141.036	-31.380	45.438				
P36-36	141.010	31.526	45.411	140.974	31.438	45.453				
P37-37	140.984	27.089	35.615	140.995	27.182	35.510	0.010	0.094	-0.104	
P38-38	150.010	-28.974	35.547	150.036	-29.031	35.479	0.026	-0.057	-0.068	
P39-39	150.073	-33.286	45.370	150.036	-33.234	45.411				
P40-40	0.042	0.021	-0.042	0.005	0.021	0.000				
P41-41	150.010	33.323	45.417	149.969	33.276	45.458				
P42-42	150.021	29.125	35.484	149.984	29.031	35.526	-0.036	-0.094	0.042	
P43-43	149.948	0.979	35.000	0.005	0.021	0.000				
P44-44	161.078	-31.339	35.464	161.042	-31.292	35.500	-0.036	0.047	0.036	
P45-45	161.052	-35.411	45.401	161.016	-35.359	45.443				
P46-46	160.755	35.385	45.422	160.969	35.443	45.464				
P47-47	161.036	31.193	35.484	161.021	31.344	35.552	-0.016	0.151	0.068	
P48-48	165.104	-32.036	35.604	165.036	-32.068	35.521	-0.068	-0.031	-0.083	
P49-49	165.083	-35.333	43.979	165.016	-35.328	44.005	-0.068	0.005	0.026	
P50-50	165.042	-36.089	45.464	165.000	-36.089	45.500	-0.042	0.000	0.036	
P51-51	165.042	-17.089	45.510	165.005	-17.099	45.526	-0.036	-0.010	0.016	
P52-52	165.057	-0.021	45.469	165.016	-0.005	45.516	-0.042	0.016	0.047	
P53-53	165.057	0.984	45.479	165.010	1.000	45.500	-0.047	0.016	0.021	
P54-54	165.068	17.068	45.557	165.021	17.094	45.469	-0.047	0.026	-0.089	
P55-55	165.042	36.089	45.453	165.021	36.089	45.490	-0.021	0.000	0.036	
P56-56	165.042	35.281	43.964	165.021	35.333	44.000	-0.021	0.052	0.036	
P57-57	165.042	31.990	35.516	165.042	31.984	35.542	0.000	-0.005	0.026	

ACMAN/ACCALC.BL A2-554S/A2-554U 06-28-93



ACMAN/ACCALC.BL A2-554S/A2-554U 06-28-93

3DP 1.39



ACMAN/ACCALC.BL A2-554S/A2-554U 06-28-93

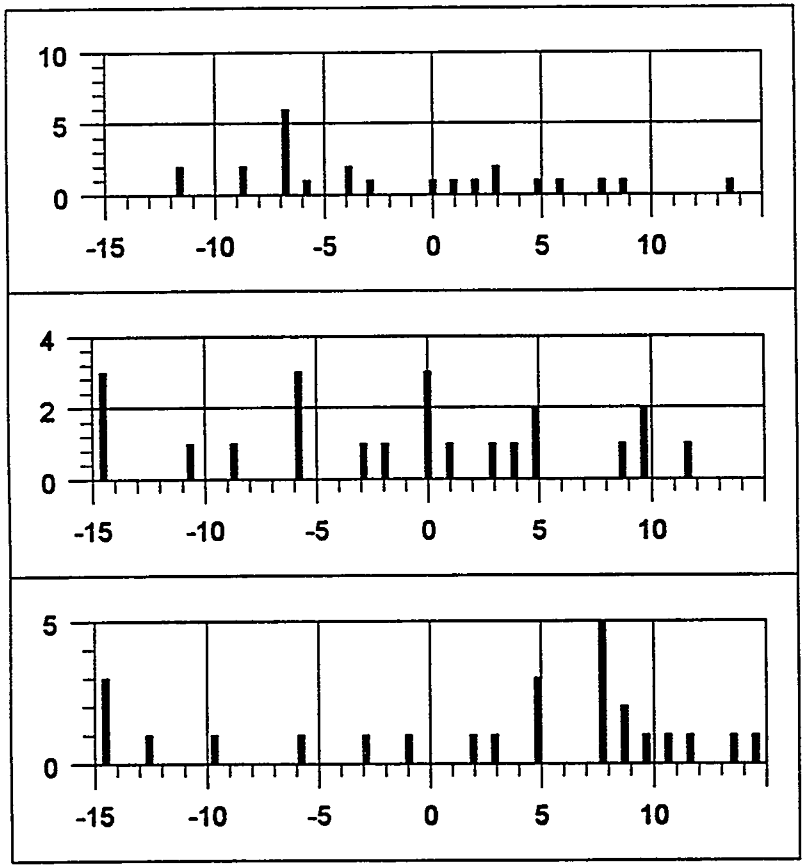
TATISTICS A2-554S/A2-554442 12:02:30

feet

X range
99.984
165.104

Y range
-36.089
36.089

Z range
35.417
45.557



1/16 INCH

X :	26
Mean :	-1
Std :	9
Min :	-13
Max :	20
Range :	33
Y :	26
Mean :	2
Std :	12
Min :	-18
Max :	29
Range :	47
Z :	26
Mean :	2
Std :	10
Min :	-20
Max :	20
Range :	40

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NSRP Coordinator
The University of Michigan
Transportation Research Institute
Marine Systems Division
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Ann Arbor, MI 48109-2150
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Fax: (313) 936-1081