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BIF-107-24045-68
Copy No. 1 of 2
Pages: 5

TO: H. Ferger

DATE: 24 October 1968

SUBJECT: A Proposal For a Vehicle Based Alignment System

FROM: W. G. Smith

1.0 Background

The Systems Design Department has reviewed the GE alignment document (PDR) and submitted comments per memo BIF-107-24004-68. The present ground alignment technique is questioned from an accuracy standpoint since the quoted GE seismic specification of 5 to 100 Hz (not obtained from site seismic survey data) includes the natural frequencies of the towers (11.6 cps calculated) and without sufficient tower damping will introduce large errors in the alignment equipment. A site seismic survey is necessary to establish the real environment (which may indicate that little or no coupling between the input frequency and the tower natural frequency is present). However, until a seismic specification is established from actual site data, the present specification is the only guideline available for evaluation of tower and instrument stability. An area which was not covered by the PDR was the effects of motions of the towers, scaffolding and MM structure with respect to the ability of an operator to resolve the motion interactions and read an instrument to sufficient accuracy.

The Aerospace Program Office recommended examination of a vehicle based approach, by GE, to simplify the alignment equipment and improve accuracy due to reduction of the effects of seismic disturbances since the alignment equipment is attached to and moving with the MM structure.

GE performed a tradeoff study of a vehicle based alignment concept and concluded that the vehicle based system is:

a. More expensive due to requirement for realignment of the fixture before each use.

b. Less accurate due to deflections of alignment fixture with respect to the theodolites.

c. Less adaptable to vehicle changes.

d. Heavy.

A review of the GE position was made by the Systems Design Department and it was concluded that the vehicle based system proposed (for comparison with

GE ground based system) by GE had many deficiences but was still, in concept, preferable to a ground based system. (See memo BIF-107-24013-68.) Therefore, further work on a vehicle based system was recommended.

2.0 Scope

This memo discusses the necessary modifications required to the GE vehicle based system to negate all the objections presented by GE.

3.0 Discussion

The GE vehicle based system has a basic inadequacy associated with its design in that it assumes the same theodolite positioning and procedures as the ground based system (towers). This arrangement necessitates use of rails with sliding theodolites and makes tooling alignment difficult (may require ground alignment verification before use). In addition, the tooling itself is used to maintain reference positions (by plunging of theodolites from one to the other) requiring unnecessary accuracy between theodolite positions. This requirement dictates use of a very stiff fixture for mounting of the theodolites and has resulted in a very heavy alignment tool. Reevaluation of the design has been accomplished with the following objectives:

a. Elimination of sliding theodolites - only fixed emplacements considered.

b. No transfer requirement for maintaining reference positions.

c. No high stiffness requirement - use gravity as basic reference between positions.

d. Relative light weight and easy transportability.

e. Eliminate checkout requirement for tool before each use - keeps cost down.

f. Permit vehicle changes without major impact on tooling - simple interface.

4.0 Proposed Design (Ref.: Figures (Pages 16 and 17) of Atch 1)

A vehicle based approach is proposed which can be used for adjusting the equipment locations initially with respect to gravity or the equipment may be installed on a prior sub-assembly to a tolerance consistent with the field of view of the gravity referenced autocollimators (20/30 $\overline{\text{min}}$ with accuracy of 1 $\overline{\text{sec}}$ over full field of view per K&E capability with additional reticle).

The vehicle based alignment tool is a welded aluminum box beam structure which is mounted on the Station 517 interface and is indexed radially to the z axis by the close tolerance tooling holes located on the interface ring. The autocollimators are all mounted rigidly. The vertically oriented autocollimators are referenced to an oil pool before use (gravity reference).

A gauging pin is inserted in the tool to measure linear position of the tripod from Station 517 ("go-no go" type). A Talyvel level is mounted to the main cross beam and is used for initial positioning of the MM structure (2^{o} off vertical). This instrument is mounted on the fixture for convenience but could be mounted directly to the MM interface or the angular positioning fixture located at the base of the MM structure. Lifting lugs are provided for handling of the tool since its weight will be such (175-200 lbs) that manual lifting will be difficult. Scaffolding is required to elevate the alignment tool operators to the Station 517 interface. This scaffolding can be of the simple building construction type (tubing and braces). Access to the upper portion of the Station 517 interface is necessary to sight through the autocollimators. If any adjustments are required on the Star Tracker, TM tripod or T-Bar, separate scaffolds will be required to permit access to these areas. The vehicle based alignment eliminates the need for a vehicle spacer at GE (only) and the height required for the scaffolds is less than the present design.

The alignment procedure is as outlined on pages 19, 20 and 21 of Attachment 1.

The alignment equipment necessary to perform the above operations is as follows:

four autocollimators (minimum)
one Talyvel electronic level plus readout gauge
one indexing pin
one alignment fixture (welded aluminum strongback)
two periscope assemblies

The vehicle modifications necessary to perform the alignment is as outlined on page 22 of Attachment 1.

It should be noted that the FAMS/COA sensor (mounted on the tripod leg adjacent to the jettisonable door) and the FAMS/Star Tracker sensor (mounted on the tripod leg adjacent to the star trackers) are presently installed on the tripod as a sub-assembly and referenced to the tripod hub reference target. Since the COA is not in place, at GE, when the alignments are performed, it is desirable to verify the position of the FAMS/COA sensor with respect to the hub reference target. This operation is performed by the proposed alignment fixture (except the target is moved to the roll axis shaft end) since the FAMS/COA sensor position cannot be checked by the flight alignment system since it is incomplete at this time. This alignment check insures alignment of the sensor with respect to the shaft reference target before shipping to PPAC. However, the FAMS/Star Tracker sensor is not checked by the alignment fixture since the star trackers are already installed and to

check the positioning of the sensor it is only necessary to turn on the light source in the star tracker (after alignment of the star tracker to the hub) and measure the output of the sensor for null position. Since the sensor is aligned to the shaft reference target (as a sub-assembly) and the star tracker is aligned to the shaft reference target by the alignment fixture, misalignment of the sensor (occurring between sub-assembly and final assembly) is easily measured by the FAMS/Star Tracker output signal.

A desirable approach, which has not been examined by the Systems Design Department to date, is to design the flight alignment system so it may be used for all ground alignments as well. It should be noted that this system requires additional complexity than is currently designed into the flight alignment system. Since it is difficult to ascertain whether the component or the sensor itself has shifted, it will be necessary to reference one system to another or a base reference system. As an example, if the star tracker is positioned with respect to the FAMS/Star Tracker sensor, it is difficult to determine if the sensor has shifted (let's say, after vibration, transportation, or hot-dogging) or the star tracker has shifted, unless both are referenced to some common point such as the shaft reference target. (This capability is provided by the proposed vehicle alignment fixture.)

5.0 Conclusions and Recommendations

The proposed alignment fixture satisfies all the original design conditions (see paragraph 3.0) and reduces the facilities problem at the associate contractors since there are no stringent environmental provisions required. The most significant advantage of the design is the reduction of seismic disturbances between the MM vehicle and the alignment equipment. The relatively simple tool which has been proposed will perform all the necessary alignment functions within an accuracy of five arc seconds. A reservation of the use of the fixture is that the Station 517 interface must be available for mounting. This requirement does not permit equipment alignment (by means of this alignment fixture) after the LM is attached. However, this contingency has been considered and bolt-on supplemental fixtures have been designed into the system (Ref.: Page 18 of Attachment 1) to permit alignment checks at DAC (after LM mating) and at VAFB when the vehicle is mated and vertical. (This requirement necessitates the addition of Talyvel levels on the critical components.) These same fixtures can be designed to check the alignments across the LM/MM interface (ATS and ARSI (attitude reference) to roll axis shaft reference target).

The material in Attachment 1 was orally presented to GE on 3 October 1968 (one copy was left with A Steinmayer of GE) and no objections were given by GE which would prevent incorporation of the concept into the program. It is therefore recommended that GE be directed to evaluate the proposed design as a possible alternate if the present or future problems with the ground alignment system cannot be resolved. It should be noted that GE is proceeding with hardware development of the ground based system and will have their facility completed by the first quarter of 1969. This will provide a basis

for evaluation of the ground based system and should any unresolvable problems be encountered at this time, it would be desirable to have an alternate system which could be implemented on a tight schedule. It is therefore imperative that the vehicle based system be studied at the earliest possible time so that vehicle modifications can be evaluated and long lead items procured.

W. G. Smith

Approved: G. M. Kelsey

WGS:dm

Attachment: 1. Briefing Charts BIF-107-24042-68, Copy 4, dated 30 September 1968, "Proposed Vehicle Based Alignment System" 30 pages

cc: J. Henry
J. Steinman
D. Willens

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BIF-107-24042-68
COPY NO. 4 OF 4
30 SEPTEMBER 1968
PAGES: 30

PROPOSED VEHICLE BASED ALIGNMENT SYSTEM

W. G. SMITH
W. H. WHITE

HANDLE VIA BYEMAN
CONTROL SYSTEM
ONLY

CONTENTS

DEFINITIONS

PPAC	-	E. K.
FAMS	-	FLIGHT ALIGNMENT MONITOR SYSTEM
TM	-	TRACKING MIRROR
COA	-	CAMERA OPTICAL AXIS

OBJECTIVES

OBJECTIVES

- TO REPLACE THE GROUND BASED TOWERS WITH A VEHICLE BASED FIXTURE
  - / PRESENT A WORKABLE CONCEPT
  - / NO ATTEMPT TO OPTIMIZE THE DESIGN
- TO CONSIDER THE SYSTEM ASPECTS, I. E., ALIGNMENT REQUIREMENTS AND FACILITIES AT EACH CONTRACTOR AND AT VAFB.

ALIGNMENT REQUIREMENTS (MEASUREMENT ONLY)

1. ALIGN TRIPOD TO STATION 517 INTERFACE (TWO AXES)

2. POSITION TRIPOD FROM STATION 517 (LINEAR MEASUREMENT - OPTIONAL)

3. ALIGN STAR TRACKERS TO ROLL AXIS SHAFT REFERENCE (THREE AXES) AND STATION 517 TOOLING HOLES (ANGLE)

4. CHECK ALIGNMENT OF FAMS WITH RESPECT TO ROLL AXIS SHAFT REFERENCE (TWO AXES)

5. ALIGN NULL POSITION OF T-BAR PITCH SHAFT SIMULATOR TO ROLL AXIS SHAFT REFERENCE (ESTABLISH ENCODER NULL POSITIONS).

6. INDEX T-BAR SIMULATOR IN PITCH AND ROLL AND READOUT VALUES USING ENCODER OUTPUTS (CALIBRATION AND MINIMUM TRAVEL CHECK).

7. CHECK NON-ORTHOGONALITY BETWEEN PITCH AND ROLL AXES.

G. E. GROUND BASED

ALIGNMENT SYSTEM

GE GROUND BASED ALIGNMENT APPROACH

- EQUIPMENT REQUIRED
  - / FIVE ALIGNMENT TOWERS (APPROXIMATELY 40 FT LONG) WITH TWO OF THE TOWERS CONNECTED BY RAILS
  - / FACILITY HAVING:
    - TEMPERATURE CONTROLLED ENVIRONMENT ($\pm 2^{\circ}$)
    - LOW AIR FLOW REQUIREMENT (1.5 FT/SEC)
    - LOW SEISMIC DISTURBANCES
- BASIC PROCEDURES
  - / USING TOWER BASED THEODOLITES SIGHT TARGETS ON HUB REFERENCE AND STAR TRACKER AND ALIGN BY AUTOCOLLIMATION
  - / SET DISTANCE OF HUB REFERENCE TARGET TO STATION 517 BY JACKSCREW ON THEODOLITE #1
  - / USING VEHICLE BASED THEODOLITE (IN POOR OPENING) CHECK ALIGNMENT BETWEEN FAMS AND HUB REFERENCE TARGET (TALYVEL OFFSET 2° AT DAC)
  - / ALIGN PITCH/ROLL SIMULATOR TO HUB REFERENCE BY AUTOCOLLIMATION
  - / CHECK ALIGNMENT OF PITCH/ROLL SIMULATOR AT SECOND POSITION AS CHECK AGAINST WEIGHTED SIMULATOR (LINEARITY CHECK)
  - / INDEX PITCH/ROLL SIMULATOR FOR CLOCKING CALIBRATION
  - / CHECK NON-ORTHOGONALITY EFFECTS USING TALYVEL ON T-BAR

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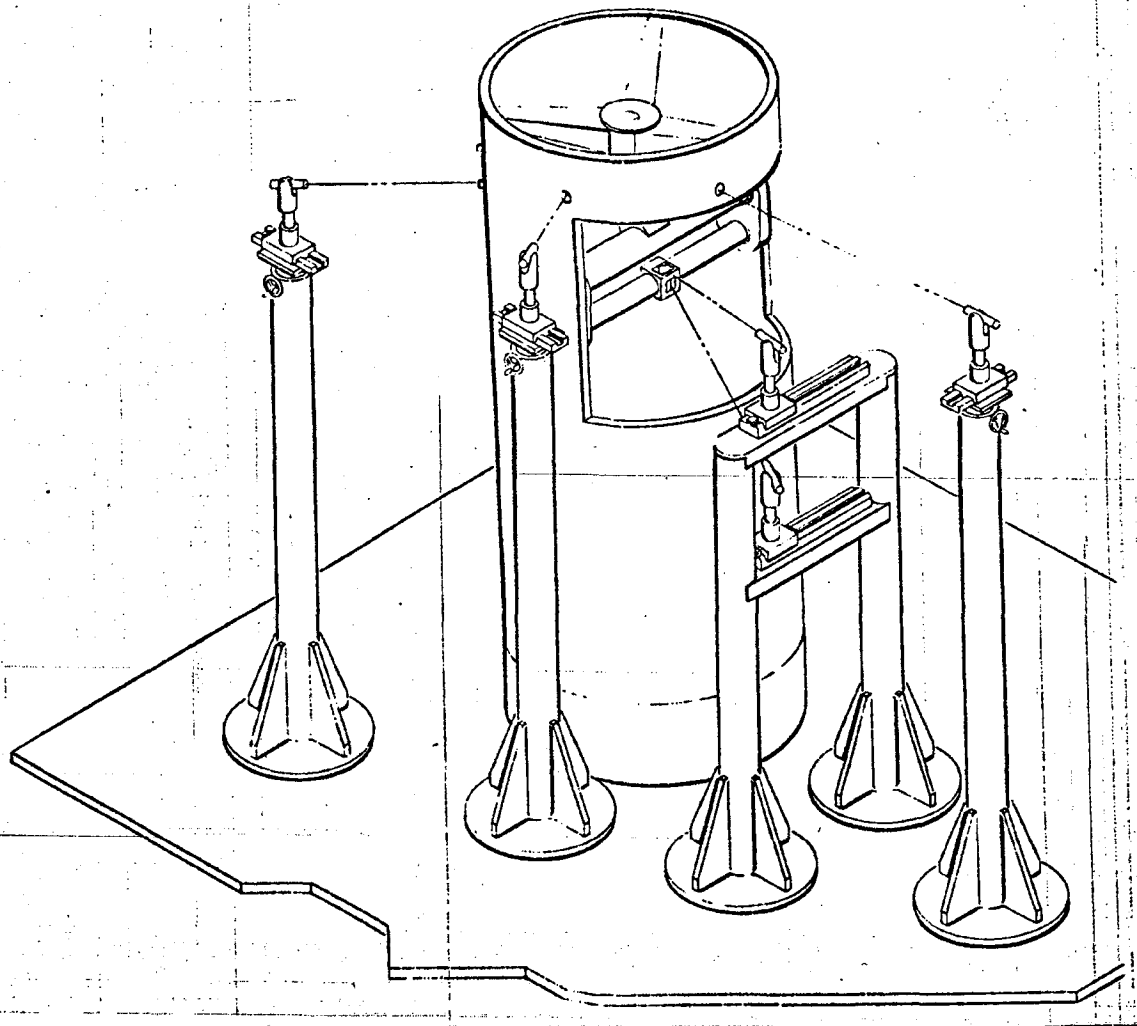
FIGURE 1

GROUND BASED-VIEWING PORTS



HIS ARE

PROBLEMS WITH PRESENT GE GROUND BASED ALIGNMENT SCHEME

- SEISMIC PROBLEMS
  - / DIFFICULTY IN PERFORMING SURVEY
  - / DAMPING DIFFICULT TO ESTIMATE
  - / SEISMIC ISOLATION MAY BE REQUIRED
- ACCURACY
  - / CANNOT ASSESS INACCURACIES INTRODUCED BY TOWER, SCAFFOLDING, MM SEPARATION
  - / TRANSFER TECHNIQUE INTRODUCES ADDITIONAL INACCURACIES
- FACILITIES
  - / FLOOR SPACE
  - / TEMPERATURE AND AIR FLOW
  - / SCAFFOLDING
- EXPENSIVE
- SCHEDULE
- CANNOT BE USED TO CHECK EQUIPMENT ALIGNMENTS AFTER:
  - / EXPOSURE TO TRANSPORTATION ENVIRONMENT
  - / REPLACEMENT OF COMPONENTS (NOT CONSIDERED FOR PAD REPLACEMENT)

  UNLESS VEHICLE IS RETURNED TO ALIGNMENT FACILITY
- SIGHTING HOLES REQUIRED IN STRUCTURE
- DOOR MUST BE REMOVED AND SUBSTITUTE DOOR INSTALLED

G.E. VEHICLE BASED

ALIGNMENT SYSTEM

GE APPROACH TO VEHICLE BASED ALIGNMENT

- ASSUMED SAME ALIGNMENT SEQUENCE AND TOOLING POSITIONS (THEODOLITES) AS GROUND BASED ALIGNMENT

IMPACT (PER GE EVALUATION)

/ UNNECESSARY STIFFNESS REQUIREMENT

/ CHECKOUT OF TOOLING PROBABLY REQUIRED BEFORE EACH USE (ROTATING ARM VERSION ONLY)

/ EXPENSIVE

/ NOT FLEXIBLE TO VEHICLE CHANGES

/ HEAVY (STIFFNESS REQUIREMENT)

FIGURE 2

VEHICLE BASED-FIXED ARM

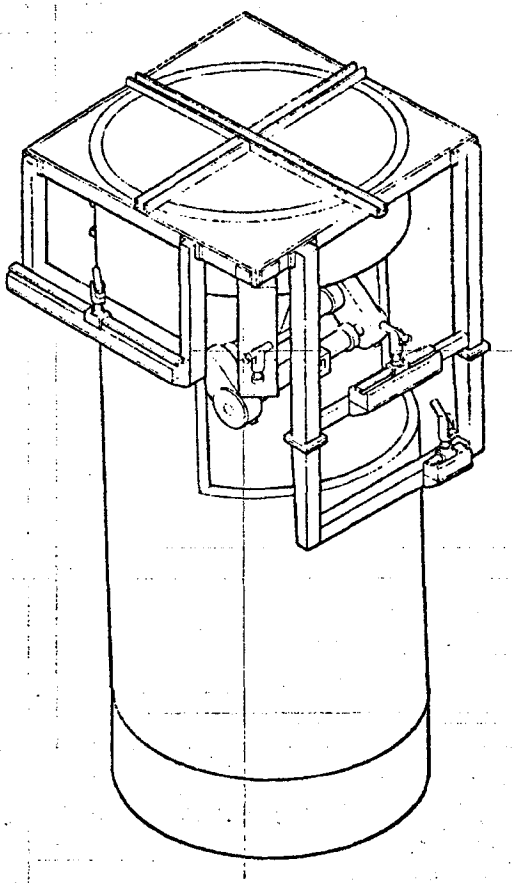
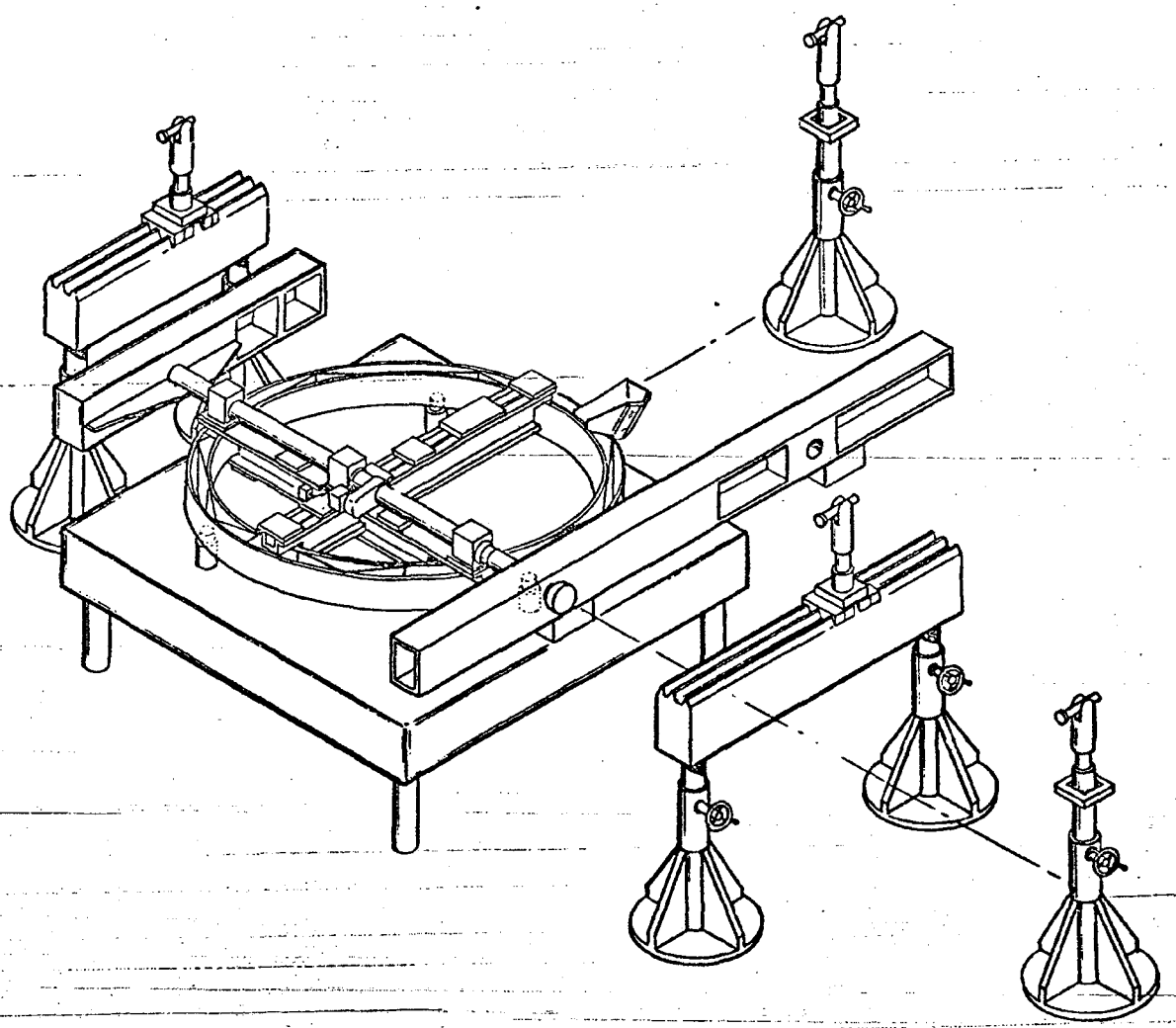


FIGURE 3

VEHICLE BASED-FIXTURE CALIBRATION EQUIPMENT



AEROSPACE PROPOSED VEHICLE BASED ALIGNMENT SYSTEM

AEROSPACE PROPOSED
VEHICLE BASED APPROACH

- BASIC DESIGN ASSUMPTIONS
  - / WOULD LIKE FIXED POSITION THEODOLITES (NO RAILS)
  - / ALL INSTRUMENTS INDEXED FROM GRAVITY (NO TOOLING REALIGNMENT REQUIRED)
  - / MUST BE LIGHT WEIGHT FOR HANDLING (TOOL DEFLECTIONS MUST NOT BE DESIGNING CRITERIA)
  - / MINIMUM IMPACT WITH VEHICLE CHANGES (MOUNT ON SINGLE BASE PLATE ON STATION 517)
  - / MUST NOT REQUIRE EXPENSIVE FACILITY
    - NO STRINGENT THERMAL REQUIREMENT
    - NO STRINGENT AIR FLOW REQUIREMENT
    - NO SUPPORT EQUIPMENT REQUIRED (SIMPLE BUILDING CONTRACTOR TYPE SCAFFOLD)
    - MINIMUM OF SEISMIC PROBLEMS
  - / NO DOOR REMOVAL REQUIRED
  - / SHOULD BE CAPABLE OF CHECKING ALIGNMENT OF COMPONENTS INSTALLED ON SUB-ASSEMBLIES OR ALIGNING DURING FINAL ASSEMBLY

(A) PROPOSED

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VEHICLE BASED ALIGNMENT FIXTURE

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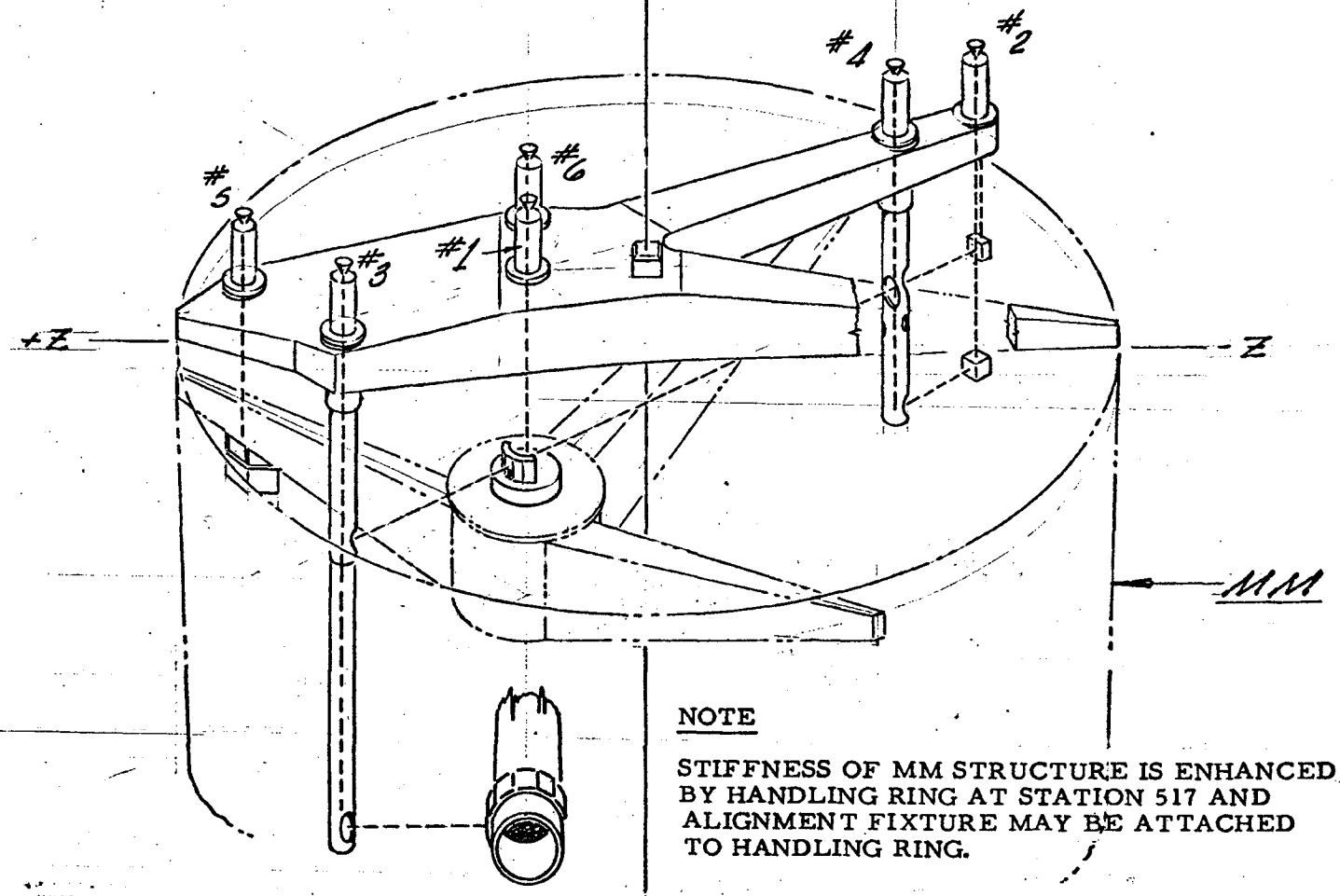

NOTE

STIFFNESS OF MM STRUCTURE IS ENHANCED BY HANDLING RING AT STATION 517 AND ALIGNMENT FIXTURE MAY BE ATTACHED TO HANDLING RING.

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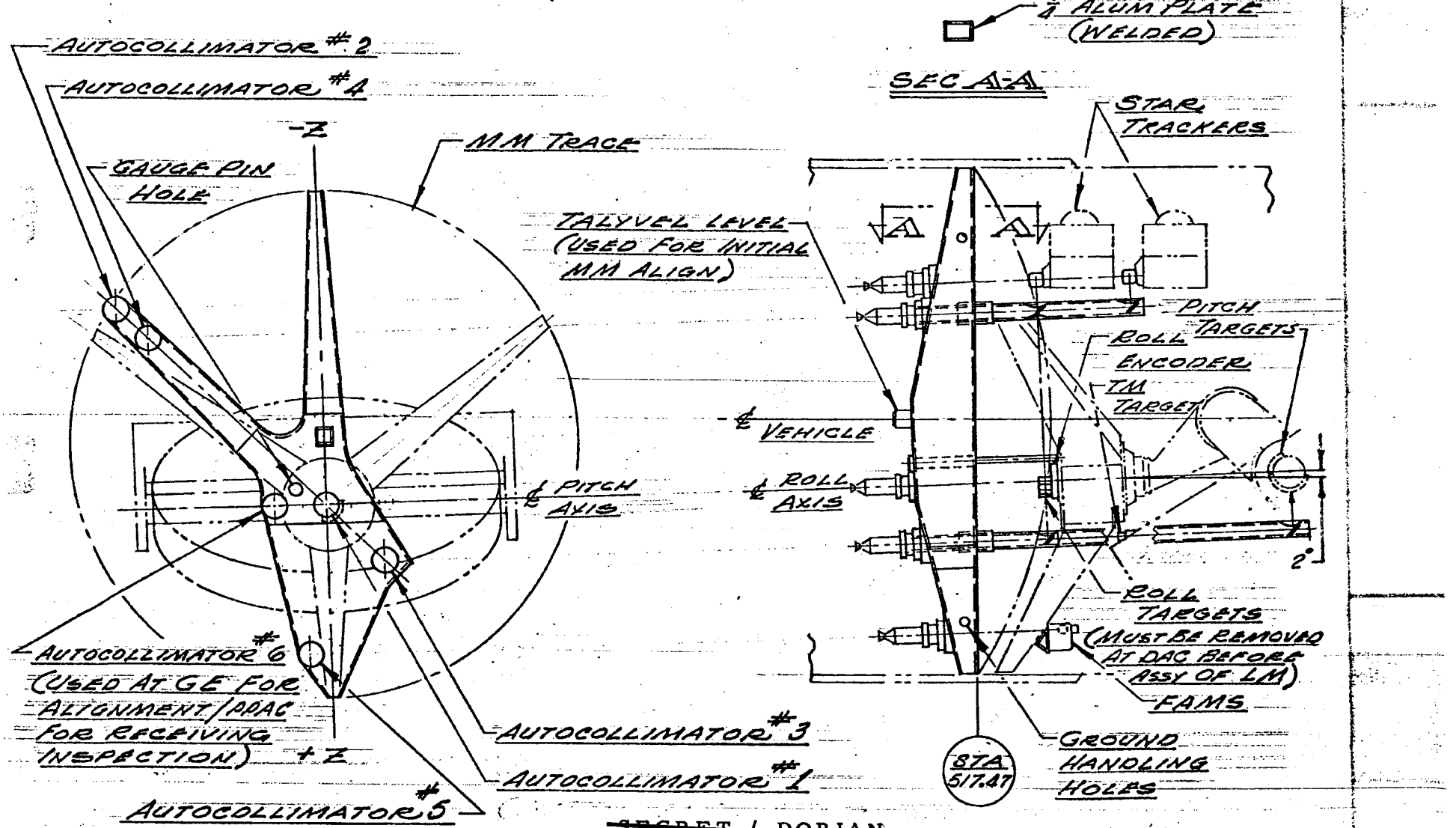
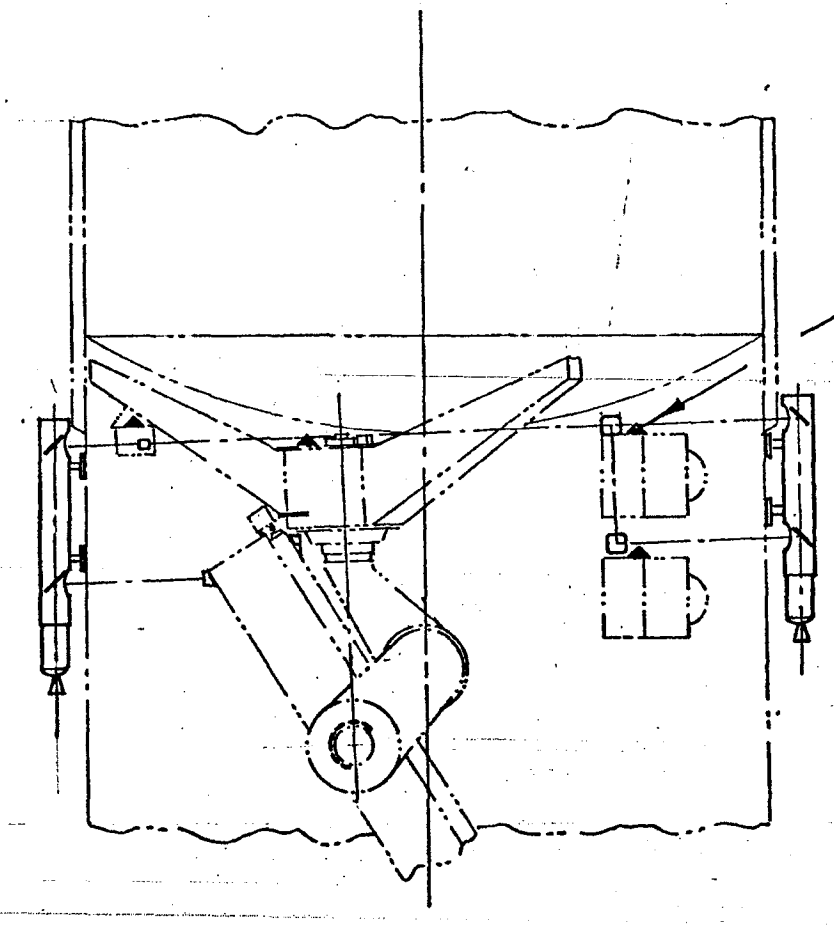
PROPOSED VEHICLE BASED SYSTEM



VEHICLE BASED ALIGNMENT SYSTEM
(SUPPLEMENTAL TOOLING)



AEROSPACE PROPOSED VEHICLE BASED ALIGNMENT STEPS

1. BOLT ALIGNMENT FIXTURE TO STATION 517 INTERFACE USING EXISTING TOOLING HOLES LOCATED ALONG Z AXIS (CLOSE TOLERANCE HOLES).

2. ACTIVATE TALYVEL LEVEL TO FIND VERTICAL (GRAVITY) REFERENCE USING ADJUSTABLE PLATFORM AT BASE OF MM VEHICLE (ORIENT MM TWO DEGREES FROM LEVEL).

3. AUTOCOLLIMATE THEODOLITE #1 TO OIL POOL (PLACED BENEATH THEODOLITE BASE) TO ESTABLISH VERTICAL (GRAVITY) REFERENCE.

4. AUTOCOLLIMATE THEODOLITE #1 TO MIRROR TARGET ON FORWARD FACE OF TM SHAFT (AFTER REMOVING OIL POOL REFERENCE).

5. PLACE GAUGING PIN IN HOLE TO ESTABLISH DISTANCE FROM STATION 517 TO TRIPOD (OPTIONAL).

6. AUTOCOLLIMATE THEODOLITE #2 TO OIL POOL TO ESTABLISH VERTICAL (GRAVITY) REFERENCE.

7. AUTOCOLLIMATE THEODOLITE #2 TO SUPPER STAR TRACKER REFERENCE CUBE.... THEN LOWER STAR TRACKER REFERENCE CUBE (STAGGERED).

8. AUTOCOLLIMATE THEODOLITE #3 TO OIL POOL TO ESTABLISH VERTICAL (GRAVITY) REFERENCE.

9. AUTOCOLLIMATE THEODOLITE #3 TO SUPPER STAR TRACKER CUBE FOR ROTATION WITH RESPECT TO THE TM SHAFT REFERENCE (USING HALF SILVERED MIRROR ON SHAFT LOCATED AT NULL POSITION).

10. AUTOCOLLIMATE THEODOLITE #4 TO OIL POOL TO ESTABLISH VERTICAL (GRAVITY) REFERENCE.

AEROSPACE PROPOSED VEHICLE BASED
ALIGNMENT STEPS
(CONTINUED)

11. AUTOCOLLIMATE THEODOLITE #4 TO UPPER STAR TRACKER TARGET THROUGH PERISCOPE USING HALF SILVERED, INCLINED MIRROR (OBSCURE LOWER PORT WHILE AUTOCOLLIMATING OFF UPPER STAR TRACKER).

12. AUTOCOLLIMATE THEODOLITE #4 TO LOWER STAR TRACKER TARGET THROUGH PERISCOPE BY SIGHTING PAST HALF SILVERED MIRROR TO LOWER FULLY SILVERED MIRROR (OBSCURE UPPER PORT WHILE AUTOCOLLIMATING OFF LOWER STAR TRACKER).

13. AUTOCOLLIMATE THEODOLITE #5 TO OIL POOL TO ESTABLISH VERTICAL (GRAVITY) REFERENCE.

14. AUTOCOLLIMATE THEODOLITE #5 TO FAMS SENSOR FOR CHECK OF ALIGNMENT TO TM SHAFT TARGET.

15. AUTOCOLLIMATE THEODOLITE #6 TO OIL POOL TO ESTABLISH VERTICAL (GRAVITY) REFERENCE.

16. AUTOCOLLIMATE THEODOLITE #6 TO PITCH TARGETS ON COUNTERBALANCED T-BAR PITCH SIMULATOR AND INDEX INCREMENTALLY TO EACH PITCH POSITION WHILE READING VALUE ON ALIGNMENT MONITORING SET. (FOR PITCH ENCODER CALIBRATION).

17. AUTOCOLLIMATE ON TM SHAFT REFERENCE TARGETS AND INDEX INCREMENTALLY TO EACH ROLL POSITION WHILE READING VALUES ON ALIGNMENT MONITORING SET (FOR ROLL ENCODER CALIBRATION).

18. NON-ORTHOGONALITY OF ROLL TO PITCH AXES IS THEN CHECKED BY THE FOLLOWING PROCEDURE:

    A. USING AUTOCOLLIMATOR #1, RECORD THE CHANGE IN COLLIMATION ANGLE VERSUS ROLL ROTATION OF THE T-BAR SHAFT (SIGHT AUTOCOLLIMATOR ON MIRROR LOCATED ON FORWARD FACE OF SHAFT. THIS PROCEDURE WILL INDICATE THE AMOUNT OF CONING PRODUCED BY THE SHAFT IN THE ROLL AXIS. PLOT THESE DATA.

AEROSPACE PROPOSED VEHICLE BASED
ALIGNMENT STEPS
(CONTINUED)

B. USING AUTOCOLLIMATOR #6, MEASURE THE BIAS OFFSET (ONE AXIS ONLY) OF THE T-BAR PITCH AXIS SHAFT BY SIGHTING ON THE NULL POSITION MIRROR TARGET LOCATED ON THE SHAFT SIMULATOR.

C. USING AUTOCOLLIMATOR #3, SIGHT ON ROLL NULL TARGET AND T-BAR PITCH SHAFT TARGET AND MEASURE RELATIVE DIFFERENCE IN COLLIMATION. THIS ANGLE DIFFERENCE IS THE BIAS OFFSET (ONE AXIS ONLY) OF THE T-BAR PITCH SHAFT WITH RESPECT TO THE ROLL AXIS NULL POSITION.

D. USING AUTOCOLLIMATOR #6, RECORD THE CHANGE IN COLLIMATION ANGLE VERSUS ROTATION OF THE PITCH AXIS BY SIGHTING ON THE T-BAR PITCH SHAFT SIMULATOR TARGETS WHILE INCREMENTALLY ROTATING THE T-BAR SHAFT SIMULATOR. THIS PROCEDURE WILL INDICATE THE AMOUNT OF CONING PRODUCED BY THE T-BAR SHAFT IN THE PITCH AXIS. PLOT THESE DATA.

E. USING ABOVE MEASURED DATA, COMPUTE NON-ORTHOGONALITY AND CONING OF PITCH AND ROLL AXES.

19. INSTALL COUNTERBALANCED WEIGHTED T-BAR SIMULATOR AND RECHECK VALUES OBTAINED IN PROCEDURES 16. AND 17.

AEROSPACE PROPOSED VEHICLE BASED ALIGNMENT SYSTEM MODIFICATIONS REQUIRED

1. MOVE STAR TRACKER TARGETS TO INSIDE OF MM STRUCTURE TO PERMIT VIEWING (STAGGER TARGETS - FWD & AFT STAR TRACKERS)

2. REMOVE PRESENT HUB REFERENCE CUBE AND INSTALL SHAFT REFERENCE WHICH HAS HALF SILVERED MIRROR AT NULL AND INCREMENTAL MIRRORS.

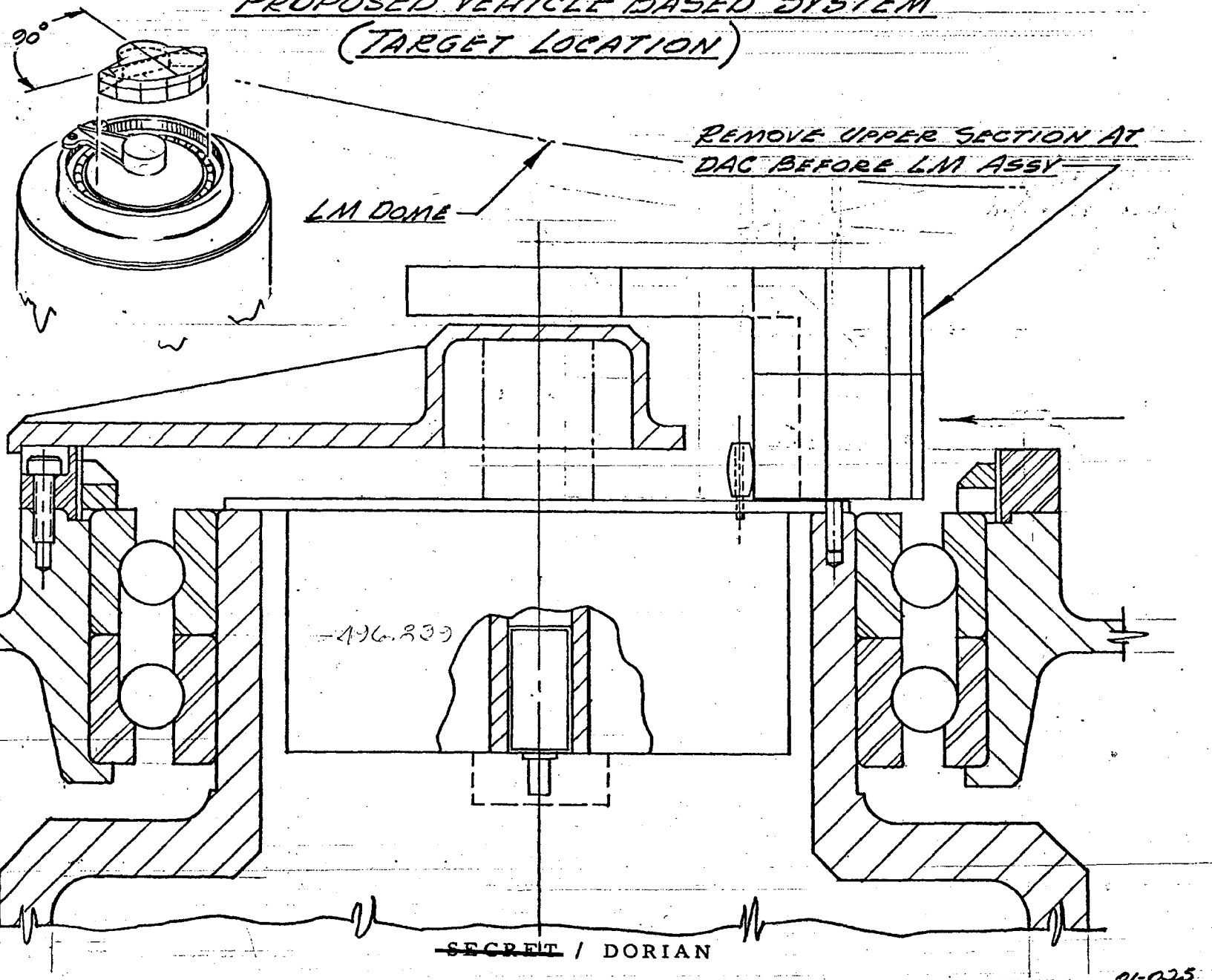
3. PROVIDE INCREMENTAL PITCH AXIS MIRRORS ON T-BAR PITCH SHAFT SIMULATOR.

4. PROVIDE PAD ON TRIPOD FOR INDEXING WITH RESPECT TO STATION 517 USING INDEXING PIN.

5. REMOVE HOLES (TWO 1.75" X 2.50") IN STRUCTURE WHICH ARE REQUIRED FOR GROUND BASED ALIGNMENT SYSTEM.

6. ELIMINATE SUBSTITUTE DOOR.

PROPOSED VEHICLE BASED SYSTEM (TARGET LOCATION)



AEROSPACE PROPOSED VEHICLE BASED ALIGNMENT SYSTEM

EQUIPMENT LIST

4	AUTOCOLLIMATORS (MINIMUM)
1	TALYVEL ELECTRONIC LEVEL PLUS READOUT GAUGE
1	INDEXING PIN
1	ALIGNMENT FIXTURE (WELDED ALUMINUM STRONGBACK)
2	PERISCOPE ASSEMBLIES
1	THEODOLITE

SYSTEM ASPECTS

SYSTEM ASPECTS

GE GROUND BASED SYSTEM

- ALIGNMENTS CAN BE CHECKED AT GE, PPAC AND DAC WITH MM VERTICAL AND MATED TO LM.
  - / DOOR SUBSTITUTE REQUIRED AT DAC (CONTAMINATION)
  - / SYSTEMS CHECKOUT GANTRY AT DAC DICTATES USE OF SEPARATE ALIGNMENT FACILITY (2° BIAS)
  - / NOT ALL ALIGNMENTS CAN BE MADE WHEN MATED TO LM
- TOWERS CANNOT BE INSTALLED AT VAFB SINCE LM/MM IS NOT VERTICAL UNTIL ON THE PAD
  - / REPLACEMENT OF COMPONENTS ON THE PAD CANNOT BE IMPLEMENTED WITH GROUND ALIGNMENT SYSTEM
- CAN USE FAMS BUT WITH LITTLE CONFIDENCE SINCE WE ARE UNABLE TO ESTABLISH IF SENSOR OR COMPONENT MOVED
  - / GROUND BASED SYSTEM CANNOT CHECK FAMS POSITIONING WITH RESPECT TO HUB REFERENCE

AEROSPACE PROPOSED VEHICLE BASED SYSTEM

- ALIGNMENTS CAN BE CHECKED AT GE, PPAC AND DAC WITH MM VERTICAL AND UNMATED TO LM.
  - / MAJOR ALIGNMENTS CAN BE CHECKED WITH LM MATED BY USE OF SUPPLEMENTAL PORTABLE TOOLING (ATTACHED TO MM EXTERIOR)
  - / ALIGNMENTS MADE WITH DOOR IN PLACE
- ALIGNMENTS CAN BE CHECKED AT VAFB WHEN ON PAD BY USING SUPPLEMENTAL PORTABLE TOOLING (ATTACHED TO MM EXTERIOR)
  - / REPLACEMENT OF COMPONENTS ON THE PAD CAN BE IMPLEMENTED BY USE OF SUPPLEMENTAL PORTABLE TOOLING (ATTACHED TO MM EXTERIOR)
- CAN USE FAMS FOR SHIFT IN COMPONENT POSITIONING IF SUPPLEMENTAL PORTABLE TOOLING (ATTACHED TO MM EXTERIOR) IS USED IN CONJUNCTION WITH FAMS.

SUMMARY

SUMMARY

GROUND BASED SYSTEM

- UNPREDICTABLE INACCURACIES DUE TO:
  - / UNKNOWN SEISMIC ENVIRONMENT AT PPAC
  - / CANNOT ASSESS ABILITY OF OPERATOR TO PERFORM ALIGNMENTS WITH MM, TOWERS AND SCAFFOLDING MOVING.
  - / UNKNOWN DAMPING CHARACTERISTICS OF TOWERS
- FIXED EMPLACEMENT TOOLING REQUIRING SEPARATE ENVIRONMENTAL CONTROLLED FACILITY
  - / SCHEDULE IMPACT AT DAC
- CANNOT BE USED AT VAFB
  - / WILL REQUIRE ADDITIONAL PORTABLE TOOLING (NOT COMPATABLE WITH EXISTING TARGET LOCATIONS - FAMS CHECKOUT REQUIRES DOOR REMOVAL)

AEROSPACE PROPOSED VEHICLE BASED ALIGNMENT SYSTEM

- ALIGNMENT FIXTURE CAPABLE OF FIVE SEC ACCURACY
  - / MINIMUM EFFECT OF SEISMIC DISTURBANCES
- ALIGNMENT FIXTURE USES GRAVITY AS A REFERENCE
- INEXPENSIVE
  - / NO STRINGENT ENVIRONMENTAL REQUIREMENTS FOR AIR FLOW AND TEMPERATURE CONTROL
  - / NO FLOOR SPACE REQUIREMENTS
- CANNOT BE USED AT VAFB
  - / REQUIRES PORTABLE TOOLING WHICH HAS BEEN DESIGNED INTO SYSTEM

RECOMMENDATION

RECOMMENDATION

- IT IS RECOMMENDED THAT GENERAL ELECTRIC CONDUCT A COMPARATIVE EVALUATION OF THE PROPOSED VEHICLE BASED CONCEPT WITH THEIR CURRENT GROUND BASED SYSTEM.