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TITLE

DEVELOPMENT OF GROUND SUPPORT EQUIPMENT CONCEPTS FOR STRUCTURAL DYNAMICS TESTING ON THE LADD PROJECT

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DEVELOPMENT OF GROUND SUPPORT EQUIPMENT CONCEPTS FOR STRUCTURAL DYNAMICS TESTING OF THE LADD PROJECT

FINAL REPORT

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DSS Contract No: 9F011-2-0975/00
Document No: RML-009-93-037

Prepared for: CANADIAN SPACE AGENCY
DIRECTORATE OF SPACE MECHANICS
3701 CARLING AVE.
P.O. BOX 11940, STATION H
SHIRLEY'S BAY
NEPEAN, ONTARIO
K2H 8S2

DATE: January 8, 1993

par Aerospace Limited
Satellite and Communications Systems Division
21025 TransCanada Highway
Ste-Anne-de-Bellevue, Quebec
Canada H9X 3R2
Telephone: (514) 457-2150
Fax: (514) 457-2724
Telex: 05-822792

SPAR

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CSA CONTRACTOR REPORT CSA-DSM-CR-93-022

CANADIAN SPACE AGENCY

TITLE: DEVELOPMENT OF GROUND SUPPORT EQUIPMENT CONCEPTS FOR STRUCTURAL DYNAMICS TESTING OF THE LADD PROJECT

FINAL REPORT

AUTHOR(S): SPAR PROJECT STAFF

ISSUED BY CONTRACTOR AS REPORT NO: RML-009-93-037

PREPARED BY: SPAR PROJECT STAFF

DEPARTMENT OF SUPPLY AND SERVICES CONTRACT NO: 9F011-2-0975/00

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1.0 Contract

This report is a review of the work undertaken by Spar Aerospace Ltd. under contract 9F011-2-0975/00, dated 27 May 1992, and subsequent Amendments 1 and 2. The work was performed for the Directorate of Space Mechanics of the Canadian Space Agency (CSA/DSM) between June and September 1992.

2.0 Scope of Work

The scope of the work initially covered by this contract was to perform a preliminary study of the ground support equipment (GSE) required for the structural dynamics testing of the LADD Test Article (LTA).

The preliminary study resulted in detailed concepts for the test GSE together with a ROM cost for manufacture.

The work included participation in project meetings with the Scientific Authority to assist in the development of test requirements and test plans for all testing related to the non-contact measurement (NCM) systems, of which the LTA tests are a part.

The original contract was extended to cover the Preliminary Design Review (PDR) of the laser NCM system GSE and the start of detailed design.

3.0 Tasks Accomplished

3.1 Meetings

Spar personnel attended LADD progress meetings and test planning meetings as required.

Spar personnel attended and participated in a presentation of the Canadian progress on non-contact measurement, modal excitation and analysis, and GSE concepts that was given to DND, the U.S. Air Force and Grumman at the Rome Laboratory, New York on July 15,1992.

Spar personnel also attended and gave a presentation on GSE status at the Laser NCM System PDR held at DFL on August 14, 1992.

3.2 GSE Concepts and Design

3.2.1 Test Set Up

Schemes were initially produced showing the projected configuration of the LTA inside the 22'x 35' thermal vacuum chamber. It was proposed to mount the LTA onto the existing VAMS platform, CSA/DFL drawing M-13,371E (ref.Fig.1) which will be installed on the 4 isolated hard points at the base of the chamber, CSA/DFL drawing M-13,319E (ref.Fig.2).

It was also proposed that exciters would be suspended from an existing Olympus support frame, Spar drawing 812393 (ref.Fig.3), mounted on the uppermost set of chamber wall hard points.

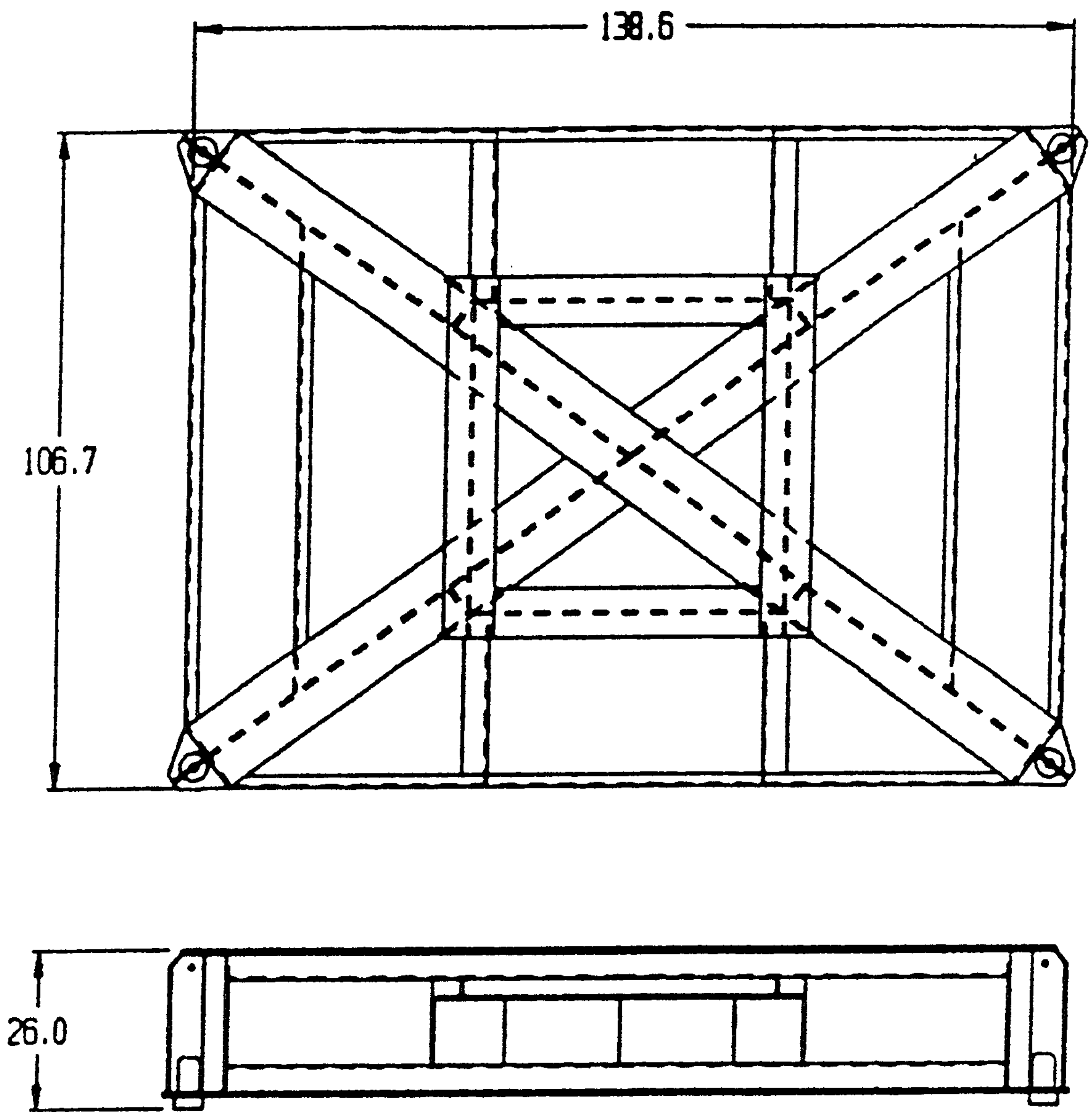

Figure 1: UNMODIFIED VAMS PLATFORM

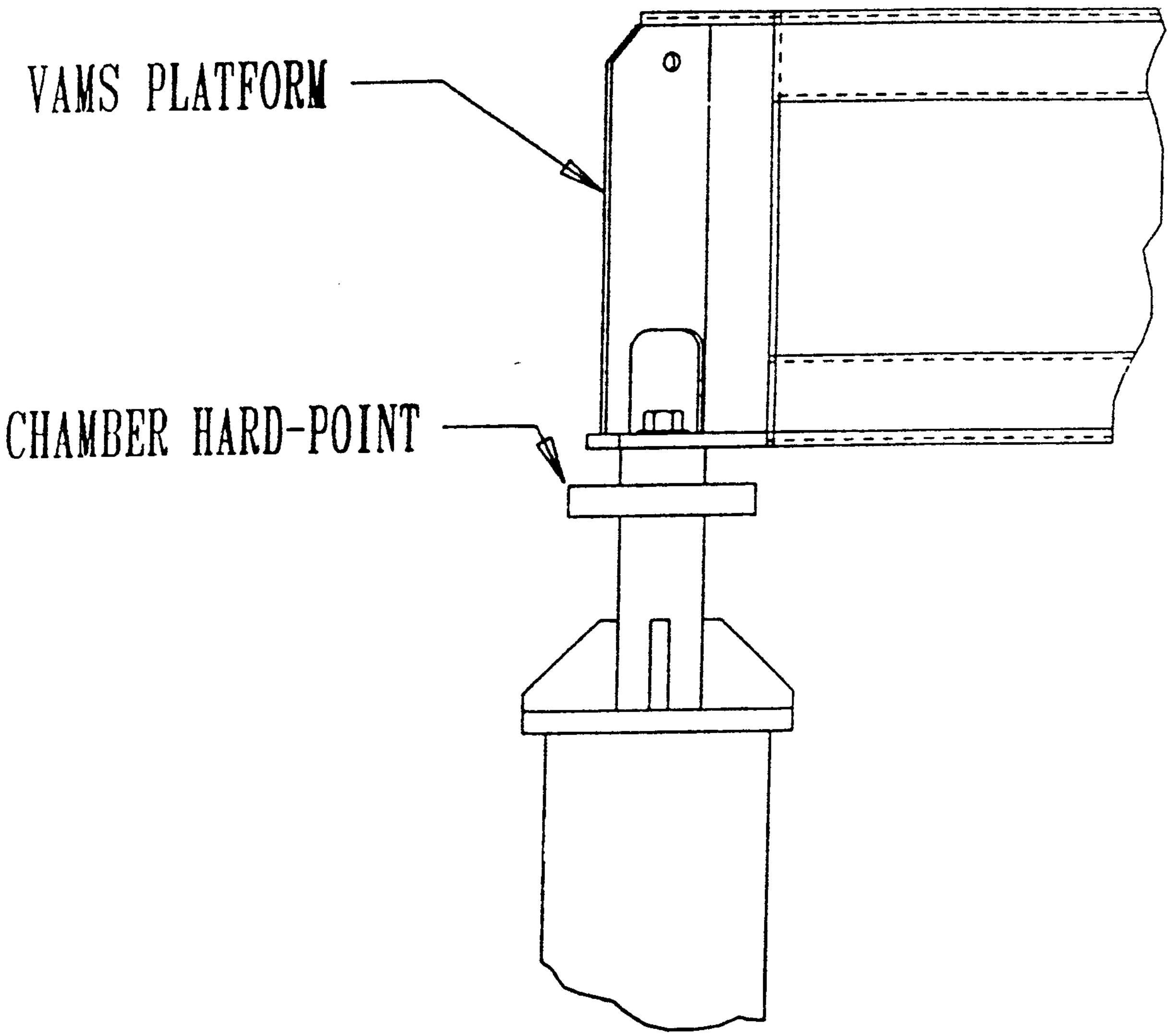

Figure 2: INSTALLATION ON CHAMBER HARD-POINT

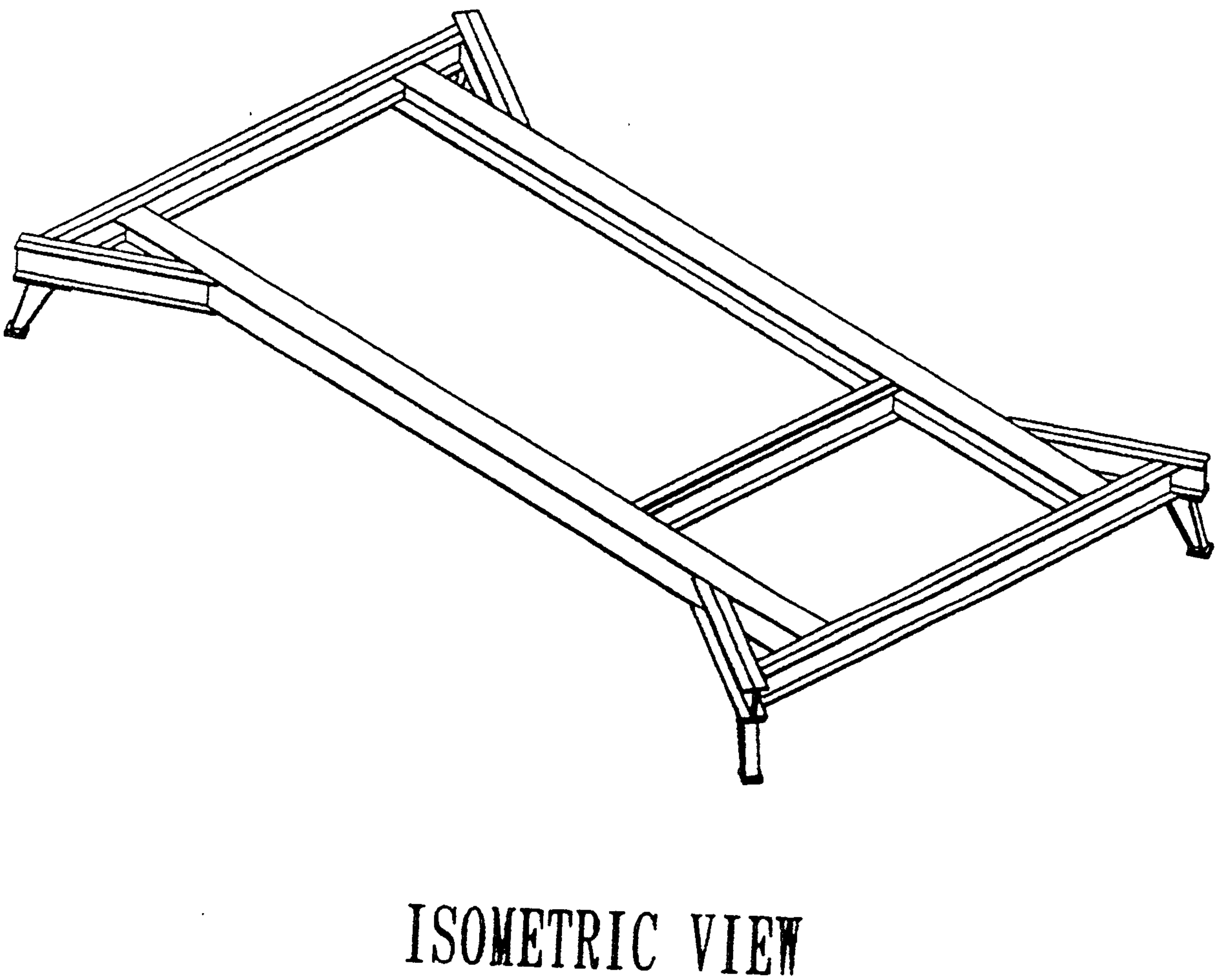

Figure 3: OLYMPUS FRAME FOR EXCITER SUPPORT

The initial scheme showed the switching platform of the laser NCM system mounted on a 12′ high stand situated at pit level and looking into the chamber via port #54, which is at the lower end of the chamber parallel section (ref.Fig.4).

This scheme provided a rigid mount for the laser that was independent of the chamber and the test article. However, the path travelled by the laser beam would be between 22′ and 35′, with the result that the image on the test article would be relatively weak in intensity and large in diameter. The main reasons why this scheme was dropped are:

1. Excessive time for mirror alignment because these alignments are required in three dimensions.

2. Possibility of mis-alignment in going from air to vacuum due to chamber port displacements and long path length.

3. Danger of COMPLETE mis-alignment of measurement channels should the platform be accidentally knocked or moved.

Following decisions taken at the laser team meeting, this scheme was replaced by another showing the laser vibrometer mounted inside the chamber on the same frame as the mirrors for the front end optics.

This scheme had the advantage that all the components of the laser system would be integral to one piece of hardware, which would reduce off-line set up and also increase alignment stability. However it meant that cooling air would have to be supplied to the laser when inside the chamber and would therefore require an air-tight container.

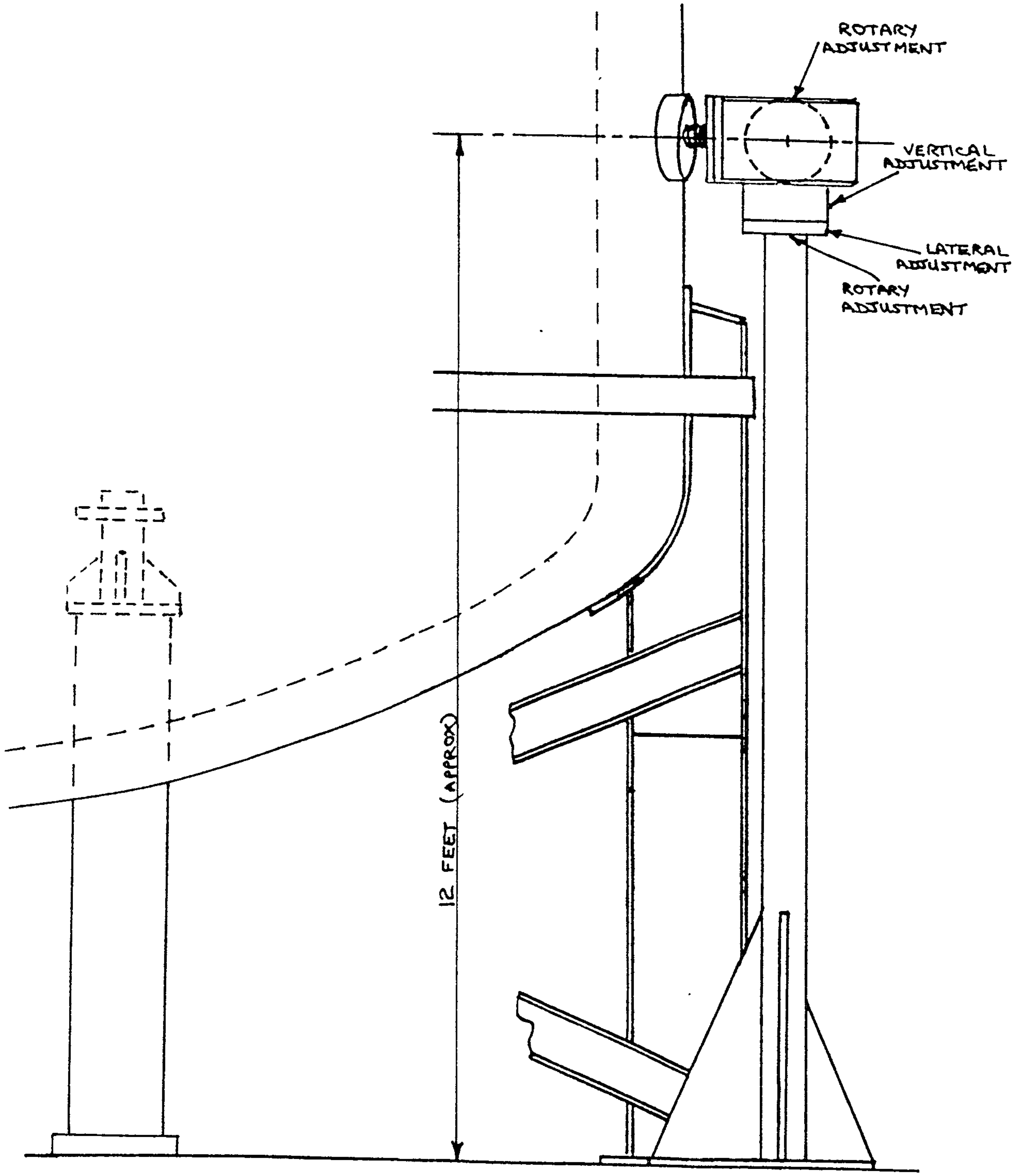

Figure 4: LASER VIBROMETER MOUNTING OUTSIDE CHAMBER

3.2.2 Mirror Frame

Following the decision to mount the laser vibrometer and the mirrors on the same frame, schemes were produced for a framework that was as generic as possible. To this end, a 110" square sub-frame was proposed with 5 separate I-beams for mounting the mirrors. The positions of the I-beams could be adjusted to suit different test requirements and could be mounted either horizontally or vertically.

The central I-beam was extended on one end to provide a mounting for the laser vibrometer. The vibrometer attachment frame and one end of the air-tight container would be an integral part of this I-beam extension to obviate relative movements between laser and mirrors.

The 18 primary mirrors would be mounted on the central I-beam, each mirror deflecting 2 beams from the laser through 90 degrees, either up or down across the face of the vertically suspended mirror frame. 9 secondary mirrors would be mounted on each of the outer I-beams, each mirror intercepting one laser beam and deflecting it through 90 degrees out of the plane of the mirror frame. By this method, a rectangular grid with 4 rows and 9 columns, giving a total of 36 laser beams, would project from the mirrors towards the test article which would be mounted parallel to the mirror frame. A view of the mirror frame is given in Figure 5 and a close up of a primary mirror in Figure 6.

The positions of all the mirrors were adjustable to aid alignment and to allow different sizes of test article to be measured. The initial configuration of the mirrors was determined by DSM, taking into account the physical dimensions of the LTA, the preferred separation distance between the mirrors and the test article, and the cavity length of the laser.

Due to the presence of 2 different frequencies in the laser, the beam exhibits a "beat" frequency with an alternating in-phase and out-of-phase output. The physical distance between each out-of-phase occurrence corresponds to the cavity length of the laser and is equal to 8". In order to consistently obtain a laser beam with minimum level noise floor, the total distance travelled by each laser beam from the vibrometer output lens to the test article must not be a multiple of 8", i.e. distances approximately midway between these multiples (12", 20", 28", 36", etc) give the best operation.

The arrangement of the laser beams as they reach the test article has been changed several times. With the original concept of the laser vibrometer mounted outside the chamber, a 6 x 6 pattern was envisaged. The six columns were equally spaced across the width of the test article and the six rows spaced so that three patterns would cover the length of the test article.

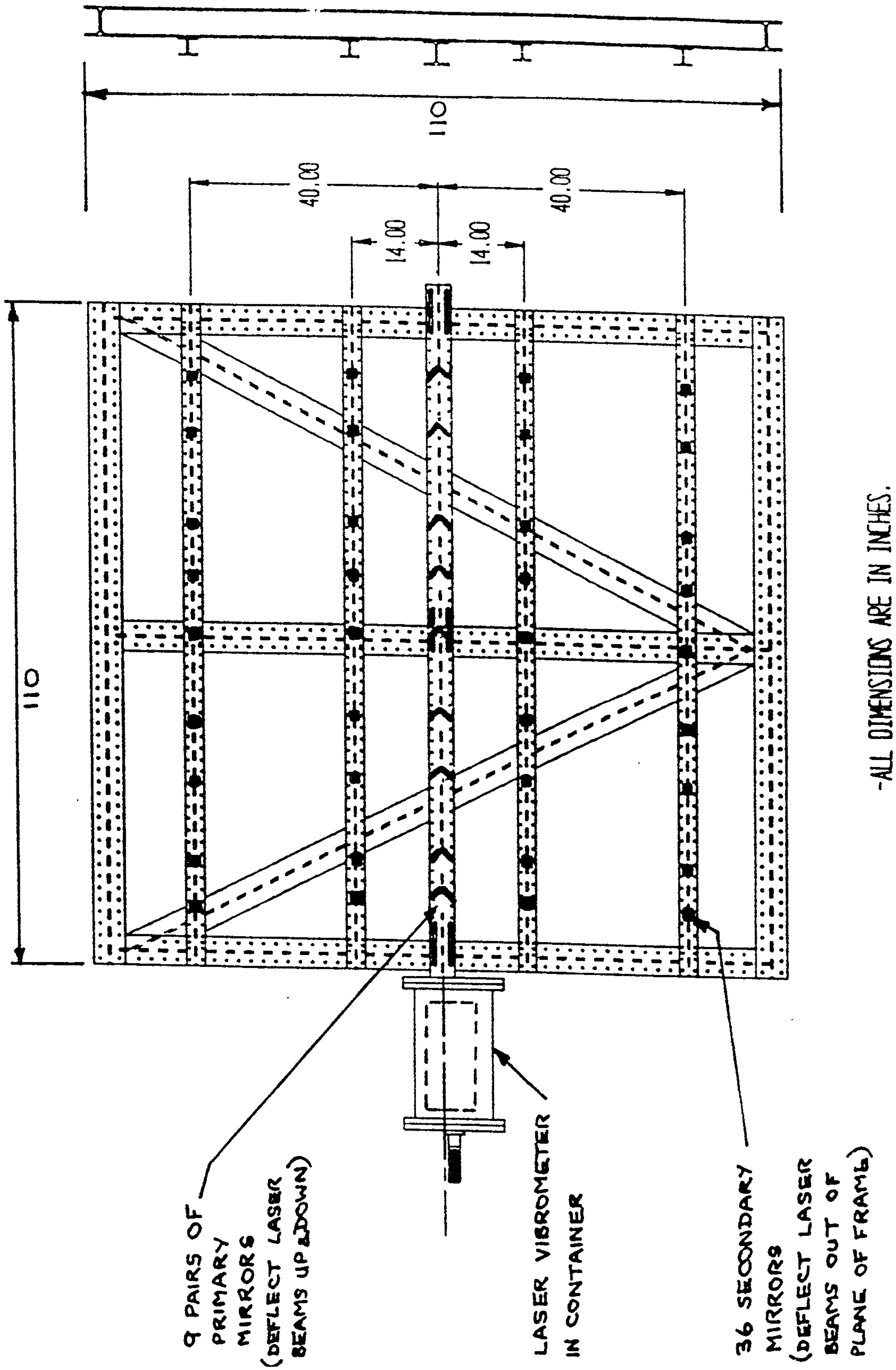

Figure 5: MIRROR FRAME ASSEMBLY

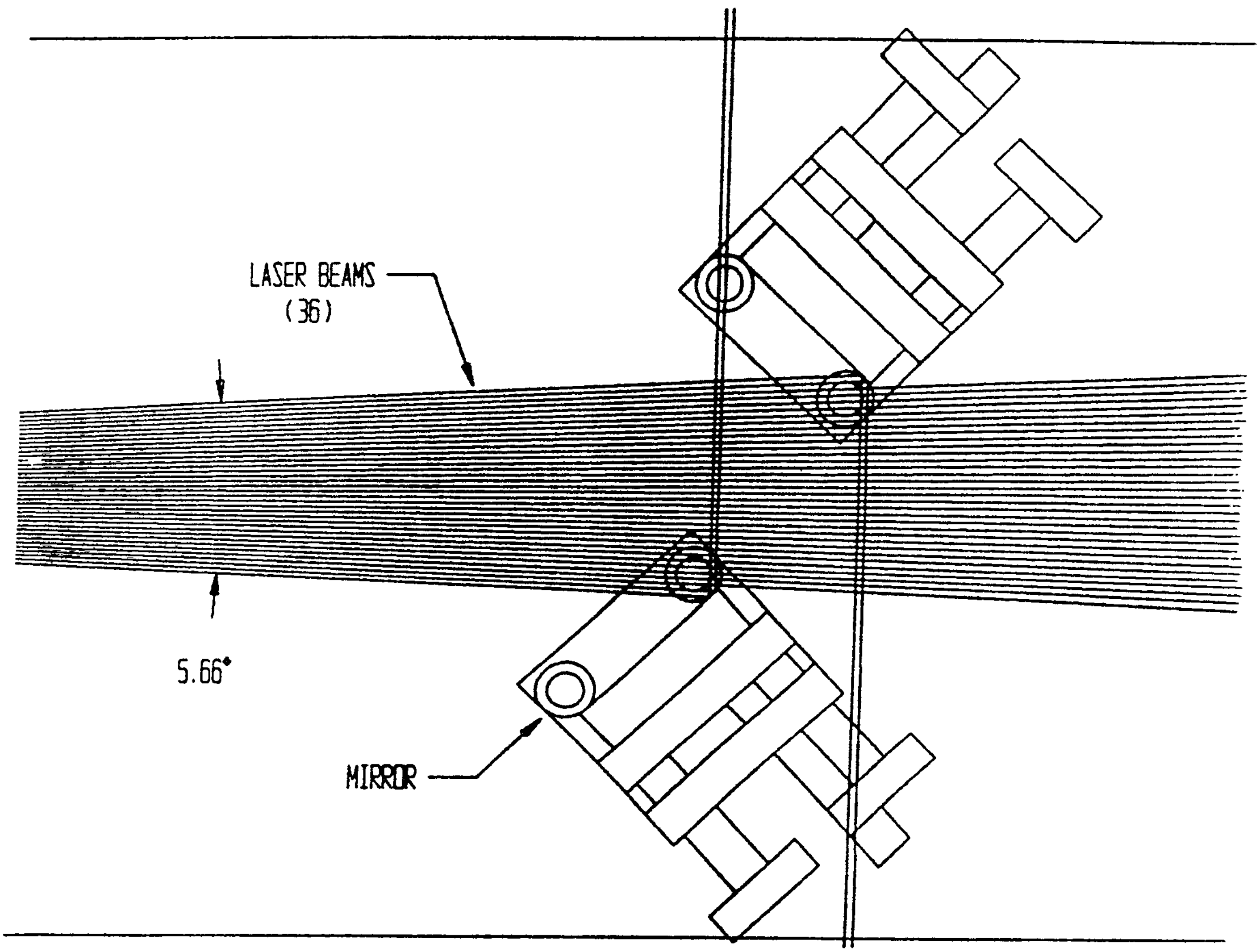

Figure 6: LASER BEAM DEFLECTIONS AT PRIMARY MIRRORS

The points of this grid did not align with all the points of interest on the LTA, which is composed of 4 longitudinal strips, each approximately 2' wide. It was therefore decided to change the pattern to a 4 x 9 grid as indicated above. The spacing was arranged to suit the layout of the dummy Transmit/Receive modules, on the LTA which are arranged with 41 columns and 121 rows.

Accordingly, it was agreed that the laser beams would be aligned with every fifth column, i.e.columns 1, 6, 11, 16, 21, 26, 31, 36 and 41. The rows would still be arranged in three groups, these being rows 1, 14, 28 and 41; 41, 54, 68 and 81; 81, 94, 108 and 121 (ref.Fig.7). Overlapping rows allows data check between the various groups.

The alignment of the mirrors on the frame is critical to the functioning of the laser vibrometer NCM system. Concern was expressed that when the mirror frame is moved, the mirror settings would be disturbed as the lifting stresses in the sub-frame would be different to the stationary stresses. The design of the frame was arranged so that the lifting points were coincident with the stationary suspension points so that any change in stresses would be minimised.

The initial sizes of the I-beams were 5" for the sub-frame, 4" for the central beam and 3" for the outer beams. In order to reduce weight (see section 3.2.3 below) the sub-frame members were reduced to 3" with the others unchanged.

The concepts for the mirror frame presented at the PDR were agreed and detailed manufacturing drawings have subsequently been started. The change in beam size mentioned above was incorporated into the drawings, detailing of which is scheduled to continue after the end of this contract.

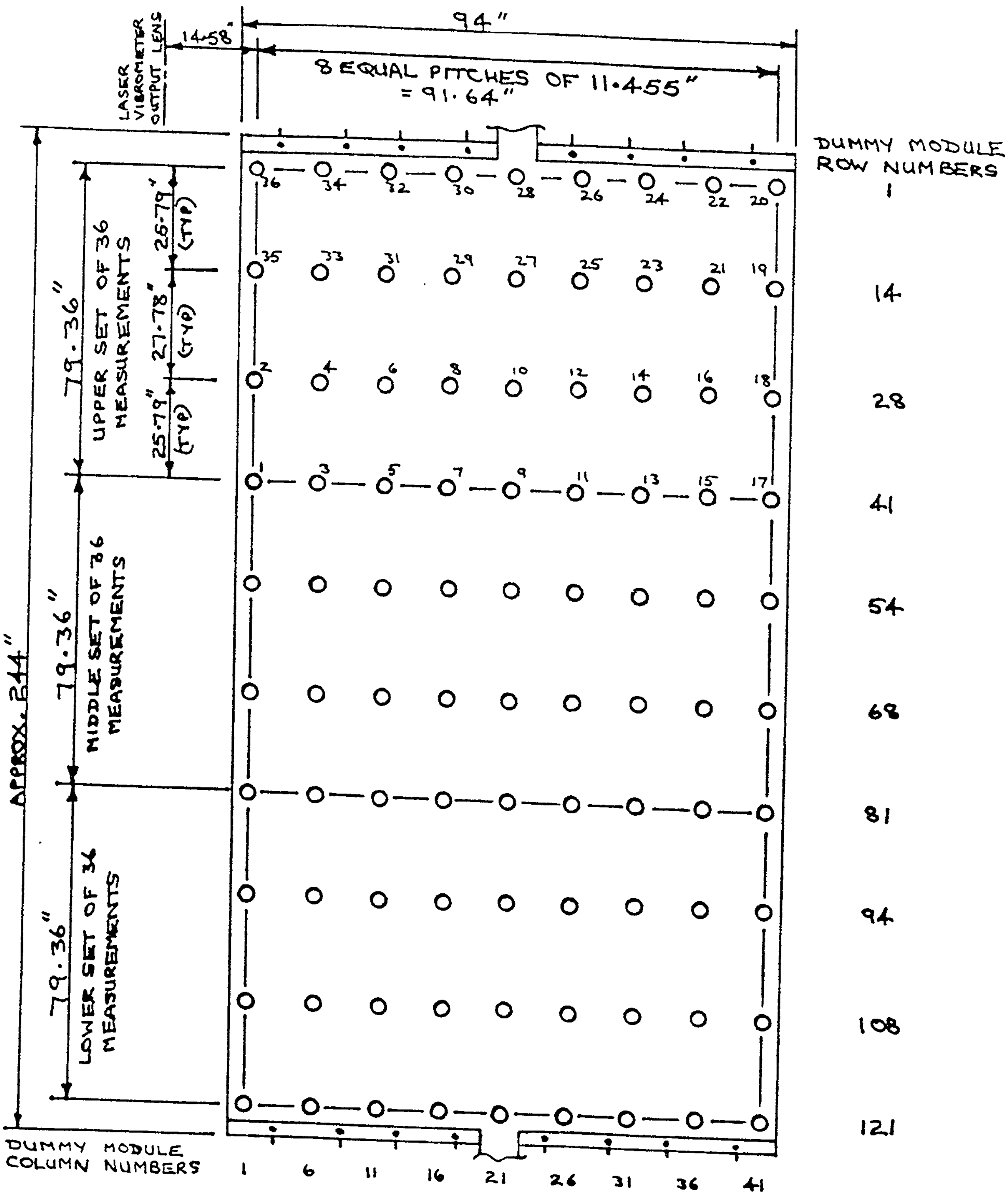

Figure 7: LASER TARGET POSITIONS

3.2.3 Main Frame

This frame, which was originally called the measurement frame, is for the purpose of supporting the mirror frame in a variety of positions to cover the measurement area of the article under test. It was initially envisaged as a simple frame measuring approximately 29' high and 100" wide, constructed from 5" channel sections held together by plates welded at regular intervals (ref.Fig.8).

However the dynamic analysis performed by DSM at the time of the PDR indicated a first natural frequency of the main frame with the mirror frame in its highest position of approximately 3 Hz. This value is too close to the frequencies predicted for LTA testing of 0 to 2 Hz and consequently a re-design of this frame became necessary, with the aim of increasing the frequency of the first mode to 20 Hz.

A process of evaluating different frame configurations was started, first by increasing the channel sizes and quantities and later by adding bracing. Bracing on the rear of the main frame, away from the test article, was limited to approximately 3 feet due to the proximity of the chamber shrouds and the difficulty of support. Interference with personnel access staging was another problem.

The effectiveness of the bracing was increased by attaching it to the front of the main frame, involving a lateral increase in brace width to pass around the test article (ref.Fig.9). Support was improved with the base of the brace attaching to the other end of the VAMS platform. Further dynamic analyses were conducted with differing material properties and were on-going at the end of the contract.

The first decision taken during this re-evaluation exercise was to reduce the mass of the mirror frame, which is a major factor in the modal calculations, especially when attached in the uppermost position. As originally planned, this weighed approximately 600 lb. By reducing the size of the I-beams for the sub-frame, this weight was reduced to approximately 450 lb.

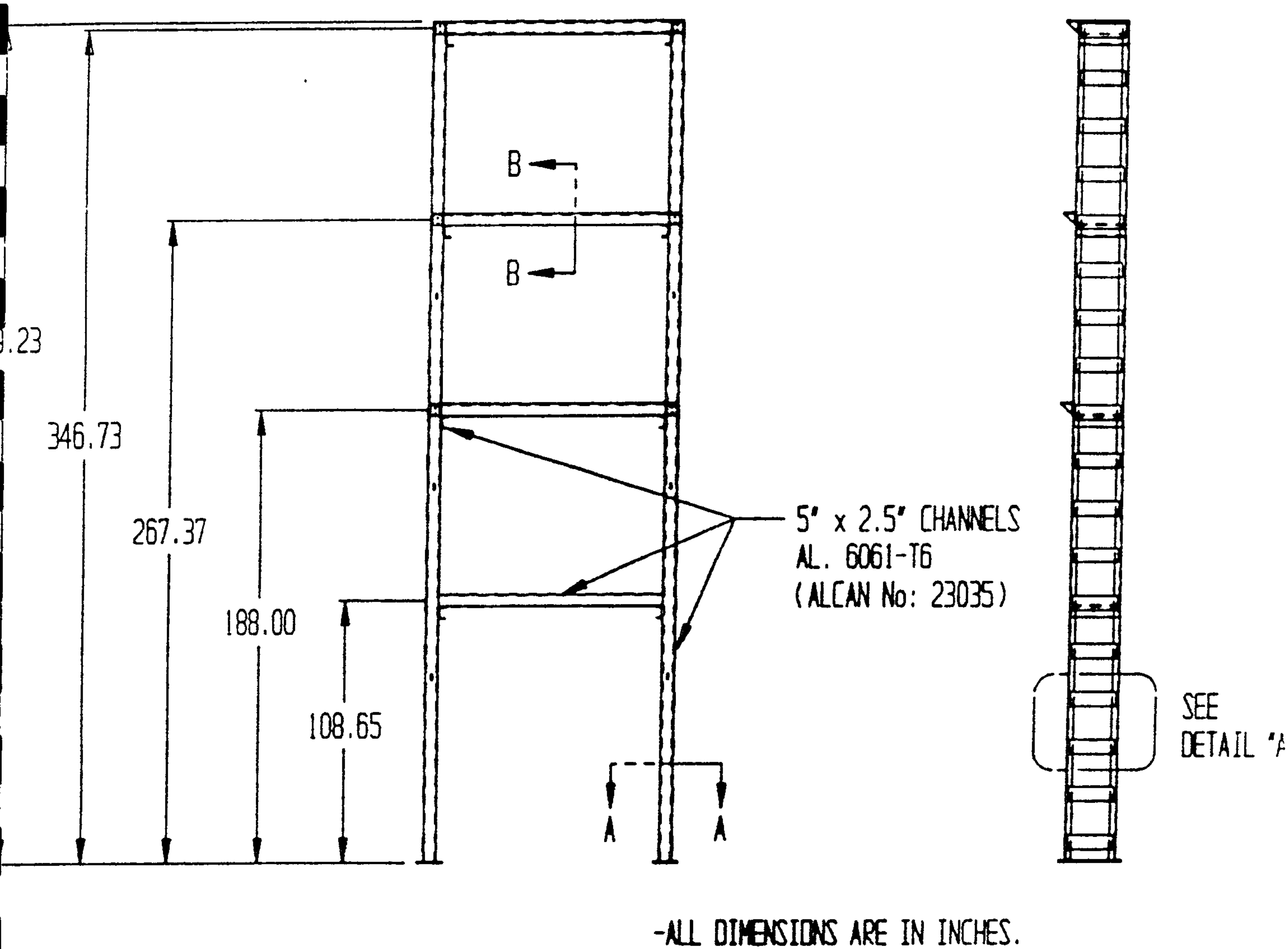

Figure 8: ORIGINAL DESIGN OF MAINFRAME

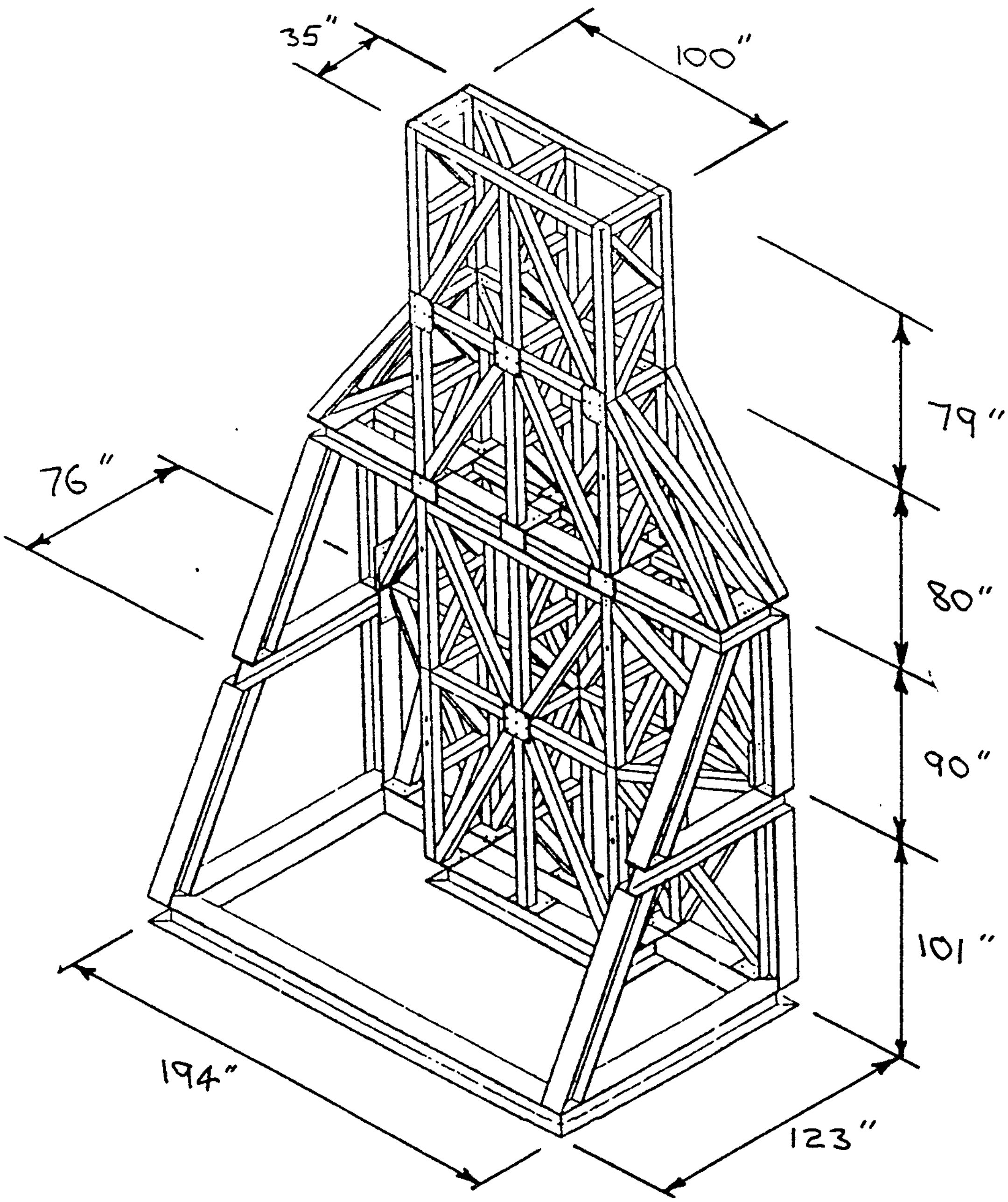

Figure 9: REVISED DESIGN OF MAIN FRAME

3.2.4 Laser Container

Two existing containers, constructed for the HAMS computer and pneumatic control unit, were originally considered for holding the laser and if necessary the associated RF driver unit. These containers were each 24" in diameter with a variety of holes in the walls. However, as they are made of steel they each weigh approximately 600 lb which was considered to be too large a mass to attach on one end of a sensitive, accurately aligned frame.

Accordingly, it was decided to construct a lighter container that could, as stated in section 3.2.2 above, be integral with the central I-beam of the mirror frame. The I-beam would have the upper flange removed where it passes through the container end flange and a framework of channel sections welded to one side to provide a base for the DSM laser platform.

The container end flange will incorporate a recess to accommodate an existing glass window that was used for the HAMS laser. The existing DSM laser platform, which measures 18" x 11", will be attached to the channel framework and adjusted so that the laser beam is aligned with the window (ref.Fig.10).

The original concept called for 3/4" to be cut off one side of the laser platform so as to fit into the largest standard sized aluminum tube of 12" diameter. This was later changed to a tube constructed from aluminum plate rolled to the required radius, the latter being sufficiently large to accommodate the laser platform without cutting.

The tube will have a flange welded onto each end so as to provide a bolted interface to the end plates. The end plate at the rear of the laser will have two hose connections, one hose for the purpose of supplying cooling air to the laser, the other to take away the exhaust air and also to provide a passage to the outside of the chamber for the laser power, control and data cables.

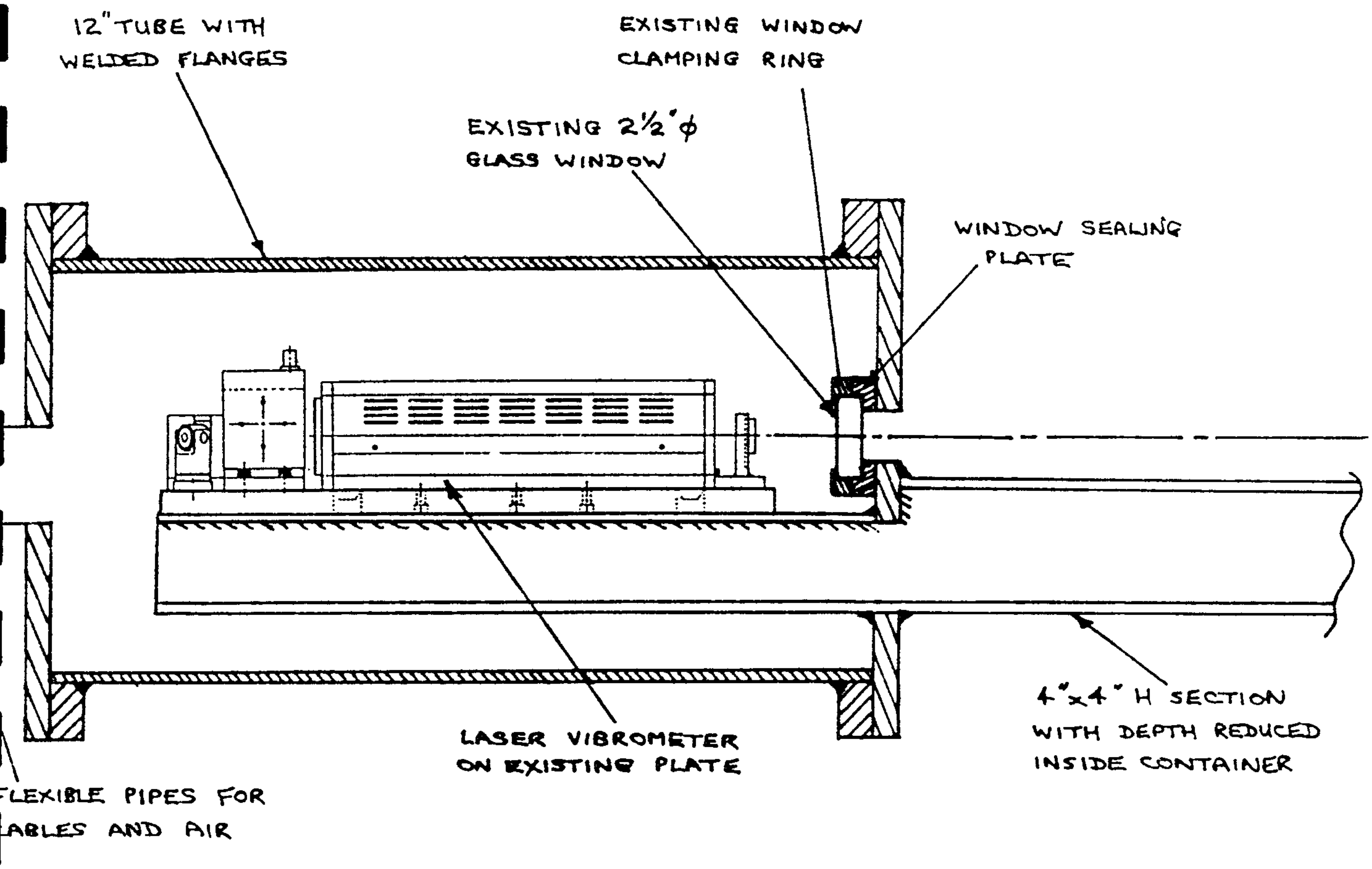

Figure 10: LASER VIBROMETER IN CONTAINER

3.2.5 Laser Supply Ports

The original concept proposed feeding the hoses to the laser container through a different port for each position of the mirror frame. The only ports existing in the chamber walls that are the same size and vertically above one another were identified as #5, 18 and 31. These are all 12" diameter ports and are approximately equally spaced on the chamber 350 degree line.

However, it was considered that having to disconnect the cables and feed them through a different port whenever the container was moved was an unnecessary complication and it was agreed to leave the cables and hoses connected to a central port at all times. The port to be used was provisionally left as # 18 but any convenient port at that height would be suitable, depending on the final orientation of the mirror frame.

The end plate for the container and the penetration plate for the chamber wall were not detailed during this contract as their design depended on the sizes to be decided upon for the hoses.

3.2.6 Exciter Containers and Supports

In order to keep the exciters cool, the original concept provided for air tight containers supplied with air from outside the chamber. No existing containers were available and a sketch of a standard 12" diameter aluminum tube with welded end flanges was shown at the PDR (ref.Fig.11).

This tube was suitable for either of the two types of exciters proposed for this testing:

- APS Electro-Seis Model 113
  30 pound thrust
  6 inch displacement (2 available)

- MB Dynamics Model 50A
  50 pound thrust
  1 inch displacement (2 available)

The concept was for the exciter body to be bolted to the rear end plate of the container with the stinger passing through a seal in the other end plate.

The containers would be suspended from the existing Olympus support frame, drawing 812393, (ref. Figure 3) which was designed to locate on the upper row of chamber wall hard points. As the six rows of hard points are nominally identical in orientation, the frame could be attached to any row to suit different sizes of test article. A system of springs would connect the containers to the frame in order to provide the required dynamic isolation.

The exciter stingers would be attached to the test article at positions to be defined by DSM. For the LTA, a report prepared by Dynacon proposed that these positions should be at the upper end of the deployed Astromasts. If these positions were agreed, the exciter suspension would be relatively compact and easy to adjust.

Grumman Aerospace, the developers of the LTA, stated that they had used an APS exciter in vacuum without a container. Pending an investigation by CSA staff of the feasability of this approach and also confirmation of the required exciter positions, no further design work was carried out on these items during this contract.

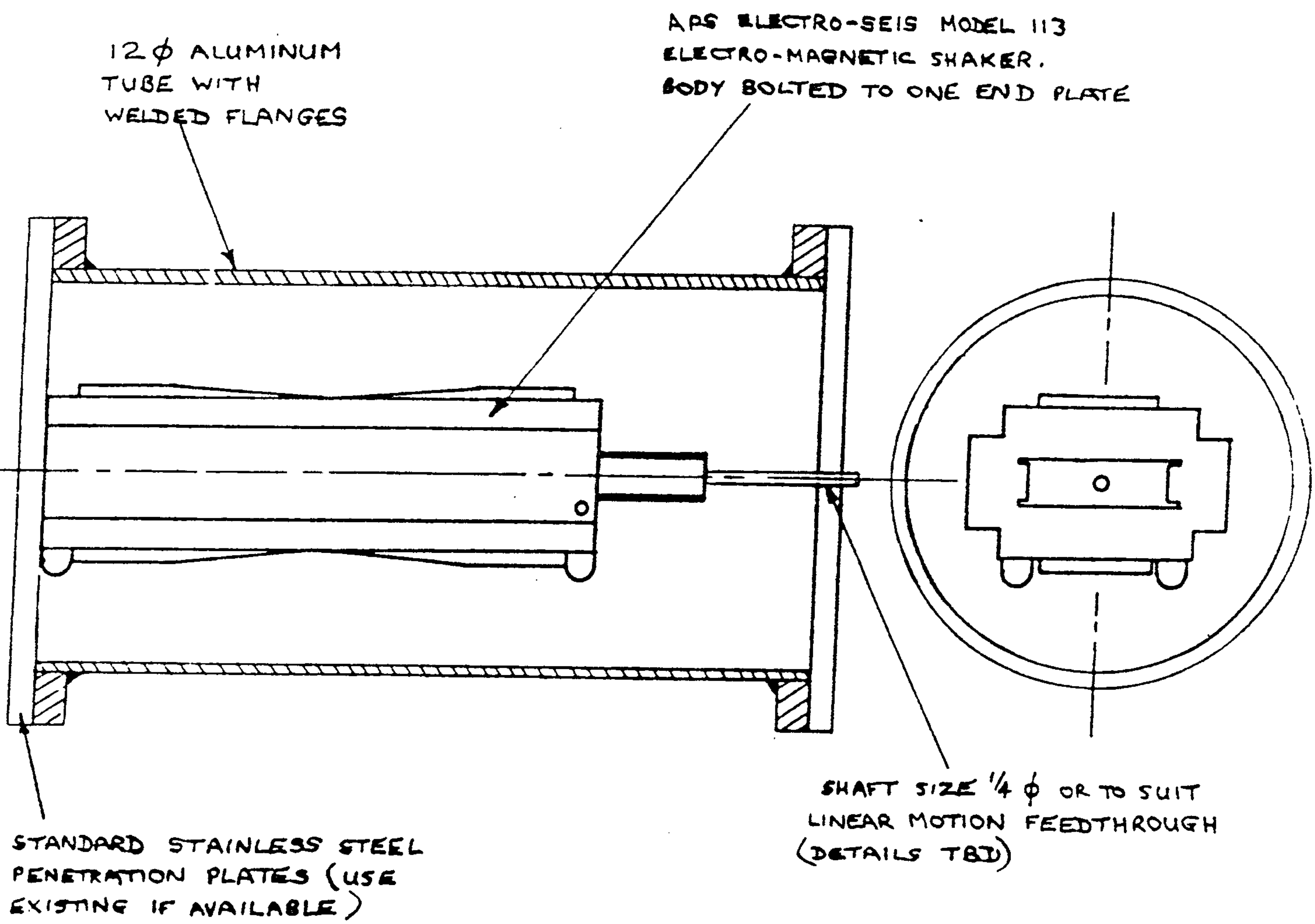

Figure 11: APS EXCITER IN CONTAINER

3.2.7 Photogrammetry System

During the course of the contract, DSM staff started the process of defining an additional non-contact measurement system. This system would be a backup to the laser vibrometer system and would draw on the experience gained on the 'Reach' project.

A concept was produced showing 2 cameras mounted on the chamber staging structure viewing the rear surface of the test article. In order to provide adequate depth of focus for the cameras, the distance between the test article and the mirror frame needed to be reduced. The chart produced by DSM showed a standoff distance of 71.35" for the laser system. This was reduced by a multiple of the cavity length to initially 31" and finally 23" to provide a minimum camera to test article distance in the range 6 to 8 feet, which is sufficient.

Design work is progressing on this task and the GSE consists of two horizontal beams that bolt to the staging vertical support rails. Brackets can be attached at intervals along the beams to support the camera containers which are of similar construction to those for the laser vibrometer (ref.Fig.12).

During the course of the contract, the quantity of cameras was increased from two to four.

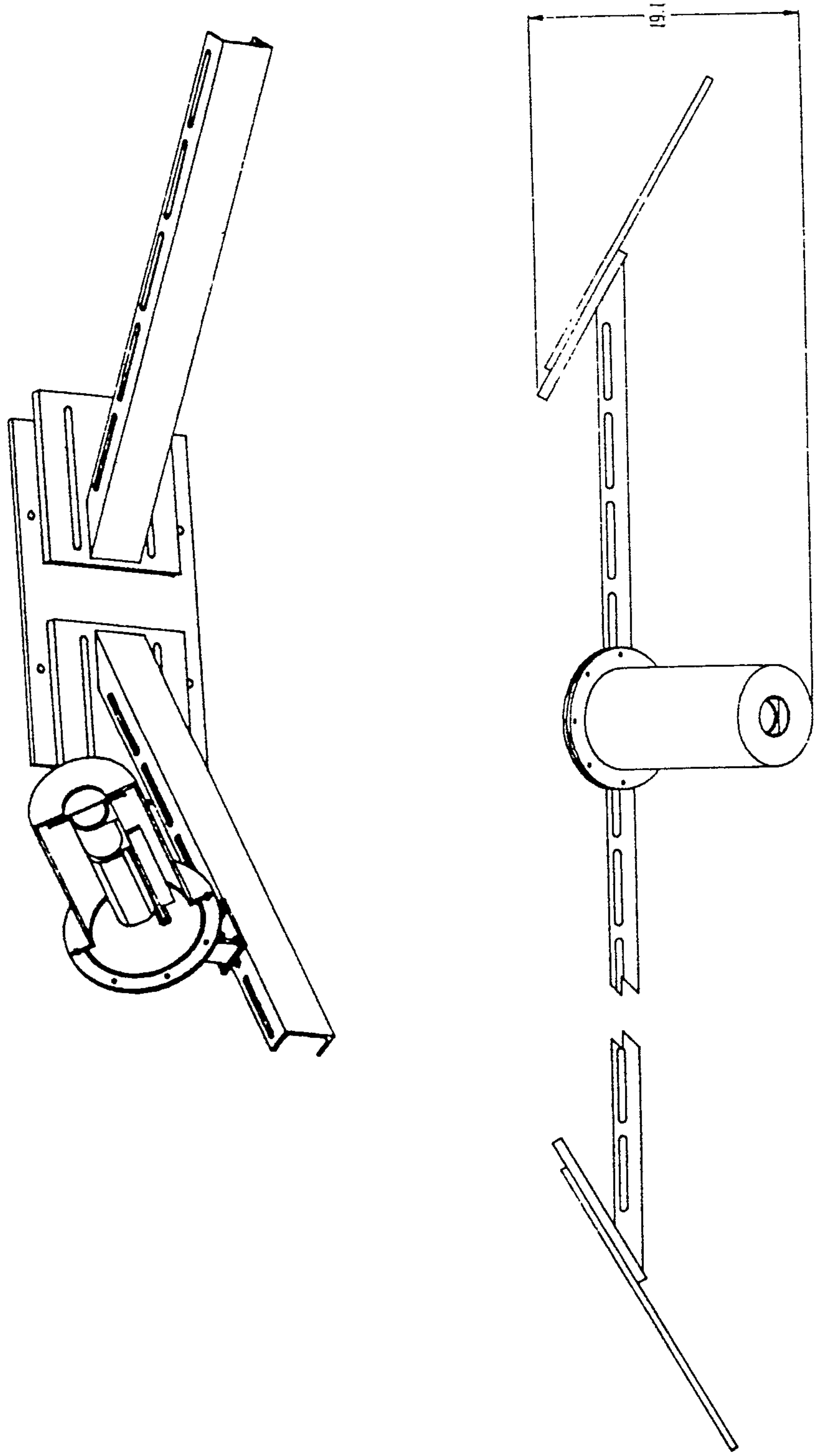

Figure 12: CAMERA CONTAINER AND SUPPORT BEAM

3.2.8 Mirror Frame Lift Beam

With the laser container on one end of the central beam of the mirror frame, the centre of gravity is towards that side of the frame. It was agreed that a dedicated lift beam would be produced to cater for this eccentric load. The beam will have an adjustable crane attachment point which will be central when lifting the beam alone but which can be readily moved across when the mirror frame is attached (ref.Fig.13). This will enable a stable lift in either configuration, a necessary feature when lifting very close to the test article inside the chamber.

Design work on this lift beam is progressing.

3.2.9 VAMS Platform

As mentioned in para. 3.2.1, it is proposed to mount the VAMS platform, CSA/DFL drawing M-13,371E on the hard points in the base of the chamber. Onto this platform will be installed the main frame and brace structure, para. 3.2.3 and the test article.

The first test article will be a membrane mounted in a DSM designed frame which will be used for validation of the various excitation and measurement systems. The final test article for this contract is the LTA.

Information was received from DSM and Grumman which was sufficient for preliminary positioning of the test articles on the VAMS platform.

With the definition of the mounting requirements for these items, it became clear that the VAMS platform as it exists does not have sufficient strength in the areas required for support.

Accordingly, arrangements were made with CSA/DFL, who own the VAMS platform, to design reinforcements in the required areas. This will involve the cutting out of 5" channel sections around the edges and replacement with 12" I-beams. Additional areas will be provided on the outside of the longer edges where required. A requirement for these modifications is that the VAMS platform must still be able to perform its original task of supporting the VAMS mass properties machine.

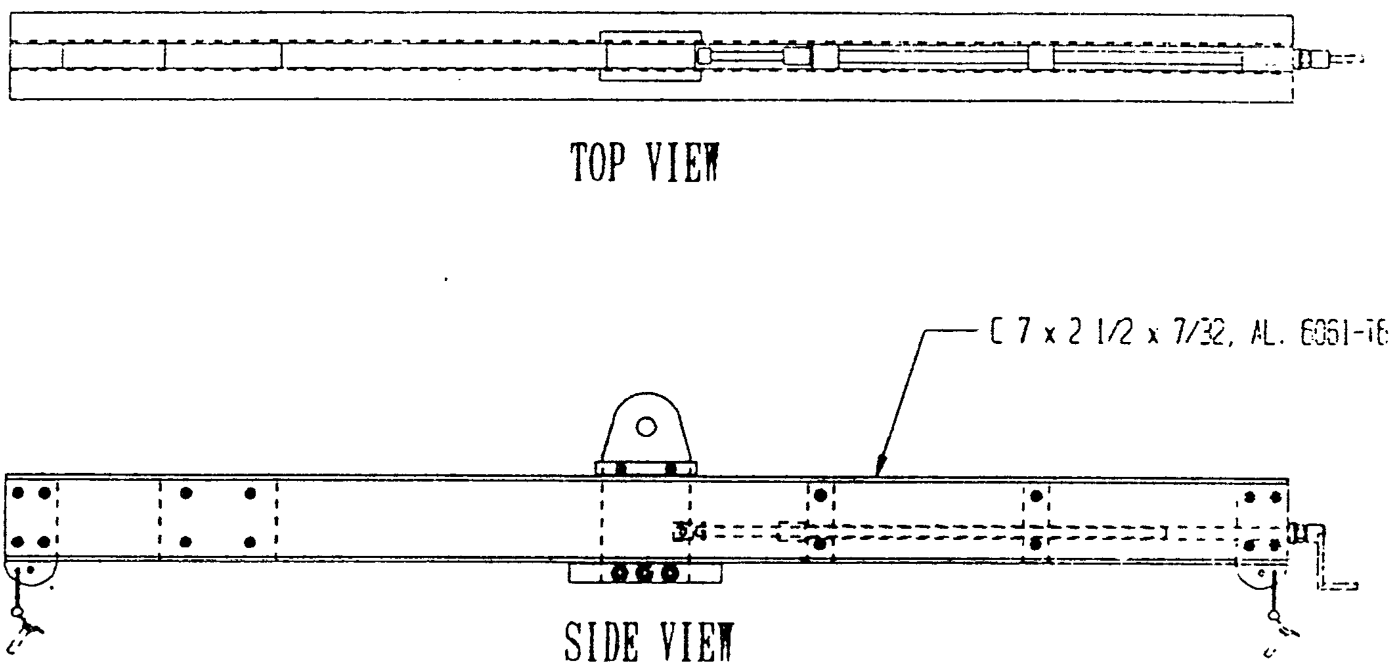

Figure 13: MIRROR FRAME LIFTING BEAM

3.3 Drawings identified

The following drawings had been identified as required by the completion of the contract. They will be produced during the timeframe of a successor contract.

DRAWING	DWG NUMBER
MAIN FRAME	
GENERAL ASSEMBLY	825930
ALUMINUM BASE STRUCTURE WELDMENT	825931
ALUMINUM LOWER MIDDLE STRUCTURE WELDMENT	825932
ALUMINUM UPPER MIDDLE STRUCTURE WELDMENT	825933
ALUMINUM TOP STRUCTURE WELDMENT	825934
STEEL BASE STRUCTURE WELDMENT	825935
STEEL LOWER MIDDLE STRUCTURE WELDMENT	825936
MIRROR FRAME LIFTING BEAM	825937
MIRROR FRAME ASSEMBLY	825938
LASER CONTAINER WINDOW FLANGE	825939
LASER CONTAINER	825940
PHOTOGRAMMETRY CAMERA	
CAMERA TEST SET-UP, ASSEMBLY	825941
CAMERA CONTAINER	825942
CAMERA SUPPORT	825943
LADD LASER PLATFORM	825944
LADD LASER CONTAINER HOOK-UP FLANGE	825945
MIRROR FRAME BRACKET INTERFACE PLATES	825946
LADD Y-JUNCTION	825947
MAIN FRAME/VAMS INTERFACE PLATE	825948

3.4 ROM costing for GSE

Manufacture of the items of GSE identified during this contract will be split between the Model Shop and outside vendors. The following table identifies the estimated costs for those items of GSE which are expected to be procured from outside vendors. Items with zero costs identified will either be made in the Model Shop, or used as are.

ITEM #	DESCRIPTION	QTY	COST PER	TOTAL COST
1	MAIN FRAME (3 PIECES & BRACE)	1	0	0.00
2	MIRROR FRAME	1	0	0.00
3	LASER CONTAINER	1	0	0.00
4	LASER AIR & CABLE FEEDTHROUGHS & HOSES	1	800	800.00
5	MODIFICATIONS TO VAMS PLATFORM	1	5000	5,000.00
6	OLYMPUS SUPPORT FRAME (USE AS IS)	1	0	0.00
7	EXCITER SUPPORT BEAMS	1	1250	1,250.00
8	EXCITER SUSPENSION SPRINGS & CABLES	1	1600	1,600.00
9	EXCITER CABLE FEEDTHROUGHS	1	800	800.00
10	CAMERA CONTAINERS	2	3250	6,500.00
11	CAMERA SUPPORT BEAMS & BRACKETS	1	3250	3,250.00
12	CAMERA AIR & CABLE FEEDTHROUGHS & HOSES	4	800	3,200.00
13	OLYMPUS STAGING (AS IS)	1	0	0.00
14	MIRROR FRAME LIFTING BEAM	1	8000	8,000.00
	SUB TOTAL, MGSE SUBCONTRACTED ITEMS			30,400.00

3.5 Test Planning

The test planning was divided into two sections as follows:

A. Actual Tests

1. Laser NCM System Tests
2. Photogrammetric NCM System Tests
3. Modal Tests of Membrane Test Articles
4. LADD Tests

B. Preliminary Tests to LADD Tests

1. Inspection and Checkout
2. Photogrammetric Target Installation and Test
3. Laser NCM System Target Installation and Test
4. Instrumentation (Accelerometers) Installation and Test
5. LTA/GSE/System Fit Checks
6. LTA Deployment/Retraction/Handling/Storage Tests
7. Ambient Check-out and Testing of Subsystems
8. Influence Coefficient Tests

Teams were assigned to each task, the leader of each team being responsible for producing inputs for his teams tasks for inclusion in the overall test plan.

Leadership of the teams for tasks B1, B5 and B6 was assigned to Spar personnel, together with membership of the team for task A4. Inputs for the three tasks were submitted to DSM in a preliminary form pending clarification of a number of outstanding points.

To assist in the preparation of these inputs, discussions were held with Grumman personnel and several drawings of LADD and LADD GSE were received. These are listed below:

P-A61B1460	Lens Test Article (LADD)
A61S1434	Sling Assembly, Hoisting Test Article & Shipping Container
A61S1437	Dolly Assembly, Handling & Transportation
A61S1438	Cover Assembly, Environment Protection, Transporter
A61S1439	Tower Installation, Deploy/Retract Test Article
A61S1480	Transporter Assembly, Shipping & Storage, Ground Handling
A61S1482	Fixture Assembly, Manufacturing & Shipping, Weldment
A61S1485	Tower Assembly, Weldment, Mast Protector Guide
A61S1487	Support Assembly, Environmental Cover, Transporter

4.0 Conclusions

The extent of the tasks involved in the performance of this contract became better defined as time progressed. The initial concepts were modified a number of times during the course of normal discussions with DSM staff. This process was helped greatly by the formation of the teams for the individual tests within the overall project, so that responsibilities could be assigned and actions placed.

As this contract has progressed it is clear that the close teamwork between the staff of CSA/DSM and Spar has enabled very effective use of the funds allotted. As concepts were modified or developed, a number of extra tasks became necessary as reflected by Amendment 2. At the end of this contract, a solid base had been established from which the detailed design and manufacture of the GSE could proceed. This will ensure a smooth transition to the ultimate goal which is the effective testing of the LADD Test Article itself.

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// This report is a review of the work performed under the contract. The work consists of a preliminary study, the preliminary design and part of the detailed design for ground support equipment (GSE) required for the structural dynamics testing of the LADD test Article (LTA). This testing is to be done inside the 22' X 35' thermal vacuum chamber which is part of the CSA David Florida Laboratory. The GSE consists mainly in the existing VAMS platform (which has to be modified) onto which the LTA, the main frame and mirror frame (with a container) of the multi-channel laser measurement system are to be supported. //

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