FINAL REPORT

GLASS SAMPLE CHARACTERIZATION

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16. Abstract

The draft of the final report details the work performed on this contract from Augsut 1989 through July 1990. The currently available capabilities at MSFC for integrated optical performance modelling for large and complex systems such as AXAF were investigated. The required hardware and software for the development of such a model have been identified. A number of design, development and testing tasks were supported to identify the debonded mirror pad, and rebuilding of the Technology Mirror Assembly (TMA). Over 300 samples of Zerodur were prepared in different sizes and shapes for acid etching, coating and polishing experiments to characterize the subsurface damage and stresses produced by the grinding and polishing operations.

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1. INTRODUCTION:

This report describes the work performed by the Center for Applied Optics (CAO), at University of Alabama in Huntsville for the Optical Systems Branch of Marshall Space Flight Center (MSFC). This work included investigations for the development of in-house integrated optical performance modelling capability at MSFC. This performance model will take into account the effects of structural & thermal distortions, as well the metrology errors in optical surfaces to predict the performance of large & complex optical systems such as Advanced X-ray Astrophysics Facility (AXAF). AXAF is currently being built by a team consisting of TRW, Kodak & Hughes Danbury Optical Systems (HDOS). Smithsonian Astrophysical Observatory (SAO) of Cambridge, MA is acting as consultant to MSFC for the design & development activities related to AXAF work. Currently, all structural, thermal and optical analysis work is being performed with stand-alone software packages such as ANSYS, SINDA and OSAC and EEGRAZ. The data input to all these software is cumbersome and time consuming and each type of distortion effects are analyzed individually. In other words, currently there is no way to determine the cumulative effects of structural & thermal distortions and metrology errors on the overall performance of an optical system. We have identified the necessary hardware and software to implement an integrated optical performance model.

The Technology Mirror Assembly (TMA) was built by Perkin-Elmer to develop fabrication and metrology techniques for AXAF mirrors. The TMA got misaligned during preparation for shipping, probably due to the failure of one out four epoxy bonds between the super invar pads and the paraboloid mirror. During the course of this past year, a number of tests were performed to pin-point the debonded pad. Moreover, the mirror mounts and assembly of the two halves of TMA has been redesigned. The TMA is planned to be disassembled, and then reassembled using this new hardware to evaluate the proof-of-concept for High Resolution Mirror Assembly (HRMA) of AXAF. CAO provided the necessary technical support to MSFC and SAO on these activities.

A large number of glass samples were also manufactured from Zerodur using the Optical Shop equipment at MSFC. These samples were ground & polished to the desired specifications, and then sent to various MSFC Labs and outside subcontractors for the coating, acid etching and subsurface damage evaluation experiments.

2. INTEGRATED OPTICAL PERFORMANCE MODEL:

At present, the structural analysis at MSFC is being performed mainly with ANSYS code, and with NASTRAN in limited cases. SINDA and TRASYS are being used for thermal analysis, and OSAC and EEGRAZ are being used for optical analysis. All these codes are installed on different computers at different Branches of MSFC. The data input to all these codes is manual, and therefore, very cumbersome and prone to errors for the analysis of large optical systems. The structural and thermal distortions are calculated independently, and then input to the optical analysis programs to predict the system performance. Moreover, presently there is no method available to include the effects of metrology errors in the optical performance analysis.

The High Resolution Mirror Assembly of AXAF, which consists of 6 pairs of hyperboloid/paraboloid mirrors is being analyzed by Kodak & SAO. Kodak uses NASTRAN & STAR programs to predict the effects of gravity, thermal and material properties variations on the optical performance. SAO is using ANSYS & OSAC for this work. They have developed in-house translation codes for automatic data translation from the structural to the optical analysis programs. None of these schemes has the capability to incorporate the metrology data into the model. As a starting point, the copies of OSAC and ANSYS to OSAC translation codes were obtained from SAO, and installed on Optical Systems Branch's MicroVAX.

As a result of this investigation into the currently available modelling capabilities, it became clear that there is an important and urgent need to develop integrated optical performance modelling capabilities at MSFC for AXAF design & development work. The first step in this process was to contact the Air Force Weapons Lab at Kirtland Air Force Base, NM. They have developed a comprehensive Integrated Systems Modelling (ISM) code, which integrates the existing thermal, structural, optical, controls and multi-body dynamic analyses software modules. The commercial and COSMIC software codes such as ANSYS, NASTRAN, SINDA, TRASYS, ACCOSV, etc. have been interfaced in ISM for automatic data interchange between these codes. DECstation 3100 is the primary hardware platform. The ISM Beta Test release, which was originally scheduled for June has been delayed until September, 1990. More details of this test plan and ISM capabilities can be found in Appendix A.

In order to save time and cost for the development of new software, it was proposed to the AXAF program management to participate in ISM Beta test. The details of this proposal are given in Appendix B. This proposal was accepted, and 2 DECstations 5000 have been ordered. These workstations are binary file compatible with the required DECstation 3100, and also offer speed & price advantages.

3. TMA TECHNICAL SUPPORT ACTIVITIES:

Technical support was provided to the Optical System Branch for the rebuild program of Technology Mirror Assembly (TMA) in the area of redesign of the mirror mounts to evaluate HRMA concepts, and the tests performed to identify the debonded paraboloid mirror pad.

The TMA consists of a hyperboloid and a paraboloid mirror. Each mirror is bonded to a graphite epoxy (GREP) cylinder through 4 super invar pads, and each cylinder is supported at both ends. The mirror support design for AXAF as proposed by Kodak uses tangential flexures bonded to each mirror at its midline. These flexures are bonded to sealed GREP cylinders, which span only half of the length of each mirror. Each half cylinder is attached, at one end only, to the central aperture plate.

SAO has proposed that TMA should be disassembled and reassembled with the new hardware per the design proposed by Kodak for HRMA. These new designs for flexures, cylinders and base flanges were reviewed for MSFC. The 9 rebuild options proposed by SAO were reviewed for technical merit and the cost. These recommendations were submitted to the Optical Systems Branch in the form of a rebuild plan included as Appendix C.

Two test/inspection procedures were performed on TMA to pin-point the debonded pads. The acousto-ultrasonic (A/U) test was performed by HSBI Technologies of Sacramento, CA under the supervision of SAO personnel. The model 301 A/U Bond test system was calibrated with a sample model of TMA. The sample graphite epoxy (GREP) piece had an invar pad bonded at one location, and a piece of zerodur bonded to an invar pad at another location. The hand-held fixture had two sensors (sender & receiver) with small rubber pads in it. This fixture was pressed against the GREP piece over the invar pad and invar pad/zerodur locations. The RMS magnitude and the shape of the return signals was recorded to differentiate a good bond from the bad bond.

All the bonds on hyperboloid & paraboloid were tested in the same fashion. The analysis of the numerical data & the pictures did not show any consistency or repeatability. It was found that the magnitude and shape of the return acoustic signal were strongly influenced by the orientation of the hand-held fixture, and the force with which it was pressed against the GREP sleeves. It was decided that these tests will be repeated with a new fixture to hold the probes with a constant force at a fixed orientation relative to each pad. SAO is going to redesign and fabricate this fixture.

The TMA was also inspected by using the stethoscopic tap tests. The GREP sleeves were gently tapped with a Quarter coin in the vicinity of each pad, while listening to the return echo from optic. It was discovered that the return echo was about the same from all the pads except for the pad at 132 degrees. location on the paraboloid side. The sound at this pad was identical to GREP sleeve with no pad. It is, therefore, suspected that paraboloid mirror has debonded from its pad at this location.

The next step is to perform a load test on TMA by applying known loads to GREP sleeves, and measure the resultant distortions. The design of fixtures and tooling and the procedure for this test were reviewed, and the recommendations were submitted to MSFC in April. These recommendations were incorporated into the revised test procedure by SAO in memo LMC-89053 dated June 18, 1990. The test fixtures are being fabricated now, and this test will be conducted at MSFC in the near future.

Other miscellaneous support activities included the review of baffle design for the for the new X-ray test facility for AXAF, and participation in several meetings and conference calls at MSFC to discuss the design and development activities related to AXAF.

4. GLASS SAMPLES PREPARATION & CHARACTERIZATION:

A very large number of samples were prepared in different sizes from Zerodur to perform various types of acid etching, grinding/polishing and coating experiments. A total of 150 samples were prepared for the acid etching experiments to study the subsurface damage and stresses caused by surface grinding. The purpose of these experiments was to determine the optimum acid etching time required to eliminate microscopic cracks & crevices. The samples were accurately weighed to 0.001 gm accuracy, and then placed in acid bath for 60 minutes in 2 minute intervals. These samples were weighed between each interval, and the removal rate was plotted versus time as shown in figure 4.1. It can be seen that the removal rate is the highest during the first 2 minutes, and 95% of the removal takes place within 15 minutes, and then becomes negligible after 30 minutes. Another 100 samples were prepare and delivered to Hughes Danbury Optical Systems of Danbury, CT for conducting similar experiments related to the fabrication of AXAF mirrors.

In the grinding/polishing experiments, zerodur samples were ground with 30μ grit compound. The surface roughness was then measured with Tallystep at CAO. This procedure was repeated for 20μ, 12μ and 5μ grit compounds.

Another 4 small zerodur flats (1" dia x 1/8" thick) were fabricated and delivered to MSFC's Physical Sciences Lab. These flats will be coated, and flown on the space shuttle to determine the effects of space environment on the surface quality. A number of other glass samples are still being made for other experiments.

A number of other tasks relating to the installation of equipment for grinding & polishing of glass samples were also performed. A new surfaced grinder was acquired, and the ancillary tooling was transferred from the old grinder to the new machine. A contamination tent was also installed on the new grinder.

5. CONCLUSIONS:

The tasks identified in the scope of work for this contract have been successfully completed. The hardware and software required for the development of an integrated optical performance model have been identified. After a careful investigation into the current capabilities at MSFC and the AXAF contractors, it has been decided to use ISM code developed by USAF Weapons Lab installed on DECstation 5000 for this development effort. We are planning to participate in the Beta test program starting in September 1990, and continuing through the next fiscal year.

A number of design, development and testing tasks were supported for the rebuilding of TMA to validate AXAF design concepts. As a result of these tests, the debonded pad on the paraboloid mirror has been identified. The load tests and the reassembly of TMA with a new set of hardware is planned for FY 91.

Finally, over 300 samples of Zerodur were prepared in various sizes and shapes by cutting, grinding and polishing techniques at MSFC optical shop. A number of experiments were conducted at MSFC and outside contractors to study the effects of these manufacturing methods on subsurface damage such as microscopic cracks, crevices and residual stresses. The results of these experiments will help in selecting the best possible manufacturing methods for the 12 AXAF mirrors.

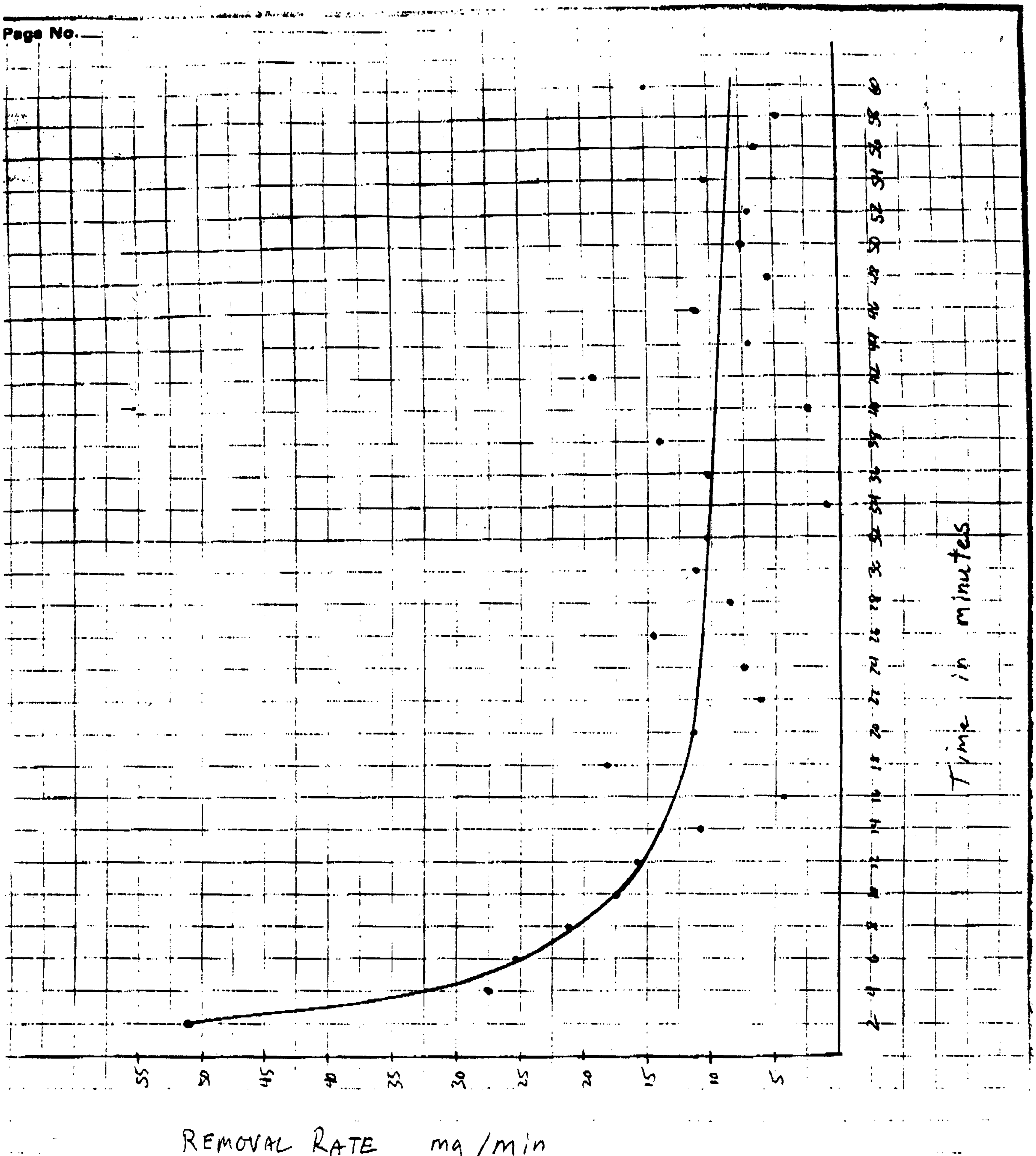


Figure 4.1: Zerodur Removal Rate Due to Acid Etching

APPENDIX A

ISM BETA TEST PLAN

BETA TEST PLAN
FOR THE
INTEGRATED SYSTEM MODELING CODE
(REV 2, 14APRIL90)

1. GENERAL

1.1 ISM:

The objective of the Integrated System Modeling (ISM) research program is to develop a comprehensive simulation, analysis, and design tool interfacing the many disciplines of structures, optics, controls, thermal analysis, and multi-body dynamics. ISM will integrate existing state-of-the-art software modules within each discipline while taking advantage of the latest computer hardware.

1.2 BETA TEST DEFINITION:

The Beta testing will be performed on the ISM software to ensure consistency with existing codes and to check the friendliness of the ISM code. This is accomplished by means of taking the preliminary version of the ISM software and sending to multiple commercial, government, and academia sites for application and evaluation.

1.3 PURPOSE OF the BETA TEST:

The purpose of the Beta test is to debug the ISM code in an intensive manner through the use of several Beta test groups, assess and help improve ISM's user friendliness, and facilitate the technology transfer of ISM to the user community.

1.4 PURPOSE OF THE BETA TEST WORKSHOP:

The purpose of this workshop is to show the various Beta testers how to use the ISM code. It will be a two day training session at the Weapons Laboratory and will be the kickoff for the beta testing period.

1.5 POST BETA TEST CONFERENCE:

A mandatory conference lasting one to two days for all Beta test groups to be held at the end of the testing period. The purpose is to exchange information on strengths, weaknesses, and possible enhancements of the ISM code.

1.6 DURATION:

The Beta testing will last four months and will be preceeded by the Beta test workshop and end with the Post Beta Test Conference/delivery of final report.

1.7 NUMBER OF MODULES TO BE TESTED:

Our goal is to test all of the disciplines which include structures, optics, controls, thermal analysis, multibody dynamics, and simplified versions of fluid dynamics.

1.8 BETA TESTER RESPONSIBILITY:

The Beta testing organizations will identify dedicated individuals to attend the workshop, provide resources needed for testing, obtain access to required computer hardware/software, provide monthly status summary reports reporting errors and suggestions for the ISM code, provide a final Beta test report and attend/brief Post Beta test Conference.

2. BETA TEST SITES

2.1 PRIVATE COMPANIES:

The private company sector offers diversity and relatively easy access to real time work such as Z-star and the NPB. Use of private companies will also facilitate the flow of technology, one of the prime motives for the Beta Test.

2.1.1 Each company will be required to have a certain level of expertise for their tests. The Weapons Lab will try to match certain modules with company expertise. Also, the Weapons Lab will require this expertise to cover different areas to maintain a broadness needed for the "overall big picture".

2.1.2 Each company will be evaluated and chosen based on their software/hardware capabilities and broadness of expertise.

2.2 UNIVERSITIES:

Universities offer one of the most challenging environments to code testing due to the unforseen test modes that the code will have to go through. In addition to the diversity of testing, universities offer (1) "inexpensive labor" in the form of dedicated students, (2) a potential long term benefit that may outlast the Beta Tests; Namely, porting certain modules to other computer systems, interfacing other existing codes, or even other upcoming codes to ISM.

2.3 GOVERNMENT AGENCIES:

Quite a few Government organizations have shown interest in being Beta Testers. This interest extends across multiples of NASA sites as well as Sandia/DOE. For a more complete list of Government agencies check attachment 2.

3. HARDWARE REQUIREMENTS

3.1 MINIMUM REQUIREMENTS: The DECstation 3100 is the basic hardware needed for ISM. This Unix machine is capable of 15 Mips (Million Instructions/Second) with the following features:

- a total of 765MB of hard disk drives (1-104MB+2-332MB drives)
- a TK50 tape drive
- a total of 24MB of RAM
- a FORTRAN compiler (COSMIC FORTRAN is available)

Ultrix (a DEC implementation of Unix) will be the operating system. This machine will give the user Beta testing capabilities. A partial list of the ISM modules running on the Decstation 3100 follows:

* 1) ISM executive
* 2) COSMIC NASTRAN(structural)
* 3) AL526(mesh interpolator)
* 4) EIGEN(structural)
5) SINDA(thermal)
6) ORACLS(controls)
7) FEMNET
8) MIMIC(mesh interpolator)

* indicates public domain codes

For a more comprehensive list of all the interfaced public domain codes, see Atch # 1.

3.2 OTHER DESIRABLE EQUIPMENT FOR THE ISM CODE: As mentioned in paragraph

3.1, the DECstation is the minimum hardware needed to run ISM, however, the following machines are desirable. These machines will broaden ISM's capability as well as produce faster runs. They may be used altogether or in any combination available (distributed processing is another benefit that ISM supports). These machines are:

- any of the VAX(VMS) series
- any of the IRIS (Silicon Graphics) high quality graphics, 4D(Unix) machines
- any of the Stardent mini supercomputer machines(Unix). This will be an asset for intensive compute purposes.

(see chart (Attachment 1) for what software runs on which machines)

All hardware referenced in this section will be the site responsiblity therefore, provided by the Beta tester.

NOTE: The Decstation will be required even if some or all of the desirable machines are available!

4. SOFTWARE REQUIREMENTS

This paragraph refers to the applications software. The operating system software is assumed to be available and will not be discussed in this document.

4.1 ISM INTEGRATING SOFTWARE:

The ISM integrating software including the executive code, the data base, the data base manager/editor, and the user interface modules will be provided by the government (WL) on reel or TK50 tapes.

4.2 PUBLIC DOMAIN SOFTWARE:

This list covers all of the software that has been government developed and placed on the public domain list. There is little or no charge for aquiring a copy of these codes from Cosmic Database. If there is a charge, it probably covers labor and media charges. Public domain software will be provided by the government on reel or TK50 tapes. If there is a service fee for any of the public domain codes needed, the Beta testers will take the responsibility of acquiring them. The following is a partial list of public codes that will be interfaced with ISM for the Beta test:

- IAC/ACE
- COSMIC NASTRAN
- MATLAB
- EIGEN
- TOPS
- PAGOS
- SINDA
- MIMIC
- AL526
- FEMNET
- ORACLS
- DISCOS

For a more comprehensive list of the public domain codes interfased to ISM see attachment 1.

4.2.1 The minimum number of software packages is a function of the Beta test problems and will be decided on as the test problems are identified.

4.3 COMMERCIAL SOFTWARE:

This list covers the codes that are interfaced with ISM and have a proprietary nature, therefore, requiring monthly/yearly fees. These fees greatly exceed the nominal charges of COSMIC database. These codes will be provided by the Beta Test Site if needed. The following is a partial list of the commercial codes that will be interfaced with ISM:

- NASTRAN
- MATRIXx
- PATRAN
- IDEAS
- EASY5

For a more comprehensive list of all commercial codes interfaced with ISM see attachment 1.

4.4 MINIMUM SOFTWARE NEEDED:

The minimum software needed is a function of the test problems, but each site is expected to have two installed commercial packages. This will be identified as the test problems are identified. Also, a network computing system (NCS) and a network filing system (NFS) will be needed. NFS comes standard on the DECstation 3100 while the NCS costs less than $600 to purchase from Hewelett Packard (APOLLO). NCS is provided free of charge by the University of Iowa to members of the University-Industry Cooperative Research Center. Ism developed software based on NCS will be provided free of charge.

5. NUMBER OF SITES NEEDED

5.1 MINIMUM SITES:

Five testing groups are needed as a minimum, with Martin-Marietta (Z-

Star) and Lockheed (SPICE) standing on their own as validation sites. The Beta sites will consist of private companies, universities, and government agencies. (WL/SETA will act as a cross-checking group for all Beta Testers)

5.2 PRIVATE COMPANIES:

Two to four sites, possibly more, will be chosen from private companies. These companies will be chosen based on the following criteria:

1- hardware/software availability. This will primarily cover the DECstation 3100/5000 to make sure that the Beta test is done properly. All of the public domain codes will be either delivered to the site or aquired from the COSMIC Database.

2- availability of one or more of the ISM commercial modules.

3- expertise at site. The broader the expertise(controls,optics, structures, multi-body dynamics, and thermal analysis), the more valuable the Beta site will become to the Weapons Lab.

5.3 UNIVERSITIES:

The Air Force Institute of Technology (AFIT) and the University of Iowa Research Center are to be Beta Test Sites.

5.4 GOVERNMENT AGENCIES:

NASA, WRDC, Sandia/DOE, Army, Navy, Astro Lab.

6. TEST PROBLEMS

6.1 BENCH TEST PROBLEM:

A standardized Bench Test problem will be analyzed by each group to ensure quality results from the Beta testing.

6.1.1 The Bench Test Problem will be TACOS. This problem will include at least three/four of the following disciplines: structures, optics, controls, multibody dynamics, and thermal analysis.

6.2. SPECIALIZED TEST PROBLEM:

Each group will also do a separate Specialized Test Problem. Possible Specialised Test problems may be components of ALS, SBL, NPB, BP, or others coordinated with the Weapons Lab.

6.3 MAXIMIZING MODULES:

WL will want to maximize the number of modules tested by the groups. Ideally, all available modules (structures, optics, controls, multi-body dynamics and thermal modules) will be tested.

6.4 MATCHING:

The WL will try to match Beta site hardware/software available to the Beta test problems. This process will divide the burden of having the commercial codes over all Beta testers.

7. DELIVERABLES

7.1 MONTHLY PROGRESS REPORTS:

Monthly progress reports will be needed from each Beta test site. The purpose of the monthly progress reports is for error reporting and suggestions for the ISM code.

7.2 MANDATORY POST BETA TEST CONFERENCE:

A mandatory Post Beta Test Conference is planned for all Beta testers. This conference will give us a face to face discussion of the strengths, weaknesses, and possible enhancements of the ISM code. This conference will be held at the Weapons Lab and will tentatively last for one day.

Aerospace Systems Technologies

Module Hosting - Anticipated Availability

Boeing Aerospace & Electronics

	VAX	DEC Station	IRIS 4D	Stardent	Cray
IAC/ACE	○√	○√	○√	○√	√
MSC NASTRAN*	√	√			○√
COSMIC NASTRAN*	○√	√			
ANSYS*	√	√			○√
SINDA85	○√	√		○√	?
TRASYS	○√	?			?
GAMMA	○√	√			√
MATRIXx*	○√	√			?
ISMLAB	○√	○√	√	○√	√
EASY5*	○√	√			?
MATLAB*	○√			○√	
TIMFST	○√	○√		○√	√
FRQRSP	○√	○√			√
PAGOS	○√	○√		√	
ACCOS V	○√				○√
OASIS	○√	√			√
EIGEN	○√	○√	○√	○√	√
DISCOS	○√	○√		√	√
SADACS		√		√	√
COMP	○√	○√		√	
INCA	○√	?			
ABC	○√	○√		√	√
TOPS	○√	○√		√	
DART	○√	○√		√	√
BCD	○√	○√			
RAVEN					√
FEMNET	○√	○√	○√	○√	√
MIMIC	○√	○√	○√	○√	√
PATRAN*	○√	√	○√		
TGD		√	√		
NCS*	√	√	√	√	√
NFS*	?	√	√	√	√

* Commercial software - availability subject to purchase/lease ○ Expected intermediate software availability

ATCH #1

ST/kwo/rgv/03/9001

APPENDIX B

INTEGRATED OPTICAL PERFORMANCE MODEL PROPOSAL

GOALS

- Develop an in-house integrated modelling capability to predict optical performance of AXAF using thermal, structural and optical codes along with metrology data.

- Will be used to predict the optical performance of AXAF (both static & dynamic) more accurately during the development phase.

- Will be used to predict performance degradation during the operation of AXAF.

CURRENT STATUS

- OSAC is installed on EB24's MicroVAX.
- EE GRAZ is installed on MicroVAX and IBM frontend.
- ANSYS is installed on Structural group's VAX (I2V4) & EADS.
- SAO has given us ANSYS to OSAC translation code, which is installed on MicroVAX.
- There is no automatic interface between thermal and structural codes and OSAC.
- No capability to incorporate metrology data into the models.

INTEGRATED SYSTEMS MODELLING (ISM) CODE

- Air Force Weapons Lab (KAFB) has developed a comprehensive modelling code by integrating existing thermal, structural, optical, controls and multi-body dynamics software modules.
- Commercial & COSMIC software codes such as ANSYS, NASTRAN, SINDA, TRASYS, ACCOSV etc. have been interfaced for automatic data interchange between these codes.
- Air Force is looking for participants to start Beta Test in June 90.
- Will provide software and training free of charge to the participants.
- DECstation 3100 is the primary hardware platform.

SOFTWARE CODES PRESENTLY INTEGRATED IN ISM

OPTICS	STRUCTURAL	THERMAL	CONTROLS
ACCOSV	NASTRAN	SINDA	ORACLS
OASIS	ANSYS	TRASYS	INCA
TOPS	DISCOS		
TGD	PATRAN		
COMP	EIGEN		

PHASE 1 – ISM BETA TEST

TASKS
- Attend a 2-day pre Beta test training workshop at Kirtland Air Force Base.
- Model a simple system given by Air Force - 2 weeks tutorial
- Model TMA or VETA using ISM
- Compare ISM results with SAO or E-K analysis results.

DURATION
- 4 months (starting on June 27, 1990)

MANPOWER
- ED63 Thermal Control Engineering Branch
- ED25 Structural Analysis Division
- EB23 Optical Systems Branch
- UAH

EQUIPMENT
- DECstation 3100 system - \$40.3K for 1 station
  - \$60K for 2 stations

PHASE 2 – POST BETA TEST

TASKS	• Modify EE GRAZ from 1D to 3D
	• Integrate HDOS optical surface metrology data into ISM
	• Integrate OSAC, EE GRAZ into ISM
	• Model HRMA with ISM
DURATION	• Software development - 1 year
MANPOWER	• EB23 Optical Systems Branch
	• ED25 Structural Analysis Division
	• ED63 Thermal Control Engineering Branch
	• ED12 Pointing Control Systems Branch
	• UAH
EQUIPMENT	• DECstation 3100

MINIMUM HARDWARE NEEDED FOR ISM

	GSA price
1. DECstation 3100 package includes: 16 MB RAM 19" color monitor Ultrix license 104 MB hard drive keyboard	21,124.00
2. 4 MB memory @ $1896.00 / each need 2 x 4 MB to reach 24 MB total	3,792.00
3. RZ 55 332 MB hard drive	4,866.00
additional 332 MB to reach 785 MB hard drive total	4,866.00
4. TK50 tape drive	3,049.00
5. Ultrix media documentation list	1,583.00
6. Fortran Compiler (optional) cosmic version avail	821.00
7. Fortran media, documentation list	242.34
Total price for 104 + 2/332 MB hard drive system	$ 40,343.34

INTERFACED CODES REQUIRED FOR AXAF MODELLING

CODE	ISM	CURRENT CAPABILITY
– ANSYS (STRUCTURAL)	Y	Y
– NASTRAN (STRUCTURAL)	Y	N
– SINDA (THERMAL)	Y	N
– TRASYS (THERMAL)	Y	N
– OSAC (OPTICAL)	N	Y
– EE GRAZ (OPTICAL)	N	N
– ORACLS (CONTROLS)	Y	N
– METROLOGY	N	N

CONCLUSIONS

- o Eliminate software development cost to integrate structural and thermal codes into the model.

- o Provide capability to incorporate HDOS metrology data into the performance model.

APPENDIX C

TMA-3 REBUILD PLAN

PROPOSED TMA REBUILD PLAN
(HRMA PROOF OF CONCEPT)

1. SCOPE:

It is proposed that the existing TMA-2 be disassembled, and then reassembled and realigned using the new parts designed per the latest HRMA designs and requirements to evaluate these concepts. In order to obtain maximum information about the causes of the existing instability, and the predicted HRMA performance, the following sequence of events is proposed for this effort:

1. Design & analysis of the new concepts for flexures, graphite epoxy cylinders and flanges.

2. Tap test of the existing TMA-2.

3. Fabrication of the new parts.

4. Assembly and alignment with the new parts.

5. Testing and performance evaluation.

The following paragraphs give the details of the proposed work in some of these area.

2. GRAPHITE EPOXY CYLINDERS:

The radial differential expansion between the mirror & the cylinder is more critical than the axial expansion, so the high axial thermal coefficient of the present cylinders should not significantly affect the mirrors' figure. Some thermal analysis should be performed to compare the thermal performance of the existing cylinders with the proposed new cylinders. Moreover, even with the new cylinders, it will be difficult to predict HRMA thermal performance since it would be difficult to simulate the HRMA thermal loads for the TMA.

If the existing cylinders deform slightly during the disassembly process, we may be able to compensate for this deformation during the bonding of the new flexures in the bond thickness between the end blocks of flexures and GR-EP cylinders.

It is, therefore, proposed that if there are funding and schedule constraints for procuring the new cylinders, TMA be reassembled with new flexures and the existing cylinders to test the gravity performance.

3. FLEXURES:

The proposed design of new flexures is quite stiff in radial direction, and can possibly subject the mirrors to high local stresses due to differential radial expansion between the mirror and the cylinder during the storage and normal operation. It is suggested that analysis be performed to evaluate this potential problem.

The proposed arrangement of using 4 flexures, 90 degrees apart needs to be further evaluated. The two flexures in 12 & 6 o'clock positions are not supporting any load; these are providing lateral stiffness only. This arrangement, therefore, does not result in equal load sharing among the 4 flexures. Moreover, the weight supported per flexure is also much lower than E-K HRMA design (30.1# for P1). It is suggested that using 3 flexures, 120 degrees apart, be considered and analyzed. If the analysis results indicate the need for 4 flexures, then the existing positions of support pads in TMA-2 at 48, 132, 228 and 312 degrees from the 12 o'clock position, would result in better load sharing among the 4 flexures.

Invar is known to have dimensional stability problems. It is suggested that at least the blade part, and possibly the end blocks bonded to the cylinders, be made from 17-4 PH type stainless steel. Only the blocks bonded to zerodur need to be made out of invar. This change will also enhance the stiffness of the mount (E=29 vs. 22 million psi). This change is possible to accomplish because of the multi-piece construction of the flexure assembly.

Another modification to the proposed 2-piece design of the bonding block needs to be considered. The spacer between the two pieces can be moved to the top of the bonding block i.e. between the block and the flexure. This change will simplify the fabrication of the block, and would improve accessibility for initial bonding and disassembly, if required.

In order to optimize the pad bonding area and bond thickness, and to study the distortions caused by epoxy shrinkage, it is proposed that SAO should conduct bonding tests on sample pieces of zerodur of the same thickness. These tests should be conducted with the same pad area, bond thickness and epoxy that will be used for the TMA rebuild.

It is , therefore, proposed that 2 sets of new flexures be fabricated per HRMA design, and both TMA mirrors be reassembled with these flexures to evaluate the gravity performance.

4. BASE FLANGES:

The possibility of reworking the existing flanges and CAP per Kodak's or LLNL precision flange design needs to be investigated to come up with a viable concept for "disassembly without realignment" (DWOR).

The pad areas of LLNL diamond machined flanges that come into contact with CAP would have to be minimized to achieve DWOR. Moreover, during the handling and assembly procedures, extra care would be required to protect the precision machined surfaces. The option to locally harden the critical pads should be investigated.

As Kodak's design concept of casting pins in epoxy is not likely to provide DWOR to the required tolerances, some modifications to improve this design should be incorporated before fabricating a base flange per this design.

It is, therefore, proposed that if the procurement of new flanges is delayed due to funding and schedule constraints, the existing flanges should be modified/reworked to proceed with the gravity tests using the new flexures, and to evaluate any new concept for DWOR.

5. REVIEW OF TMA-3 REBUILD OPTIONS:

SAO's proposed 9 options for rebuilding TMA-3 to evaluate HRMA design concepts can be evaluated on the basis of cost and the resulting information obtained in the following areas:

1. Gravity performance i.e. mirror distortions when supported by flexures per HRMA design.

2. Thermal performance i.e. mirror distortions and misalignment due to ambient temperature changes.

3. Evaluation of the design concepts which will allow disassembly of GREP sleeves from CAP, without requiring the realignment of the mirrors.

The following table lists the cost of new parts for each option, and the results obtained in the above-mentioned areas:

OPTION NO.	COST	INFORMATION OBTAINED
1	NONE	Evaluation of taper pin design for disassembly without realignment (DWOR) concept.
2	6K	Gravity performance (GP) of paraboloid only.
3	12K	GP of paraboloid & hyperboloid.
4	23K	GP & thermal performance (TP) of paraboloid.

5	40K	GP and TP of both mirrors.
6	21K	GP & DWOR of paraboloid.
7	77K	GP & DWOR for both mirrors.
8	38K	GP, TP & DWOR for paraboloid.
9	105K	GP, TP & DWOR for both mirrors.

The cost figures given above are based on the following item costs:

ITEM	QTY	COST
- Flexures	4	6K
- GREP Sleeves	1	17K
	2	28K
- E-K Flange	1	15K
- LLNL Flange	1	50K

6. SELECTION OF REBUILD OPTIONS:

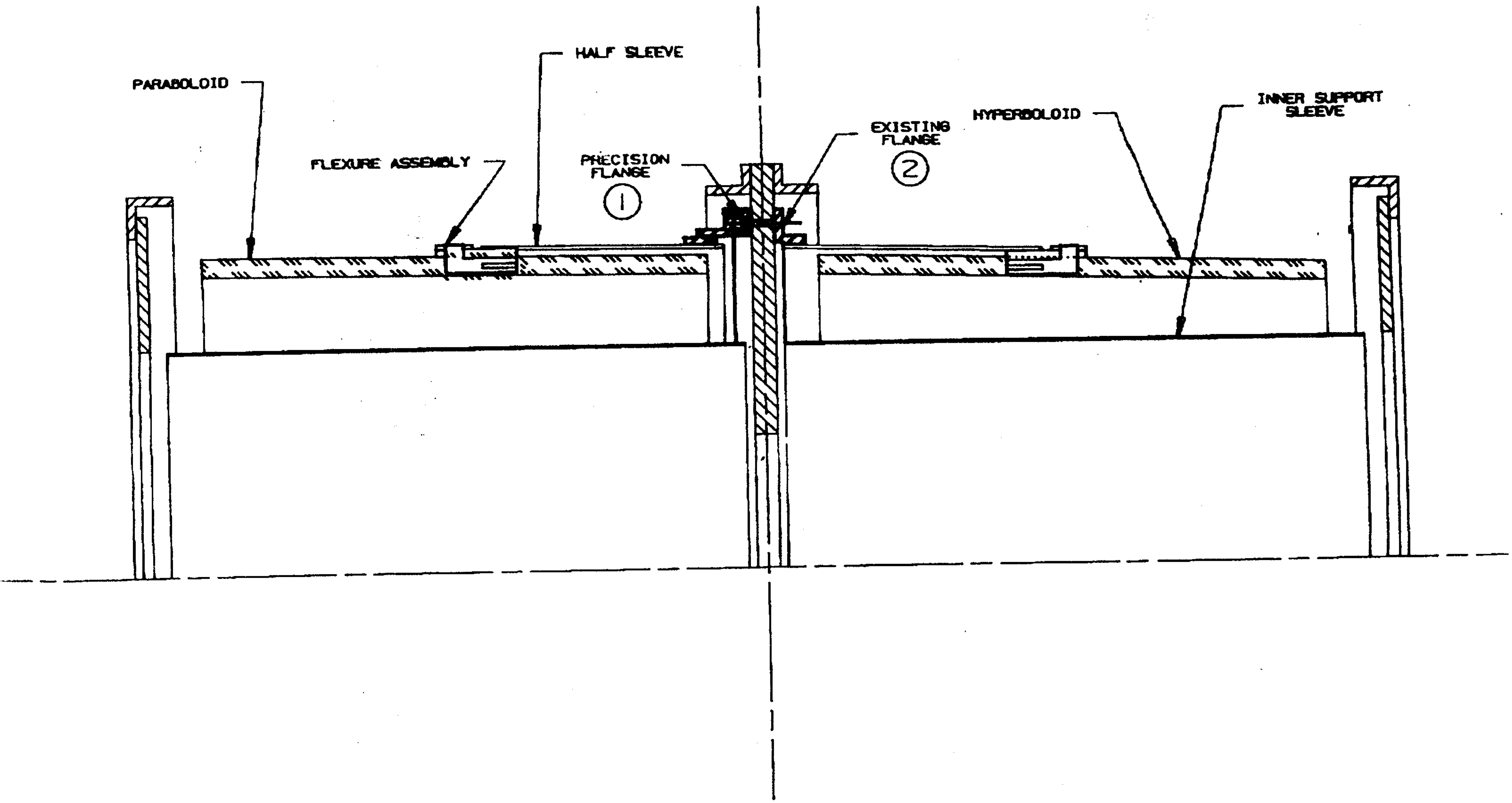
In order to obtain maximum useful information from the rebuild effort, it is proposed that this effort be completed in phases. This will also help in isolating the effects or results of the design changes made in flexures, GREP cylinders and flanges. Based on the cost and the resulting information obtained, it is recommended that the TMA should be rebuilt per the following options in the listed sequence. It is being assumed that we will be able to disassemble the parts without damage when proceeding to the next phase.

Phase 1: Fix the debonded pad , Option 1.

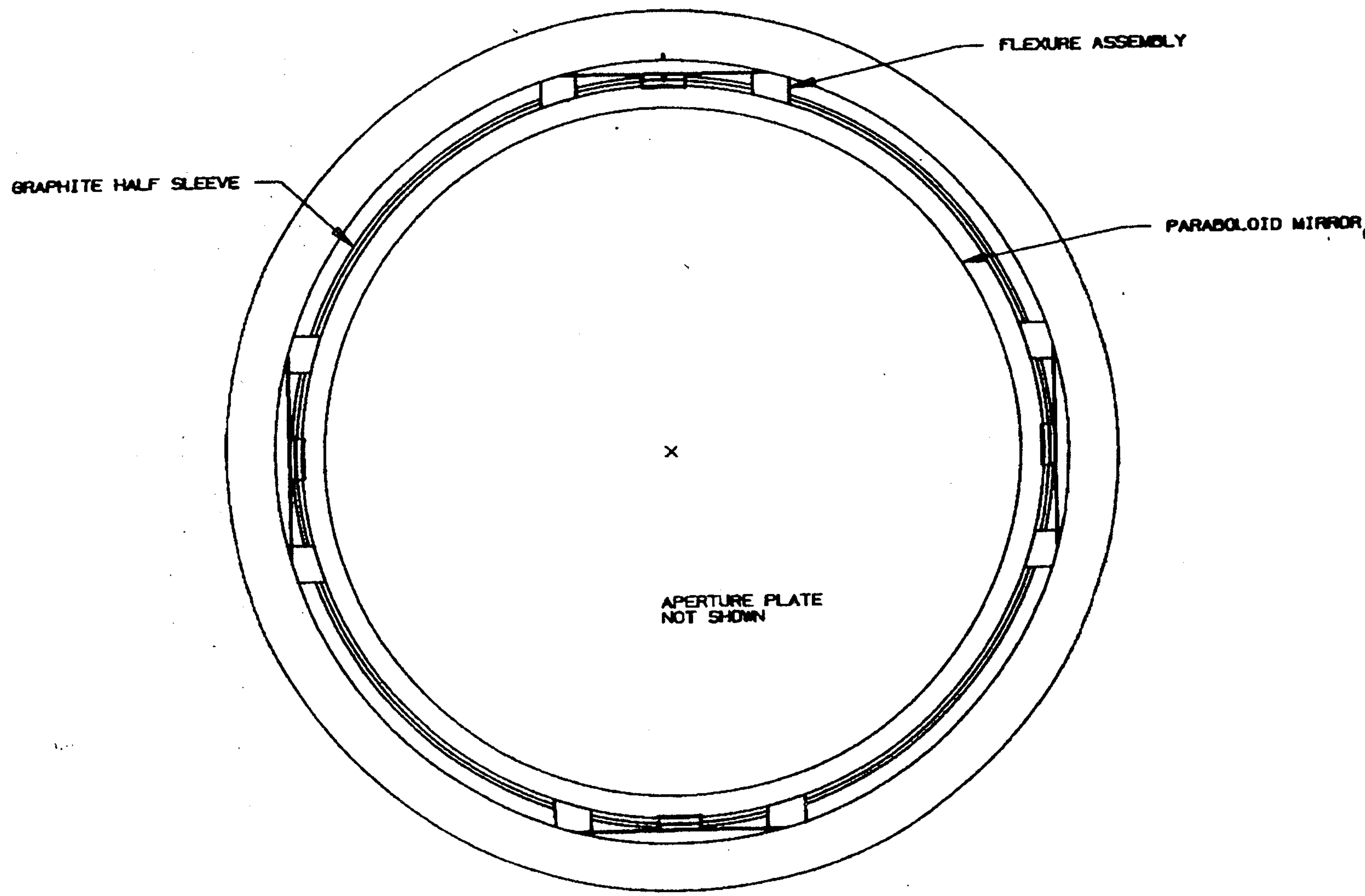
Phase 2: Reassemble both mirrors with new flexures to test the gravity performance, Option 3.

Phase 3: Reassemble both mirrors with new flexures and new GREP sleeves to test gravity and thermal performance, Option 5.

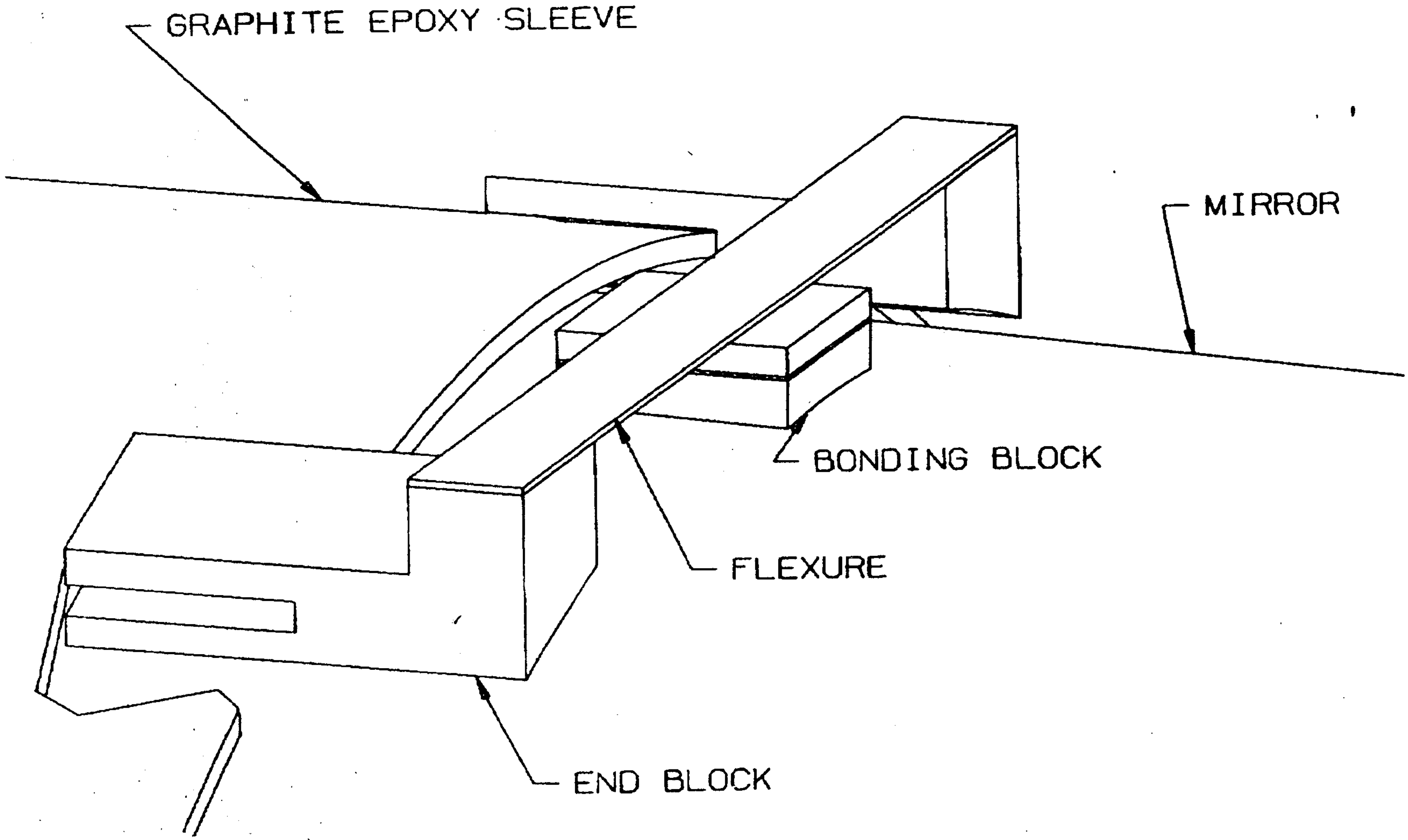
Phase 4: Rebuild with new flexures, sleeves and flanges, Option 9.



TMA--REASSEMBLED WITH HALF SLEEVES AND FLEXURES
TWO BASE FLANGE OPTIONS SHOWN (1 + 2)



FRONT VIEW OF THE TMA -- FOUR FLEXURES SHOW



PROPOSED MIRROR SUPPORT FLEXURE   SCALE 1.5:1