MEMO #13

T I W SYSTEMS, INC.
1284 Geneva Drive
Sunnyvale, CA 94089-1196

(408) 734-3900
(408) 734-9012 Fax

FAX COVERSHEET

DATE 13 April 1990 **TIME** ______ am/pm

TO Bill Bruckman **FROM** Johanna MacAloney

FIRM HSAO **FAX #** (617) 495-7105

SUBJECT Responses to Questions **JOB #** I-348

NUMBER OF PAGES (INCLUDING COVERSHEET) 12

Please call (408)734-3900 if this fax is received incomplete

Attached please find a copy of TIW's responses to your questions on the report. A hard copy is being sent by mail.

If you need anything else, please let me know.

Sincerely,

TIW SYSTEMS, INC.

Johanna MacAloney
Director, Scientific Instruments
Business Area

TIW SYSTEMS, INC.
1284 Geneva Drive
Sunnyvale, California 94089-1196

13 April 1990

Harvard Smithsonian Center for Astrophysics
60 Garden Street
Cambridge, MA 02138

Attn: Mr. William R. Bruckman

Ref: Questions on Final Report

Dear Bill:

Enclosed please find TIW's responses to your questions on our final report. After you have had a chance to review these, it may be worthwhile to talk again about the results to make sure that we all understand each other.

In responding to the questions, the issue of best fit came up, which we had discussed earlier in relation to positioning the subreflector. TIW is currently looking at actively controlling the secondary in real time for a somewhat larger antenna, but it occurred to us that an actively controlled secondary might be beneficial for your antenna. The need to control the secondary may be determined by a pointing error analysis, but based on the work we are doing now on another project, it does seem feasible for your antenna.

If you have any questions concerning the enclosed information, please feel free to call.

Sincerely,

TIW SYSTEMS, INC.

Johanna MacAloney

Johanna MacAloney
Director, Scientific Instruments
Business Area

JM/ajh

Enclosure

Telephone: (408) 734-3900 Telex: 346352 Fax: (408) 734-9012

I-348
13 April 1990

RESPONSES TO QUESTIONS

SIX-METER ANTENNA STUDY
FOR
SMITHSONIAN ASTROPHYSICAL OBSERVATORY

P.O. #SAO-21901

SUBMITTED TO:

Harvard Smithsonian
Astrophysical Observatory
60 Garden Street
Cambridge, MA 02138

SUBMITTED BY:

TIW Systems, Inc.
1284 Geneva Drive
Sunnyvale, CA 94089

Telephone: (408) 734-3900
Fax: (408) 734-9012

Question 1

What are the elevation angles for the gravity load case? Are two elevation angles considered: one where the dish is set (i.e., these deflections are subtracted since it is assumed that they are adjusted out) and then the worst-case elevation angle relative to that?

TIW Response

The worst-case values are presented in the tables. In the analysis, it was assumed that the dish was set at 45° so that the gravity errors would be nearly equally split between horizon and zenith. Performance could be optimized for any angle between zenith and horizon depending on the most-used look angles.

Question 2

In Table 2-2, were there changes to the section properties/geometry of the model or were the only changes to material properties and the weights applied to the panel-support points?

TIW Response

The section properties/geometry were not changed; changes in the material properties only were made in the model.

Question 3

Are the accuracies shown in Table 2-2 best-fit rms?

TIW Response

Yes, the accuracies are best-fit rms.

Question 4

Given the much greater stiffness-to-weight ratio of the composite material vs. steel (2.6:1 advantage for composite), why doesn't the composite structure outperform steel for gravity-load cases?

TIW Response

Because the supporting elevation wheel structure was configured for a steel reflector, the support structure is not optimized for a composite. In this case, the supporting structure is controlling the design. Another consideration is the room provided for the feed behind the main dish; the configuration of this space dictates how the loads can be carried from the dish into the support structure.

Question 5

What is the significance of optimizing the structure so that the performance is independent of panel weight? What are the best criteria to compare various design approaches and optimize them?

TIW Response

The importance of this aspect of the study was to assess how the overall error budget is tied to weight and to determine how important it is to keep the weight of the panels low. This in turn has an impact on the surface accuracy available for the total reflector, antenna pointing error, and cost. To compare design approaches, all aspects of the design must be considered including performance, expected life, cost, and other relevant factors. The result of TIW's report is that the selection of panel type can be independent of backstructure material selection.

Question 6

Can you provide equations for the undeflected parabolic surface and for the best-fit deformed surfaces for the gravity load cases. Also, we would like to know the amount the best-fit surface is rotated and translated relative to the undeflected surface.

TIW Response

The equation for the undeflected parabolic surface is

$$y = x^2/403.2(\text{inch}).$$

TIW studied over fifty cases and/or configurations and found that the rigid body motion of the best-fit surface is in the range of 0.005 to 0.011 inch; the axial and lateral translations are in the range of 0.001 to 0.020 inches and the rotation is in the range of 0.015° to 0.022°. The magnitude of rigid body motion depends on several factors, including stiffness, load distribution, and weight densities, and, therefore, varies from case to case. In general, cases with higher stiffness/weight ratios yielded less rigid body motion. The rotation and translation of the selected configuration with the steel backup structure under the gravity load are as follows:

Axial Translation	0.0093 inch
Lateral Translation	0.0012 inch
Rotation at Vertex	0.018°

Question 7

What is the rms accuracy for the various load cases without best fitting? i.e., how benefit is gained by using the principle of homology?

TIW Response

The rms surface accuracy with and without best fitting for the various loading cases are shown below.

	RMS Surface Accuracy with Best Fitting	RMS Surface Accuracy without Best Fitting
Gravity (with 5 psf panels)		
Steel	.00107	.02210
Aluminum	.00170	.01665
INVAR	.00123	.02272
Carbon	.00104	.01440
Thermal (1°F across depth)		
Steel	.000107	.000448
Aluminum	.000202	.000892
INVAR	.000018	.000061
Carbon	.000007	.000008
Thermal (1°F across diameter)		
Steel	.000054	.000252
Aluminum	.000103	.000498
INVAR	.000008	.000034
Carbon	.000003	.000004
20 mph Front Wind		
Steel	.000027	.000516
Aluminum	.000043	.000651
INVAR	.000031	.000541
Carbon	.000034	.000566

Question 8

In Table 2-1, is the "reflector weight" the weight for the backup structure only or does it include the elevation wheel?

TIW Response

The reflector weight shown is the backup structure only. The elevation wheel weight, counterweight, and panel weight are not included.

Question 9

What alloy of steel is used? The CTE seems low. Most alloy steels have CTEs of about 8×10^{6}.

TIW Response

ASTM-A36 steel was used. The value used for the CTE was taken from the AISC Steel Construction Manual, page 6-7.

Question 10

The negative slopes of the curves in Figure 2-1 for aluminum and carbon suggest that the structure is too stiff, i.e., as the panel load increases the effects of homology are improved and the surface accuracy becomes better. Is this because the original design was optimized for steel and not aluminum or carbon?

TIW Response

The negative slope occurs because the original elevation wheel was optimized for steel. This is not an optimum design for aluminum or carbon.

Question 11

In Figure 2-2 is the top curve invar and the bottom curve steel? What kind of attachment scheme is used between the elevation wheel and the reflector? Could it be modified to reduce the CTE mismatch problems for the aluminum and carbon fiber backstructures which are illustrated in Table 2-3? Also, what effect will the CTE mismatch problem between aluminum panels and a steel backup have on the performance?

TIW Response

A corrected version of Figure 2-2 is attached showing the top curve as invar and the bottom curve as steel.

There is a flange connection between the reflector hub and the elevation wheel. Some design modifications could be studied that would reduce the mismatch.

The CTE mismatch between the panels and the backup structure has been taken care of in the panel-mounting design, which allows the panels to expand and contract within the designed gap between panels.

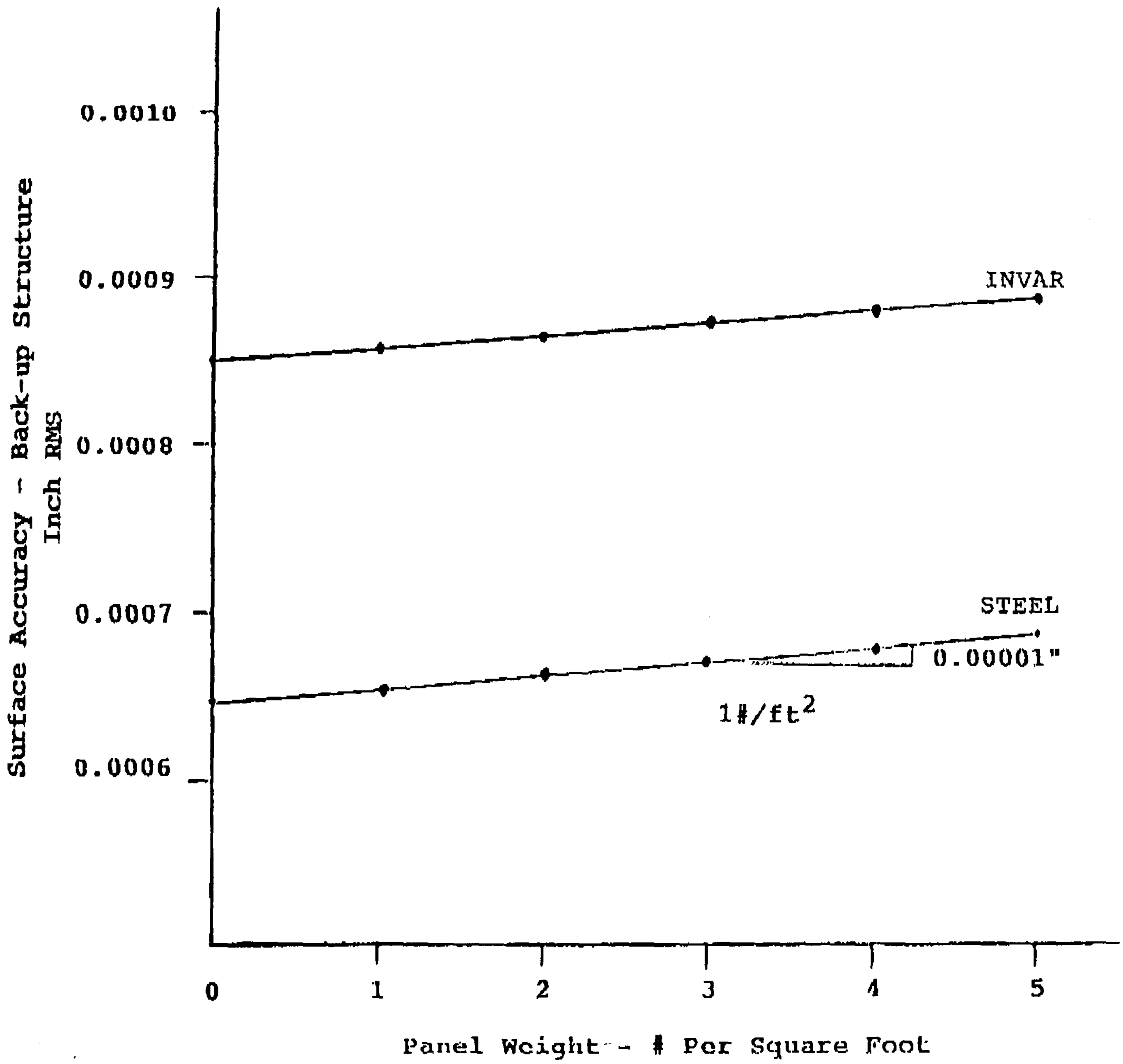

FIGURE 2-2

REFLECTOR GRAVITY DEFORMATION

FIRST LEVEL OPTIMIZATION - STEEL & INVAR

2/26/90
Rev. A 4/13/90

TABLE 2-6

PANEL COST TRADE STUDY SUMMARY

Panel Type	Non-Recurring Cost Divided by Six (6)	Material	Labor	Packaging	Total Cost Per Reflector
Carbon* (Composite)	$60,000	$50,000	$98,000	$6,000	$214,000
Machined Aluminum Castings	$15,000	$50,000**	$65,000	$7,000	$137,000

*Costs are based on preliminary material estimates from Hexcel combined with TIW's estimate of the manufactured cost.

**Includes castings.

Question 12

Is the worst case wind you describe blowing straight into the front of the reflector or is it hitting the reflector from the side? Our experience has been that a front wind, i.e., one blowing perpendicular to the elevation axis, is not worst case because the load is symmetric and the effects of homology work very well. We have found that a rear quartering wind with an elevation angle of 0 generally produces a worst case best fit rms surface accuracy. Please comment.

TIW Response

The case we used was for the wind blowing directly into the back of the reflector. We agree that the wind hitting the back of the reflector at an angle would produce a slightly larger error, but our experience has been that this is a very small increase.

Question 13

What is the geometry of the subreflector supports? Are they evenly spaced at 120 degrees? If not, what is the spacing and the rationale for it?

TIW Response

The geometry is shown in Figure 1-2. The legs are not evenly spaced. This is typically done for electromagnetic reasons and to minimize subreflector deflections.

The subreflector supports and subreflector positioning mechanism should be studied in more detail as the design progresses. The thermal stability of this subsystem is also critical to the antenna pointing error budget and to positioning of the subreflector.

Question 14

In Table 2-6, what is the basis for the cost data for the aluminum panels?

TIW Response

A revised version of Table 2-6 is attached that includes an update from Hexcel on the non-recurring cost for the composite panels.

The cost for the aluminum panels is based on casting costs for other programs that TIW has completed and on machining rates for similar work. TIW has considerable experience in metal fabrication work and believes this is a good estimate. The panels would be machined by a qualified vendor, and TIW is currently pursuing competitive bids for these panels.

Question 15

Can you provide estimates of operating costs for providing the air flow required to maintain a temperature gradient of 1 degree within the reflector? Also, have you considered the effects of radiation cooling of the reflector at night?

TIW Response

We have not specifically estimated this. Only a very small blower is required, and the power consumption would be equivalent to a few light-bulbs. A large fan/motor is not required.

We have not addressed the radiant cooling of the reflector at night. Experience at other sites indicates that an aluminum reflective surface (unpainted) would provide good performance. There are many thermal issues related to the antenna, and several aspects need to be addressed in more detail.