NICMOS Anomaly Report

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

23391

Reply to Attn of: 440

September 19, 1997

TO: 440/Associate Director of Flight Projects for HST

FROM: 440/Deputy Associate Director of Flight Projects for HST

SUBJECT: Final Report of the NICMOS Dewar Anomalous On-Orbit Warming Anomaly Review Board

The NICMOS Dewar Anomalous On-Orbit Warming Anomaly Review Board (ARB) has completed its investigation. The results of this work are documented in the enclosed report, entitled "NICMOS Dewar Anomalous On-Orbit Warming Anomaly Review Board Final Report", dated September 17, 1997.

George W. Morrow

Enclosure

cc:
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NICMOS Dewar Anomalous On-Orbit Warming

Anomaly Review Board

Final Report

September 17, 1997

NICMOS Dewar Anomalous On-Orbit Warming
Anomaly Review Board
Signature Page

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EXECUTIVE SUMMARY

The initial in-orbit performance of the NICMOS dewar appeared nominal until March 4, 1997, when the rate of detector temperature rise increased and the Vapor Cooled Shield (VCS) cooldown rate accelerated. This anomalous behavior was caused by a step increase in the rate of heat flowing into the Dewar.

The source of this additional heat is a thermal short between the VCS and the cryogen tank in the area of the cold bench baffles/VCS baffles at the forward end of the Dewar/Coldwell assembly.

As the nitrogen warmed from its launch temperature toward its steady state temperature of 58°K, it expanded. This expansion pushed the coldwell/tank head forward until the cold bench light baffle contacted the VCS light baffle. Additional warming of the solid nitrogen cryogen occurred as the VCS began transferring heat to the cryogen tank, resulting in additional forward movement of the coldwell. The heat load on the cryogen thus increased from the design value of 200 mw to 478 mw.

In addition, the forward movement of the coldwell resulted in an out-of-focus condition on Camera 3, based on a maximum useful Pupil Adjust Mechanism (PAM) focus point in detector space of approximately 6 mm. From March 4, 1997, to March 28, 1997, total movement of the coldwell in the forward direction was 3.69 mm (6.36 mm to 10.05 mm). As the nitrogen sublimes, expansion pressure on the coldwell is relieved, allowing the coldwell to move in the aft direction. Total aft movement through August 25, 1997, is 2.00 mm (10.05 mm to 8.05 mm). Structural modeling indicates a total rebound of approximately 3.0 mm can be expected. In addition, structural modeling indicates that plastic deformation of components in the areas forward of the coldwell has occurred. Therefore, although total rebound is estimated to be less than total expansion, a break of the thermal short cannot be ruled out.

Aft movement of the coldwell allows Camera 3 to continue to approach a scientifically useful PAM focus position. As with the thermal short, prediction of the probability that this will occur is not possible.

As coldwell rebound has progressed, thermal analysis shows the dewar heat load is slowly decreasing from a maximum of 478 mw.

The work of the ARB has resulted in a good physical understanding of the NICMOS dewar anomaly and its cause. The NICMOS instrument will be capable of producing unprecedented science data through Cameras 1 and 2 for a minimum lifetime of 1.7 years (through December 1998). While breakage of the thermal short and a return of Camera 3 to useful focus are not probable, they cannot be ruled out. Breakage of the thermal short will result in a normal duration lifetime from that point forward.

INTRODUCTION

This report describes the Anomaly Review Board (ARB) charter as defined in Reference (1). The report then provides a Summary of ARB Conclusions for each of the charter elements, with added technical detail provided in Attachments (2) through (7).

The ARB held six meetings between March 19, 1997 and April 8, 1997. Minutes of the meetings are included as Attachments (8) through (13). A final meeting was held on April 14, 1997, to review the status of all Charter items and to assign closure actions. This final report is the result of the last meeting.

The membership of the ARB, as assigned in Reference (1), was as follows:

George Morrow, Chairman	Code 442
David Ratzow, Secretary	Jackson & Tull FS&S
Paul Geithner	Code 442
Malcolm Niedner	Code 680
Eric Mentzell	Code 717
Richard Johnson	BECD
Timothy Kelly	BECD
Chris Miller	BECD
John Troeltzsch	BECD
Richard Dame	MEGA Engineering
Laurie Furey	OAI
Ethan Schreier	STScI
William Sparks	STScI
Glenn Schneider	University of Arizona

The following individuals were added to the ARB membership at the second meeting on March 21, 1997:

Robert Sticka	Code 303
Harvey Moseley	Code 680
Mike DiPirro	Code 713

Each of the ARB conclusions was agreed to unanimously by all ARB members. The activities of the ARB are concluded with the issuance of this report, and the ARB is hereby dissolved.

REFERENCES

(1) Memorandum from the Associate Director of Flight Projects for HST, dated March 17, 1997, subject: Formation of an Anomaly Review Board to Investigate the Anomalous Warming of the NICMOS Dewar

ATTACHMENTS

(1) A Post Launch Thermal Expansion Analysis of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) Cryogenic Subsystem's Dewar, April 28, 1997, Mega Engineering

(2) A Note on the Temporal On-Orbit History of the Position of the NICMOS Coronographic Hole, Glenn Schneider, U of A, April 28, 1997

(3) Thermal Contact Conductance of the Dewar Baffle Tube and Cold Bench Cover (SER-135)

(4) NICMOS in Cold Safe with Dewar Heaters Disabled, J&T Technical Note, April 14, 1997

(5) Nitrogen Material Property Test Results, Mega Engineering Memo, April 22, 1997

(6) Cryo Energy Balance, email from Chris Miller, BECD, May 27, 1997

(7) Energy Balance Plots, email from Chris Miller, BECD, June 11, 1997

(8) Energy Balance plots from Day 46-157

(9) Energy Balance plots from Day 80-140

(10) NICMOS Dewar ARB Minutes, March 19, 1997

(11) NICMOS Dewar ARB Minutes, March 21, 1997

(12) NICMOS Dewar ARB Minutes, March 28, 1997

(13) NICMOS Dewar ARB Minutes, March 31, 1997

(14) NICMOS Dewar ARB Minutes, April 3, 1997

(15) NICMOS Dewar ARB Minutes, April 8, 1997

DESCRIPTION OF ANOMALY

The initial in-orbit performance of the NICMOS dewar appeared nominal with the Vapor Cooled Shield (VCS) temperature at 152°K, the solid nitrogen cryogen temperature rising slowly to 56.2°K, and the nitrogen flow rate at 28 grams/day. The first anomaly symptom noted was on March 4, 1997, when the rate of detector temperature rise increased from 0.22°K/day to 0.50°K/day. At the same time the VCS cooldown rate accelerated from -2.5°K/day to -6.5°K/day. These new rates were caused by a step change in the rate of heat flowing into the Dewar.

Over the next few days, temperature gradients of about 1°K were established in the VCS and the cryogen tank.

The Anomaly Review Board was appointed on March 17, 1997, to investigate the anomalous warming of the NICMOS Dewar.

ARB CHARTER

The charter elements, as defined in Reference (1), were as follows:

- Determine the most likely cause of the increased heat flow.
- Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.
- Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.
- Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.
- Estimate the probable long-term changes in focus and tip/tilt of the three cameras.
- Recommend options, if any, for on-orbit management of heat flow and optical alignment.

SUMMARY OF ARB CONCLUSIONS

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the VCS and the cryogen tank in the area of the cold bench baffles and the VCS baffles at the forward end of the Dewar.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed, it expanded and pushed the coldwell/tank head (containing the detector bench) forward until, at about 56°K, the cold bench baffle contacted the VCS baffle. An unintended thermal path was thus established. Cooling of the VCS then began as heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps (a second order effect).

A second source of detector bench movement has also been identified. Forward expansion of the cryogen at the aft end behind the cold-well cap has compressed the cap and caused contact between the cap and the coldbench screw heads near Cameras 1 and 2, providing more forward motion to the detector bench.

Structural and thermal modeling indicates all three baffles are in contact. Attachment (4) provides additional details of these modeling efforts.

Movement of the coldwell as the nitrogen cryogen warms and cools was first noted as a problem during the investigations performed during another ARB convened in 1996 to study NICMOS unexpected focus changes. At that time, the Pupil Adjust Mechanism was modified to allow a greater range of focus, and new recool procedures were implemented. It is now apparent that the details of the anomaly mechanism which remained unknown at that time were significant.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

Thermal Analysis indicates that the dewar heat load reached a maximum of approximately 478 mw following initiation of the short versus a design condition of about 200 mw. As coldwell rebound has progressed, thermal analysis shows that dewar heat load is slowly decreasing to 437 mw as of June 1, 1997. The decreasing heat load will result in a longer useful lifetime. If this most recent heat load continues to end-of-life, and using a heat of sublimation of 244 J/g, the useful life would end in December 1998.

If the thermal short were to be broken, then the useful lifetime from that point forward will be of a normal duration and be based upon the amount of cryogen remaining at that point. Due to the unpredictable effects of plastic deformation in the structural components forward of the coldwell, ultimate breakage of the short cannot be ruled out, but is unlikely. This will be discussed in more detail under Charter Item Number 4.

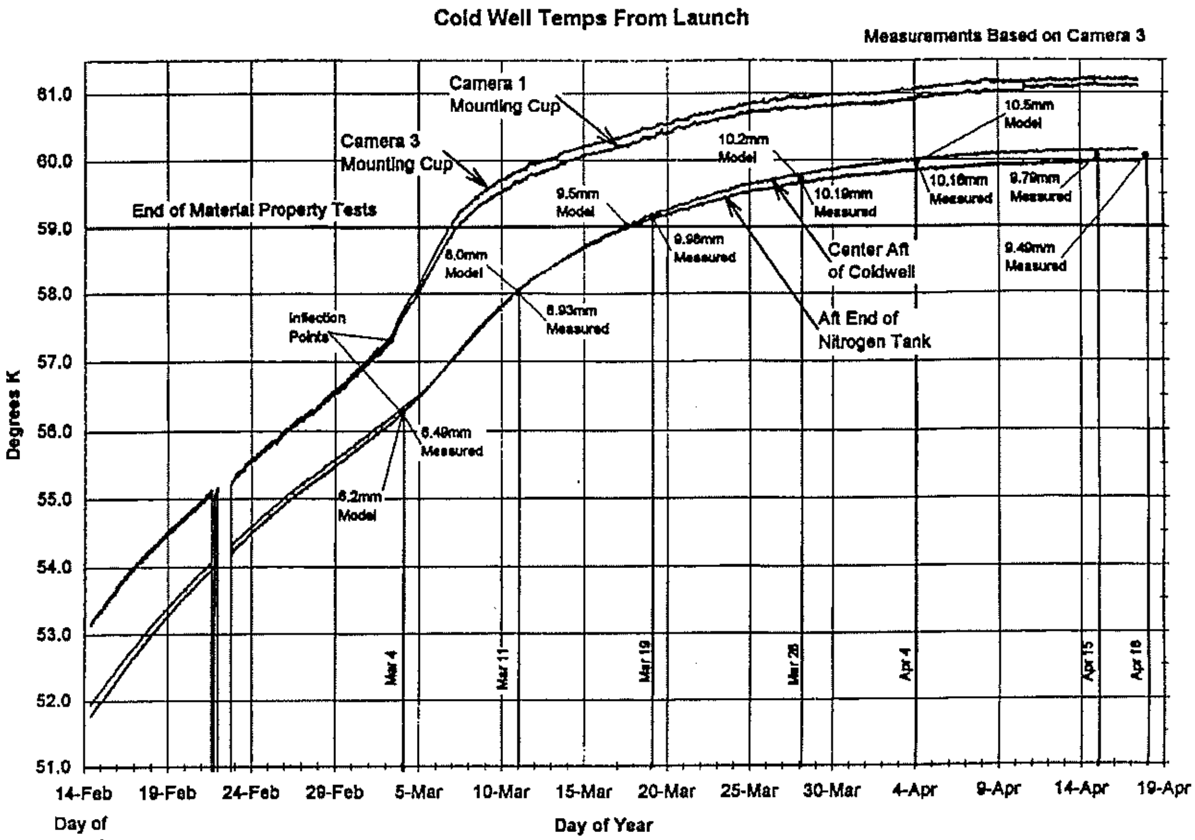
A low temperature baffle thermal conductance test was performed to determine the relationship between contact force and thermal conductance. The test data indicated that contact conductance decreased with decreasing load with the dependence weak, but not insignificant. Attachment (3) provides additional details of this test. Attachments (7) through (10) discuss how the heat load has changed over time. It is now felt that the decreasing contact force is the cause of reduction in heat load.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

NICMOS data from 25 separate observation sets have now been reduced. The results are very consistent from all images at widely different focus settings. The data have been reduced in several different ways and all give mutually consistent results. As of August 25, 1997, the position of Camera 3 in dectector space was 8.05mm with best focus able to be achieved with the PAM mechanism at approximately 6mm.

The non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, have been correlated. ARB directed work in the areas of cryogen sublimation characteristics, debonding of the reticulated foam at the coldwell cap, coldwell cap contact with the cruciform, and physical properties of the nitrogen/foam between 59°K and 61°K as well as educated assumptions resulted in this correlation. Reference Figure 1 for a comparison of actual data with model data and Attachment (6) for the material property test results.

This modeling and test effort has produced an excellent understanding of the physical relationships of the NICMOS dewar/detector assembly. The root cause of the pre-launch and on-orbit anomaly was an inadequate understanding of the behavior of the solid nitrogen and the stresses imparted to the cryogen tank during the warmup/recool cycles. This was further complicated by the lack of mechanical properties of the solid nitrogen necessary to accurately model system behavior. This resulted in a less than optimum dewar initial fill/cooldown strategy which set up initial on-orbit stresses much higher than anticipated in the design.



Variation of Model's Cruciform Motion Vs. Temperature
Figure 9

Figure 1
Motion vs. Temperature

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected has been investigated. As the nitrogen is used up, cryogen pressure on the coldwell decreases, allowing the coldwell to move aft (about 2.00 mm through August 25, 1997). If the coldwell would move aft far enough, the thermal short would be broken.

On-orbit observables indicate that a maximum interference between the VCS and cryogen tank of approximately 3.69 mm existed. Structural modeling indicates that the maximum interference was approximately 3.75 mm, an excellent correlation. Structural modeling also indicates that a rebound of approximately 3.0 mm can be expected. Further, the modeling effort indicates that the VCS and coldwell baffles, the coldwell coverplate, and the filter wheel housing have experienced some amount of plastic (that is, permanent) deformation. Because the effects of plastic deformation are inherently difficult to predict, breakage of the short cannot be ruled out but is unlikely.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

The detectors, after having reached their maximum forward movement on March 28, 1997, are now moving in the aft direction (see Figure 2 for Camera 3 motion data). Encircled Energy, Phase Retrieval, and Plate Scale analyses on these data are in general agreement.

Camera data indicates that there has also been some lateral movement of the detectors, mostly in the -y direction. The pivot point is approximately 116 mm behind the pupil plane or at about the coldwell mounting flange. Total movement was approximately 15 - 16 pixels in Camera 2 and the rate of movement was decreasing.. The cause of this movement may be some built up stress that is now releasing in the lateral direction. This lateral movement can be compensated for and is not expected to be detrimental to camera focus. Monitoring of motion is continuing.

Dewar rebound analysis indicates a total recovery of 3.0 mm over the next year. Without an Optical Telescope Assembly (OTA) refocus, analysis indicates that this will not be sufficient to bring Camera 3 into optimal focus, however it has been estimated that if a PAM space position of -11.75 mm (7.10 mm in detector space) is achieved, valuable science data could be obtained. The NICMOS Operations Team will continue to evaluate this movement and determine whether this may be sufficient to make Camera 3 useful for some spectroscopic science.

Another long term change not related to camera focus or alignment has been identified. A greater rate of detector temperature change over life is expected due to the presence of the thermal short. Dewar temperatures will rise to somewhat less than 63°K until November 1998. This is not expected to affect performance, but may require more frequent calibration activities.

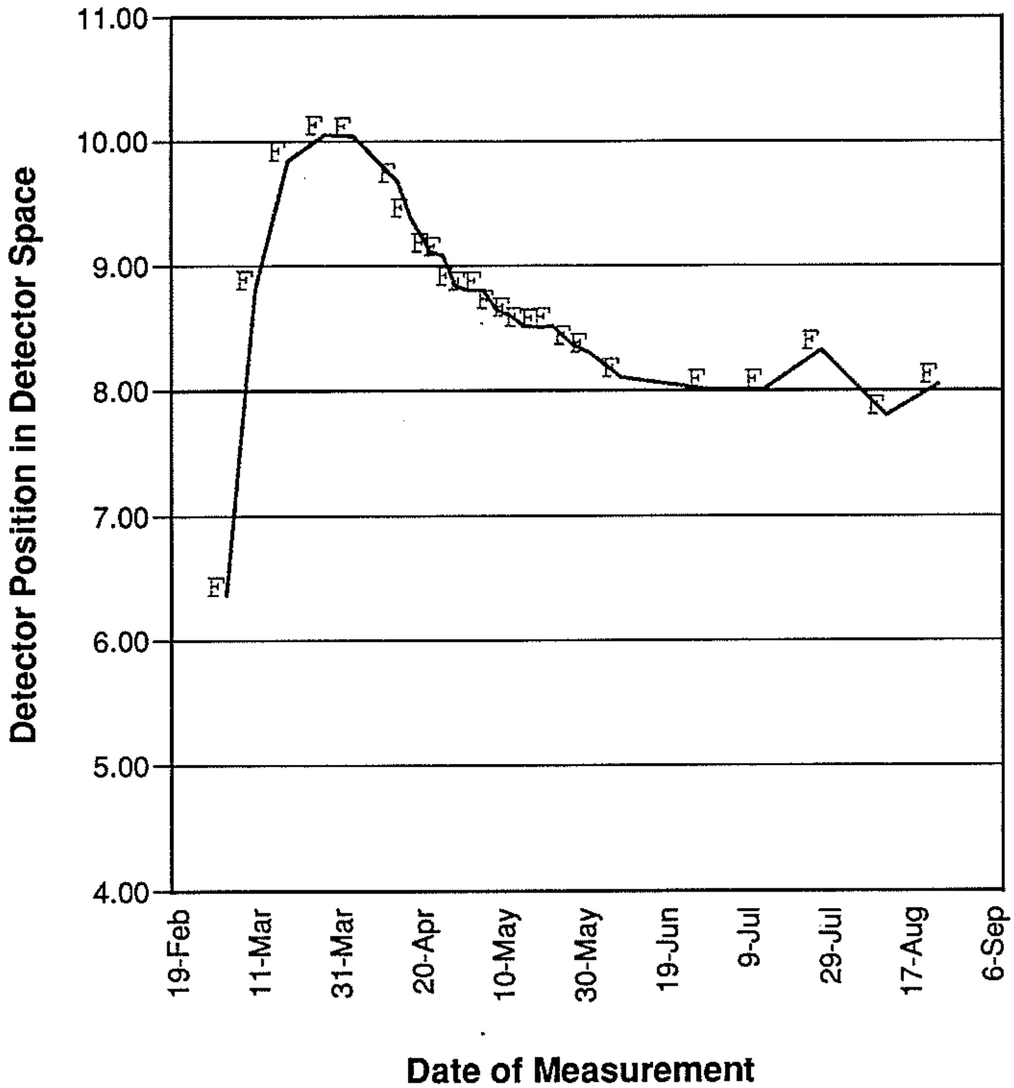


Figure 2
Camera 3 Position in Dectector Space

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any long-term positive effect on the thermal short. The combination will result in a maximum VCS temperature of 124°K, a 26°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Further, this additional heat input will exacerbate the condition and further reduce cryogen lifetime. Other options have not been identified.

All controllable sources of heat input to the dewar should be reduced to a minimum. Outer shell heaters have been disabled to prevent inadvertent activation during normal operations and also during safe-mode.

FINAL THOUGHTS

Although the NICMOS Dewar thermal short is an unfortunate situation, the Instrument will provide good scientific data from Cameras 1 and 2 until approximately December 1998, or longer if the observed dewar rebound and decline in cryogen heat load continues.

A POST LAUNCH THERMAL EXPANSION ANALYSIS OF THE NEAR INFRARED CAMERA AND MULTI-OBJECT SPECTROMETER (NICMOS) CRYOGENIC SUBSYSTEM'S DEWAR

MEGA

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Attachment 1

A POST LAUNCH THERMAL EXPANSION ANALYSIS OF THE NEAR INFRARED CAMERA AND MULTI-OBJECT SPECTROMETER (NICMOS) CRYOGENIC SUBSYSTEM'S DEWAR

PREPARED FOR:

THE HUBBLE TELESCOPE NICMOS SECOND
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UNDER SUB-CONTRACT
SC00891 FOR
FAIRCHILD SPACE CONTRACT NAS5-32539

April 28, 1997

1.0 Summary

An unexpected racheting effect coupled with the high thermal expansion of the solid nitrogen cryogen within the NICMOS Dewar during warm-up and subsequent cool-down cycles, has caused a shift in all three cameras within the instrument (see Figure 1 for a general arrangement of the instrument's parts). During transport from the manufacturer (Ball Aerospace of Boulder, Colorado) to Kennedy Space Flight Center an additional focal shift was recorded. This report provides the results of the analytical model calculations which confirmed that a thermal short has developed between parts of the Dewar. These models also show that the forward motion and lateral motions of the cameras can be confirmed. Finally, the model shows that the system should re-bound by 3 mm, as much of the cryogen is removed from around the coldwell. However, since the interference between the baffles and the coldwell is around 3.75 mm, the thermal short probably will not be broken.

1.1 Background

The assembly of the NICMOS Dewar provided a room temperature gap of 5 $\pm$1.2 mm between the cryogen tank's forward closure cover and the Vapor Cool Shield (VCS) at three baffles (see Figure - 2). The VCS surrounds the nitrogen tank and is cooled with sublimed vapors from the cryogen. After launch of the NICMOS experiment, this gap apparently closed due to this nitrogen racheting and the added shift during shipment. This closure provides a contact and a thermal short between the warmer VCS and the colder nitrogen tank (see Figures 3 and 4).

The Dewar heat load is approximately 473 mw compared to the original design condition of 200 mw. This thermal short has resulted in a more rapid loss of cryogen than originally planned reducing the cryogen lifetime to 1.7 years. Further, the higher heat loads into the nitrogen tank have increased the temperature of the cryogen to a higher than expected level with a corresponding larger thermal expansion of the cryogen (the nominal design anticipated a 58° K cryogen temperature and the current temperature is 60° K). This same thermal short has caused the VCS temperature to decrease well below its expected on-orbit temperature. This reduced VCS temperature, in turn, causes a further decrease in the separation between the VCS and nitrogen tank parts. Since the VCS is supported by the same straps that support the nitrogen tank (see Figure-5), a "closed load/reaction path" has developed between the VCS baffles and nitrogen tank, which is capable of developing high forces between these parts.

1.2 Model Development History

Prior to launch of the NICMOS experiment, detailed non-linear DYNA3D and NIKE3D finite element models were developed by Mega Engineering, which were used to compare the analytical positions of the three cameras with their measured positions. These cameras were mounted within the coldwell on a "coldbench" (see Figure 6). The models were run on the CRAY at NASA/GSFC and used over 13,000 elements and 15,000 nodes. Material tests were conducted in 1996 to determine the compressive yield and ultimate strengths of solid nitrogen and reticulated aluminum foam filled nitrogen in the 40° K to 58° K temperature range. Tests were conducted on 5083-0 aluminum to determine its properties at cryogenic temperatures. These properties along with various geometric refinements were added to the finite element model to provide good correlation between these measured deformations and analytical values (see Figure 7).

1.3 Model Focus Calculations

By October of 1996 the model's calculated deformations correlated to within 10% of the measured values (see Figure 8a and Figure 8b). It should be noted however, that the predictions at higher cryogen temperatures were consistently lower than measured values. Based upon these model results, nomographs were made which could then be used by the HST personnel to project the expected camera positions extrapolated from previous measured camera locations. The displacement positions of the camera's mounting structure were predictable through the launch phase simulator tests, thermal vacuum tests and up to the time of shipment from the manufacturer. Using the last focus measurement, which was made at the Ball Aerospace facility, the model predicted a focal position of 4.75 mm for 58° K. On December 6, 1996 a measurement of the coldbench position showed 4.21 mm with the coldwell temperature at 59.1° K.

After shipment from Ball Aerospace, the displacement of the coldbench took an unexpected .5 mm jump in its forward deformation. The final pre-launch position of the coldbench was measured at 3.12 mm (at a cryogen temperature of 48.8° K) on January 15 1997. On February 14 NICMOS was launched. Around March 4, 1997, temperature profiles within the nitrogen tank and the VCS changed noticeably (see Figure 9). The most likely cause was the initiation of a thermal short.

Subsequent to that discovery, the finite element model was re-run to compare its calculated baffle and coldwell cover positions at the in-orbit temperature profiles. Since the model calculations for camera positions were lower than the January 15 measurement by -.5 mm, the model was cycled through additional thermal cycles, so that it produced a camera position change of 3.1 mm, when the cryogen temperature in the model was 48.8° K. Next, the model was modified to incorporate the gap between the baffles, which was set at 5 mm at room temperature and which closed as the Dewar cycled and as the cold bench ratcheted forward.

1.4 Creation of a Small Model Used to Expedite Run Calculation Turnaround

With the increased element details required to model the baffles, the baffle support straps, the filter wheel housing, the VCS support details and improved details for the forward cover, the finite element model grew in size to a point that the model required more than 14 hours of cpu time on the CRAY computer at NASA/GSFC. To provide more rapid turn-around for model response calculations, a smaller model was created and used to conduct sensitivity studies. These studies included analysis of deformations as a function of material property changes and evaluation of the effect of removing cryogen from the Dewar. Both models were bench marked against the actual measured focal positions and found to provide similar results for deformations. The large model had better detail of the nitrogen within the tank and more elements from which local stresses could be analyzed. But the smaller model also provided close estimates of these same stresses and deformations. The small model used 3570 elements (3260 nodes) compared to the 13,000 elements used in the large model. Figure 14 shows a section through this small model. This small model was used for test runs and when any changes were made and tested, the large model was modified to incorporate these changes and it was then run on the CRAY computer. In addition, the small model ran in parallel on the CRAY to assure that similar response predictions were calculated.

1.5 Use of the Model to Confirm Contact Between Parts

The model was then subjected to temperature increases which matched the measured values. The model calculated that the gap between the coldwell cover and the baffles would close at a temperature of 56.3° K. The focal position measurements that were made on March 4 indicated that the focus was actually 6.5 mm. The subsequent model calculations and actual measurements were compared at different dates and temperatures. The model's calculated coldbench positions were initially found to be consistently lower than the measured values by 12-17 %. After recent material tests this difference dropped to around 5%

1.6 Improved Material Properties Above 58° K

The model was using "look-up" table values for the cryogen properties, which were based upon the actual measured property values at 58° K. These test values were then extrapolated to provide estimates of properties for the higher cryogen temperature near 61° K. The problem with this approach was that there were few original measurements of material properties at the 58° K temperature, and if those were in error, the entire set of predictions would be erroneously biased at the higher temperatures. It was decided that additional tests should be performed on the nitrogen to provide properties at 60° and 61° K.

Figures (10 and 11) show the yield stress, ultimate stress and Young's modulus for the cryogen at the higher temperatures. In addition, the previous regression analysis projections for Young's modulus are shown. Values for yield stresses are approximately 60% higher than those previously used in the model. This increased strength and increased Young's modulus, drive the deformations in the model to larger values at higher temperatures than those previously calculated. When we couple this with an anticipated temperature in the upper cryogen regions near 61°K, we find that the maximum deformations calculated by the model are closer to those values measured. The large model calculated 9.8 -10.0 mm maximum deformations and the measured values are 10.15 mm at 59.8° K cryogen temperature. Figure 9 shows the final measured and calculated position changes for camera 3.

1.7 Improved Focus Calculations with New Properties

Figure 12 shows a plot of deformations versus temperatures for the reduced size model while Figure 13 shows a similar plot for the more detailed model. The variation of the calculated camera 3 positions between the two models is less than .5 mm at the upper temperatures. Using these higher nitrogen material values produce calculated deformation values which are within 5% of the measured values. Failure to use these higher properties was a significant reason why the model had consistently under-predicted the motion of the cameras at the higher temperatures. Figures 14a and 14b show details and parts of the smaller model.

1.8 Deformations and Stresses Calculated by Model

Contact surfaces were defined and material adhesion properties were defined in the model for the cryogen and foam around the coldwell. Once the models were reasonably well correlated with the measured positions of camera 3, the contact forces and elasto-plastic strains were evaluated. Animations were developed with the model, which showed a sequence of contact "make and break" points between parts. During this process, it was observed that several screw heads near the back of the coldbench made contact with the aft cold-well end cap as the nitrogen expanded. The sequences of contacts calculated by the model included:

a. VCS Baffles contact the forward coldwell cover (see Figure 15)
b. The baffles push the coldwell cover aft deforming it toward the PC board
c. The baffles push the baffle support straps up against the filter wheel housing, eventually developing contact forces around 300 lbs (1334 Newtons).
d. The forward cover is eccentrically loaded by the three baffles and since this cover is supported by the coldbench, the coldbench is rotated about its lateral X (yaw) and Y (Pitch) axis and is twisted about its Z (Roll) axis (see Figure 16).
e. The forward expansion of the cryogen at the aft end behind the cold-well cap compresses the cap and causes contact between the cap and the coldbench screw heads near cameras 1 and 2.
f. The contact forces between the coldwell cap and the coldbench caused a lateral Y (pitch axis motion) of the aft end of the coldbench coldbench.
g. Bonds between the coldwell and the nitrogen at the forward end above the baffles are broken during the initial cool-down cycles. Bonds behind the coldwell cap are not expected to break.

The types of contacts between the baffles and the coldwell cover plate are shown in Figures 15 and 16. Note that the three baffles are not equally loaded and the pressures applied by the baffles are not uniform. As these baffles are forced forward, the baffle strap pushes into the lower cover of the filter wheel housing.

The forward cover plate deflects in the aft direction at points where the baffles make contact. These deformations are large enough to bend the plate slightly into its plastic strain region. The relative deformation between the cover's supports and the baffle's contact points is 3.3 mm when the coldwell is fully extended to 10 mm. At 60°K, the yield strength of 5083-0 is

24.6 Ksi (170 Mpa). Stresses in the cover plate are slightly higher than the yield stresses at 25500 psi (172 Mpa). The maximum surface strains are around .5% in this forward cover. Therefore, the cover is expected to remain primarily elastic. This means that any permanent set would be small and the cover must travel forward almost the full interference distance before any contact with the baffles is broken.

The combined effects of items d. and f. above cause the coldbench to move laterally. The combination of X and Y motions is shown in Figure 17. The maximum change in the Y lateral motion (+Y toward camera 3) is calculated to be .74 mm between 54.5° K and 60° K. The measured change in lateral motion between temperatures of 54.5° K and 60° K was .78 mm. This appears to be in good agreement. The X lateral motion is much smaller and the change in this motion between 54.5° K and 60° K was calculated to be .07 mm, while the measured X direction change was .021 mm. The error in the measured X values is larger than this delta change, which makes this last comparison somewhat invalid.

From reviews of the model's calculated motion with changes in temperatures, it appears that there is a non-linear relation between the lateral motion and temperature. This is suspected to be due to the combined effects of the eccentric baffle load forces applied and the forces applied through point contacts between the coldwell and the aft cap-screws on the coldbench near cameras 2 and 1.

1.9 Sensitivity of Coldwell Motions to Material Property Changes

Next, the small model was used to examine the effects of thermal expansion from variations in material properties. From observations with the small model, it was found that varying the properties of the nitrogen in the forward part of the Dewar, near the straps and coldwell flange, had the most significant effect.

From the models, it appears that the solid nitrogen located above these upper baffles acts much like an ice dam or plug, which restricts free movement of the lower entrapped nitrogen from the back of the coldwell into the free ullage space. The passage way from the back of the coldwell is further constricted by the inner and outer baffles. Nitrogen is therefore prevented from moving upward through the zone between these inner and outer baffles and into the forward ullage. As this forward ice plug is either structurally weakened by its increasing temperature or is removed by sublimation, the compressed ice behind this plug can eventually force its way up by breaking through the residual portions of the forward ice plug. When the yield strength of the nitrogen in this area is reduced, the hydrostatic stresses behind the coldwell are also reduced.

Figures 18 and 19 show two calculations made for two different values of yield strength in the forward nitrogen. In Figure 18, the yield strength was 50 psi (.34 Mpa) throughout the nitrogen. In Figure 19, the yield strength was reduced by elevating the temperature in the forward portion of the Dewar. It can be seen that the maximum von Mises stresses in the nitrogen, behind the coldwell, are reduced from 255 psi (1.76 MPa) to 160 psi (1.1 Mpa) a reduction of 37 %.

Either removal or weakening of the cryogen in the forward coldwell baffle area has the effect of reducing the stresses in the nitrogen behind the coldwell.

1.10 Estimates of Rebound in The Coldwell as the Nitrogen Sublimes Away

Finally, the model was used to estimate how much rebound the coldbench would have after the solid nitrogen begins to sublime away. This removal process is a function of the heat load paths and the magnitude of the heat load into the cryogen tank. Heat is currently applied to the tank through its support straps, through the aft cooling coil plumbing and through the thermal short created at the forward cover and VCS baffle contact points. The heat flow through the contacts is estimated at 273 mw. Nitrogen is therefore expected to sublime away from the strap pockets and from the forward part of the nitrogen tank, near the coldbench attachment ring. The location and the amount of nitrogen removed from that location will make a difference in the timing of any rebound.

Since the exact location of the nitrogen being removed is unknown, calculations of the rebound were made by first removing all of the cryogen from around the coldwell's vertical sides in one step. Of course this would never happen, nitrogen would be slowly removed over time. But in order to provide some estimates of the coldwell's re-bound, approximately 45 kg of nitrogen were removed from around the coldwell after the coldwell had fully extended 10 mm at 60° K (see Figure 20). The model was then restarted, allowed to settle down and the final position of the coldbench was recorded. The coldbench was observed to return approximately 3 mm. Figure 22 shows the rebound motion.

The results of that last run do not imply that the focal position would not move back until the entire 45 Kg of nitrogen was removed. In fact the coldbench should start to rebound as nitrogen is sublimed away from the front end of the Dewar. This run was simply intended to supply an estimate of the amount of focus rebound that could be expected after that amount of nitrogen was removed and after the coldbench had experienced a forward motion of over 10 mm. Previously, a run was made in which only 3 lbs of cryogen was removed from around the coldwell near the coldbench mounting flange. The model was restarted, and the stresses behind the coldwell were observed to drop by 70 psi (from 255 to 185 psi as shown in Figure 21). The forward motion of the coldbench was found to rebound by .7 mm. The location where cryogen is removed is therefore quite important and yet this is unknown.

The measured rate of the coldbench's motion change with temperature has been erratic. It is expected that the rebound should also be erratic with time. The graphs shown in Figures 22, 23 and 24 show that sharp peaks could not be predicted with temperature changes alone. The initial large changes in actual rebound motions observed, coincide with very small changes in the temperatures of the VCS, the guard shell and the coldwell (see actual deformations plotted in Figure 8c). The only jumps in temperatures observed for these times are those on the coldbench itself (see for example the temperature jump at the camera 1 mounting cup after April 9 as shown in Figure 9). This last temperature jump could be due to either local cryogen removal from around the coldwell neck or by the breaking of a thermal contact between the coldbench and the coldwell (either at the back screw head contacts or at the front mounting ring). Most likely, the erratic motion with small temperature change, is a function of release of the built up strain energy within the parts. Since the finite element model is driven by temperature changes alone, and since data dumps are requested only at specified temperature intervals, the plots shown (such as in Figures 12 and 13) would miss such "jump" points and would only show the final effect of this erratic motion.

2.0 Summary and Conclusions

Finite element models correlate with measured deformations both before and after contact between the coldwell cover and baffles. These models indicate that the maximum forward extension of the coldbench should retract around 3 mm after 45 kg of nitrogen is lost. This rebound is slightly less than the interference 3.75 mm required to break the thermal short between the coldwell cover and the VCS baffles. However, this interference is also based on a measured room temperature gap of 5 mm provided by the manufacturer.

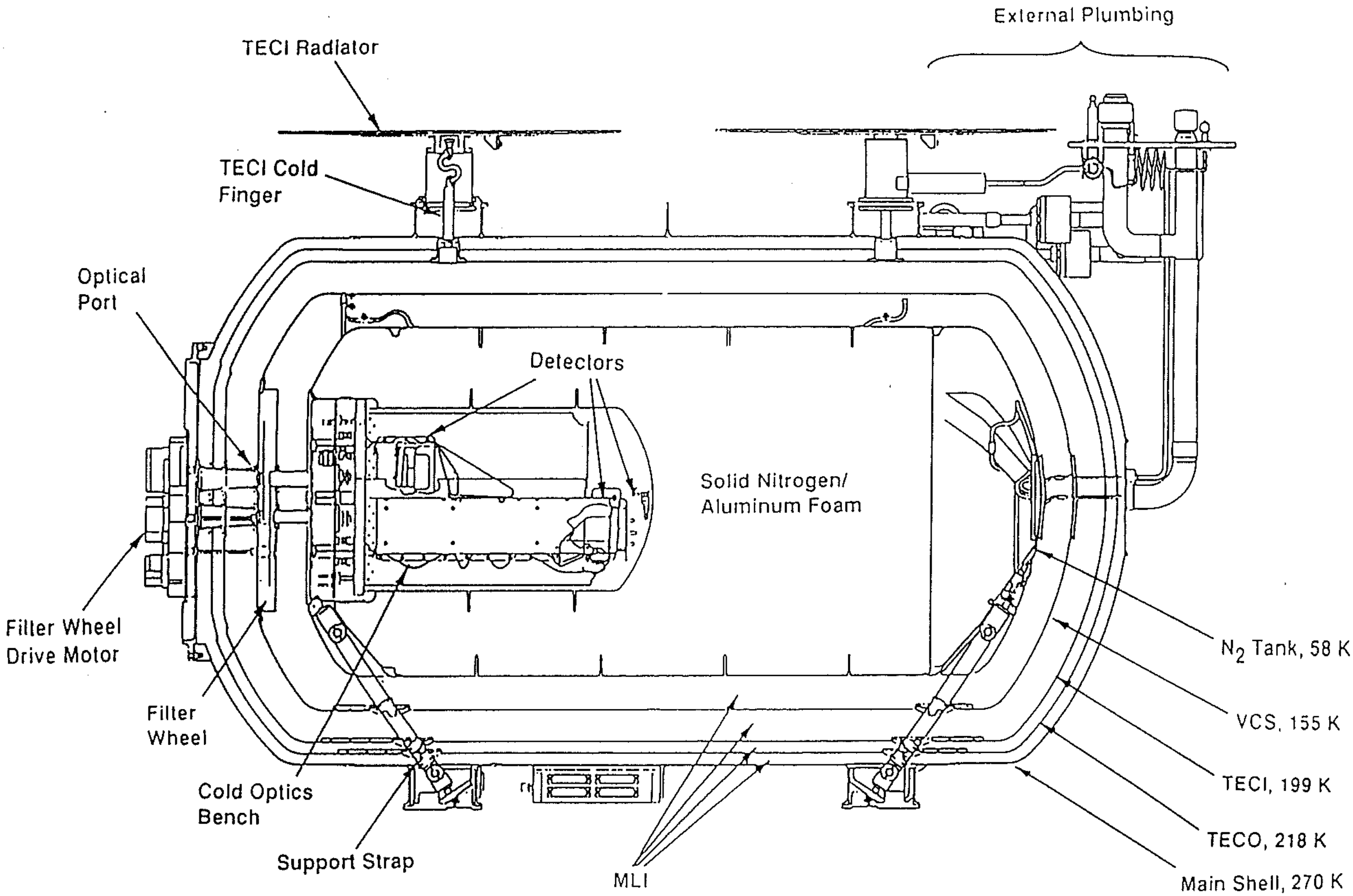


Figure-1 A Section Through the NICMOS Dewar's Main Shell and Nitrogen Tank

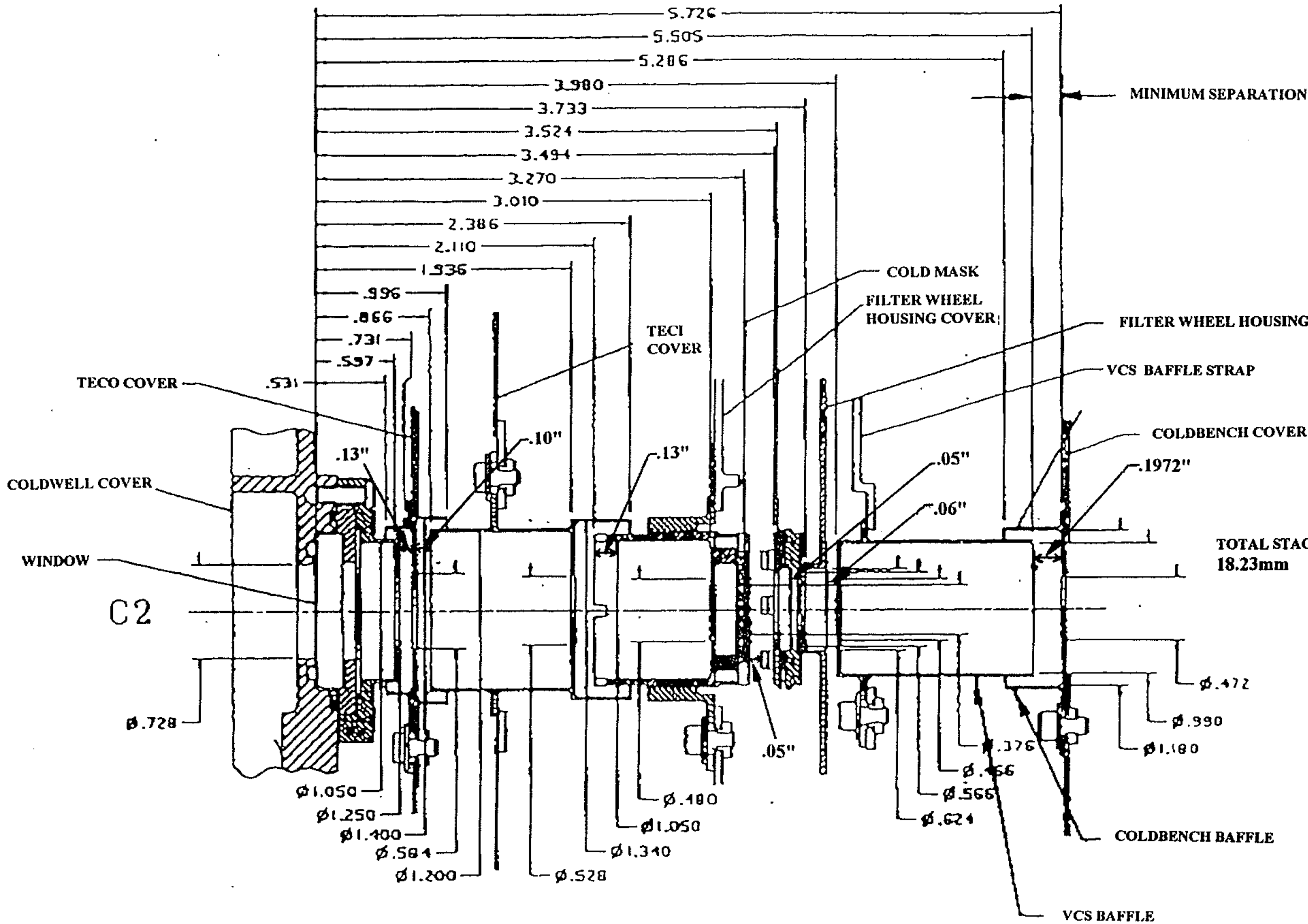


Figure-2
Measured Part Gaps
at Room Temperature Assembly

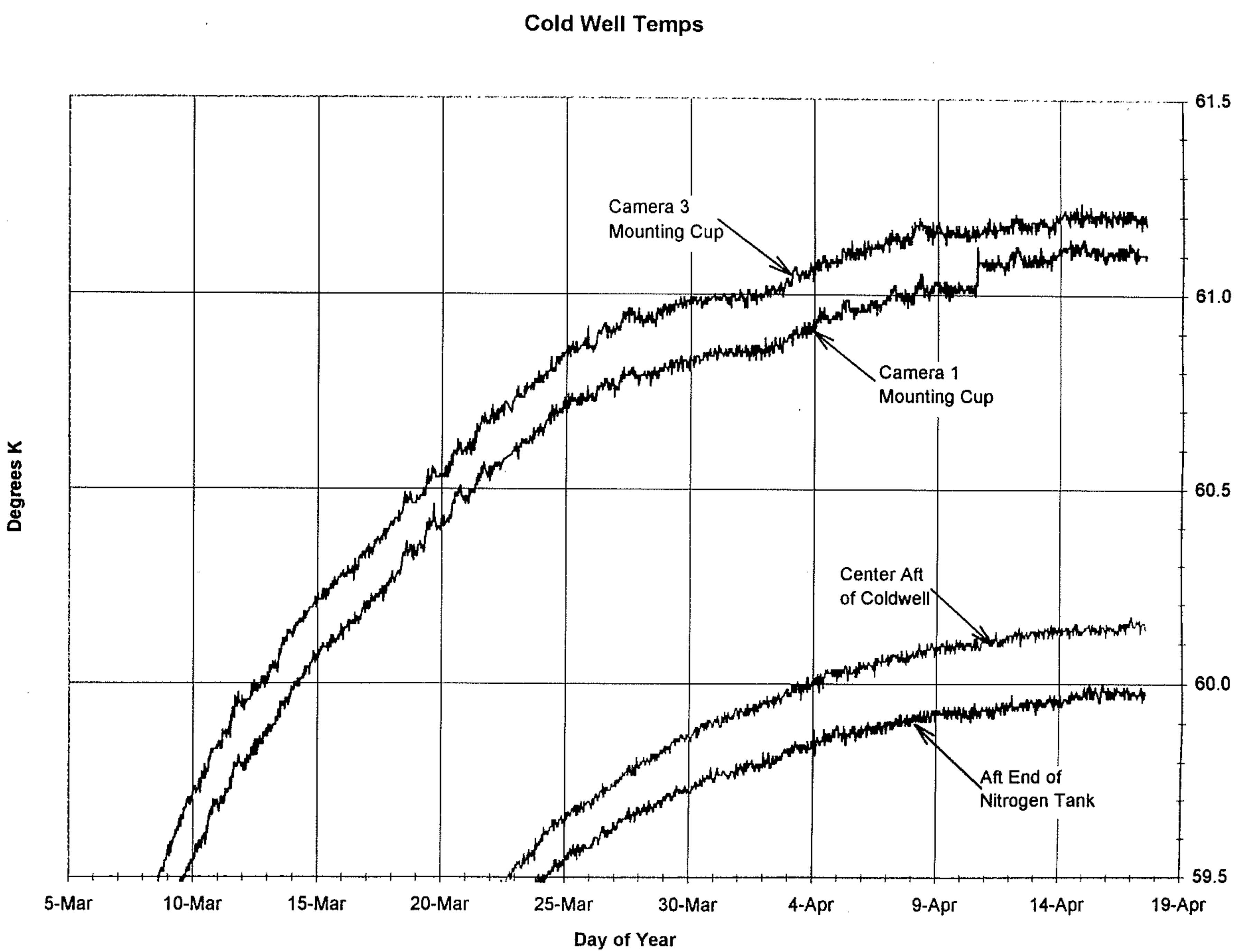


Figure-3 Nitrogen Tank Temperatures

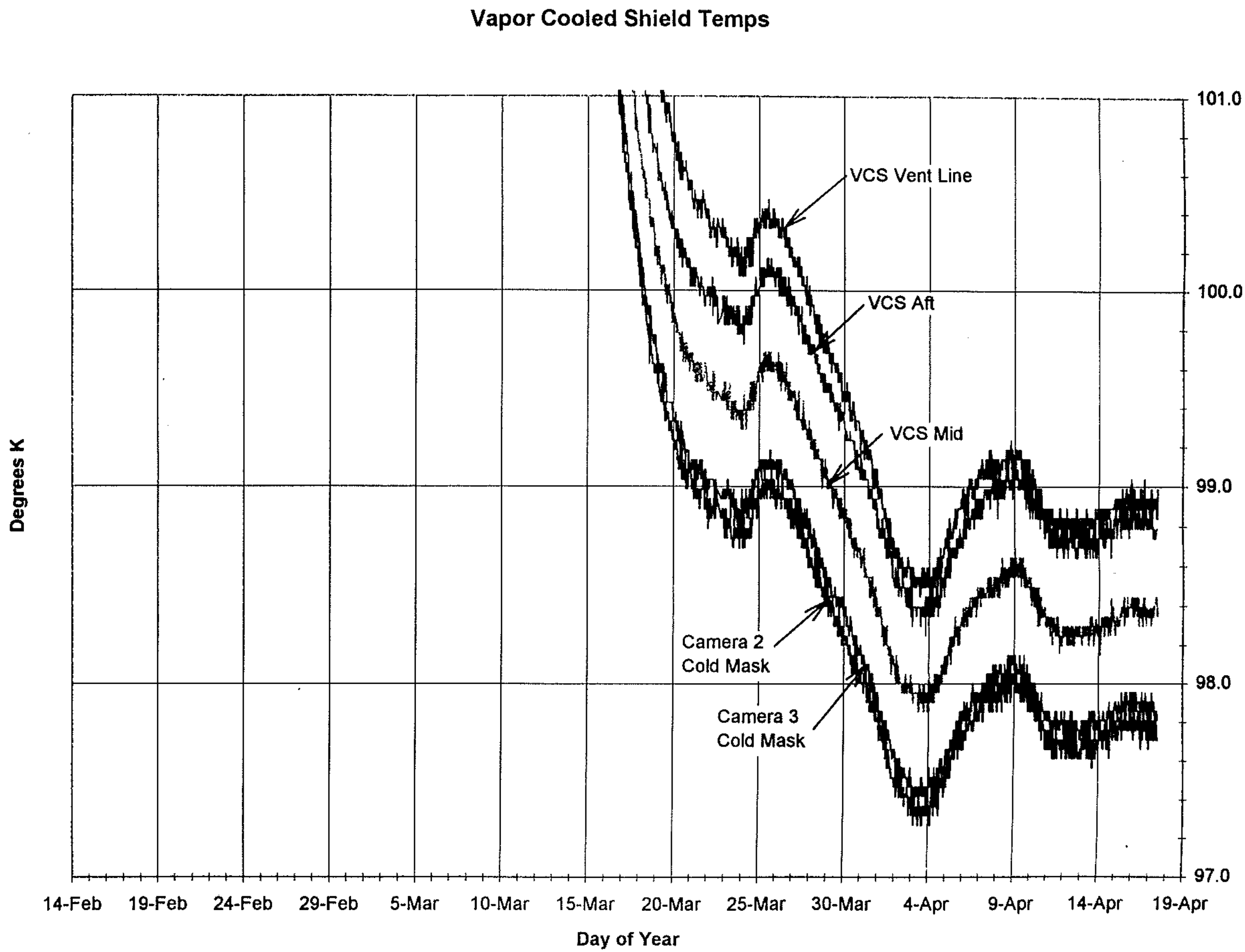


Figure-4 VCS Temperatures

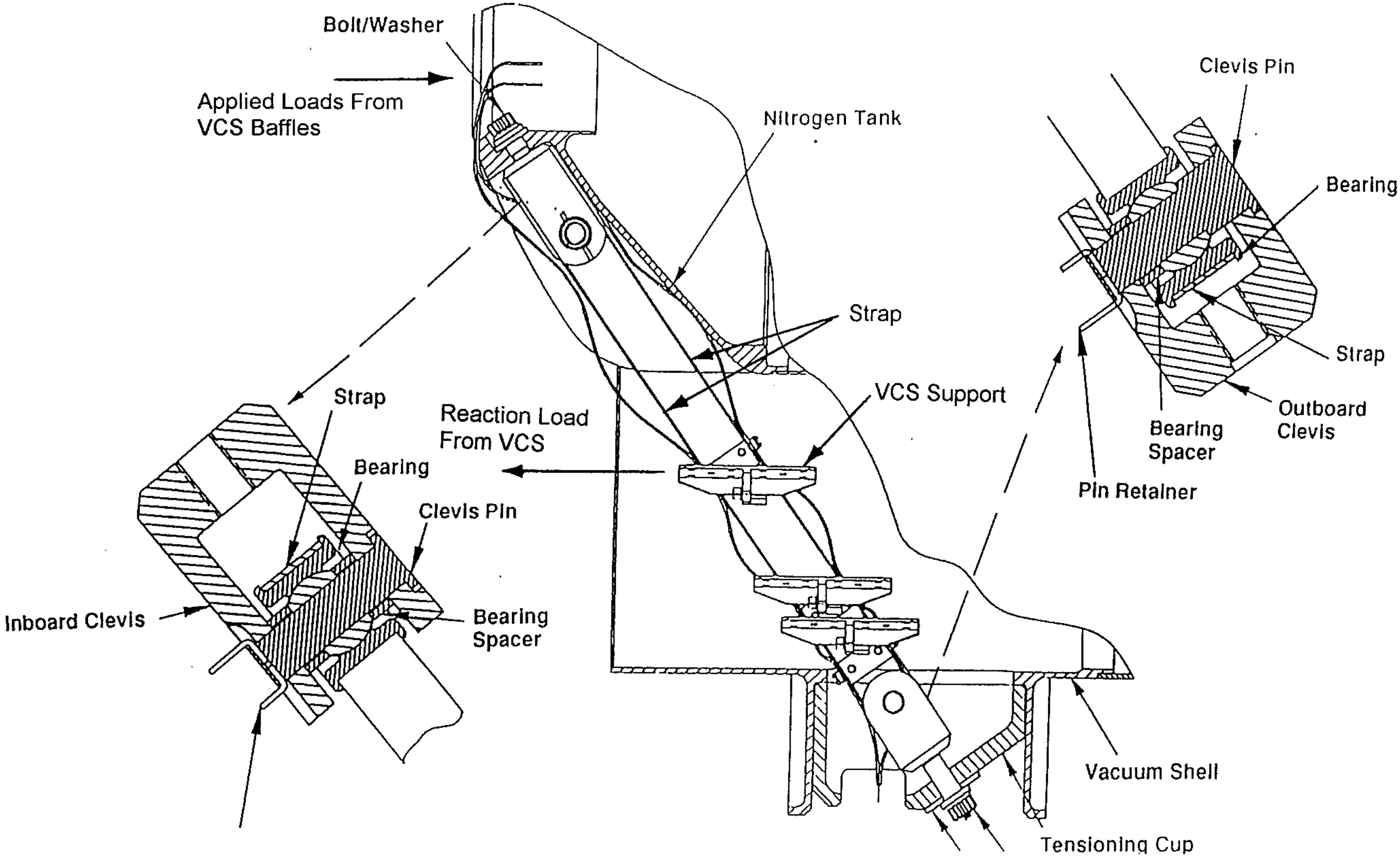


Figure-5
Reaction Path Between VCS and Nitrogen Tank

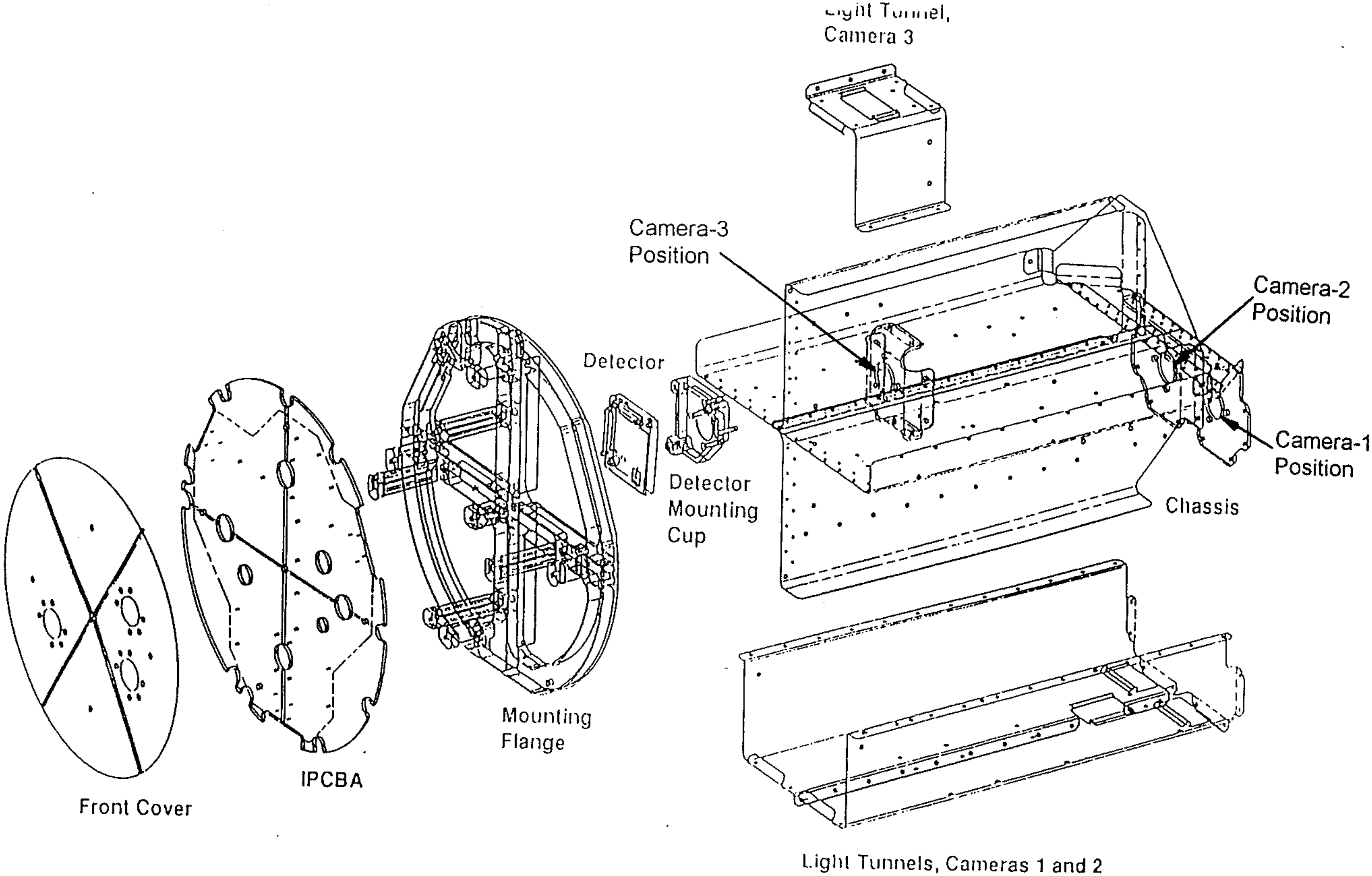


Figure-6
Details of the Detector's Mounting
Structure Within the Coldwell

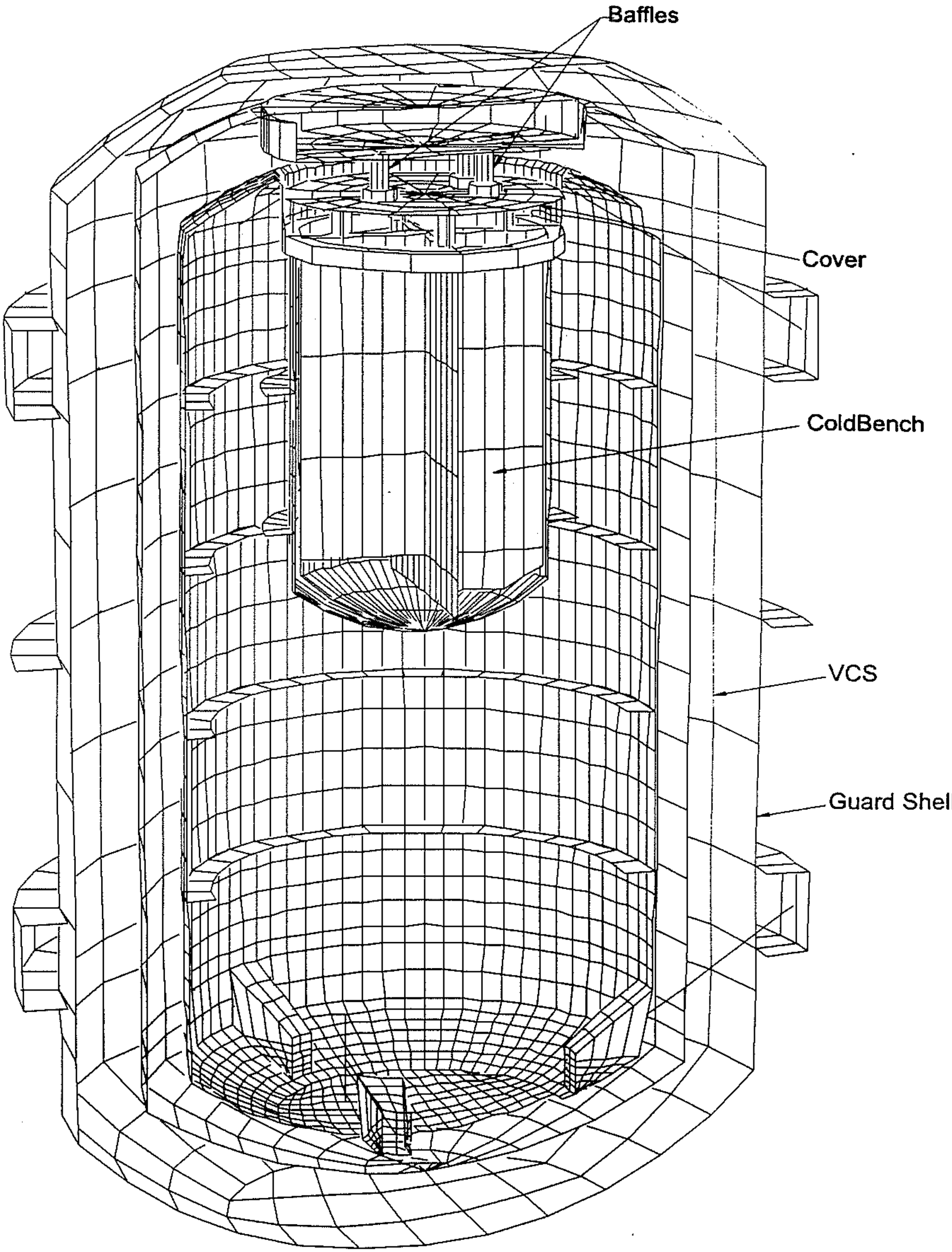


Figure-7
Initial Finite Element Model of Nicmos

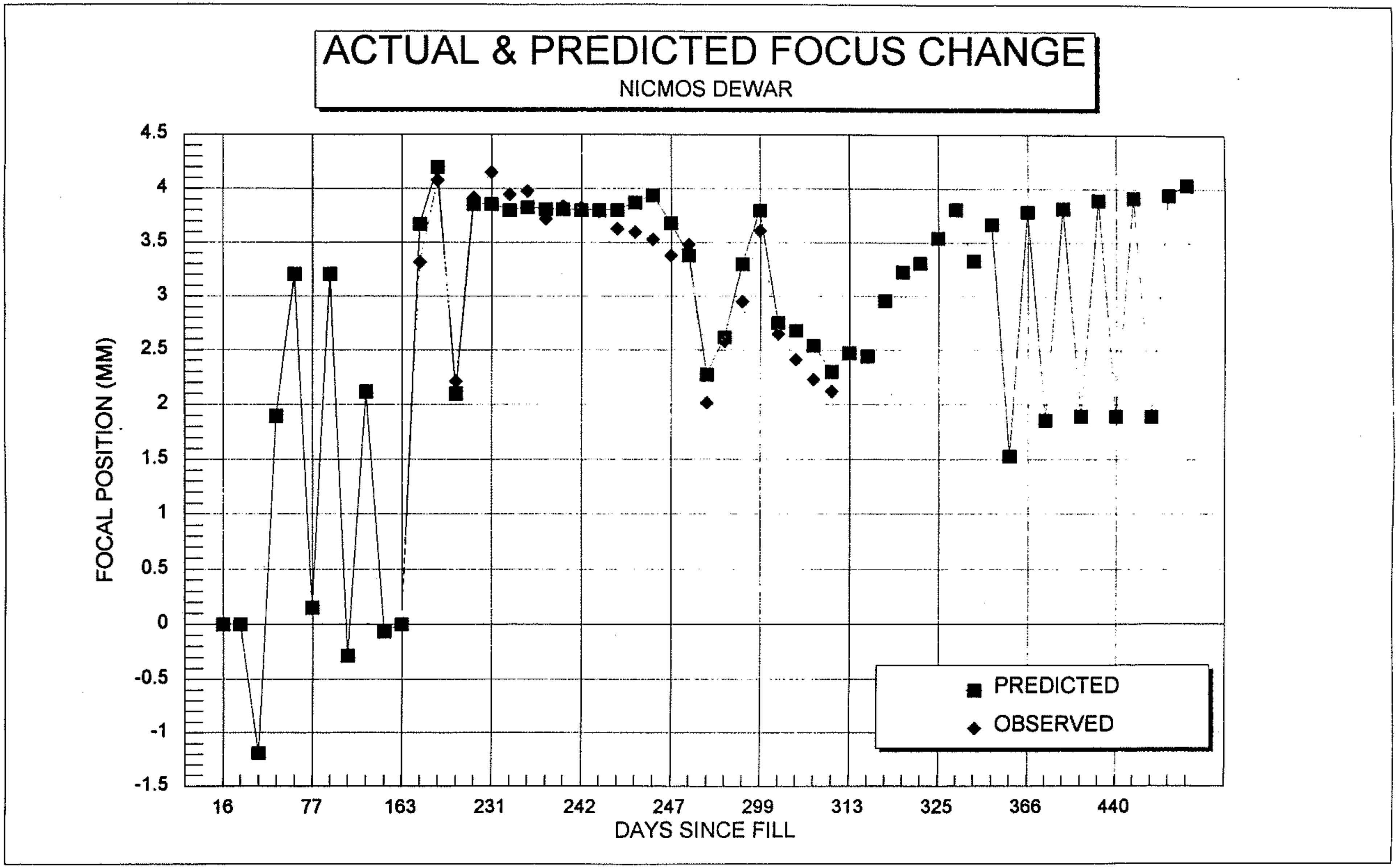
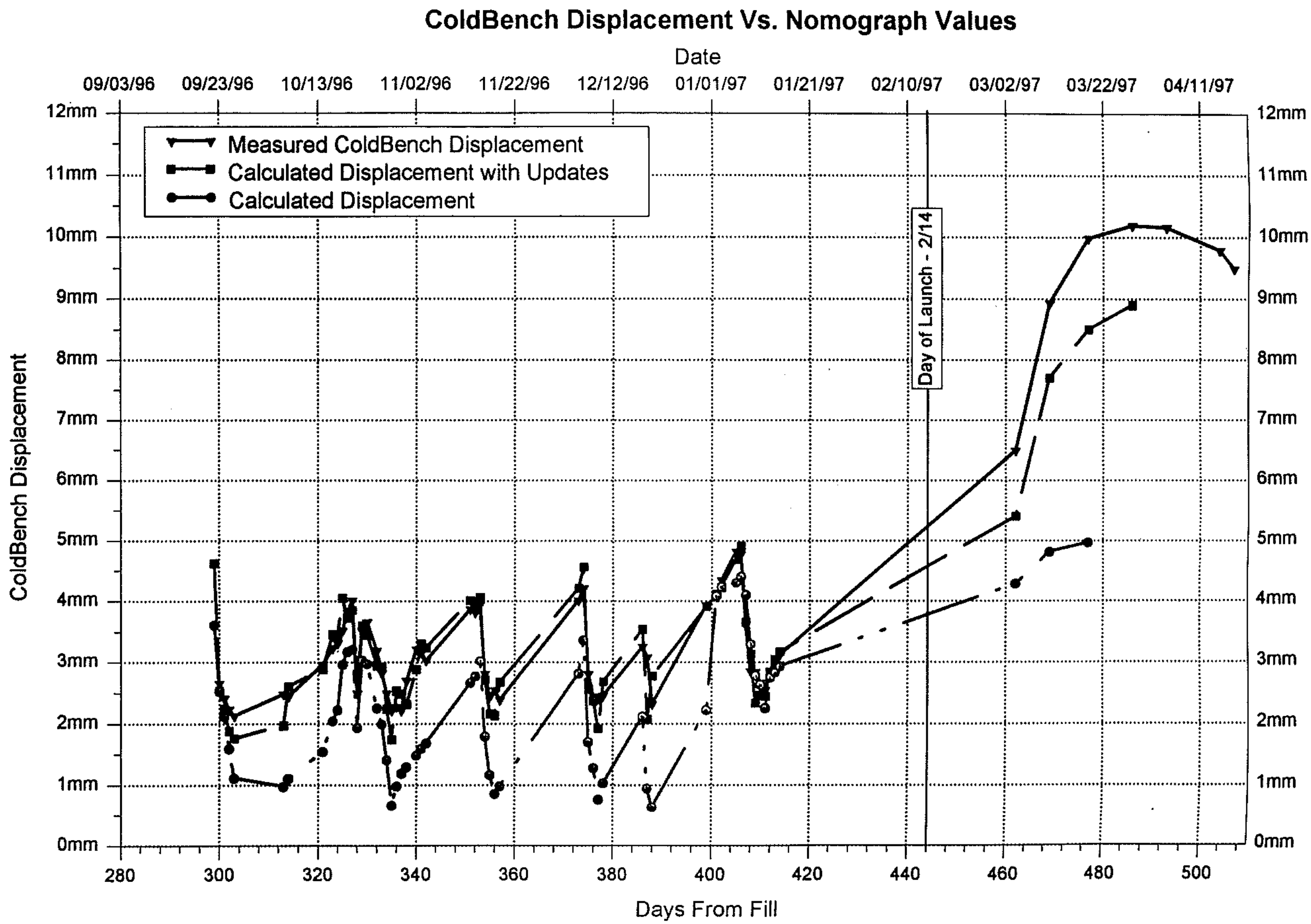
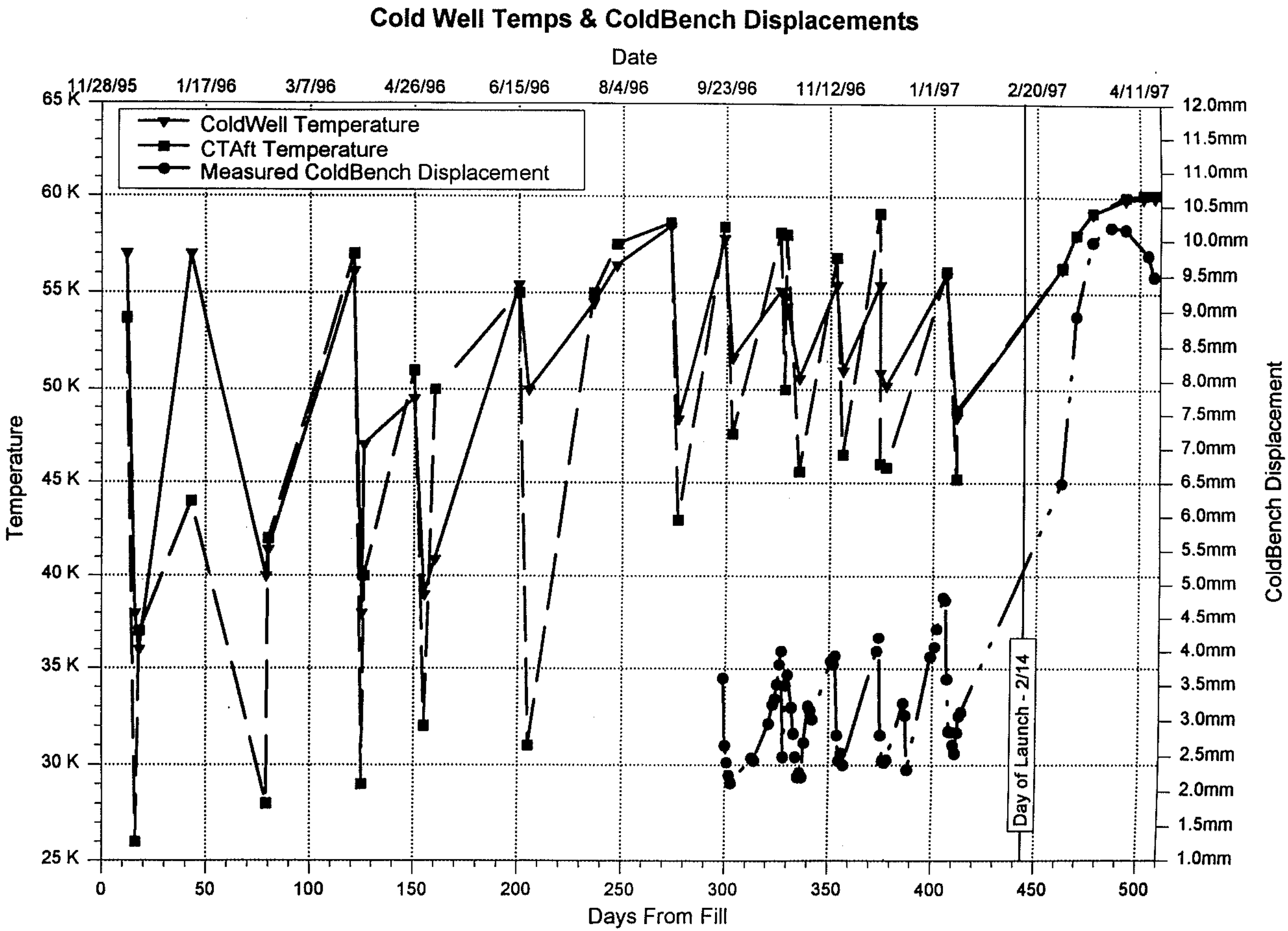


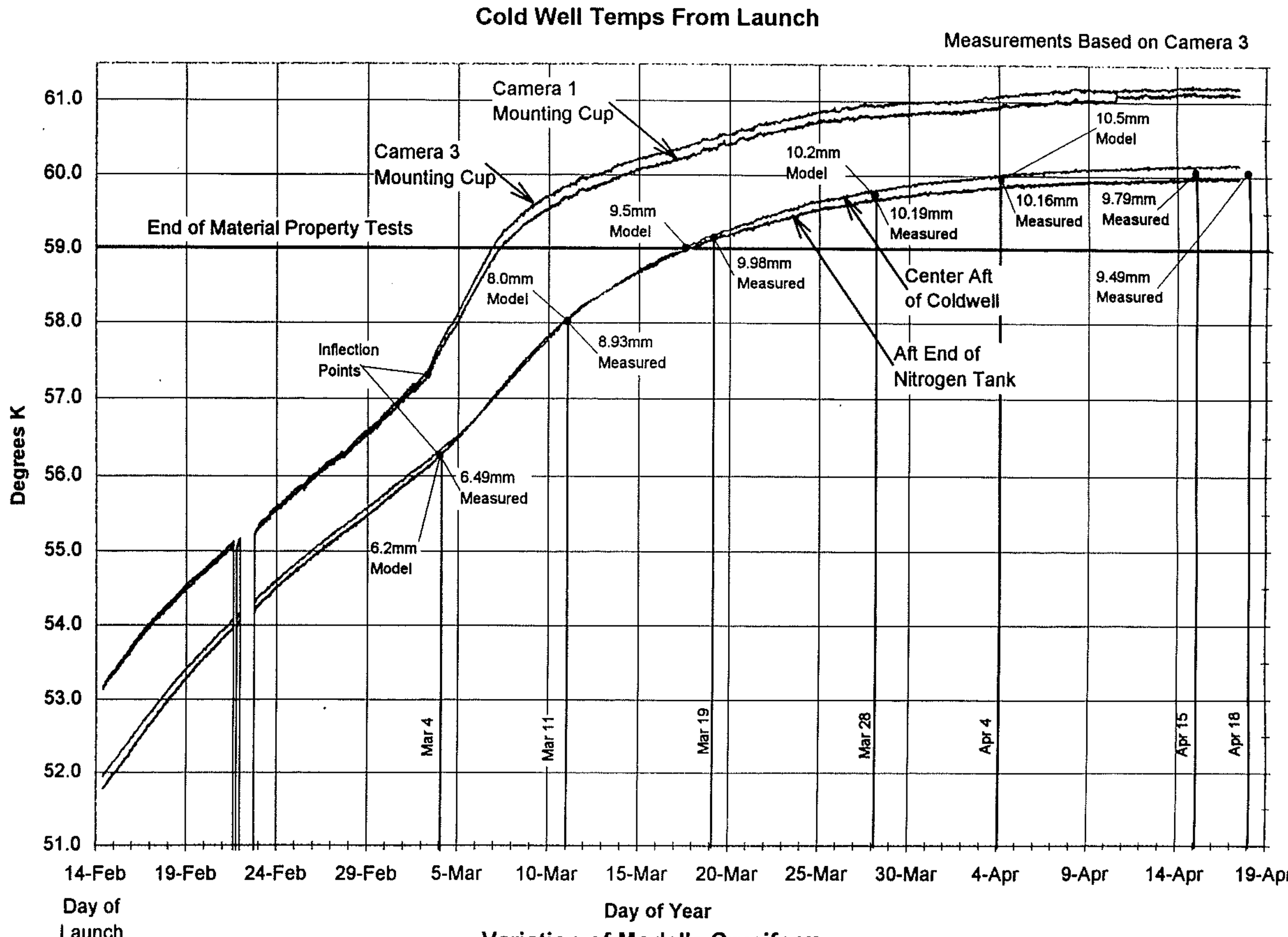
Figure-8a Calculated and Measured Focus Changes


ColdBench Displacement Vs. Nomograph Values
Date
09/03/96
09/23/96
10/13/96
11/02/96
11/22/96
12/12/96
01/01/97
01/21/97
02/10/97
03/02/97
03/22/97
04/11/97
Measured ColdBench Displacement
Calculated Displacement with Updates
Calculated Displacement
Day of Launch - 2/14
ColdBench Displacement
12mm
11mm
10mm
9mm
8mm
7mm
6mm
5mm
4mm
3mm
2mm
1mm
0mm
280
300
320
340
360
380
400
420
440
460
480
500
Days From Fill
Figure-8b



Cold Well Temps & ColdBench Displacements
Date
11/28/95
1/17/96
3/7/96
4/26/96
6/15/96
8/4/96
9/23/96
11/12/96
1/1/97
2/20/97
4/11/97
ColdWell Temperature
CTAft Temperature
Measured ColdBench Displacement
Temperature
65 K
60 K
55 K
50 K
45 K
40 K
35 K
30 K
25 K
ColdBench Displacement
12.0mm
11.5mm
11.0mm
10.5mm
10.0mm
9.5mm
9.0mm
8.5mm
8.0mm
7.5mm
7.0mm
6.5mm
6.0mm
5.5mm
5.0mm
4.5mm
4.0mm
3.5mm
3.0mm
2.5mm
2.0mm
1.5mm
1.0mm
Day of Launch - 2/14
0
50
100
150
200
250
300
350
400
450
500
Days From Fill

Figure-8c



Variation of Model's Cruciform Motion Vs. Temperature

Figure 9

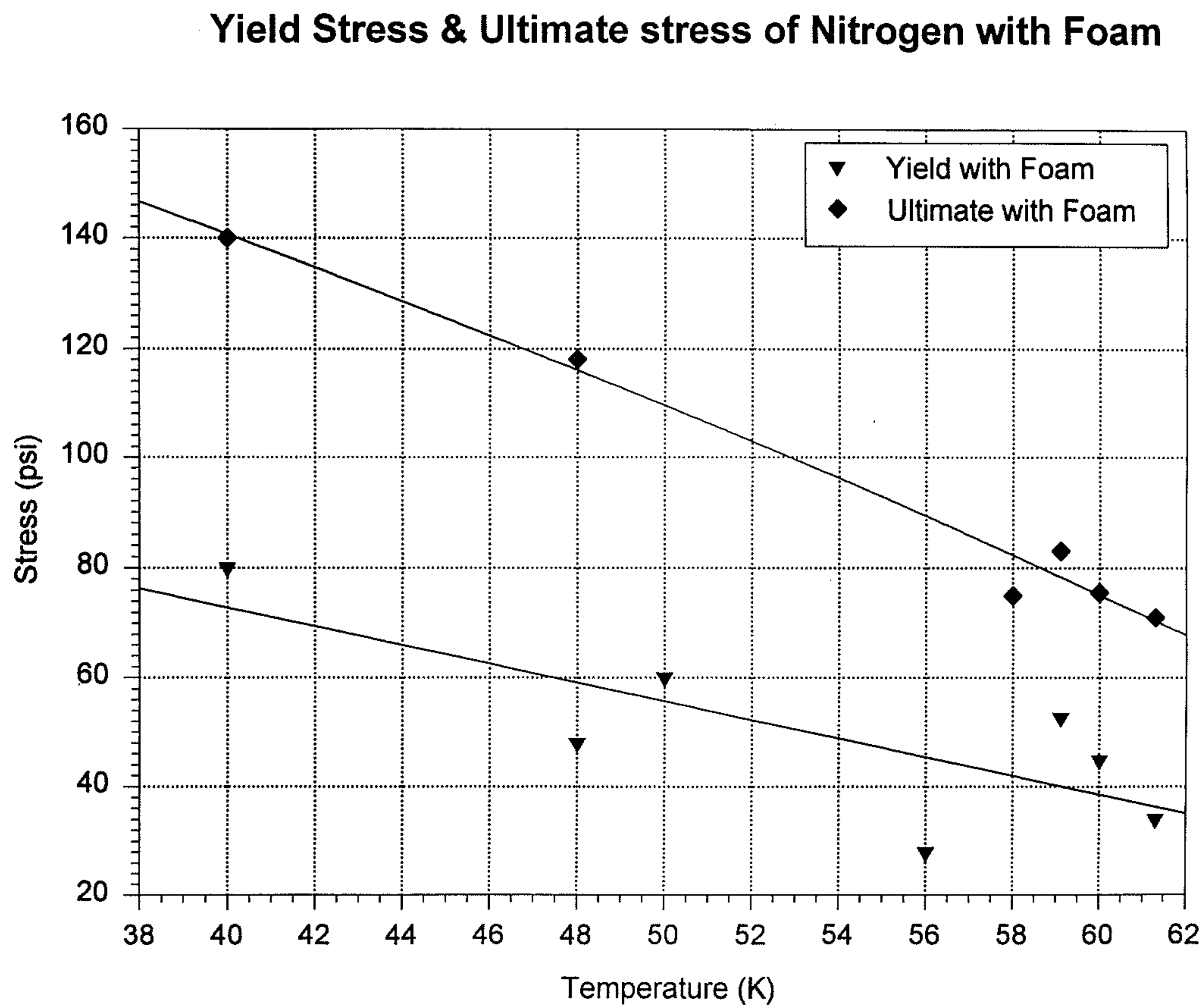
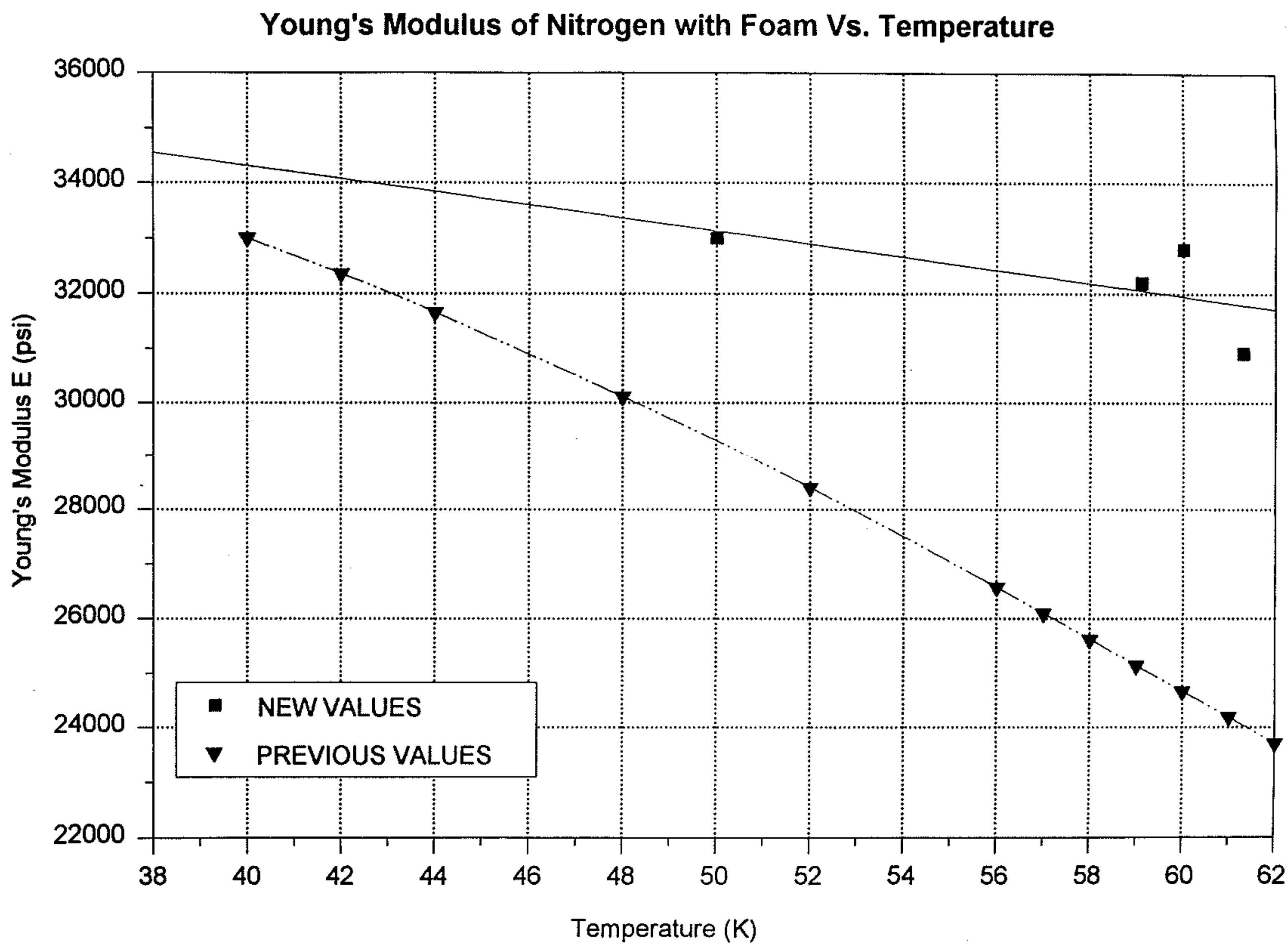

Yield Stress & Ultimate stress of Nitrogen with Foam
Yield with Foam
Ultimate with Foam
160
140
120
100
80
60
40
20
Stress (psi)
38
40
42
44
46
48
50
52
54
56
58
60
62
Temperature (K)

Figure-10



Young's Modulus of Nitrogen with Foam Vs. Temperature
36000
34000
32000
30000
28000
26000
24000
22000
Young's Modulus E (psi)
38
40
42
44
46
48
50
52
54
56
58
60
62
Temperature (K)
NEW VALUES
PREVIOUS VALUES

Figure-11

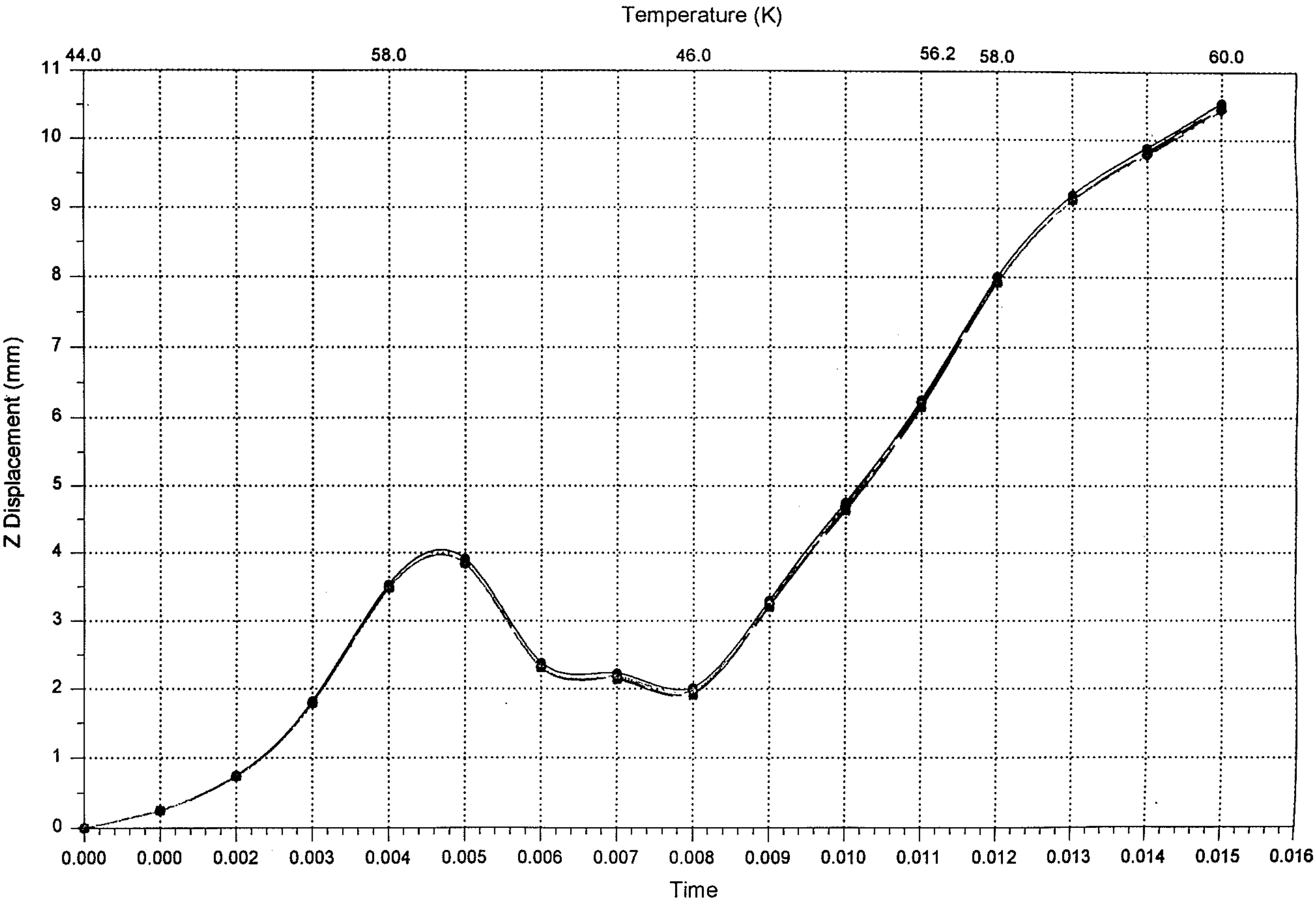


Figure-12
Detailed (Large) Model Calculations of Camera 3 Motion

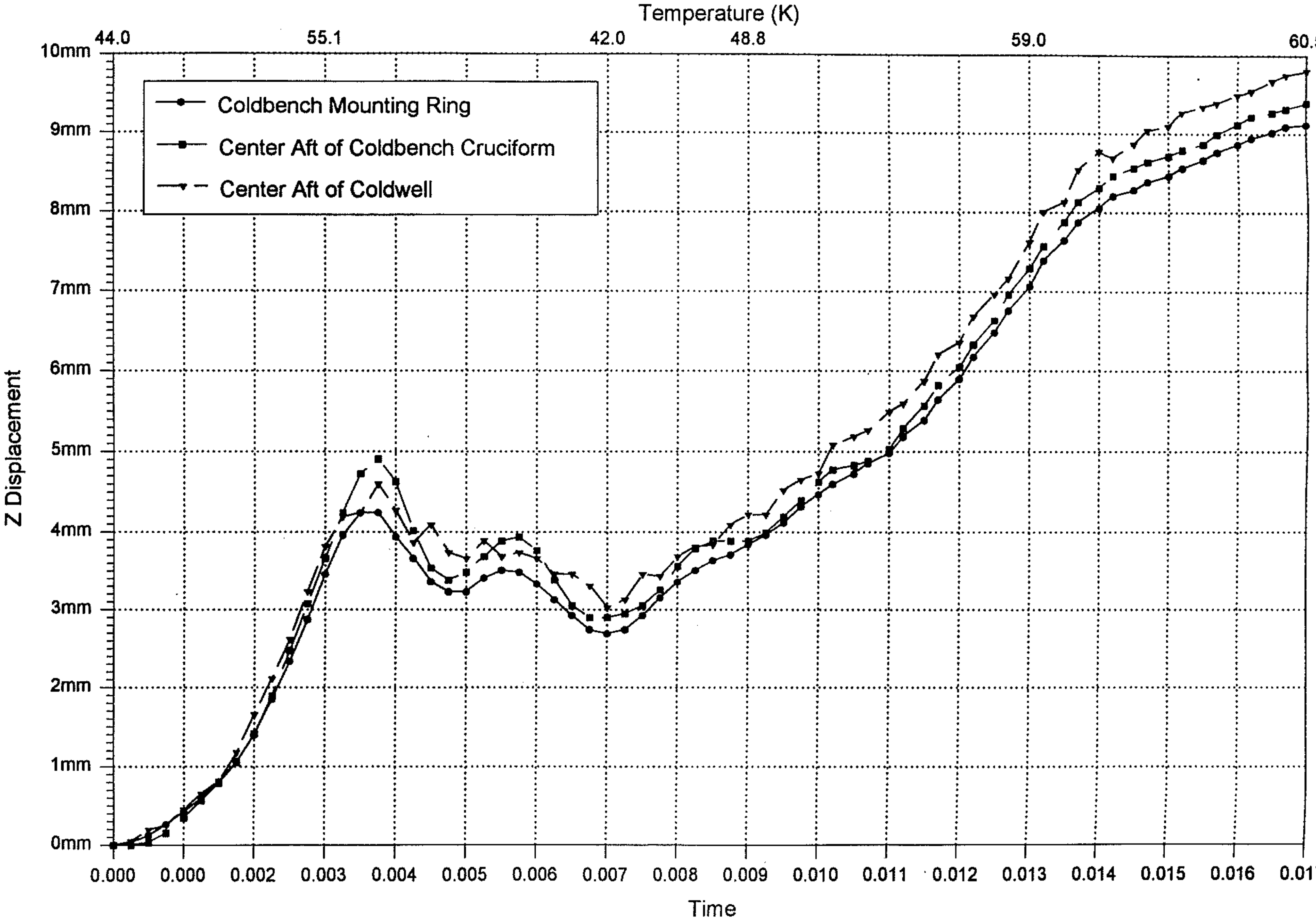


Figure-13
Small Model Calculations of Camera 3 Motion

NICMOS Small Model

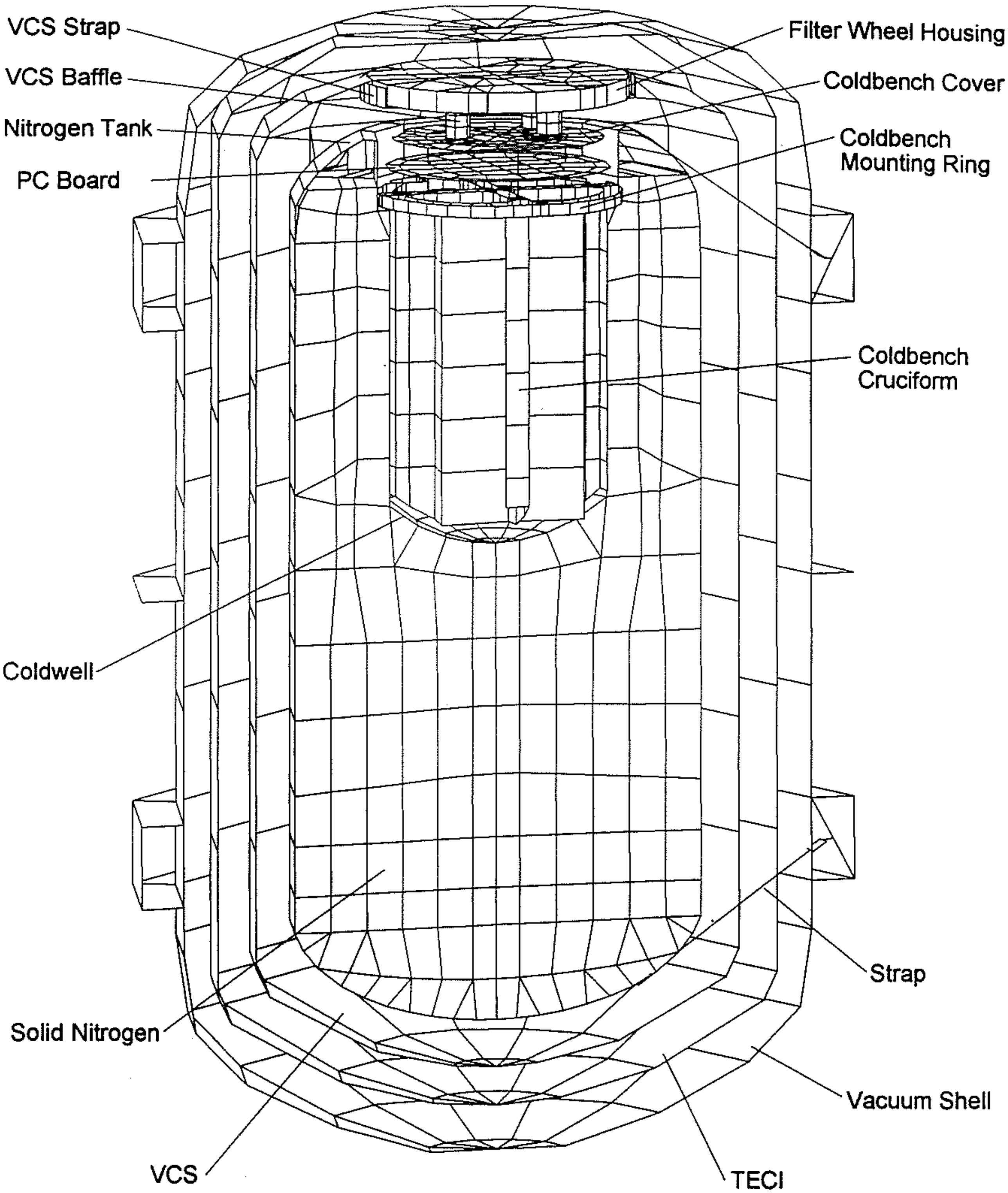


Figure-14a Section Through Small Model

NICMOS Forward Component Deformed Shape

(Shown 2X actual deformation)

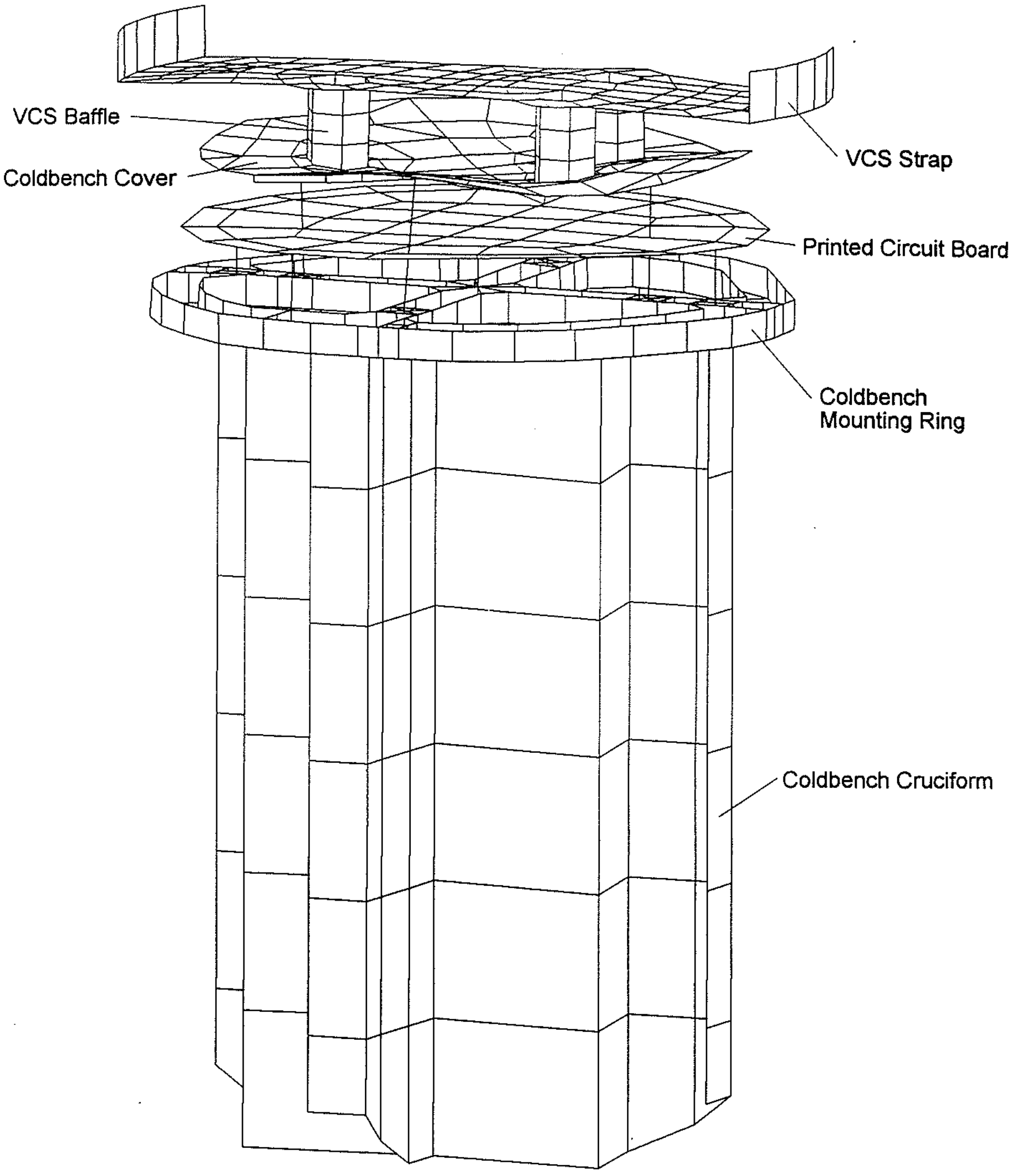


Figure-14b Forward Component Deformed Shape

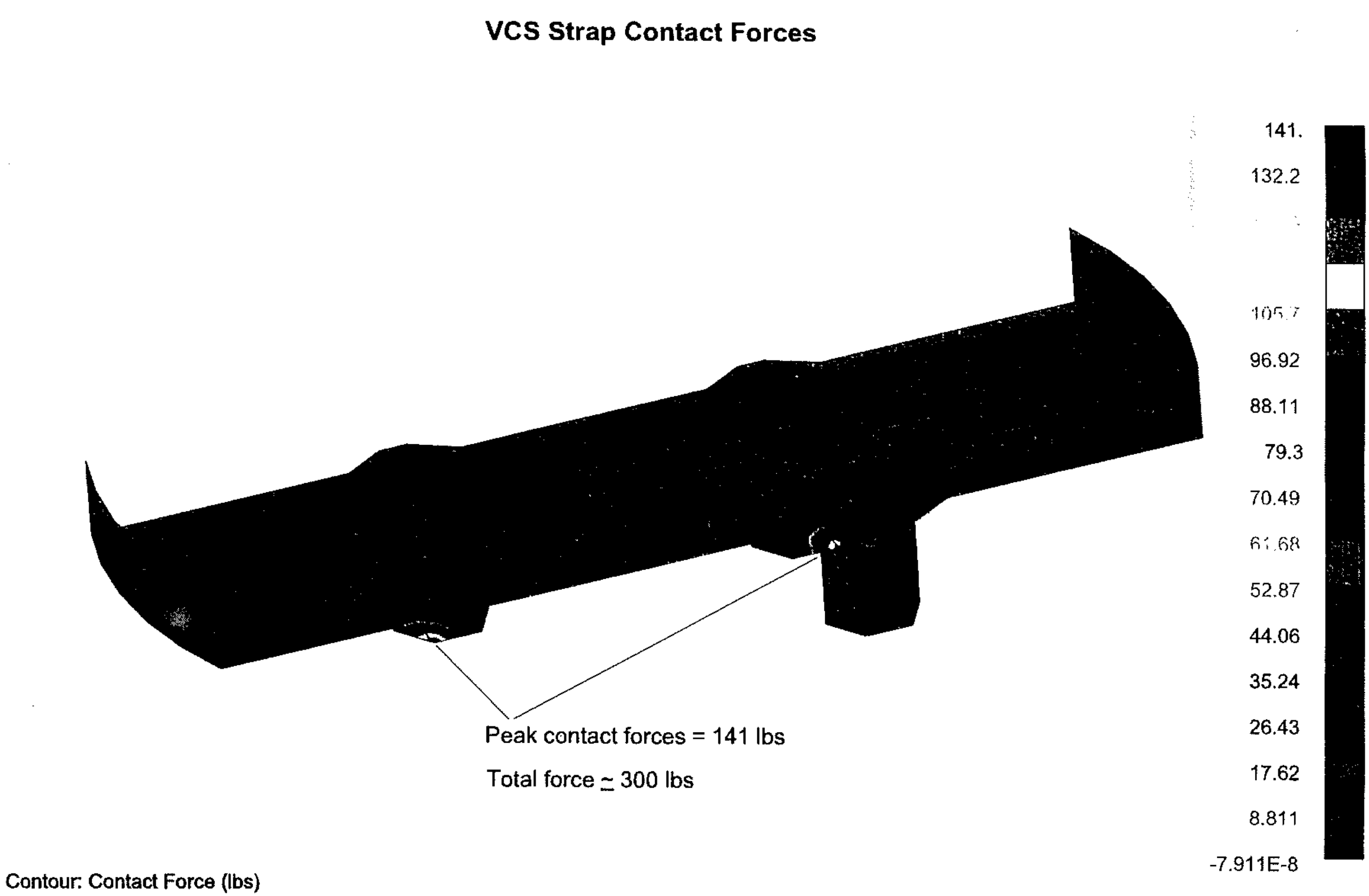


Figure-15 VCS Contact Forces

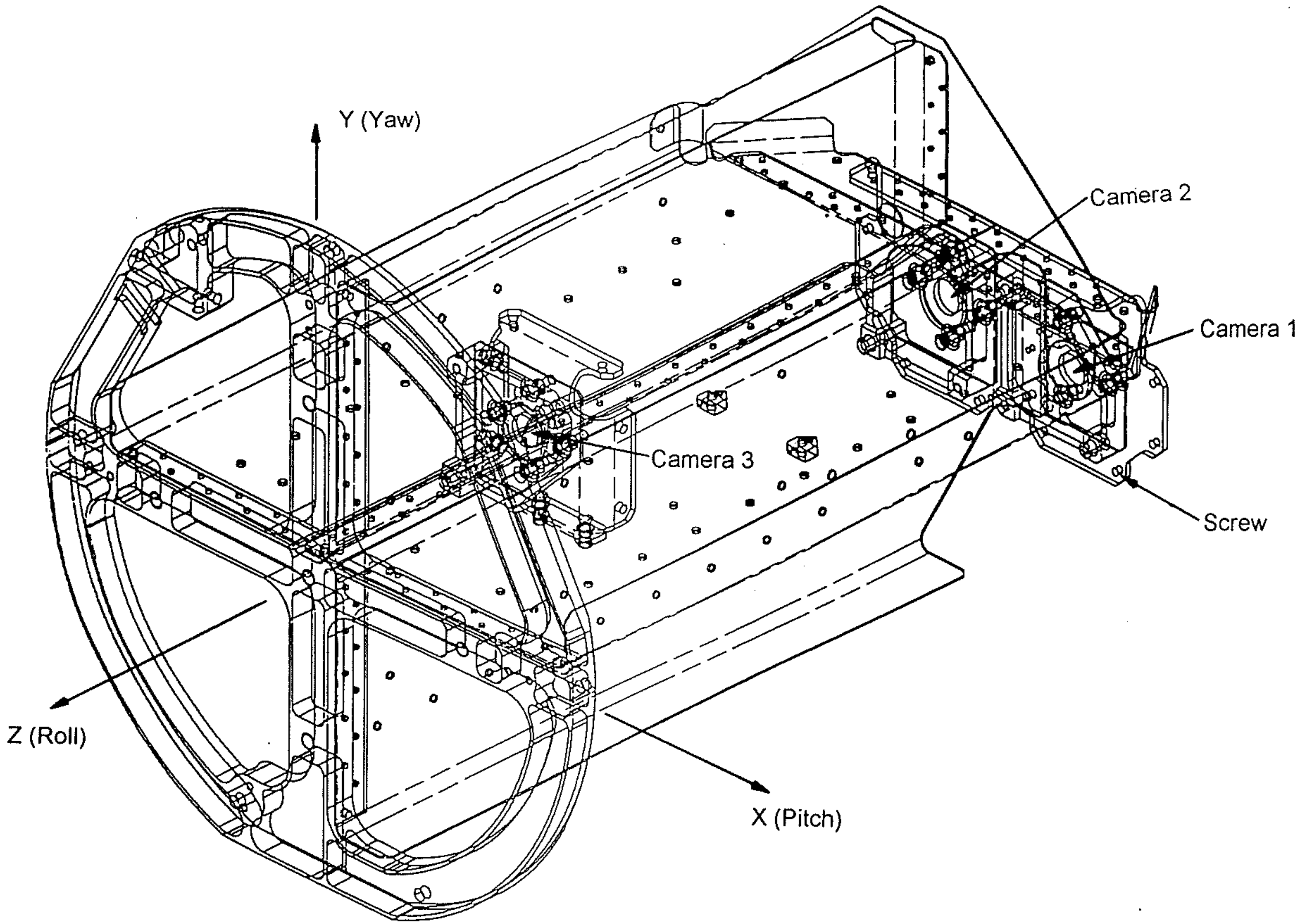


Figure-16
Axis Locations Related to Camera 3

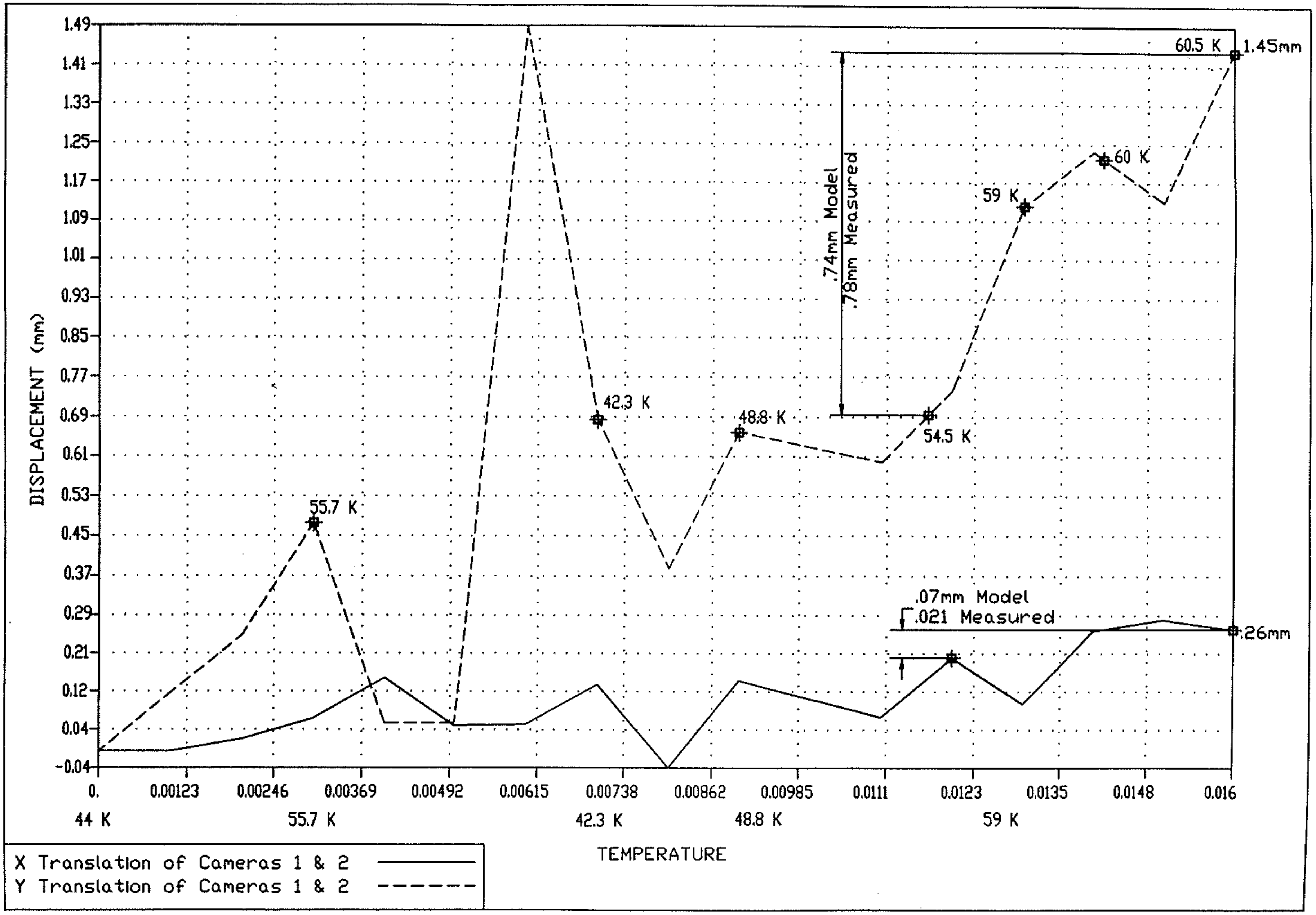


Figure-17
Small Model X-Y Motion
of Cameras 1 & 2

NICMOS Model -- Isothermal Loading

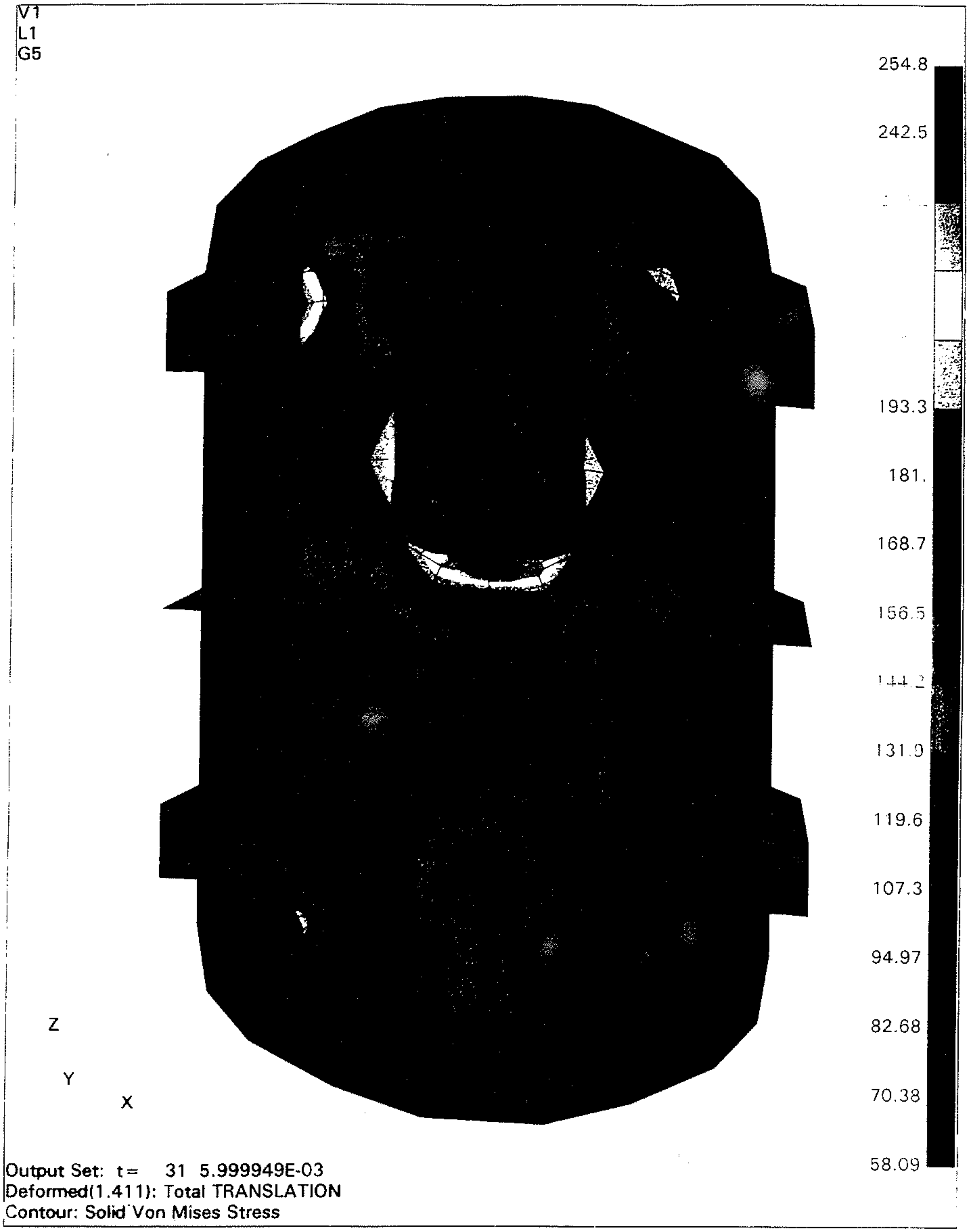


Figure-18
Nitrogen Stresses with Material
Properties at Full Values

Model s400 -- Forward Nitrogen 1.5 K Warmer

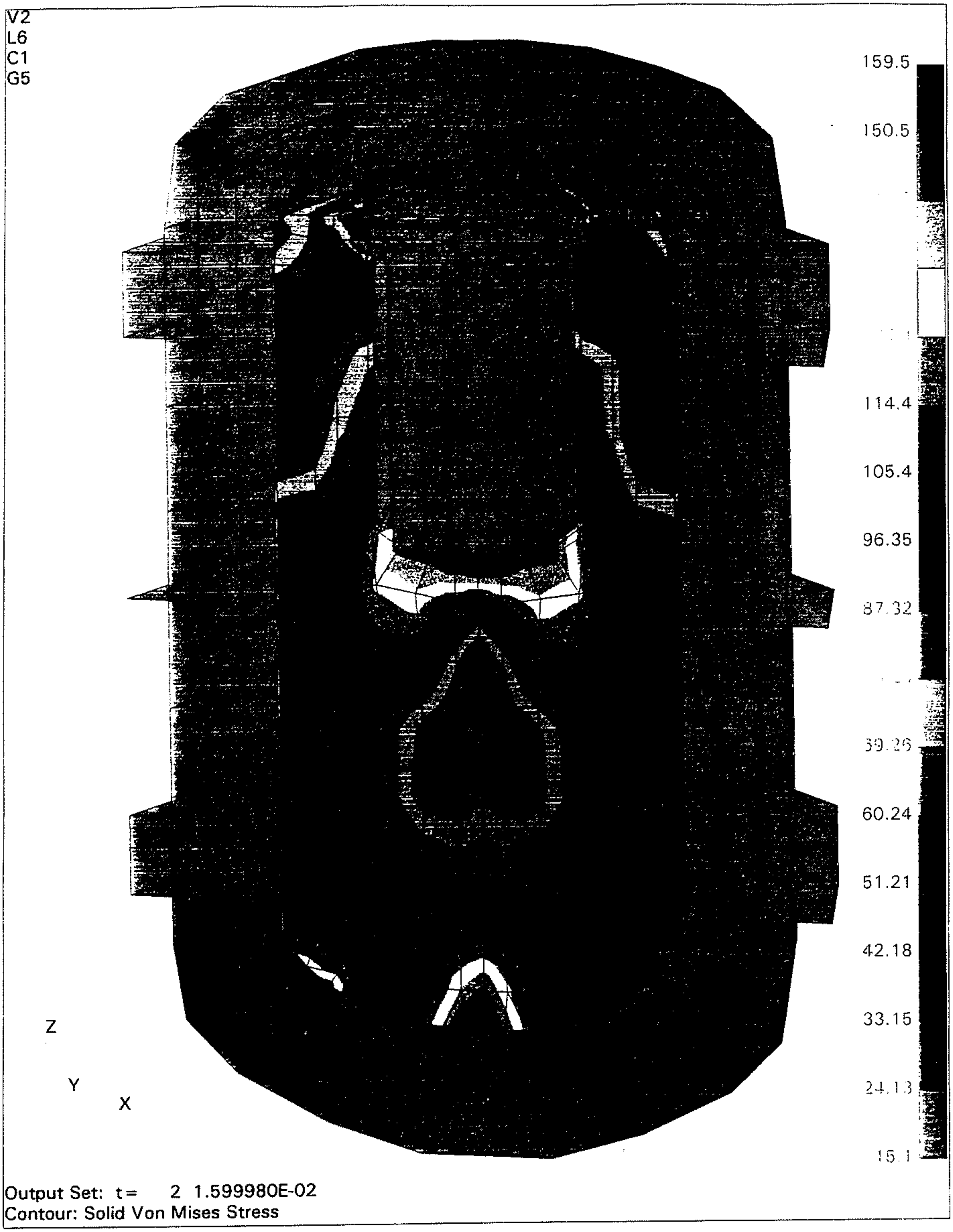


Figure-19
Reduced Stresses in Nitrogen Due to Reduced Mechanical Properties in Upper Nitrogen

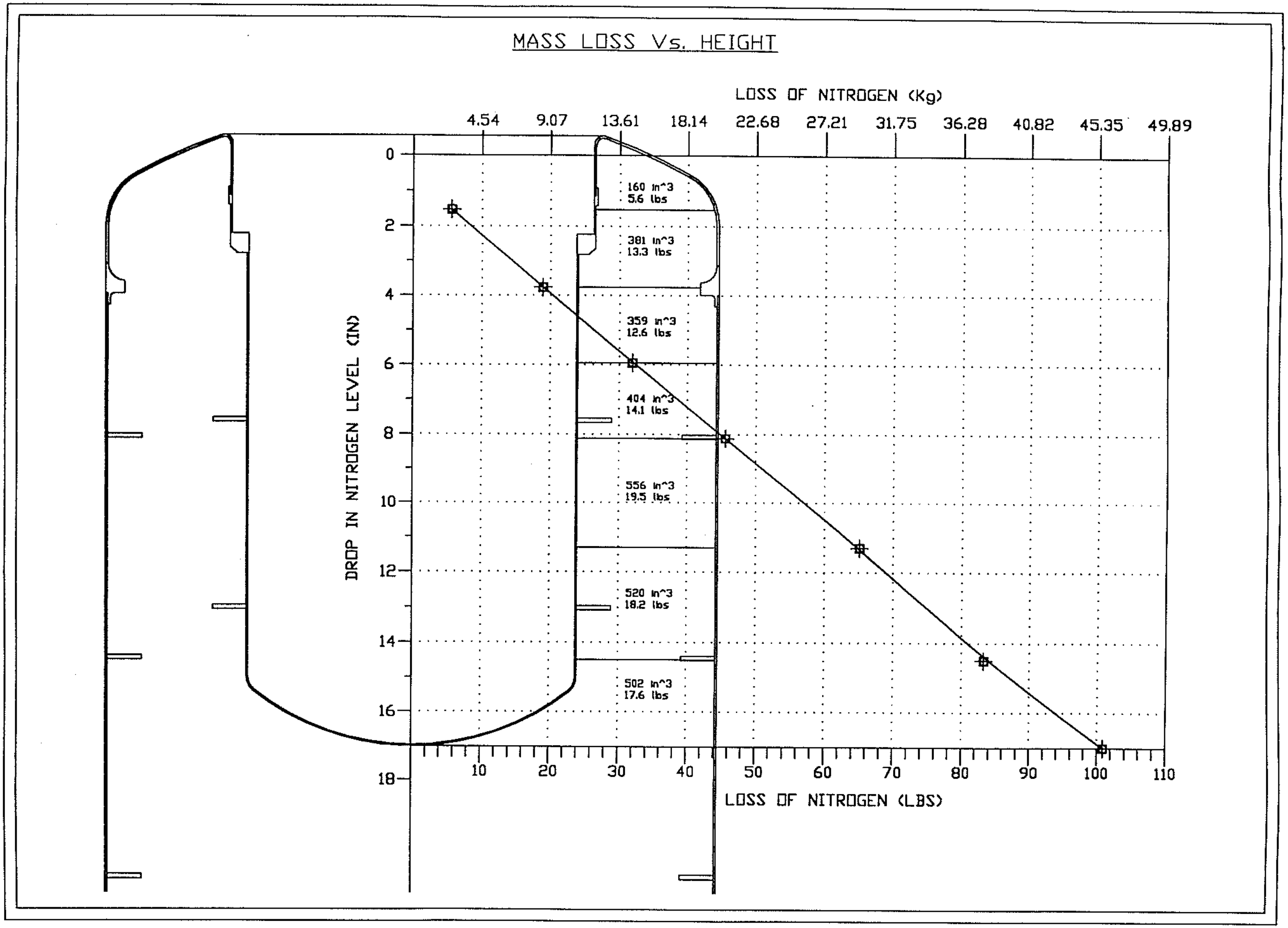

MASS LOSS Vs. HEIGHT
LOSS OF NITROGEN (Kg)
4.54
9.07
13.61
18.14
22.68
27.21
31.75
36.28
40.82
45.35
49.89
DROP IN NITROGEN LEVEL (IN)
0
2
4
6
8
10
12
14
16
18
160 in^3
5.6 lbs
381 in^3
13.3 lbs
359 in^3
12.6 lbs
404 in^3
14.1 lbs
556 in^3
19.5 lbs
520 in^3
18.2 lbs
502 in^3
17.6 lbs
10
20
30
40
50
60
70
80
90
100
110
LOSS OF NITROGEN (LBS)

Figure-20

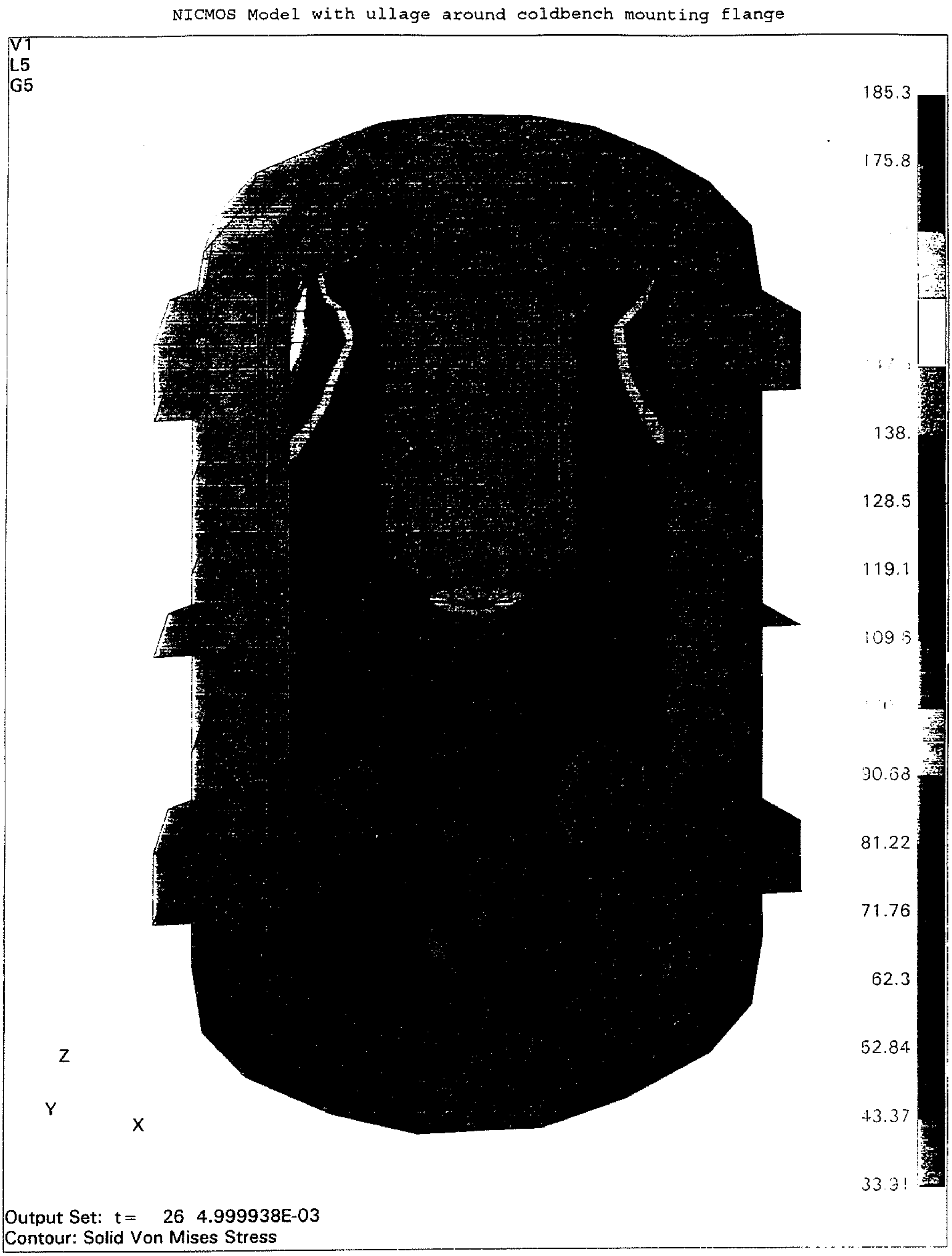


Figure-21
Nitrogen Stresses with 3 lbs of Cryogen
Removed From Around the Coldwell Neck

Fig 22

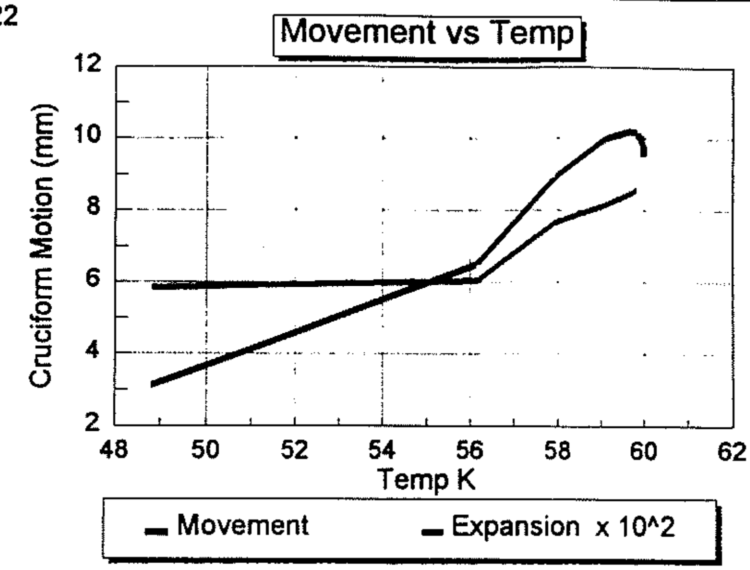


Fig 23

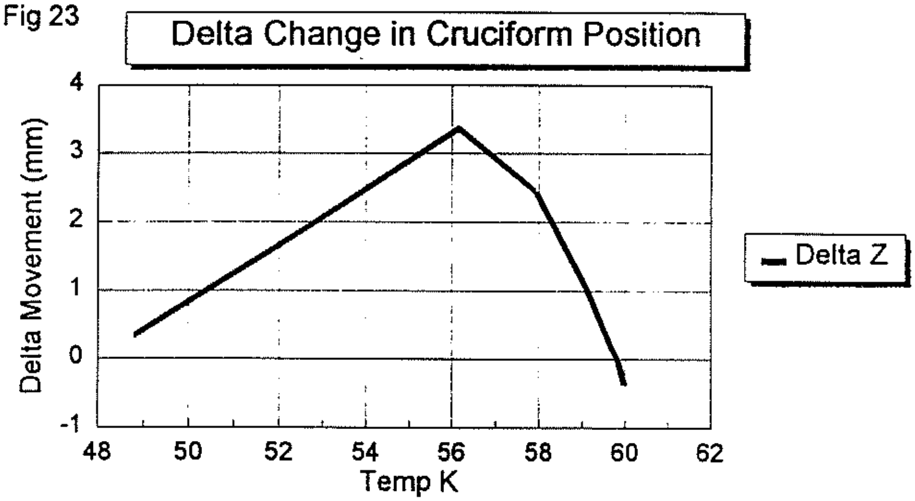
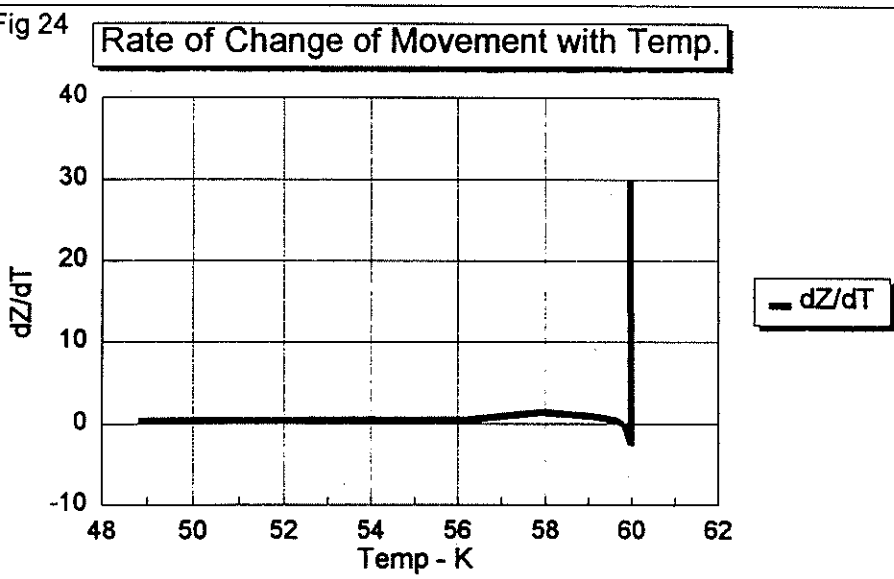


Fig 24



Figures 22, 23, & 24

A Note on the Temporal On-Orbit History of the Position of the NICMOS Coronagraphic Hole

Glenn, Schneider, UofA

4/28/97

The position of the image of the NICMOS coronagraphic hole (C-Hole), located on the C2 field divider mirror, on the Camera 2 Focal Plane Array (FPA) has been changing continually since installation during SM-97. The ultimate position and understanding of the spatial and temporal stability of the C-Hole is required for enabling NICMOS Mode-2 target acquisitions and coronagraphic science. The migration of the C-Hole image at the C2 FPA also provides an independent measure of the translative motion of the camera 2 detector (and cold bench at that axial position). The latter may be important in better understanding the mechanical dynamics of the NICMOS dewar and associated structures.

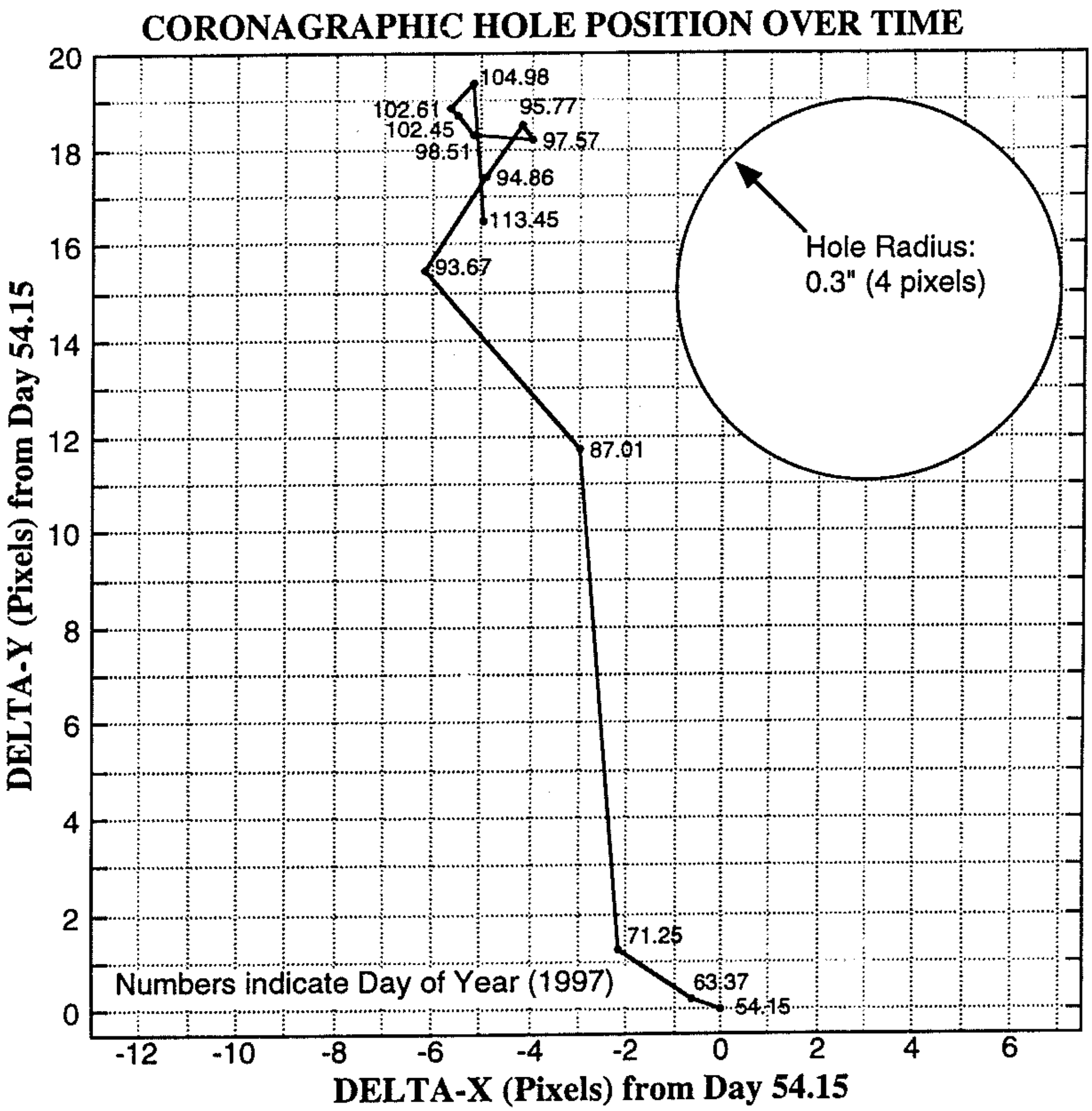
The location of the C-Hole was first measured from internal flat field (IFF) images taken during the NICMOS on-orbit functional test. Though a shift in position due to zero-gee unloading of the Fore-Optics Bracket was anticipated, a larger than expected shift was seen. This was quickly ascertained to be due to the unusually high temperature of NICMOS enclosure and outer shell on removal from the SIPE. The on-orbit functional was run immediately after installation and the warm temperature resulted in a radial expansion (between the K-fitting and the optical centerline), displacing the position of the coronagraphic hole.

Following the thermal equilibration of the NICMOS instrument enclosure and outer shell the position of the C-Hole image was determined from IFF images taken on day 1997.5415 as part of the NICMOS filter wheel mechanism test (7035). This position, (X,Y) = [77.490, 199.51] (in the OPUS data coordinate frame) established a fiducial point for subsequent measurements of the internal stability of the C-Hole. Subsequent measures over time have been made from on-orbit IFF calibration exposures taken from an assemblage of SMOV and ERO programs. To date these positions which are reported in this note have been derived from the following activities:

PROPOSAL	DOY (1997)
7035	54.150
7134	63.370
7041	71.250
7042	87.010
7116	93.670
7150	94.860
7117	95.770
7115	97.570
7034	98.510
7111	102.45, 102.61, 104.98
7154	113.45

Attachment 2

The following figure illustrates the change in position of the center of the coronagraphic hole over a 2-month period starting on day 54.15. Motion is seen in both axes, though predominately toward +Y through day 104.98. This is dominated by a large +Y excursion between days 71 and 95 (approximately 0.71 pixels/day). Until the change between 104.98 and 113.45 significant Y-axis motion was only in the +Y direction. It is at the start of this interval, approximately, that the axial motion of the cold bench inferred from Camera 3 focus measurements also changed direction.



It is interesting to note that the Camera 3 focus turned-around (i.e., moved back toward less negative "best focus" in PAM space) sometime between the focus measurements made on days 94 and 105. A number of physical mechanisms, discussed by the NICMOS dewar ARB, have been posited to explain the lateral motion of the C-Hole. One might speculate that the lateral motion of the C-Hole, resulting from a tilt of the cold bench, could be reversed with a change in direction of the detector bench itself.

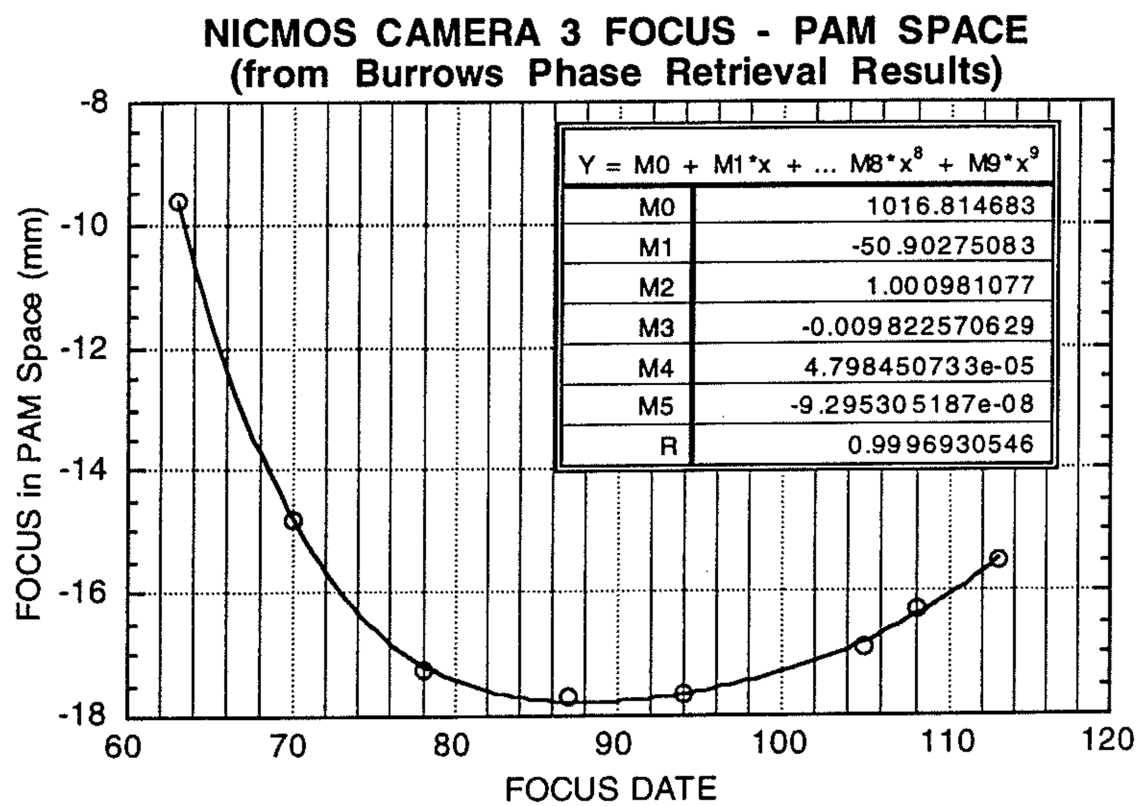
The axial motion of the dewar/cold bench structure resulting from the thermal expansion of the N_2 ice has been monitored on-orbit since ~day 63. Continuing a trend since pre-launch, the detectors had continued to move forward with the bulk temperature of the cryogen until approximately day 94, when the forward motion stopped. Subsequently, as the ice temperature asymptotically approached equilibration the position of the detectors (mounted on the cold bench) was seen to reverse.

The principle metric for the axial position of the detectors is the setting of the PAM to achieve "best focus" in Camera 3 (which provides the most sensitive measure of detector motion). The monitoring of focus over time has been described in separate memos by Burrows, Mentzell, Schneider and others and also discussed in the dewar ARB. The lateral motion of the coronagraphic hole from (X/Y detector bench motion) was correlated with the axial motion of the C3 focus (Z motion of the detector bench) determined, primarily, from Phase Retrieval results supplied by Chris Burrows.

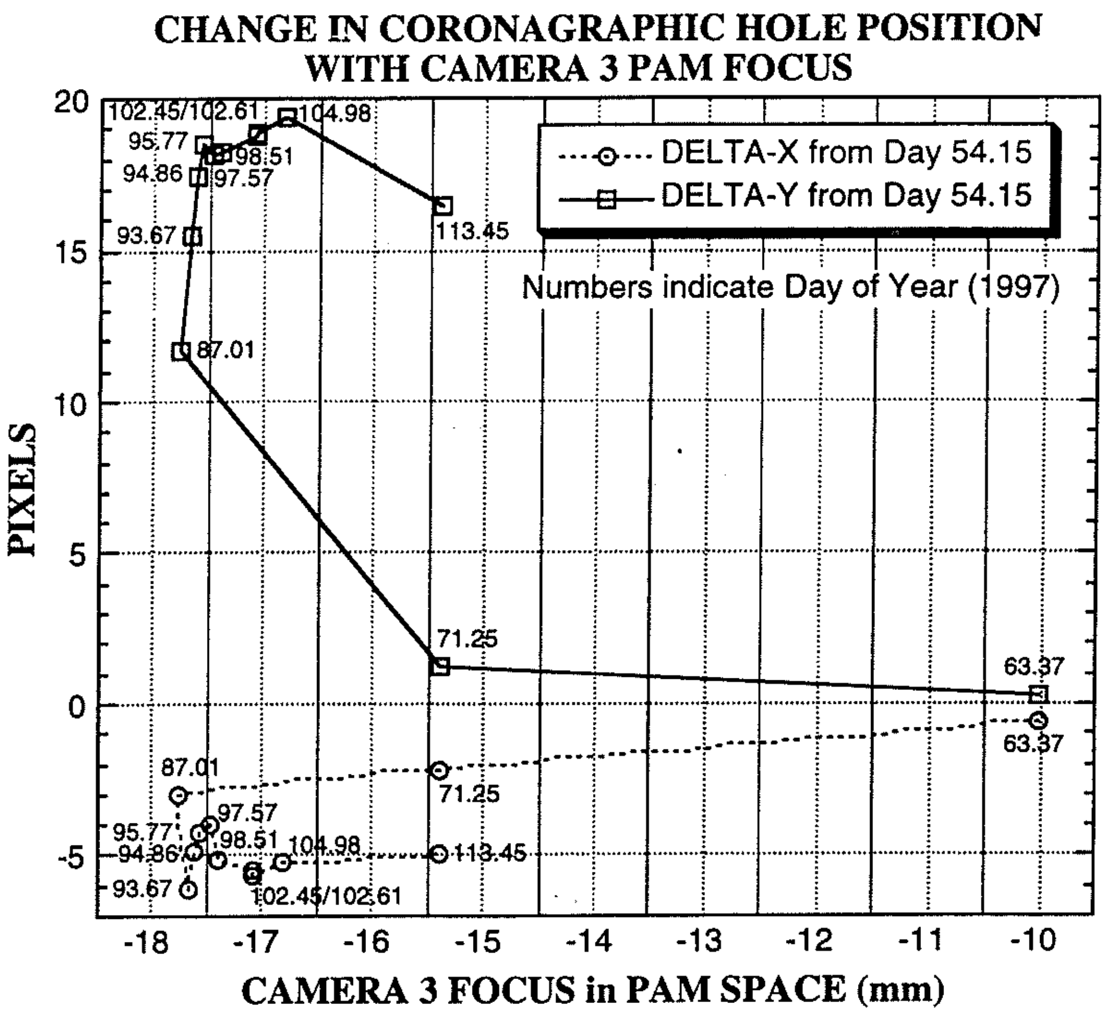
Camera 3 "best focus" positions in PAM space for the times/dates of C-Hole location measurements were approximated from a 5th order polynomial fit Burrow's focus determinations. As seen in the figure below, between days 62 (Pre-Alignment Checkout) and 113 (Focus Monitor, iteration #2), the Camera 3 focus position is fit very well by:

$$\text{Focus} = 1016.814 - 50.903T + 1.00098T^2 - 0.0098226T^3 + 4.798E\text{-}5T^4 - 9.2953E\text{-}8T^5$$

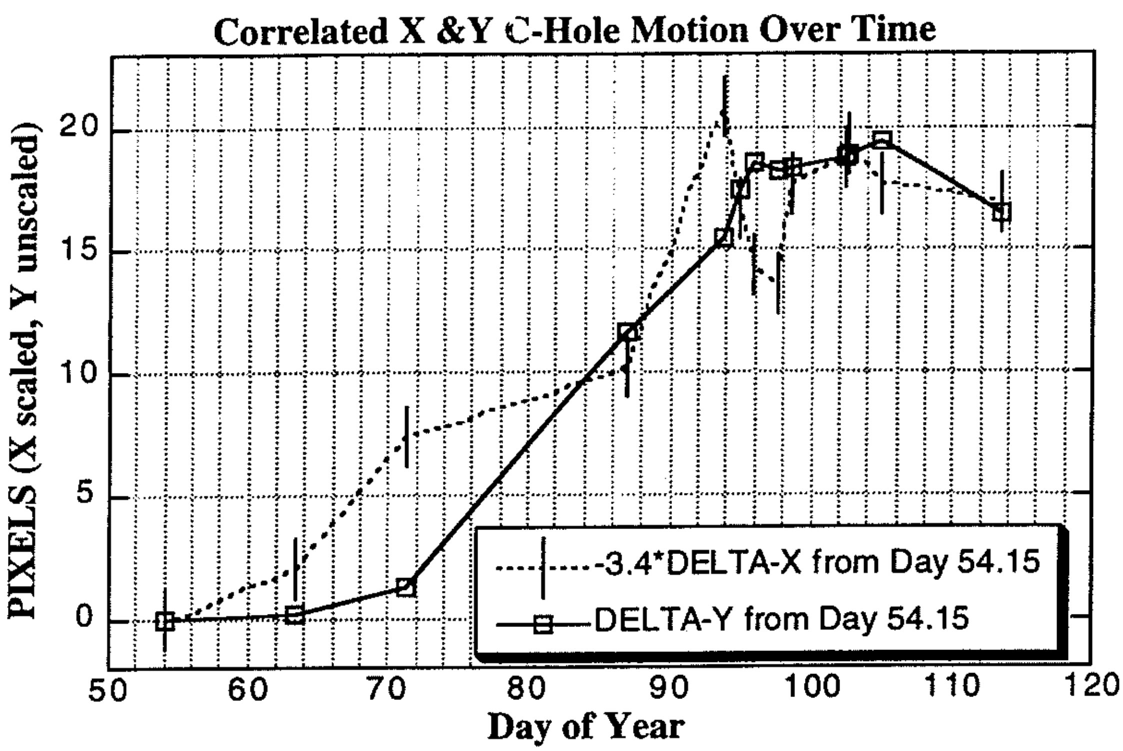
The asymmetry in the relaxation of the focus position from maximum excursion (on ~day 89) is obvious in this figure. An attempt to extrapolate this fit to a point where the image could be brought into focus by the PAM (at -10mm) would be risky given the complex physical nature of the structural and mechanical properties of the dewar. If this trend were to continue, however, one would venture (over-optimistically) that Camera 3 could be brought into focus (PAM = +9.5mm) on or about day 134 (May 14).



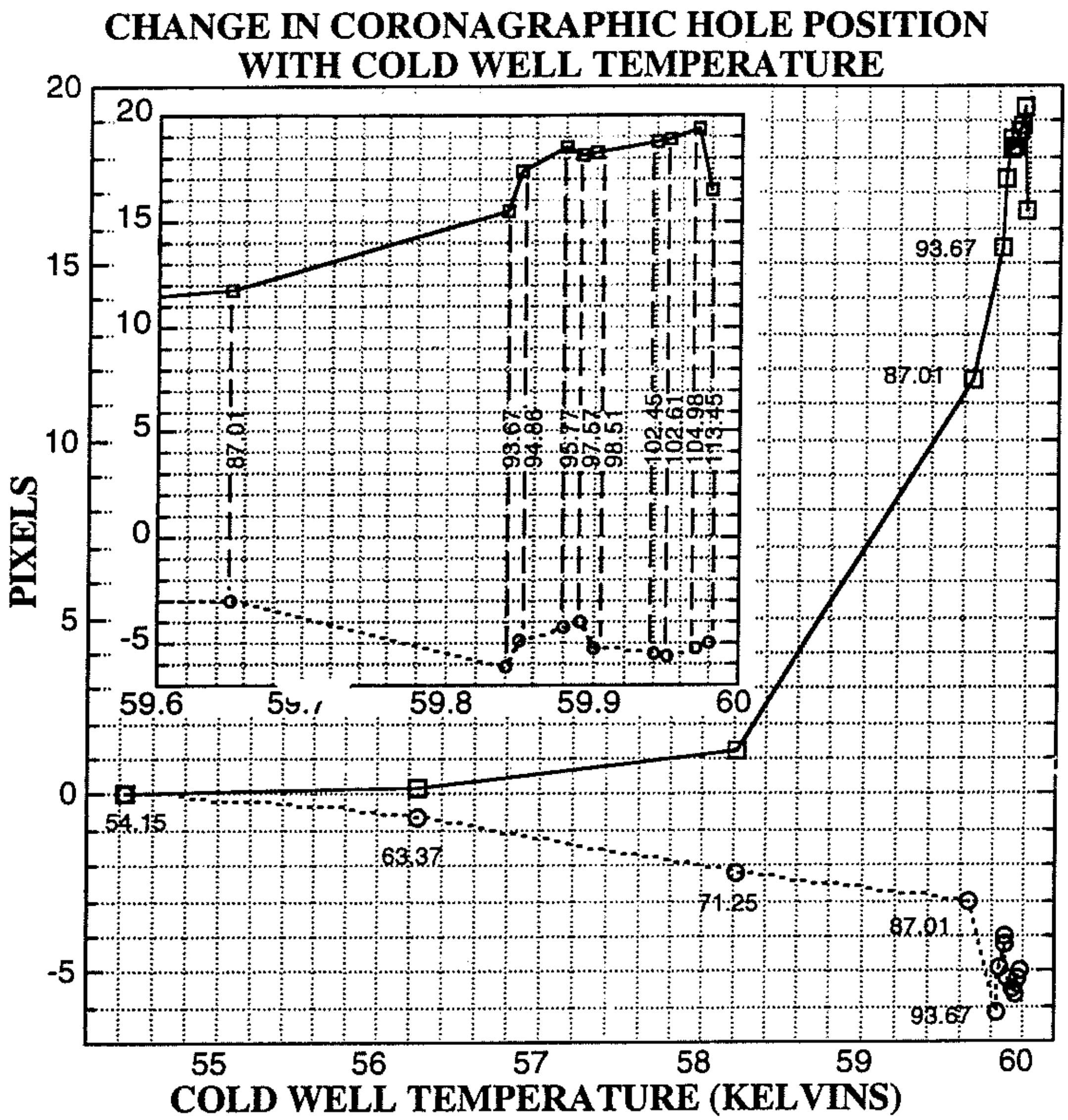
The change X and Y components of the position of the C-Hole as functions of the C3 focus from the previously discussed polynomial fit is illustrated in the figure below. One can see large initial positive motion in +Y, and correspondingly smaller motion in -X. While only one point in time, the reversal in Y direction between days 104.98 and 113.45 is readily apparent.



The larger-scale component motions of the C-Hole in X and Y are anticorrelated with time, implying a secular tilt (or axial displacement) of the detector rather than random motion. This is illustrated in the figure below where the X component motion has been scaled to approximately match the amplitude, and sign, of the Y component motion. Significant local deviations from such a simple scaling are obvious, though the global nature of the anticorrelation is apparent.



The change in the C-Hole X and Y position components was also plotted as a function of the bulk temperature of the Nitrogen ice as measured by the CTAFT temperature sensor. Deviations in both X and Y changed progressively with temperature until ~ day 93, which is near the time of the maximum -Y focus excursion in camera 3. Following this, at nearly the same epoch the camera 3 focus began to turn (with the bulk ice temperature at ~59.84K) the X component of C-hole motion began to resemble the Y component motion. An obvious departure from this occurred with the most recent measure taken on day 113.



We will continue to closely monitor the migration of the C-hole from on-orbit IFF images and correlate future measures with subsequent focal changes and other related phenomena.

Thanks to Nadine Dinshaw for her assistance in the image analysis, and Chris Burrows for supplying the Camera 3 focus positions.

Ball Aerospace
& Technologies Corp.
Aerospace Systems Division

Systems Engineering Report

P.O. Box 1062
Boulder, Colorado 80306

PROJECT TITLE	CAGE CODE	CII
NICMOS	13993	PROJECT CODE

SUBJECT TITLE

Thermal Contact Conductance of the Dewar Baffle Tube and Cold Bench Cover

PREPARED BY	SIGNATURE	DATE	DEPT. NO.	APPROVED BY	DATE
Gary Mills		5/30/97	V7240		

SCOPE/TEXT (ATTACH ADDITIONAL SHEETS AS REQUIRED)

Summary

I have measured the thermal contact conductance (resistance) between parts that simulate the dewar cold bench cover and baffle tube in contact with various loads, temperatures, surface finishes and angles. This was done as part of the investigation to determine the possible cause of the high dewar heat leak that is being observed for the NICMOS dewar on-orbit. I estimated the possible error that might come from various sources in the measurement and have presented the data with the estimated radiative conductance removed and with estimated error bars.

Conclusions

- The conductance of these parts with flight surface finishes and a contact force of 844 grams is between 0 and 0.8 milliwatts/Kelvin with the best estimate being 0.3 milliwatts/Kelvin for the conductance for the parts shimmed to the estimated angle.
- The flight surface finish on the parts reduces the contact conductance over an order of magnitude, in some cases, compared to the bare aluminum. This is plausible because the flight surface finish involves heavily etching one of the parts, chromate conversion coating both parts, and painting the part that was not etched. All of these surface finish operations can reduce the conductance.
- The relatively large uncertainty for the contact conductance with the flight finish is due to the small value of the contact conductance in relation to the radiative conductance.
- Overall, the contact conductance increases with increasing load. This is consistent with the available literature on the subject (references 1, 2).

Recommendation

If data with less uncertainty is required, the measurement could be repeated with the radiative conductance reduced by using less heater power and changing the test configuration to put the load weights outside the radiation shield. This would also allow larger loads to be used.

DISTRIBUTION

Ball Library, Program Files, Chris Miller

Attachment 3

Background

Nitrogen flow data and dewar temperatures for the NICMOS instrument indicates that the heat leak of the dewar is higher than measured in ground testing. The most likely cause of this high heat leak is that the expansion of the solid nitrogen caused the cold bench cover baffle tubes to contact the VCS baffle tubes, which are at a higher temperature. The purpose of this test was to measure the conductance of similar parts under similar conditions to determine if the magnitude of this conductance was consistent with the heat leak being observed.

Test Configuration

The overall test configuration is shown in the photos in Figures 1, 2 and 3. Figure 1 shows the simulated baffle tube on top of the simulated optical cold bench cover. The simulated baffle tube is made from 6061 aluminum and has a heater wire bonded to the upper end with polyurethane adhesive. A silicon diode thermometer is attached to the inside, and the wires run out a small hole in the side (not visible). The simulated cold bench cover is made from 6061 aluminum and has a silicon diode attached to it.The cold bench cover is screwed down to the vacuum chamber cold plate. The silicon diodes and heater were wired with 4 wire, 32 gauge, phosphor bronze ribbon cable.

The vacuum chamber, Ball 2, had a cold plate that could be cooled by liquid nitrogen flow. The vacuum chamber pressure was less than 10^{-5} torr whenever data was being taken.

In order to quickly get some data, the first set of tests were done with the simulated baffle tube and optical cold bench cover having no surface finish (bare aluminum) Later, the baffle tube was chromate conversion coated and painted and the optical cold bench cover was etched and chromate conversion coated, using the same procedures that were used on the flight parts. Since it had been estimated that the baffle tube contacted the cold bench cover at a slight angle, a set of data was taken with a Kapton shim .002 inches thick by .13 inches wide under one edge.

Figure 2 shows the baffle tube with the stainless steel cylinder that was used to increase the load to 844 grams. Figure 3 shows the baffle tube, load mass and optical bench cover enclosed in an aluminum shield. A silicon diode is mounted on the top of the shield. The wires that come off the test parts are taped down to the cold plate to thermally anchor them.

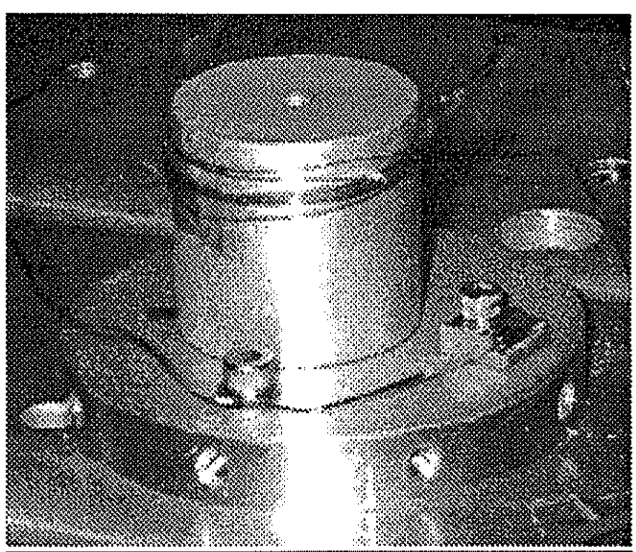
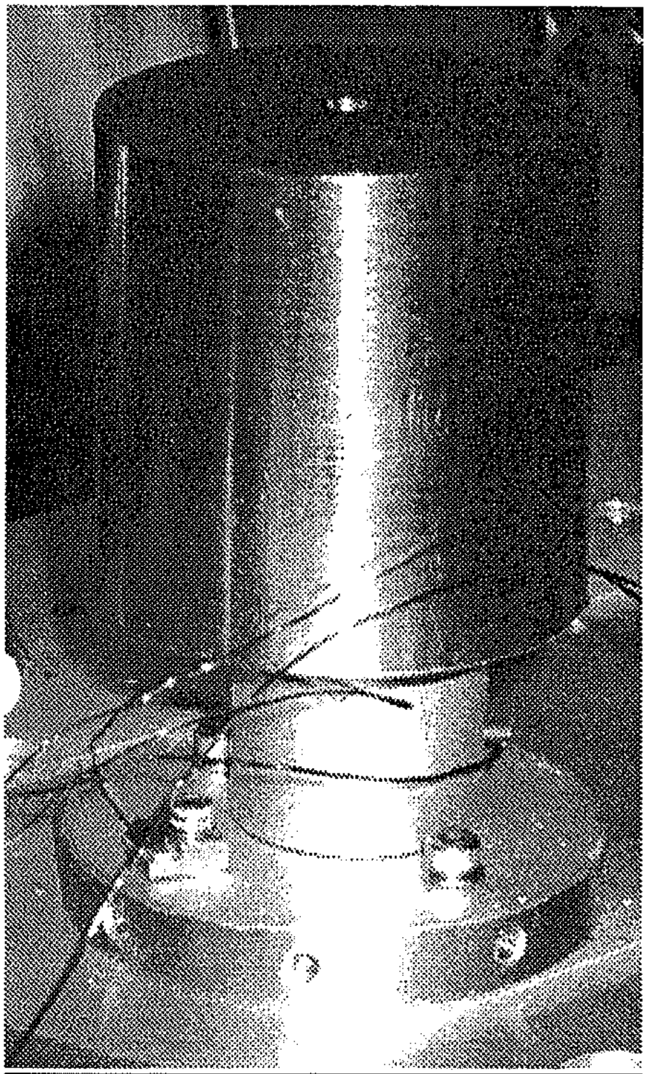


Figure 1: Simulated baffle tube and cold bench cover. The tube outside diameter is .990 inches.



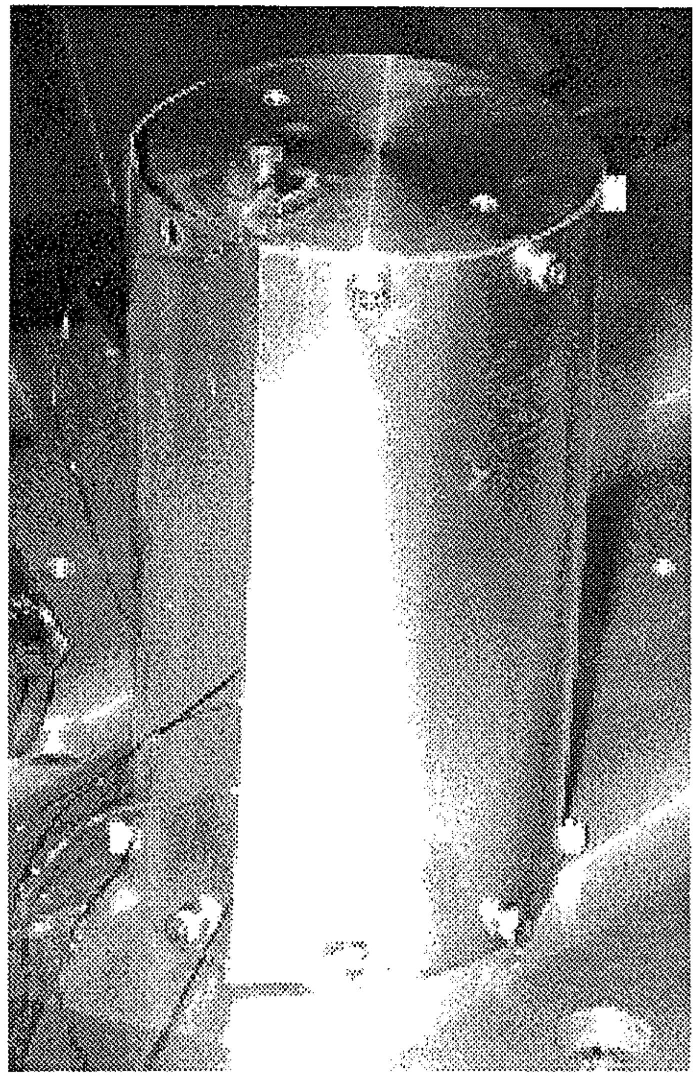


Figure 2: Test pieces with load mass.

Figure 3: Thermal shield enclosing test pieces and load mass

Results

The results are shown in Table 1, 2, 3 and 4 and in Figure 4. SD1 is the silicon diode that measured the simulated baffle tube temperature and SD2 is the silicon diode that measured the simulated optical bench cover temperature. The temperature on top of the shield was also measured, but it always tracked the optical bench cover temperature within one degree K. The heater power was calculated by multiplying the measured heater current by the heater voltage measured at the heater.

The radiative power was calculated using the temperature of the simulated baffle tube, the temperature of ıe shield (which was the same as the temperature of the simulated optical bench cover), the exposed area of the simulated baffle tube, the exposed area of the load mass and the baseline effective emissivities shown in Table 4. The radiative power was subtracted from the heater power and the difference was divided by the difference in temperature to obtain the conductance.

Table1: Test results for bare aluminum test pieces.

Force, grams	SD1 temp.,K	SD2 temp.,K	delta T K	Heater Watts	Radiative Watts	Conductance mW/K	+ error mW/K	- error mW/K
21.1	150.4	89.1	61.3	0.293	0.011	4.6	4.7	4.6
338.0	124.9	88.5	36.4	0.293	0.007	7.8	7.9	7.8
338.0	121.2	88.8	32.4	0.346	0.006	10.5	10.5	10.4
844.0	104.0	90.6	13.4	0.293	0.002	21.6	21.7	21.6
21.1	320.0	293.4	26.5	0.293	0.075	8.2	8.9	7.5
338.0	296.6	292.2	4.4	0.293	0.017	62.5	63.4	61.5
844.0	296.2	292.9	3.3	0.293	0.016	83.9	85.2	82.7

Table 2: Results for test pieces with flight finish

Force, grams	SD1 temp.,K	SD2 temp.,K	delta T K	Heater Watts	Radiative Watts	Conductance mW/K	+ error mW/K	- error mW/K
21.1	299.2	86.9	212.3	0.297	0.194	0.5	0.7	0.3
338.0	259.3	89.5	169.8	0.299	0.165	0.8	1.0	0.5
844.0	260.3	88.2	172.1	0.298	0.221	0.4	0.8	0.1
21.1	344.2	293.4	50.8	0.295	0.161	2.6	3.4	1.8
338.0	325.3	295.7	29.6	0.296	0.132	5.6	6.7	4.5
844.0	311.7	294.4	17.3	0.297	0.094	11.7	13.1	10.4

Table 3 : Results for test pieces with flight finish and shim under one edge.

Force, grams	SD1 temp.,K	SD2 temp.,K	delta T K	Heater Watts	Radiative Watts	Conductance mW/K	+ error mW/K	- error mW/K
21.1	310.9	81.6	229.3	0.295	0.226	0.3	0.5	0.1
338.0	287.3	88.1	199.2	0.296	0.250	0.2	0.5	0.0
844.0	265.1	89.4	175.7	0.297	0.238	0.3	0.7	0.0
21.1	347.8	290.8	57.0	0.293	0.182	1.9	2.7	1.1
338.0	320.7	295.7	25.0	0.150	0.109	1.7	2.7	0.6
338.0	336.8	296.9	39.9	0.293	0.189	2.6	3.8	1.4
844.0	316.8	296.0	20.8	0.293	0.117	8.5	9.9	7.1

Table 4: Effective emissivities used in calculating radiative load.

	Baseline conductance	+error conductance	- error conductance
aluminum baffle tube to aluminum shield	0.04	0.03	0.05

aluminum shield to brass weight	0.04	0.03	0.05
aluminum shield to SST weight	0.04	0.03	0.05
urethane potting to aluminum shield	0.7	0.56	0.88

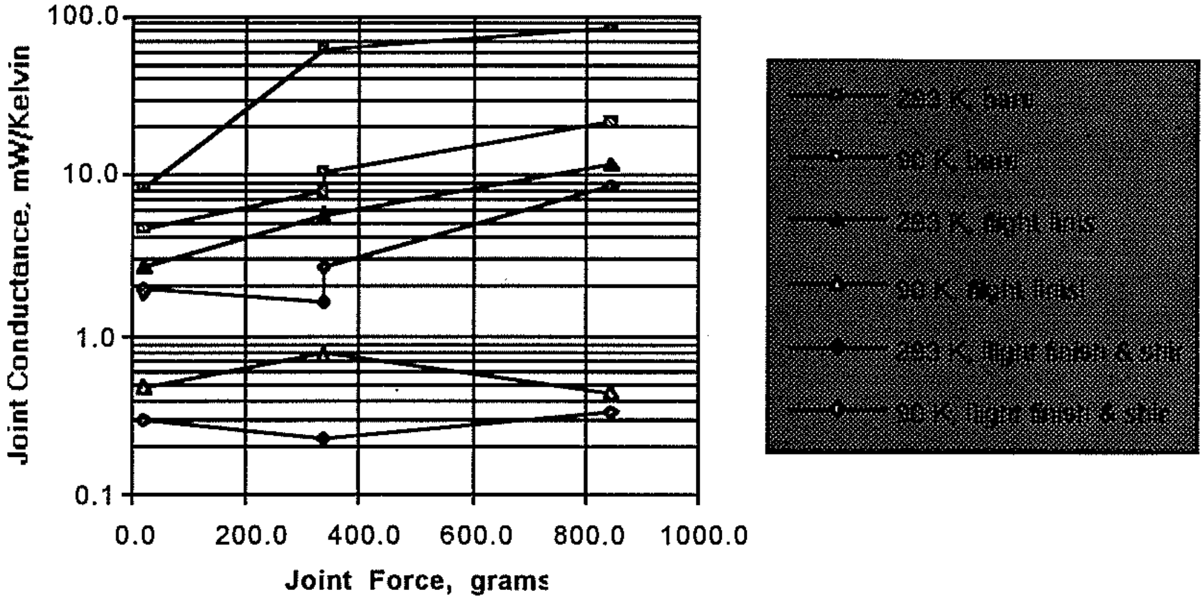


Figure 4: Plot of the baseline data contained in tables 1 through 3.

Error analysis

There were three possible sources of significant error in this measurement: temperature sensor uncertainty, heater power uncertainty, and uncertainty in the radiation conductance between the parts being tested. The temperature sensors have a rated absolute accuracy of ± .5 degrees below 100 K and ± 1.0 K above 100 K. However, the silicon diodes used in this test were purchased at the same time and were very well matched. When they were allowed to come to sit overnight at room temperature in the vacuum chamber they appeared to read the same voltage to within 0.1 millivolts, which corresponds to .04 Kelvin. This means that the error due to the temperature sensors is approximately 1% in the worst case, and much less than that in most cases. The heater power uncertainty is also much less than 1%, since both voltage and current were measured with calibrated digital meters that have 4 digit readouts.

The source of the uncertainty due to the radiative conductance is due to the uncertainty in the effective emissivity between the parts. Typical values for these materials and surface finish were used, but these can easily vary by as much as 25%. The range of values used are shown in table 5.

The percent uncertainty due to the radiative conductance is low in the bare aluminum case, but the percent uncertainty increases significantly in the flight finish cases for two reasons. The absolute value of the contact conductance decreases by approximately an order of magnitude, which makes the radiation conductance relatively greater. In addition, since a constant 300 milliwatts was used for most of the measurements, the temperature difference between the parts increased, increasing the radiative conductance. The 300 milliwatt heater power was used, since that was the estimated increased heat leak into the NICMOS dewar.

Further Work

If data with less uncertainty is required, the tests could be repeated with several changes that would accomplish this. The heater power could be reduced several-fold which would reduce the temperature difference between the parts. This would reduce the radiative conductance without increasing the uncertainty due to the temperature sensors to significant levels. The force between the parts could be achieved by having a low conductance shaft carry the force from weights that are outside the shield to the test parts that are inside the shield. This would greatly reduce the radiative conductance by reducing the surface area and would also allow larger loads to be used.

References

1.) J. Maddren, E. Marshall, "Predicting Thermal Contact Resistance at Cryogenic Temperatures for Spacecraft Applications", Journal of Spacecraft and Rockets, Vol. 32, No. 3, May-June 1995.
2.) J. F. Siebert, W.T. Deshler, "Thermal Conductance Measurements of Bolted and Gasketed Aluminum-Aluminum Joints from 1.5 to 300K." Proceedings of the Tenth International Cryogenic Engineering Conference, Helsinki, Finland, 1984

Jackson and Tull

TECHNICAL NOTE

TO: Daniel Nguyen

FROM: Teri H. Gregory

DATE: April 14, 1997

REPORT: JT97-TN016

SUBJECT: NICMOS in Cold Safe with Dewar Heaters Disabled

cc: C. Wiggins (J&T), Y. Yoshikawa (LTOC), P. Geithner (GSFC), J. Troeltzsch (Ball), J. Bacinski (StScI), HST Library

Introduction:

During the Hubble Space Telescope Second Servicing Mission (HST SM-2), the Near Infrared Camera and Multi-object Spectrometer (NICMOS) was inserted in the HST in place of the Faint Object Spectrograph (FOS). On day 97:083, a dewar heater anomaly occurred in which the dewar heater set points were corrupted during the South Atlantic Anomaly (SAA) causing the heaters to come on with full power erroneously for approximately 20 hours.

The NICMOS software has now been modified such that the dewar heater set points are refreshed automatically every five minutes. This software fix will prevent any future dewar anomalies due to the corruption of the set point from lasting more than five minutes. However, in the event that the instrument is safed, the software can not refresh the set points and it would be possible for the heaters to be activated erroneously without the ability to disable them until NICMOS is recovered from safe.

In order to avoid this anomaly, a proposal has been made to the Space Telescope Science Institute to disable the dewar heaters when the instrument is safed. This report predicts the effect this action could have on the temperature of the NICMOS components if the instrument should safe in a cold environment.

Additionally, this report analyzes the amount of time required to recover from this cold state by warming all components to their acceptance limit temperatures.

Attachment 4

Discussion:

This analysis assumes worse case effective sinks and allows the instrument temperatures to reach their steady state values under those circumstances in order to account for the possibility of an extended safing event in a cold orientation.

The telemetry derived effective sinks were studied over the last 16 months and the coldest sinks found were used in this analysis. These sinks are -30°C for +V2 and -19°C for -V3. Note that these sinks are 3 - 8°C colder than sinks usually seen by NICMOS, were seen only for a very short time and were seen only once during the 16 months studied. Therefore, these effective sinks represent a worse case environment for the instrument.

The power profiles used in these analyses are listed in Table 1. The second column lists the power applied during the first steady state cold safe analysis. As this shows, the total power in the instrument during a safing with the dewar heaters disabled is 54.9 W.

Table 1 also lists the powers applied during the two recovery scenarios studied. In the first case, the MEB is turned on and the heater controller is activated, although the dewar heaters are not turned on, which gives a total of 131.5 W into the instrument. In the second case, the MEB and the dewar heaters are turned on for a total of 171.4 W.

Table 1: NICMOS Power Profiles

Component	Safe, No Heaters (W)	MEB On, Heaters Off (W)	MEB On, Heaters On (W)
LVPS	20.0	48.4	48.4
MEB	0.0	48.2	48.2
Buffer Boxes	0.0	0.0	0.0
RIUs	5.1	5.1	5.1
Pressure Transducer	0.7	0.7	0.7
TECs	29.1	29.1	29.1
Heater Power	0.0	0.0	39.9
Total Power	54.9 W	131.5 W	171.4 W

The thermal math model used in this analysis is based on the correlated NICMOS Reduced Integrated Model received from Ball Aerospace dated 26 July 1996.

Results:

Table 1 lists the steady state temperatures reached during an extended safing event under the cold environments described in the previous section. As this table shows, five components break or very nearly break their acceptance limits under these circumstances but no component reaches its survival limit. The components closest to their survival limits are the buffer boxes. These components come within 4 degrees of their -23°C survival limit when they reach almost -19°C.

Table 2: NICMOS Temperatures Under Worse Case Cold Sinks

Component	Node	Survival Limits (°C)	Acceptance Limits (°C)	Safe, No Htrs (°C)	MEB On, No Htrs No Buff Boxes (°C)	MEB On, Htrs On Full Power No Buff Boxes (°C)
Buffer Box 1	15	-23	-12	**-18.5**	**-12.3**	7.2
Buffer Box 2	17	-23	-12	**-18.1**	**-11.5**	10.8
Buffer Box 3	13	-23	-12	**-18.7**	**-12.6**	7.0
FW Motor *	901	-28	-16	**~-19.2**	~-14.7	~4.5
FOM Motor *	888	-30	-20	**~-19.3**	~-16.1	~-2.6
PAM Motor *	1111	-32	-16	**~-18.7**	**~-16.1**	~-5.5
Dewar Shell	795	-24	-17	**-18.3**	-11.6	8.7
Foreoptics	888	-30	-20	-19.3	-16.1	-2.6
Truss (Fore)	1111	-30	-20	-18.7	-16.1	-5.5
Truss (Mid)	1112	-30	-20	-17.9	-10.9	8.1
Truss (Aft)	1113	-30	-20	-14.4	1.7	10.6
MEB 1	2502	-48	-37	-17.0	10.9	14.4
MEB 2	2402	-48	-37	-11.5	10.7	14.1
RIU A	72	-50	-40	0.3	17.8	20.5
RIU B	73	-50	-40	-5.4	13.6	16.2
DIT Box *	604	-30	-17	~-12.0	~-10.8	~-5.9
TECI V2 Rad	5131	-60	-40	-11.7	-10.8	-8.4
TECI V3 Rad	4131	-60	-40	-4.2	-3.5	-1.4
TECO Fore Rad	1031	-60	-40	-16.0	-14.7	-10.2
TECO Aft Rad	1041	-60	-40	-15.9	-14.3	-11.6
Inboard Panel	313	-60	-40	-18.5	-13.6	-2.4
Outboard Panel	512	-60	-40	-27.7	-26.3	-20.7
Aft Bulkhead	704	-60	-40	-14.5	3.5	5.7
Fore Bulkhead	604	-60	-40	-12.0	-10.8	-5.8

* NOTE: Thermal model is not modeling this component directly; temperature shown is for the nearest structure node

Table 2 also lists the steady state temperatures of NICMOS under the recovery scenarios studied. As the table shows, the buffer boxes and the PAM will not warm sufficiently to reach their acceptance limits under the cold sinks with the first power profile studied, namely with the MEB powered but no dewar heater power.

However, when the dewar heaters are activated, all components easily reach their acceptance limits. In this case, the amount of time required to reach their limit is an important piece of information. Figures 1 - 3 show the transient responses of the five components which had broken or nearly broken their acceptance limits. Note again, that the NICMOS TMM does not model the Filter Wheels, FOM, and PAM directly. Therefore, the temperatures plotted in Figure 2 represent the mechanism's nearest structural node.

As these figures show, the last component to reach its acceptance limit is the PAM which reaches -16°C in approximately 3.6 hours. Buffer box 2 reaches its -12°C acceptance limit in approximately 3.0 hours.

Conclusions:

This analysis shows that all the NICMOS components will remain above their minimum survival limits during a long safing event even without any dewar heater power. The component closest to its survival limit is the buffer box which remains 4 degrees above its survival limit of -23°C.

Although all components remain above their survival limits, five components reach or very nearly reach their acceptance limits under which they may not be operated. These components are the buffer boxes, the filter wheels, the FOM, the PAM, and the dewar. Table 2 lists the steady state temperatures of each of these components.

Finally, this analysis shows that, if NICMOS was safed for an extended period under cold sinks, the optimum recovery scenario requires the dewar heaters. With the MEB, the LVPS, the TECs and the dewar heaters on, the PAM reaches its acceptance limit in approximately 3.6 hours, while the buffer boxes recover to within their operating temperature range in approximately 3.0 hours.

Teri H Gregory

Teri H. Gregory
Sr. Thermal Engineer

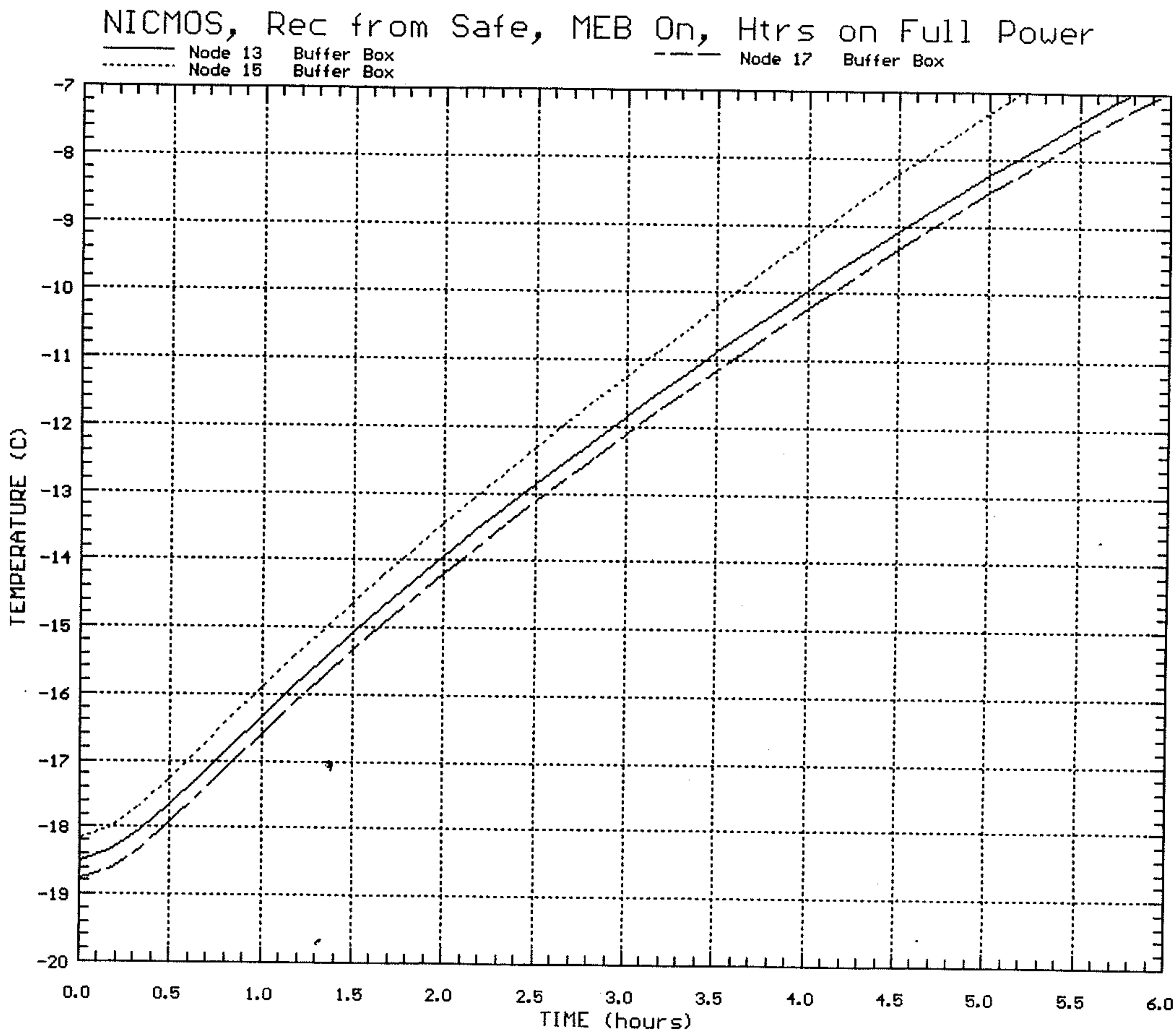


Figure 1: Buffer Box Recovery from Safe, Dewar Heaters On

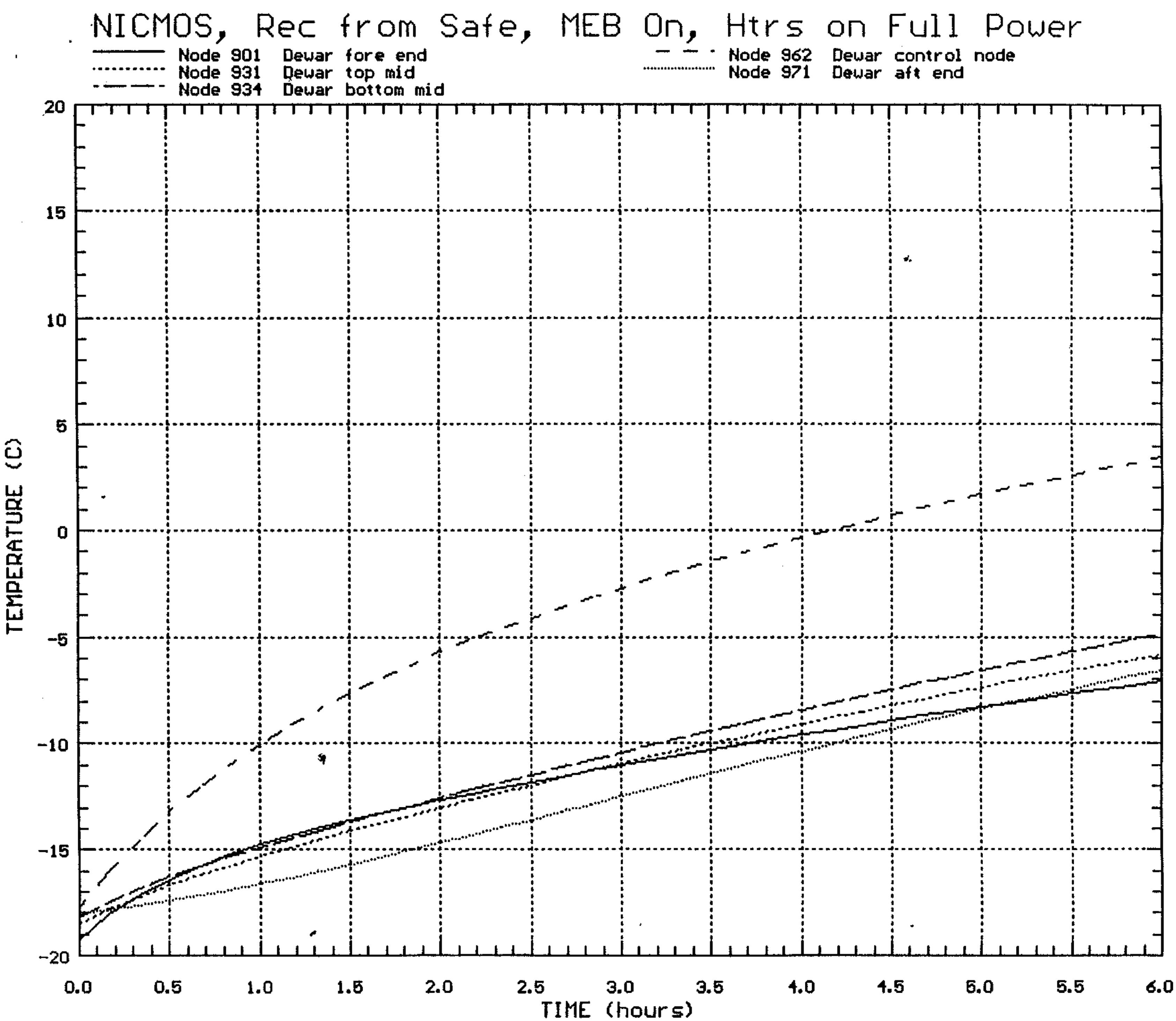


Figure 2: Mechanisms Recovery from Safe, Dewar Heaters O

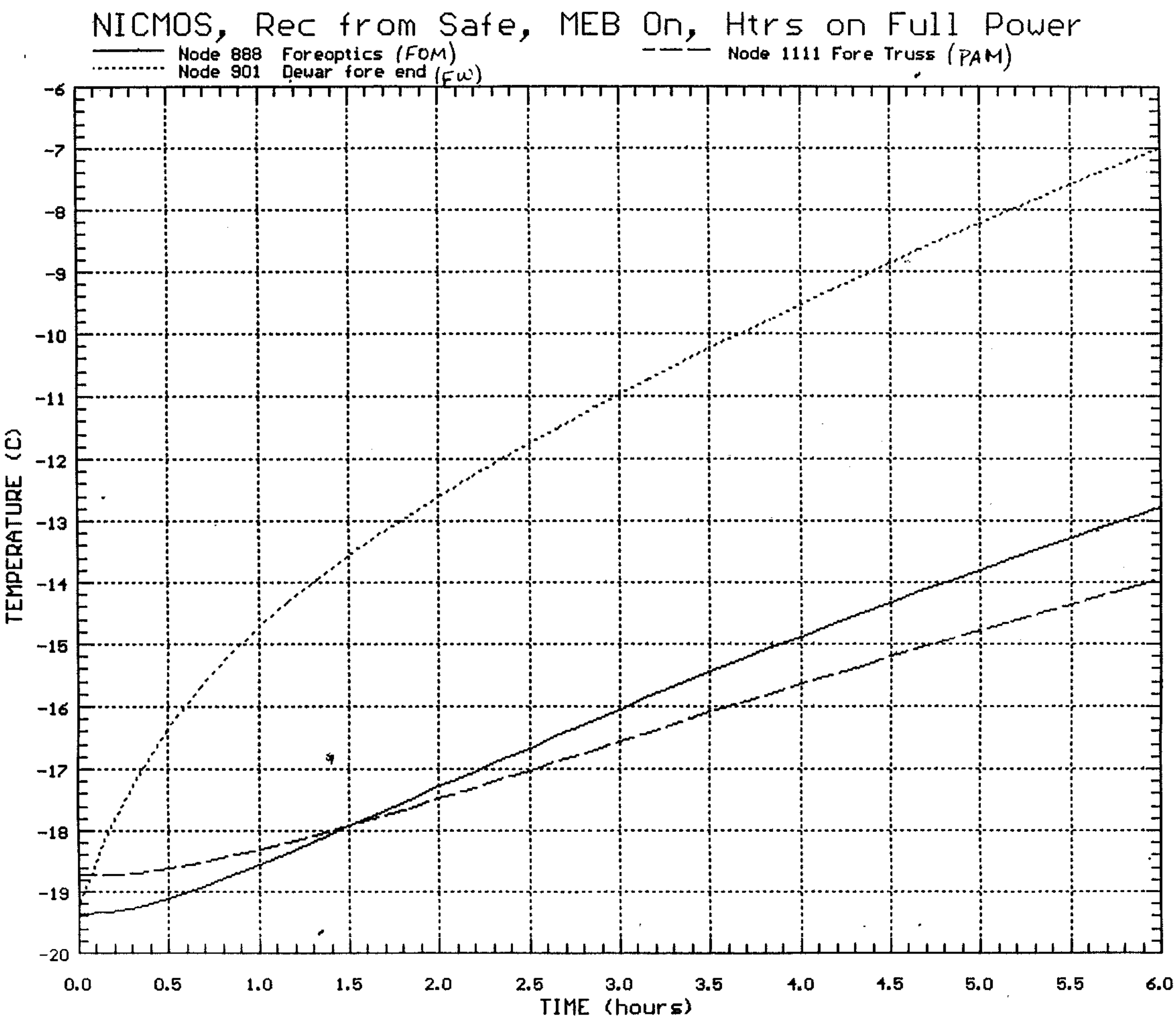


Figure 3: Dewar Recovery from Safe, Dewar Heaters On

Orinet Errat_16

Mega Engineering

10800 Lockwood Drive, Suite 205
Silver Spring, MD 20901-1554
(301) 681-4778
Fax: (301) 681-5683

FAX TRANSMISSION COVER SHEET

Date: *April 22, 1997*

To: *George Morrow*

Fax: *286-0210*

Re: *Nitrogen Material Property Test Results*

Sender: *Richard Dame*

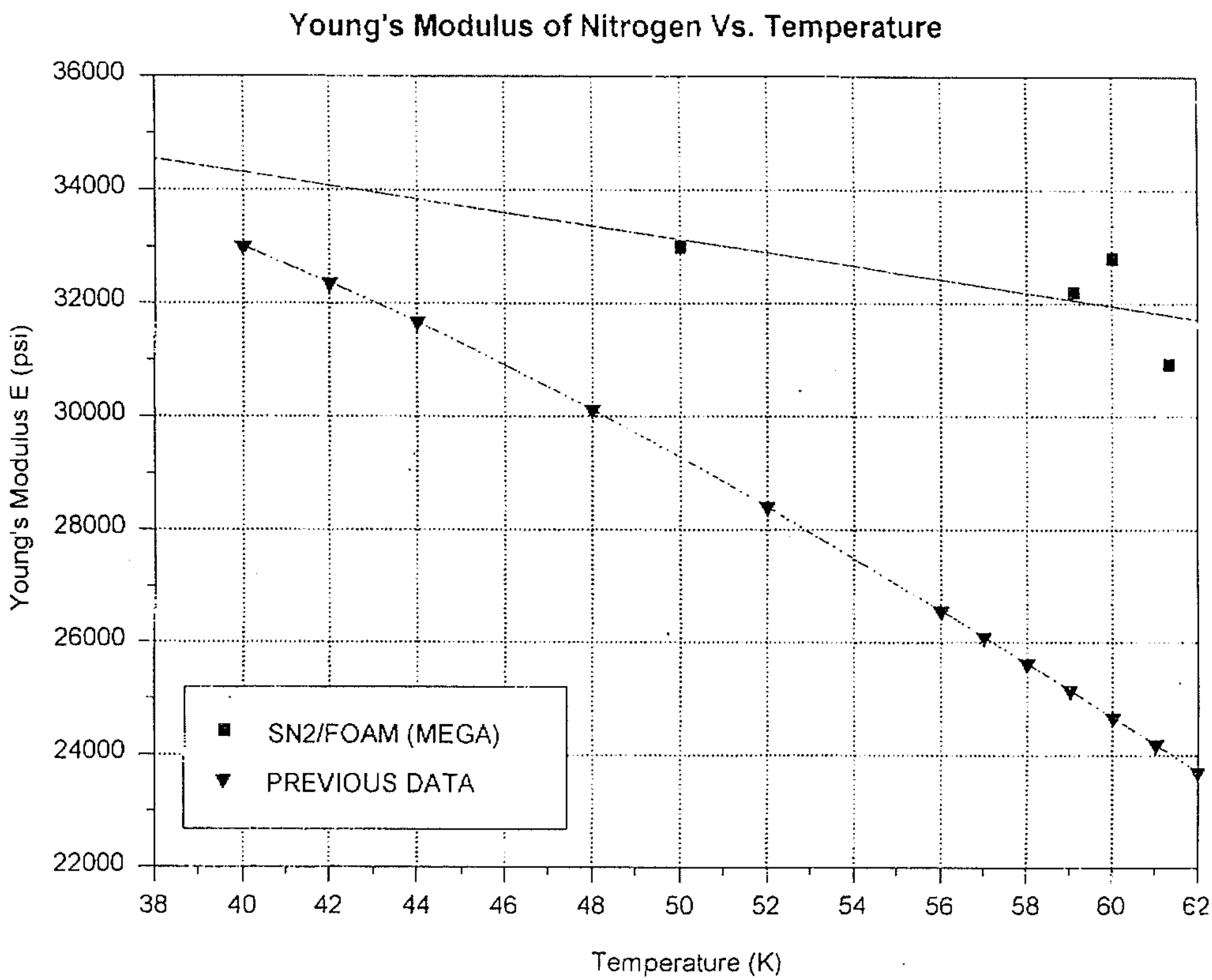
YOU SHOULD RECEIVE 4 PAGE(S), INCLUDING THIS COVER SHEET. IF YOU DO NOT RECEIVE ALL THE PAGES, PLEASE CALL (301) 681-4778.

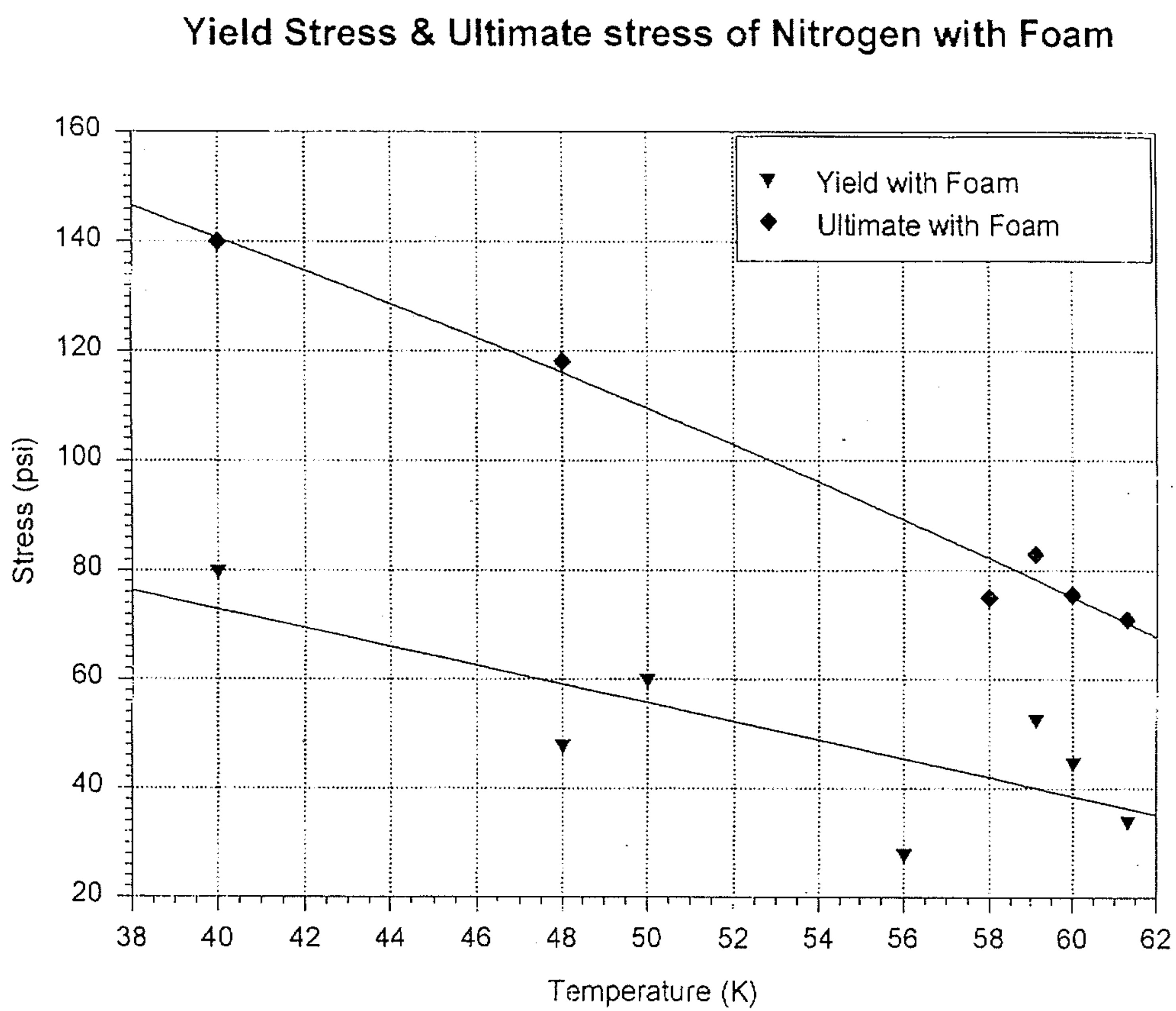
Material Testing Results and Subsequent Material Property Changes in NICMOS Model

Material testing results for Nitrogen and Nitrogen with foam at the NICMOS upper temperature bounds have yielded the following:

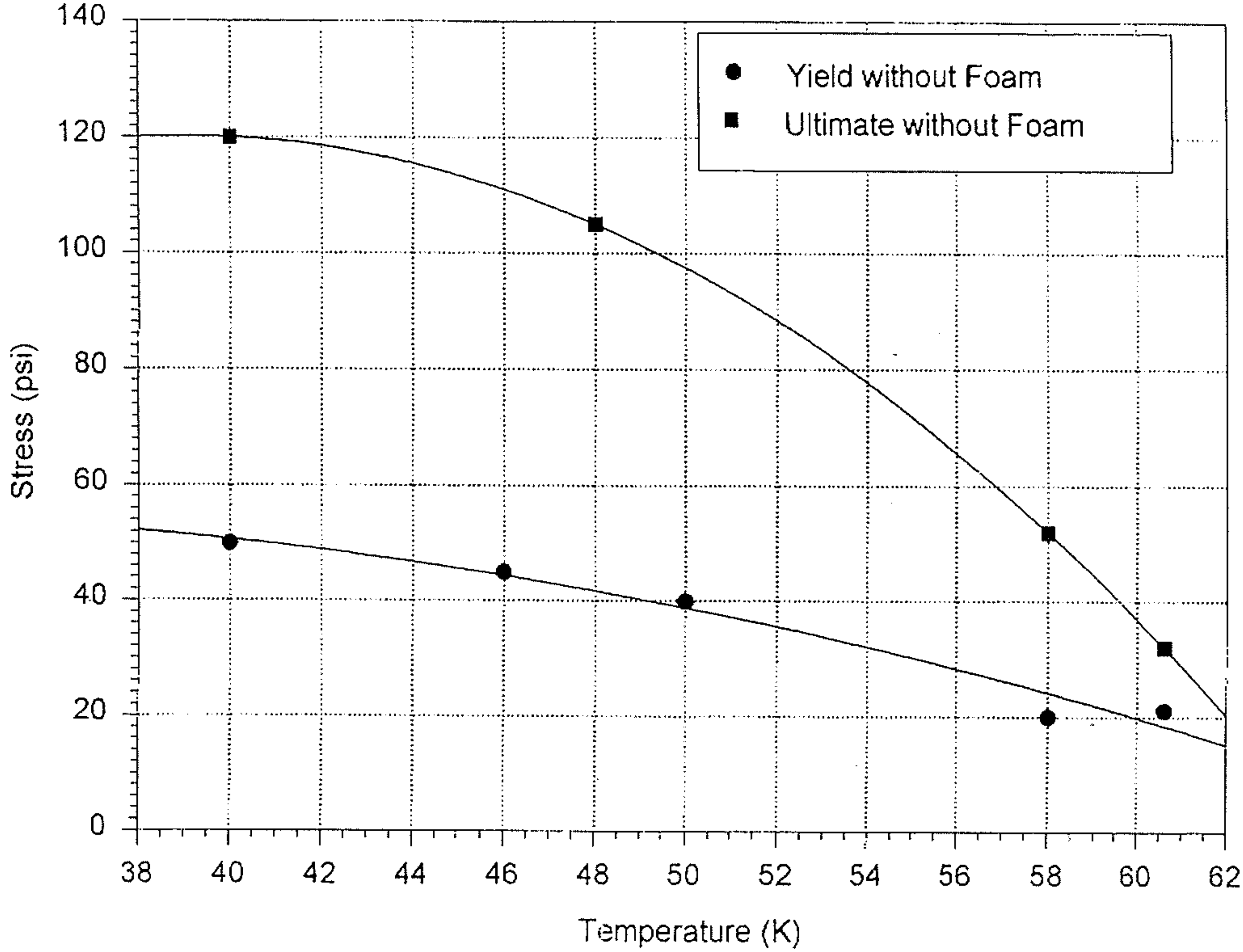
- Higher values for yield strength for Nitrogen with foam at 60 K
- Higher values for ultimate strength for Nitrogen with foam at 60 K
- Higher values for yield strength for Nitrogen at 60 K
- Equivalent values for ultimate strength for Nitrogen at 60 K
- Higher values for Young's Modulus for Nitrogen with foam at 60 K

See the following figures for quantitative data.


Young's Modulus of Nitrogen Vs. Temperature
Young's Modulus E (psi)
36000
34000
32000
30000
28000
26000
24000
22000
38
40
42
44
46
48
50
52
54
56
58
60
62
Temperature (K)
SN2/FOAM (MEGA)
PREVIOUS DATA


Yield Stress & Ultimate stress of Nitrogen with Foam
Yield with Foam
Ultimate with Foam
Stress (psi)
160
140
120
100
80
60
40
20
38
40
42
44
46
48
50
52
54
56
58
60
62
Temperature (K)

Yield Stress & Ultimate Stress of Nitrogen without Foam



X-Sender: gmorrow@mail.hst.nasa.gov
Mime-Version: 1.0
Date: Tue, 10 Jun 1997 15:55:25 +0100
To: dratzow@hst.nasa.gov
From: "George W. Morrow" <gmorrow@hst.nasa.gov>
Subject: Cryo energy balance

Dave,

FYI

George

>From: "Chris D. Miller" <cdmiller@ball.com>
>To: "George W. Morrow" <gmorrow@hst.nasa.gov>
>Subject: Cryo energy balance
>Date: Tue, 27 May 1997 14:37:00 -0600
>X-Priority: 3
>
>George,
>
>I have been monitoring the energy balance on the cryogen tank since the
>anomaly began, and thought you may be interested in seeing the trend in
>cryogen heat load vs. time:
>
>
>As you recall, the energy balance calculation takes into account both
>the energy resulting in a temperature change of the cryogen as well as
>the energy resulting in cryogen sublimation. At the extreme of the
>Camera 3 focus position (days 80-90), the energy balance calculation
>yielded an average heat load of 478 mW. This heat load has become more
>stable since that time, but has also consistently decreased. For days
>130-140 the average heat load was calculated to be 437 mW.
>
>Should it continue, this trend would result in an increased dewar
>lifetime compared to earlier predictions.
>
>On another topic, we have reduced the raw data for the baffle
>conductance tests, and the trend is toward lower actual conductance
>values than indicated by the preliminary data, due to effects of
>radiation loss from the heated baffle to its surroundings. We have
>calculated conductance values to be 0.2 - 0.8 mW/K for flight-like
>baffles under loads of 850g or less. The data reduction took longer than
>expected, but I expect to have the writeup to you by Thursday.
>
> - Chris
>
>
>

Attachment converted: Dave's Home Page:NRG_BAL.XLS (XLS4/XCEL) (0000D2DB)

Attachment 6

From: "Chris D. Miller" <cdmiller@ball.com>
To: "David A. Ratzow" <David.A.Ratzow.1@gsfc.nasa.gov>,
"George W. Morrow"
<gmorrow@hst.nasa.gov>
Subject: Energy balance plots
Date: Wed, 11 Jun 1997 10:52:00 -0600
X-Priority: 3

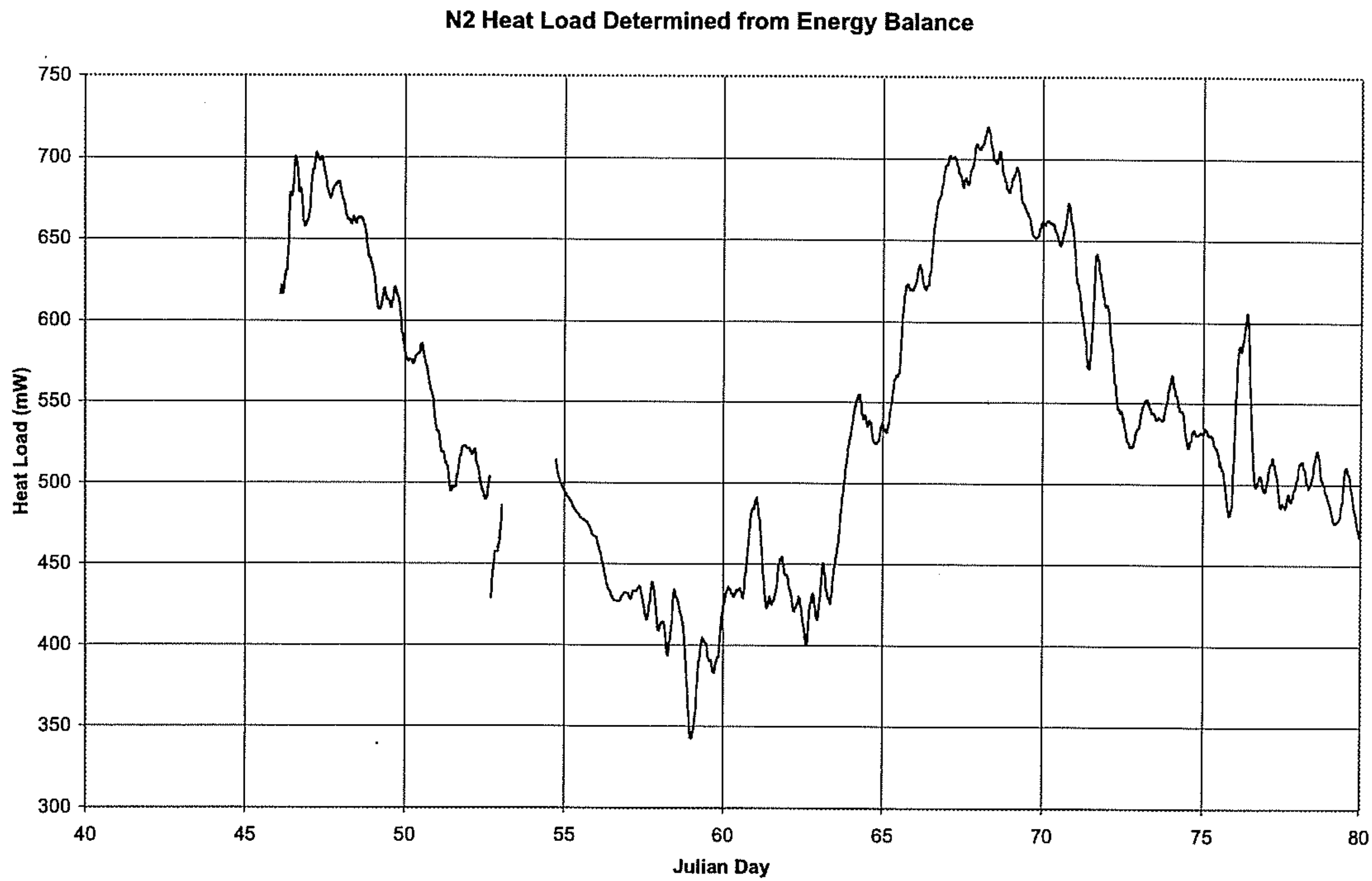
Gentlemen,

Attached is a spreadsheet containing three plots of the cryo tank energy balance. The plots span the period from day 46 to day 157 (6/6/97). They are plotted on the same y-axis scale to facilitate comparison. The first plot shows two transients, one from the initial on-orbit cooldown, and the second as the tank absorbs energy when the baffles contact. To a first order, the decline in heat load seems to track the focus position, suggesting that the baffle contact force is decreasing over time, as one would expect.

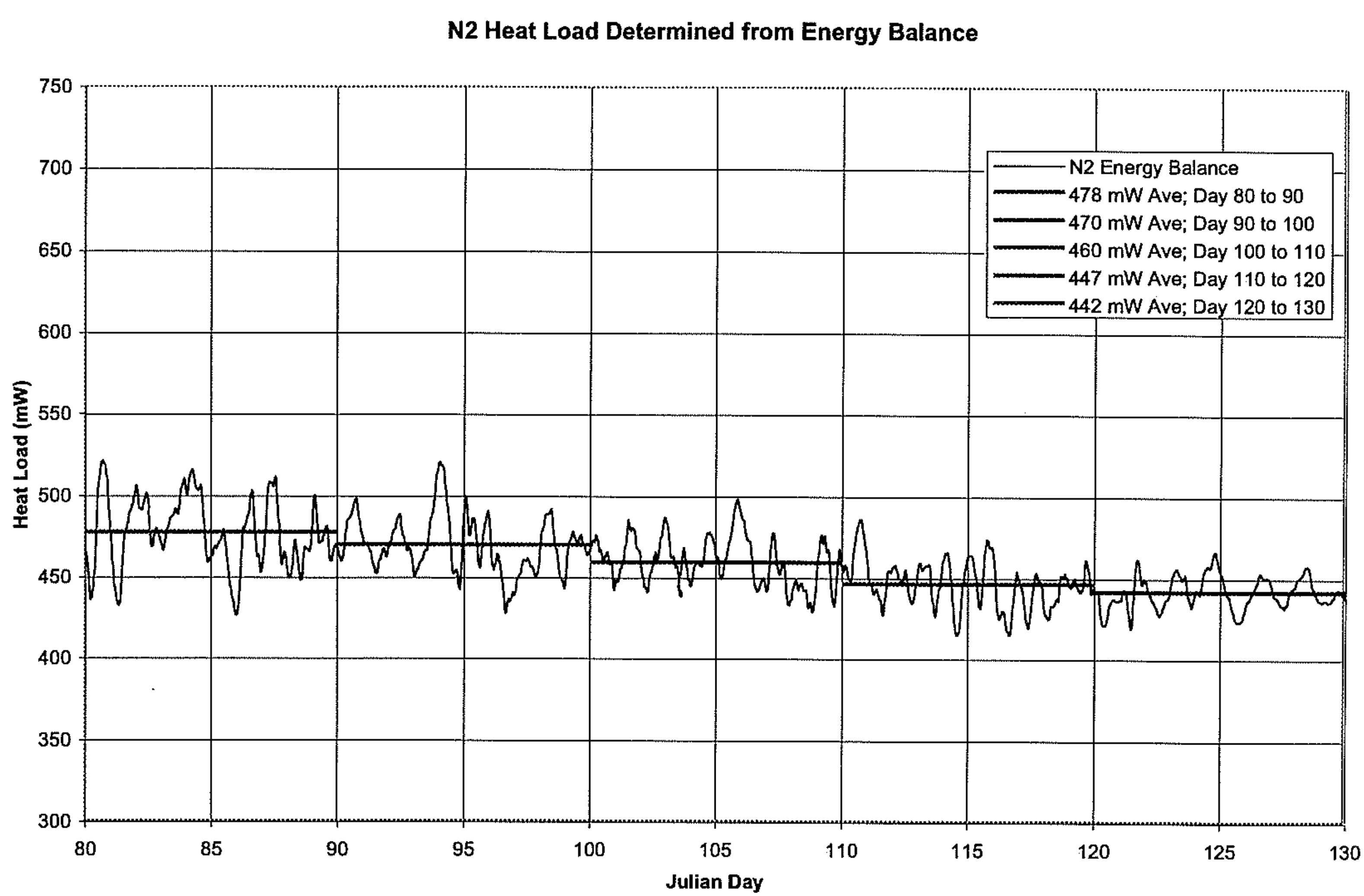
The remaining mass on Day 157 was 89.45 kg. Assuming the most recent average heat load of 433 mW continues to end-of life, and using a heat of sublimation of 244 J/g, yields a remaining life of 583 days. End of cryogen life would be approx. 1/10/99, but useful life would probably be several weeks less, due to rapid temperature rise during last 30 days.

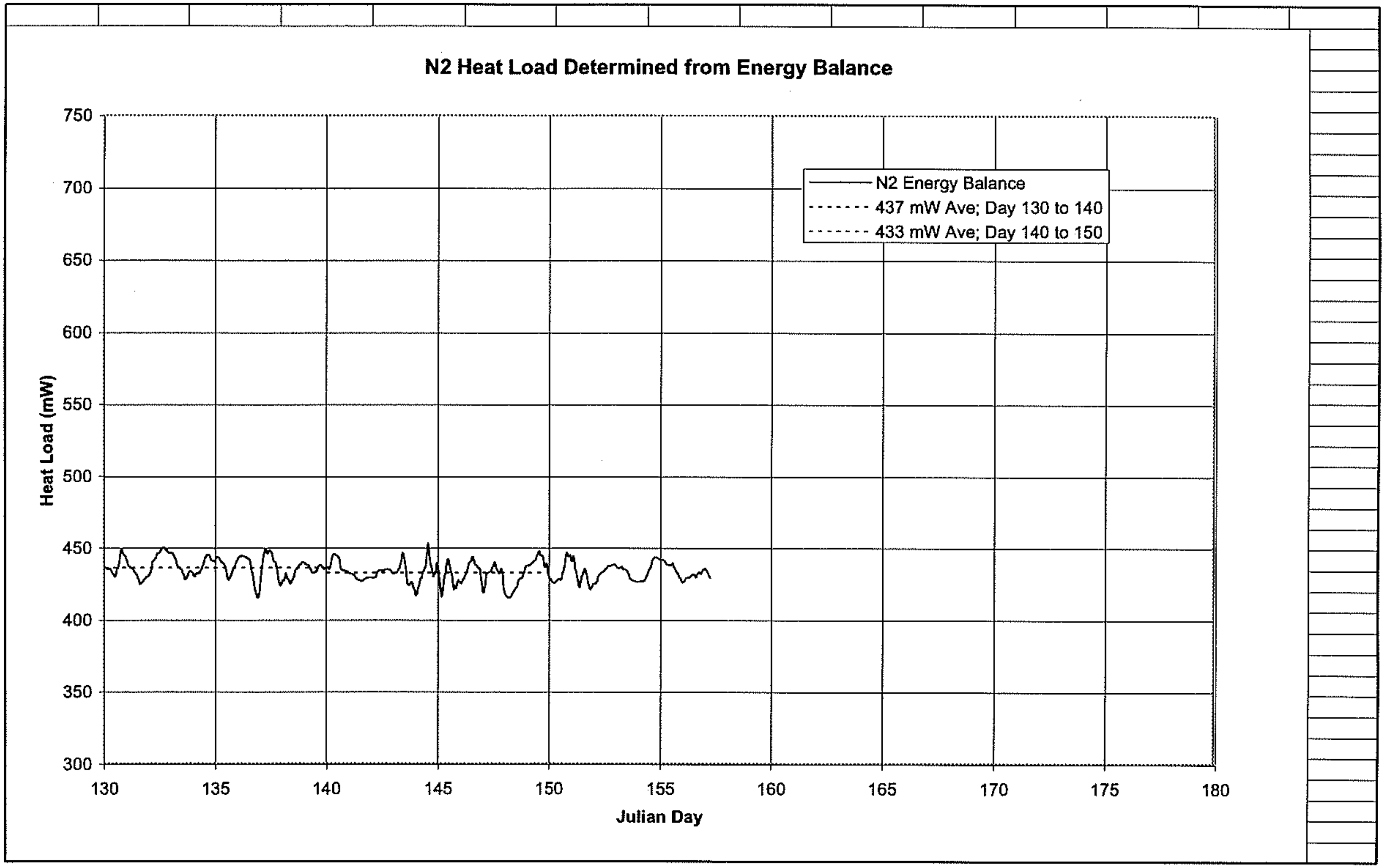
Attachment converted: Dave's Home Page:ENRG_PLT.XLS (XLS4/XCEL) (0000D323)

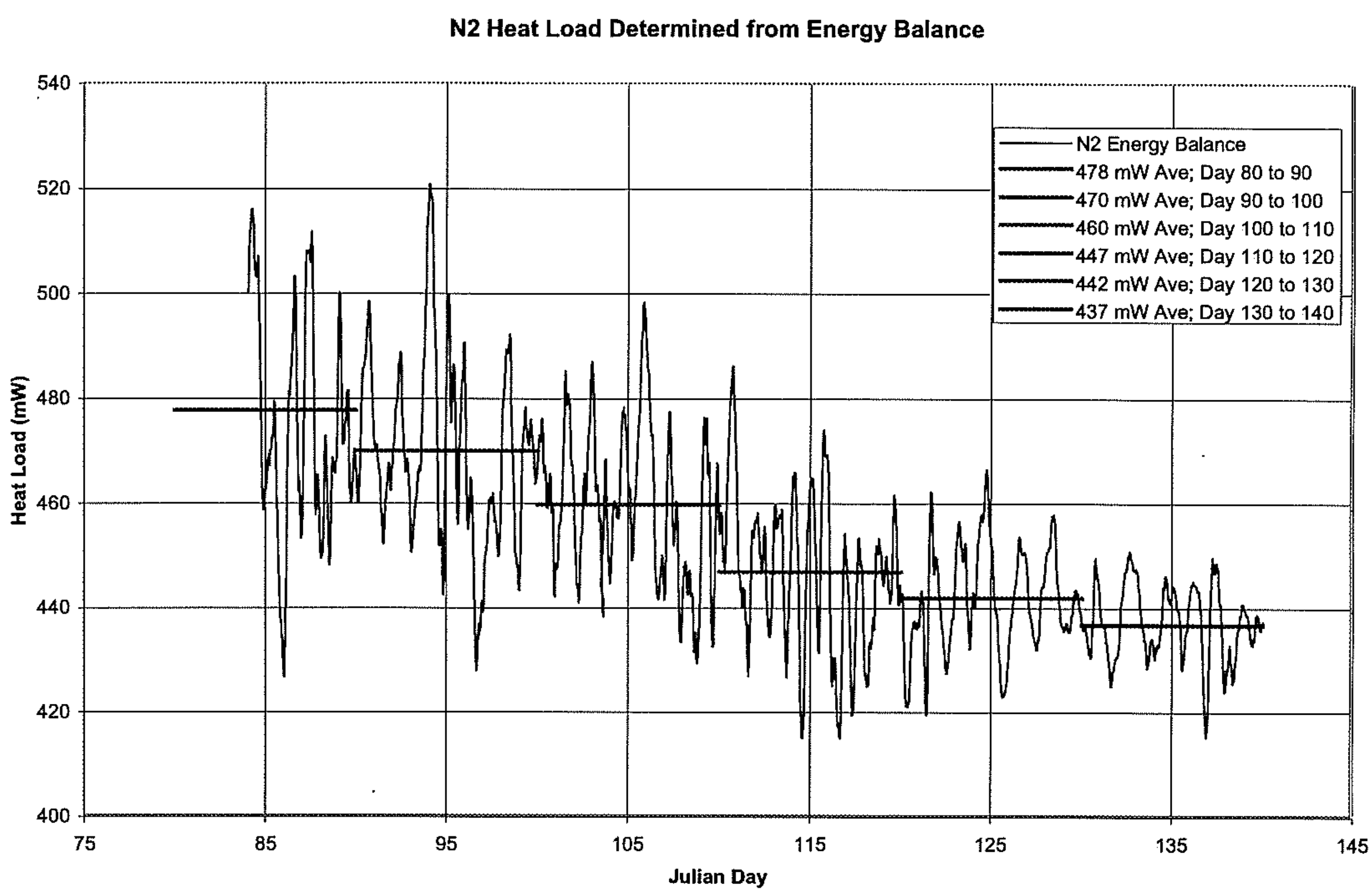
Attachment 7



Attachment 8


N2 Heat Load Determined from Energy Balance
Heat Load (mW)
750
700
650
600
550
500
450
400
350
300
80
85
90
95
100
105
110
115
120
125
130
Julian Day
N2 Energy Balance
478 mW Ave; Day 80 to 90
470 mW Ave; Day 90 to 100
460 mW Ave; Day 100 to 110
447 mW Ave; Day 110 to 120
442 mW Ave; Day 120 to 130


N2 Heat Load Determined from Energy Balance
N2 Energy Balance
437 mW Ave; Day 130 to 140
433 mW Ave; Day 140 to 150
Heat Load (mW)
750
700
650
600
550
500
450
400
350
300
130
135
140
145
150
155
160
165
170
175
180
Julian Day



Attachment 9

NICMOS Dewar Anomalous On-Orbit Warming
Anomaly Review Board
Status Meeting Report
March 19, 1997

ATTENDEES: Richard Dame, Emmanuel Cofie, Daniel Nguyen, Ethan Schreier, Malcolm Niedner, Bill Sparks, Eric Mentzell, Frank Cepollina, George Morrow, Dave Ratzow, Paul Geithner, Glenn Schneider,

TELECON: Tim Kelly, Chris Miller, Rich Johnson, John Troeltzch, Wally Meyer, Chris Burrows

NEXT MEETING: Friday, March 21, 1997, 3:00-5:00, 29/200

I. General

On March 4, 1997, the rate of change of various parameters associated with the normal warming of the NICMOS Dewar took a step change. These new rates appear to be caused by a step change in the rate of heat flowing into the Dewar.

To investigate this anomalous behavior, an Anomaly Review Board has been convened. The charter, per J. Campbell memo, is:

1. Determine the most likely cause of the increased heat flow.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

The ARB shall complete its investigation no later than April 15, 1997.

Attachment 10

II. Observables

Paul Geithner presented an overview of the NICMOS Dewar and associated hardware items.

Chris Miller then provided detail on the thermal performance of the dewar. The initial on-orbit performance appeared nominal. Initially, the Vapor Cooled Shield (VCS) temperature was 152°K, the N2 temperature was 56.2°K, and the N2 flow rate was 28 grams/day. The first anomaly symptom noted was on Day 17 after installation when the rate of detector temperature rise increased from 0.22°K/day to 0.50°K/day. At the same time the VCS cooldown rate also accelerated from -2.5°K/day to -6.5°K/day.

Over the next few days, temperature gradients of about 1°K were established in the VCS and the cryogen tank. Ball will generate a model to determine the isotherms within the Dewar.

III. Approach

During subsequent discussions, a wide range of topics were discussed. Organized by charter item, they are:

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the Vapor Cooled Shield (VCS) and the cryogen tank in the area of the cold bench baffle and the VCS baffle at the forward end of the Dewar. The telemetered thermal data and trends are inconsistent with a nitrogen leak as this would severely affect the temperatures of all dewar shields. This has not been observed.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed to about 56°K, it expanded. This in turn pushed the coldwell forward until the cold bench baffle contacted the VCS baffle. This is consistent with as designed clearances closing with observed dewar expansion. The thermal path was thus established. Cooling of the VCS then began as its heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps.

There is a possibility that the first anomalous behavior began about Day 14 after installation when a slight change in N2 tank temperature gradients showed a slight rise and the VCS temperature may have deviated from its expected leveling off trend. Both of these indications will be investigated further by Chris Miller.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

After the thermal short was established, cryogen usage has been increasing from the initial 28 grams/day to over 110 grams/day presently, although there is some indication that this may be reaching a plateau. Normal Steady State Cryogen usage was estimated to be 71 grams/day. This is documented in Ball SCR123. Total dewar heat load is estimated at approximately 370 mw versus a design condition of about 200 mw.

Should the current heat load continue throughout the mission, the cryogen lifetime is projected to be 2.2 years. This was estimated by establishing a new heat input rate through parametric thermal analysis and arriving at a steady-state nitrogen depletion rate.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

The correlation between the non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, was not good. The predicted focus using the model was 6.4 mm at 58.6°K, while the actual focus was measured to be approximately 8.7 mm at the same temperature. This difference of about 2 mm can not yet be explained, and is being investigated.

Cold mask movement relative to the detectors could affect focus estimates from on-orbit observations. Chris Burrows will analyze a cold mask position 1 mm closer to determine focus calculation sensitivity. This is thought to be a small effect.

Mega will make improvements to their model through parametric runs in the areas of cryogen removal and Nitrogen breakaway shear in an attempt to provide correlation to the current on-orbit observables.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected was discussed. As the Nitrogen is used up the expansion pressure on the coldwell will decrease. This may allow the coldwell to move aft, breaking the thermal short contact. Until a correlated model can be achieved, predictions in this area are pure conjecture.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

Pupil Adjustment Mechanism (PAM) focus settings - Two analyses were performed, Encircled Energy and Phase Retrieval. Both analyses were in agreement and showed that all detectors are moving as a group. At the time of the pre-alignment (Day 18), the detectors had moved forward by about 6.4 mm. By the time of the coarse alignment (Day 25), they had moved an additional 2.3 mm, to 8.7 mm. This shows that the focus for Camera 3 has moved well outside of the available PAM adjustment range at approximately 18.6 mm. In addition, Cameras 1 and 2 are now far enough apart that a single focus position will not be possible. This will eliminate the ability to accomplish internal parallel observations with Cameras 1 and 2.

Glenn Schneider will write up the results of the correlation of pre-align/coarse align data via. plate scale analysis. This is a third independent indication of the magnitude of detector motion on-orbit.

So far, the only data to indicate any x-y motion is a slight motion of the coronographic hole, which has moved about 1 pixel. This will be evaluated with subsequent observations.

Analysis of cryogen tank and VCS movement as a function of cryogen usage will be pursued by Ball. This will include a prediction of how detector temperatures will vary as the nitrogen ice is depleted in the presence of the thermal short.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any effect on the short. The combination will result in a VCS temperature of 138°K, a 40°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Other options are not apparent at this time.

IV. Other Discussion Items

After extensive discussion, the Board reached a consensus that the Filter Wheel assemblies are at no risk to jamming due to expansive dewar loading in the current state. In addition, it is the consensus of the Board that a thermal short between the VCS and the TEC inner shield (evidenced by extreme dewar temperature fluctuations) will occur before the Filter Wheels are at risk. This will be confirmed by additional Ball analysis.

V. Action Item Summary

1. Chris Burrows to assess nominal cold mask position and a position 1mm closer to detectors.

2. Chris Miller to review VCS cooldown data prior to Day 17 to assure it was consistent with prelaunch predictions.

3. Chris Miller to calculate detector temperatures after the nitrogen ice loses physical contact with the coldwell in the presence of the short and assess possibility of instability.

4. Eric Mentzell to add CDM and HOMS data to on-orbit focus data charts.

5. Glenn Schneider to provide write-up of plate scale analysis used to independently assess focus.

6. Ball to provide Dewar isotherm model.

7. Mega to improve non-linear finite element model by incorporating realistic cryogen removal and breakaway shear.

8. Ball to structurally analyze forward dewar components being loaded by expansion to assess risk to filter wheel assemblies..

VI. Next Meeting

The next ARB meeting will be held at 3:00 p.m. EST on March 21, 1997, at GSFC in Building 29, Room 200.

In addition, an ARB meeting is tentatively scheduled for the morning of March 28, 1997, at GSFC.

NICMOS Dewar Anomalous On-Orbit Warming
Anomaly Review Board
Status Meeting Report
March 21, 1997

ATTENDEES: George Morrow, Dave Ratzow, Paul Geithner, Wayne Sours, David Leckrone, Richard Dame, Emmanuel Cofie, Malcolm Niedner, Eric Mentzell, Mike Dipirro, Steve DePalo, Rob, Sticka

TELECON: Ethan Schreier, Tim Kelly, Chris Miller, Rich Johnson, John Troeltzch, Wally Meyer, Chris Burrows, Laurie Furey

NEXT MEETING: Friday, March 28, 1997, 9:00-11:00, 29/213

I. General

Three new members were appointed to the Anomaly Review Board. They are:

- Rob Sticka
- Mike Dipirro
- Harvey Mosley

A revised Membership list is provided as an attachment to these minutes.

The Agenda for today's meeting included the following items:

- Ball Aerospace filter wheel analysis
- Optical analysis from most recent observation
- Mega model results

II. Ball Aerospace Filter Wheel Analysis

This analysis was performed to determine whether the Filter Wheel housing is in danger of collapse, and to determine the order in which parts can be expected to fail, if the coldwell continues to move forward.

Ball's analysis assumed that, as the expansion of the Nitrogen ice continues, all gaps close in sequence, and the three light baffles become rigid columns. This assumption is supported by structural analysis. Further, telemetry data that indicates that the current heat load is consistent with all three baffles in contact with the VCS at this time.

The analysis indicated that, when all gaps close, a thermal short will be established between the VCS and the Thermal Electric Cooler Inner (TECI) shell. Then at about 50# of force, the dewar cover will deflect about 0.4 inches and fail at about the same time that it contacts the circuit board. The second item that should fail is the Filter Wheel housing. At about 75-100# of force the housing will be deflected enough to make contact with the Filter Wheel itself.

Ball was tasked to document their structural analysis and to provide the dimensions of the rigid light baffle column. Richard Dame will assist with data on deflections vs. Temperatures.

Paul Geithner will have Chuck Wiggins/Teri Gregory start the thermal analysis to determine the effect of a TECI thermal short on the dewar. Prior safety analysis indicates that even in the event of a catastrophic dewar failure there will be no propagation beyond NICMOS. Analysis also indicates that the HST attitude control system can tolerate the forces associated with the opening of the burst disk and subsequent vent rates.

III. Optical Analysis from Most Recent Observation

Chris Burrows presented the data on detector movement in the past week. Camera 3 showed another 0.9 mm of movement. The Encircled Energy and Phase Retrieval analyses still agree.

IV. Mega Model Results

The Mega Engineering model has been modified for reduced strength of nitrogen in the region around the upper end of the coldwell. The model now predicts 7.7 mm of coldwell motion. This differs from the actual 9.8 mm of motion.

The model now shows that the foam at the back of the coldwell at or before the bondline is in tension. The foam ligaments can break leaving the coldwell cap unsupported. The reticulated foam is capable of supporting 45 psi in tension at room temperature. The coldwell cap has been tested at 33 psig at room temperature. The compressive stress in the Nitrogen behind the coldwell cap is estimated to be over 100 psi. The result is that the coldwell is subject to an oil can effect. If the coldwell cap collapsed, pushing the detector cruciform forward, this effect would account for the missing 2.2 mm of detector motion. Although the model run in this manner produces the proper motions, the coldwell temperatures do not agree. Paul Geithner will task Chuck Wiggins/Teri Gregory to also look at the thermal model to determine the expected temperature of detector mounting cups vs. the coldwell temperatures, both in the case with the thermal short only and also with the thermal short and collapsed coldwell cap.

V. Charter Item Running Summary

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the Vapor Cooled Shield (VCS) and the cryogen tank in the area of the cold bench baffle and the VCS baffle at the forward end of the Dewar.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed to about 56°K, it expanded. This in turn pushed the coldwell forward until the cold bench baffle contacted the VCS baffle. The thermal path was thus established. Cooling of the VCS then began as its heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps (a second order effect).

A second source of detector bench movement has been theorized. Debonding of the reticulated foam at the aft end of the coldwell has allowed the cap to collapse, providing more forward motion to the detector bench. This theory is being investigated through thermal analysis of the coldwell and cruciform.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

Additional analysis supports the previous conclusion that the dewar heat load is approximately 370 mw versus a design condition of about 200 mw.

Should the current heat load continue throughout the mission, the cryogen lifetime is still projected to be 2.2 years. However, if a thermal short is established to the TECI shell, then this estimate may be optimistic. This is under investigation through thermal analysis.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

The correlation between the non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, has improved with the inclusion of lower Nitrogen shear values. Work continues in the areas of cryogen sublimation characteristics and debonding of the reticulated foam at the coldwell cap.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected has been discussed. As the Nitrogen is used up the expansion pressure on the coldwell will decrease. This may allow the coldwell to move aft, breaking the thermal short contact. Until a correlated model can be achieved, predictions in this area are pure conjecture.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

Total movement of the detectors at the time of the Intermediate alignment on Day 32 is now 9.8 mm, an additional 1.2 mm since Day 25. Encircled Energy and Phase Retrieval analyses are still in agreement.

Camera data continues to indicate that there is no significant x-y motion.

Glenn Schneider provided the results of the correlation of pre-align/coarse align data from plate scale analysis. This analysis yielded focus numbers that were in good agreement with those obtained through Encircled Energy and Phase Retrieval analysis.

Analysis of cryogen tank and VCS movement as a function of cryogen usage continues to be pursued by Ball. This will include a prediction of how detector temperatures will vary as the nitrogen ice is depleted in the presence of the thermal short.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any effect on the short. The combination will result in a VCS temperature of 138°K, a 40°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Other options are not apparent at this time.

IV. Other Discussion Items

Ethan Schreier stressed the importance of the STScI knowing as soon as possible any changes in the estimated lifetime of the NICMOS. The science that would be done for a two year instrument is different than what would be done for an instrument with a two month life. We still have two very good cameras, and it is imperative that we do as much science, as soon as possible, with these cameras.

V. Action Item Summary

1. Chris Burrows to assess nominal cold mask position and a position 1mm closer to detectors. OPEN

2. Chris Miller to review VCS cooldown data prior to Day 17 to assure it was consistent with prelaunch predictions. CLOSED. Chris Miller discussed the cooldown rates. The on-orbit data compared well with the predicted values up to approximately Day 17 after installation. The heat load with curve fit shows about 370 mw of steady state load and agrees well with previous analysis.

3. Chris Miller to calculate detector temperatures after the nitrogen ice loses physical contact with the coldwell in the presence of the short and assess possibility of instability. OPEN

4. Eric Mentzell to add CDM and HOMS data to on-orbit focus data charts. OPEN

5. Glenn Schneider to provide write-up of plate scale analysis used to independently assess focus. CLOSED. Analysis write-up provided.

6. Ball to provide Dewar isotherm model. OPEN

7. Mega to improve non-linear finite element model by incorporating realistic cryogen removal and breakaway shear. OPEN

8. Ball to structurally analyze forward dewar components being loaded by expansion to assess risk to filter wheel assemblies. OPEN. Analysis provided, write-up due.

9. Paul Geithner to direct the start of a TECI thermal short thermal analysis. NEW

10. Paul Geithner to direct the investigation of the thermal model to show the expected temperature of the detector mounting cups vs. the coldwell both in the case of the thermal short only and also with the thermal short and a collapsed coldwell cap. NEW

VI. Next Meeting

The next ARB meeting will be held at 9:00 a.m. EST on March 28, 1997, at GSFC in Building 29, Room 213.

NICMOS DEWAR ANOMALOUS WARM-UP ANOMALY REVIEW BOARD MEMBERS

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STScI Conf Room	STScI	410-338-4578		

NICMOS Dewar Anomalous On-Orbit Warming
Anomaly Review Board
Status Meeting Report
March 28, 1997

ATTENDEES: George Morrow, Dave Ratzow, Paul Geithner, Wayne Sours, Richard Dame, Malcolm Niedner, Mike Dipirro, Tom Cygnarowicz, Stephen Volz, Bob Coladonato, Teri Gregory, Steve Brodeur, Tim Kelly, Rich Johnson, Bill Sparks, Chris Miller, Holly Richardson, Chuck Wiggins, Rodger Thompson

TELECON: Ethan Schreier, Harvey Moseley, Rodger Doxsey, Bob Williams, Keith Kalinowski, John Troeltzch, Wally Meyer

NEXT MEETINGS: Monday, March 31, 1997, 11:00-12:30, 29/200
Thursday, April 3, 1997, 1:00-3:00, 29/200

I. General

The Agenda for today's meeting included the following items:

- Mega model audit review with Ball Aerospace
- New model results by Richard Dame
- Thermal Analyses
    - TECI thermal short analysis
    - Results of investigation into the thermal model to show detector mounting cup vs coldwell temperature for a.) thermal short only, and b.) thermal short and collapsed coldwell cap.
    - Effects of extended outer shell heater operation (hold and safemode)
    - Assessment of small but controllable external dewar heat loads
- Results of latest focus measurements

This ARB meeting was preceded by a discussion of possible anomalous Filter Wheel operation. A summary of this discussion is provided in Other Discussion Items.

II. Mega model audit review with Ball Aerospace

The audit was performed the week of March 24. The results are summarized in Attachment 1. No "smoking guns" were noted.

III. New model results by Richard Dame

Attachment 12

The Mega model was run with various amounts of Nitrogen removed from the forward end of the cryogen tank. It was found that the removal of three pounds of Nitrogen in a critical area near the attachment ring reduced the stresses by 18% to 20%. Also, the hydrostatic stresses behind the coldwell cap were reduced by 15% to 20%. This indicates that the expansion effect is reversible. Mega was tasked to complete a rebound model to determine how far back the dewar has to move to break the thermal short taking into account plastic deformations that have occurred.

IV. Thermal Analyses

A. TECI thermal short analysis

Chuck Wiggins presented the results of a thermal analysis to determine the effect of an added heat leak between the VCS and TECI shell. In the nominal case, assuming an additional 8 mw/K heat leak, the VCS temperature will rise from 101°K to 133°K and the TECI shell temperature will drop from 192°K to 190°K. The temperature of the outer TEC (TECO) shell will rise from 213°K to 221°K and the Main Shell temperature will not be affected. Effects of nitrogen sublimation rate and resulting lifetime are still in work.

B. Results of investigation into the thermal model to show detector mounting cup vs coldwell temperature for a.) thermal short only, and b.) thermal short and collapsed coldwell cap.

The analysis indicates that if the coldwell contacts the cruciform, there would be no indications of the event either from thermal data or from optical bench tilt information. The contact points are on two stainless steel bolt heads. Because the area of contact is very small, and stainless steel is not a good thermal conductor, there would be minimal heat flow, and the temperature changes would not be noticeable. Analysis also indicates that as contact is made, all movement should be axial.

C. Effects of extended outer shell heater operation (hold and safemode)

Chuck Wiggins presented analysis data which showed that with the dewar heaters on, steady state will be achieved in 400 hours and will raise the VCS temperature by 12°K. The temperature rise in the short term is predicted to be very much in agreement with the on-orbit data.

The long term effects of having the heaters continuously on are not known, and this continues to be investigated. Further, the heaters provide little benefit in the current design, even in the cold case.

As a result, the Board recommended that the heaters be disabled when safemode is triggered to guard against inadvertent heater turn-ons.

D. Assessment of small but controllable external dewar heat loads

Chuck Wiggins took an action to look into this and to determine ways to reduce them.

V. Results of latest focus measurements

The data indicate that Camera 3 has moved another 0.30 mm - 1 mm in PAM space, or about 0.15 mm to 0.5 mm in detector space. Correlation data from Encircled Energy and Phase Retrieval analyses was not yet available. This movement was less than the previous week's movement of 1 mm and tends to indicate that axial movement has nearly stopped. Completed focus data analysis will be presented at the March 31 ARB meeting.

VI. Charter Item Running Summary

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the Vapor Cooled Shield (VCS) and the cryogen tank in the area of the cold bench baffle and the VCS baffle at the forward end of the Dewar.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed to about 56°K, it expanded. This in turn pushed the coldwell forward until the cold bench baffle contacted the VCS baffle. The thermal path was thus established. Cooling of the VCS then began as its heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps (a second order effect).

A second source of detector bench movement has been theorized. Debonding of the reticulated foam at the aft end of the coldwell has allowed the cap to collapse, providing more forward motion to the detector bench. This theory is being investigated through thermal analysis of the coldwell and cruciform.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

Additional analysis supports the previous conclusion that the dewar heat load is approximately 370 mw versus a design condition of about 200 mw.

Should the current heat load continue throughout the mission, the cryogen lifetime is still projected to be 2.2 years. However, if a thermal short is established to the TECI shell, then this estimate may be optimistic. This is under investigation through thermal analysis.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

The correlation between the non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, has improved with the inclusion of lower Nitrogen shear values. Work continues in the areas of cryogen sublimation characteristics, debonding of the reticulated foam at the coldwell cap, and coldwell cap contact with the cruciform.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected has been discussed. As the Nitrogen is used up the expansion pressure on the coldwell will decrease. This may allow the coldwell to move aft, breaking the thermal short contact. A preliminary model confirms this possibility. The amount of time it will take for this to happen has not been determined.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

Total movement of the detectors at the time of the Fine alignment on Day 39 is now 9.97 mm, an additional 0.17 mm since Day 32. Encircled Energy and Phase Retrieval analyses on this latest data are still in work.

Camera data continues to indicate that there is no significant x-y motion. (Although data received after the meeting indicates a translation of approximately 10 pixels.)

Analysis of coldwell movement tends to indicate that there is some deformation of the coldwell cap which may not be recoverable as expansion pressures decrease. However, it is expected that, as the coldwell moves aft, Camera 3 could once again regain focus. No estimate as to when this could happen.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any effect on the short. The combination will result in a VCS temperature of 138°K, a 40°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Other options are not apparent at this time.

VII. Other Discussion Items

The operation of the Filter Wheels experienced different performance than what has seen previously. Filter Wheel 2 experienced 14 retry events in 51 events. Filter Wheel 3 experienced 1 retry event in 51 events. However Filter Wheel 1 experienced no retry events.

There is a possibility that the retry events are merely normal Filter Wheel operation, or they may be a result of the thermal short and the continuing movement of the VCS. The Board decided that we should consider collecting some trending data, and directed Ball to come up with a diagnostic test procedure. This test plan will be the primary topic of discussion at the March 31 ARB meeting.

VIII. Action Item Summary

1. Chris Burrows to assess nominal cold mask position and a position 1mm closer to detectors. OPEN

2. Chris Miller to review VCS cooldown data prior to Day 17 to assure it was consistent with prelaunch predictions. CLOSED. Chris Miller discussed the cooldown rates. The on-orbit data compared well with the predicted values up to approximately Day 17 after installation. The heat load with curve fit shows about 370 mw of steady state load and agrees well with previous analysis.

3. Chris Miller to calculate detector temperatures after the nitrogen ice loses physical contact with the coldwell in the presence of the short and assess possibility of instability. OPEN

4. Eric Mentzell to add CDM and HOMS data to on-orbit focus data charts. OPEN

5. Glenn Schneider to provide write-up of plate scale analysis used to independently assess focus. CLOSED. Analysis write-up provided.

6. Ball to provide Dewar isotherm model. CLOSED. Chris Miller presented the isotherm model results which indicates that the Nitrogen sublimes from the coldwell neck area first, and progresses in stages down the length of the coldwell.

- Approximately 90-100# of Nitrogen will have sublimed by the time the entire coldwell is exposed.

7. Mega to improve non-linear finite element model by incorporating realistic cryogen removal and breakaway shear. OPEN

8. Ball to structurally analyze forward dewar components being loaded by expansion to assess risk to filter wheel assemblies. OPEN. Analysis provided, write-up due.

9. Paul Geithner to direct the start of a TECI thermal short thermal analysis. NEW

10. Paul Geithner to direct the investigation of the thermal model to show the expected temperature of the detector mounting cups vs. the coldwell both in the case of the thermal short only and also with the thermal short and a collapsed coldwell cap. CLOSED. No thermal indications are expected from these conditions.

11. Mega to complete their rebound model. NEW

12. Chris Miller to perform a baffle conductance test. NEW

13. George Morrow to request Rodger Doxsey to change safemode to keep the dewar shell heaters off. NEW

14. Chuck Wiggins to perform analyses on TECI shell to VCS thermal short. NEW

15. Chuck Wiggins to assess what can be done to control small external dewar heat loads. NEW

VI. Next Meeting

The next ARB meeting will be held at 11:00 a.m. EST on March 31, 1997, at GSFC in Building 29, Room 200.

Another ARB meeting will be held at 1:00 p.m. EST on April 3, 1997, at GSFC in Building 29, Room 200.

NICMOS Dewar Anomalous On-Orbit Warming
Anomaly Review Board
Status Meeting Report
March 31, 1997

ATTENDEES: George Morrow, Dave Ratzow, Paul Geithner, Wayne Sours, Richard Dame, Malcolm Niedner, Keith Kalinowski, Emmanuel Cofie, Harvey Moseley, Cornelis deKramer, Chris Wilkinson, Frank Cepollina

TELECON: Tim Kelly, Rodger Thompson, Rodger Doxsey, John Troeltzch

NEXT MEETING: Thursday, April 3, 1997, 1:00-3:00, 29/200

I. General

The Agenda for today's meeting included the following items:

- Results of latest focus measurements
- Preliminary flat field analysis measurements
- Discussion of Filter Wheel Diagnostic Test Procedure

I. Results of latest focus measurements

Chris Burrows presented a summary of preliminary NICMOS focus phase retrieval results. NICMOS data from four separate observation sets in all three cameras have now been reduced. The results are very consistent from all images at widely different focus settings. The data have been reduced in several different ways and all give mutually consistent results. The four datasets (spaced roughly by a week in each case) give the following longitudinal detector shifts, if we assume that the detectors are parfocal at their nominal position.

Camera	1	2	3
Pre-alignment	6.79 ± 2.1 mm	5.37 ± 0.85 mm	6.49 ± 0.11 mm
Coarse Alignment	10.55 ± 1.99	9.03 ± 0.74	8.93 ± 0.01
Intermed. Alignment	9.19 ± 1.78	8.74 ± 0.85	9.97 ± 0.04
Fine Alignment	12.78 ± 2.33	10.35 ± 0.96	10.14 ± 0.04

Thus in the last week Camera 3 moved by 0.17 ±0.06 mm. Other reduction techniques give 0.18 ±0.12 mm, 0.30 ± 0.06 mm, and 0.34 ± 0.12 mm.

A reasonable summary is that the cameras moved by 2.5 mm in the first week, 1 mm in the second, and 0.25 ± 0.15 mm in the third.

II. Flat Field Analysis

Quick look data from the latest flat field data analysis indicates some lateral (x-y) motion of the detectors. A 10 pixel shift was seen in the coronographic spot on Camera 2. Data from Cameras 1 and 3 have not been looked at yet. This is the first time we have seen any significant lateral movement of the detectors. Prior to this, all movement has been in the axial direction. Ball Aerospace will put together a written report on this for the next ARB meeting. At that time the detector plane tilt data will also be available.

III. Discussion of Filter Wheel Diagnostic Test Procedure

John Troeltzsch presented his Filter Wheel 2 retry analysis. During the Fine Alignment Test on Day 87 (March 28), Filter Wheel 2 experienced 14 retry events during the C2 Fine Focus Sweep. This sweep had 17 PAM positions and at each position, images were taken with 3 filters (F110W, F180M, and F171M). There was one occultation during the sweep where the Filter Wheels were BLANKed. At each focus position the filters were used in the same order.

Movement of the Filter Wheel began at Filter 1 (at 0°), moved counter-clockwise 55° to F110W (at 305°), moved clockwise 175° to F180M (at 120°), moved counter-clockwise to F171M (at 103°), and returned 158° in the counter-clockwise direction to F110W. The Filter Wheel was then ready to support the next PAM position. All the retry events occurred during the move to filter F180M when the Filter Wheel came up 2 steps short of the required position. All retry events were successful. Coming up short may imply some sort of increased friction in the vicinity of F110W. The type of friction can not yet be determined, and may still be simply normal operation of the Filter Wheel. However, in order to better characterize the operation of the Filter Wheels, both for analysis of the current behavior and to serve as a benchmark for future analysis, a Diagnostic Test Procedure has been prepared.

The Diagnostic Test is divided into 4 tests. Any of the tests may be run stand-alone and will use real-time PSTOL commanding to initiate a series of Filter Wheel motions during collection of diagnostic data. Each test is expected to take approximately 15 minutes to perform. The proposed tests are:

• Test 1 - Inductosyn Performance Test. Used to baseline inductosyn performance to be sure no shift has been seen in-orbit since ground test. This is a repeat of the March 1996 characterization test.

• Test 2 - Filter Wheel Performance Test. Used to collect analog data of motor current, drive voltage, and temperature to give a motor performance baseline.

• Test 3 - Filter Wheel FSW Performance Test. Used to tell if the retries are a result of a hardware of software problem.

• Test 4 - Fine Alignment Retry Test. This is a repeat of the March 28 slews but without observations. Higher resolution data can then be obtained.

It is expected that preliminary results will be available within 24 hours of data receipt with final analysis completed within one week.

Tests 1, 2, and 4 will be run once. Test 3 could be repeated, but the amount of time that it will take for data analysis precludes it from being run on a daily basis.

Test risks, if any, need to be identified in time for the Flight Readiness Review to be held later this day.

Test #4 was performed on April 1, 1997. Out of 15 repetitions, 13 retries of 2 steps resulted. Tests 1, 2, and 3 will be performed April 2, 1997.

IV. Charter Item Running Summary

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the Vapor Cooled Shield (VCS) and the cryogen tank in the area of the cold bench baffle and the VCS baffle at the forward end of the Dewar.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed to about 56°K, it expanded. This in turn pushed the coldwell (containing the detector bench) forward until the cold bench baffle contacted the VCS baffle. The thermal path was thus established. Cooling of the VCS then began as its heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps (a second order effect).

A second source of detector bench movement has been theorized. Debonding of the reticulated foam at the aft end of the coldwell has allowed the cap to collapse, providing more forward motion to the detector bench. This theory is being investigated through thermal analysis of the coldwell and cruciform.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

Additional analysis supports the previous conclusion that the dewar heat load is approximately 370 mw versus a design condition of about 200 mw.

Should the current heat load continue throughout the mission, the cryogen lifetime is still projected to be 2.2 years. However, if a thermal short is established to the TECI shell, then this estimate may be optimistic. This is under investigation through thermal analysis.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

The correlation between the non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, has improved with the inclusion of lower Nitrogen shear values. Work continues in the areas of cryogen sublimation characteristics, debonding of the reticulated foam at the coldwell cap, and coldwell cap contact with the cruciform.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected has been discussed. As the Nitrogen is used up the expansion pressure on the coldwell will decrease. This may allow the coldwell to move aft, breaking the thermal short contact. A preliminary model seems to confirm this possibility. The amount of time it will take for this to happen has not been determined.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

Total movement of the detectors at the time of the Fine alignment on Day 39 (March 27) is now 9.97 mm, an additional 0.17 mm since Day 32 (March 20). Encircled Energy and Phase Retrieval analyses on this latest data are still in work.

Camera data from March 28 now indicates that there is some x-y motion in Camera 2. Analysis is continuing.

Analysis of coldwell movement tends to indicate that there is some deformation of the coldwell cap which may not be recoverable as expansion pressures decrease. However, it is expected that, as the coldwell moves aft, Camera 3 could once again regain focus. No estimate as to when this could happen.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any effect on the short. The combination will result in a VCS temperature of 138°K, a 40°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Other options are not apparent at this time.

V. Action Item Summary

1. Chris Burrows to assess nominal cold mask position and a position 1mm closer to detectors. OPEN

2. Chris Miller to review VCS cooldown data prior to Day 17 to assure it was consistent with prelaunch predictions. CLOSED. Chris Miller discussed the cooldown rates. The on-orbit data compared well with the predicted values up to approximately Day 17 after installation. The heat load with curve fit shows about 370 mw of steady state load and agrees well with previous analysis.

3. Chris Miller to calculate detector temperatures after the nitrogen ice loses physical contact with the coldwell in the presence of the short and assess possibility of instability. OPEN

4. Eric Mentzell to add CDM and HOMS data to on-orbit focus data charts. OPEN

5. Glenn Schneider to provide write-up of plate scale analysis used to independently assess focus. CLOSED. Analysis write-up provided.

6. Ball to provide Dewar isotherm model. CLOSED. Chris Miller presented the isotherm model results which indicates that the Nitrogen sublimes from the coldwell neck area first, and progresses in stages down the length of the coldwell. Approximately 90-100# of Nitrogen will have sublimed by the time the entire coldwell is exposed.

7. Mega to improve non-linear finite element model by incorporating realistic cryogen removal and breakaway shear. OPEN

8. Ball to structurally analyze forward dewar components being loaded by expansion to assess risk to filter wheel assemblies. OPEN. Analysis provided, write-up due.

9. Paul Geithner to direct the start of a TECI thermal short thermal analysis. OPEN

10. Paul Geithner to direct the investigation of the thermal model to show the expected temperature of the detector mounting cups vs. the coldwell both in the case of the thermal short only and also with the thermal short and a collapsed coldwell cap. CLOSED. No thermal indications are expected from these conditions.

11. Mega to complete their rebound model. OPEN

12. Chris Miller to perform a baffle conductance test. OPEN

13. George Morrow to request Rodger Doxsey to change safemode to keep the dewar shell heaters off. OPEN

14. Chuck Wiggins to perform analyses on TECI shell to VCS thermal short. OPEN

15. Chuck Wiggins to assess what can be done to control small external dewar heat loads. OPEN

16. Ball to provide a write-up of Camera 1, 2, and 3 flat field data analysis from the March 28 observations. NEW

VI. Next Meeting

The next ARB meeting will be held at 1:00 p.m. EST on April 3, 1997, at GSFC in Building 29, Room 200.

Attachment 1

Summary of Ball Review of Mega's Model Input

Summary of Input Data Presented to Ball

- Geometry (including gaps)
- Material properties
- Temperatures
- Strength of foam

Points from Ball Aerospace to Mega

- Last nitrogen tests from MRE indicated values for E 1/10 those used by MEGA
- Mega used values from last ball test data sets and would re-visit data
- Mega would run a sensitivity analysis of the effect of E variation
- Gauge sizes for parts in Mega's model were correct
- Gap between VCS baffle and TECI to be corrected to .050" min at RT.
- Mega model with cover I K warmer than cruciform appeared OK
- Filter wheel housing temperature same as VCS, strap support lK colder
- Run break strength of model's foam contact to correct for actual foam density

Discussed the VCS Baffle to Forward Cover Gap

- Calculated at 5.01 mm at RT
- Combined nitrogen/tank expansion reduced this value at launch
- SER statement needed to be clarified

Reviewed .028" Gap Estimate at Back of Coldwell and Cruciform Screw Head

- Used dimensions from drawings

Mega Requested Statement from Ball Packaging Group Concerning PCB Connector Contact

- Clearance between top of connector and cold well cover
- Potential for damage and breaking connections

NICMOS Dewar Anomalous On-Orbit Warming
Anomaly Review Board
Status Meeting Report
April 3, 1997

ATTENDEES: George Morrow, Dave Ratzow, Frank Cepollina, Paul Geithner, David Leckrone, Richard Dame, Emmanuel Cofie, Malcolm Niedner, Barry Kirkham, Teri Gregory, Chuck Wiggins, Cornelis deKramer, Bill Sparks, Ethan Schreier, Dave Cissell, Glenn Schneider, Mike DiPirro, Art Rankin, Holly Richardson, Colleen Townsley, Andrew Dougherty, Eric Mentzell, Dave Weiss

TELECON: Tim Kelly, Rodger Thompson, Rodger Doxsey, John Troeltzch, Chris Miller, Rich Johnson, Laurie Furey

NEXT MEETING: Tuesday, April 8, 1997, 10:00-11:00, 29/200

I. General

The Agenda for today's meeting included the following items:

- Analysis of Coronographic Spot Shift
- Mega Plots on Expansion vs Temperature Correlations
- Correlation of Detector Shift with Expected Motion Due to Coldwell Contact With Bolts on Cruciform
- Filter Wheel Diagnostic Test Results
- Explanation of Reduced N2 Sublimation During Outer Shell Heater Operation
- On-orbit Thermal Performance Update
- Mega Rebound Analysis and Additional Model Enhancement Results
- Assessment of Small but Controllable Heat Loads
- Further Estimate of Cryo Lifetime in the Presence of a VCS to TECI Short

I. Analysis of Coronographic spot Shift

A coronographic spot shift of about 12 pixels from expected was seen in the initial Functional Test. This was an effect of transient temperatures. However, at the time of the Fine Alignment, the following approximate lateral motion of the detectors was noted as compared to the Intermediate Alignment:

	Detector Shift	
Camera	Y (Pixels)	X (Pixels)
1	8	3
2	11	2.5
3	1	0.5

Analysis shows that the pivot point of this movement is 116 mm from the pupil plane, which is at about the forward attachment ring which supports the optical bench. We can not yet determine the cause of this movement, it could be cruciform movement, coldwell movement, dewar shift, or optical bench shift. It could be due to the transient heater condition or expansion. Additional measurements are planned for April 5 to aid in this analysis.

II. Mega Plots on Expansion vs Temperature Correlations

The Mega model still does not fully explain the observed step change in cruciform movement when the coldwell temperature exceeded 57°K. Although the model is 1.2 mm to 1.3 mm low in predicting total movement, it now appears that the model is accurate enough for delta predictions.

III. Correlation of Detector Shift with Expected Motion Due to Coldwell Contact With Bolts on Cruciform

The Mega model indicates that a concentrated load at each of two baffle points is transmitted down the ring. Since this load is offset about the forward cover, this causes the cruciform to swing. Also the expansion of the cryogen tank as it is warmed and shrinkage of the Vapor Cooled Shell (VCS) as it is cooled can also give some lateral movement. We may be seeing some thermally induced distortions of the struts and shells. Ball Aerospace will perform a complete thermal structural analysis in this area. Chuck Wiggins will provide plots of all relevant temperatures to aid in this analysis.

IV. Filter Wheel Diagnostic Test Results

The Filter Wheel Diagnostic Tests were run on Day 91 (March 31).

The results of Diagnostic Test #1 indicated no significant change since 1996. Filter Wheels 2 and 3 inductosyn performance was marginal for Flight Software operation.

The results of Diagnostic Test #2 indicated that all mechanism bus voltages and currents were normal and motor temperatures were nominal.

Diagnostic Test #3 resulted in one retry during Filter Wheel 3 counter-clockwise test, in moving to F166N. This is under further investigation.

Diagnostic Test #4, the Filter Wheel 3 Retry Analysis provided data that was more repeatable than that obtained on Day 87 (March 28) although every move to F180M came up 2 steps short and required a retry. Every retry was successful. A potentially serious operations problem was discovered. It was found that overshoots and retries which occur within 10 ms of the previous move cause an unwanted torque input into the soda straw during maximum oscillation. It was also seen that the inductosyn indicates an oscillation of ± 100 counts after the motor stops moving to F110W as compared to ± 1 count for the other positions. This may be the cause of the retries to F180M.

These tests indicated that the Filter Wheels are healthy. There are no Filter Wheel problems that are related to dewar expansion and it is the decision of the Board that the daily trend tests can be suspended. John Troeltzsch will prepare a test plan for the compilation of Filter Wheel trending data as part of the normal NICMOS Operations team.

Resolution of the problems discovered during Diagnostic Test #4 are also the responsibility of the NICMOS Operations Team. It was reported that these problems can be resolved in 3-4 weeks through software changes.

V. Explanation of Reduced N2 Sublimation During Outer Shell Heater Operation

Chris Miller presented the results of his analysis. The sublimation rate decreased temporarily because of an increase in capillary line temperature. This is because the flowrate is a function of both the inlet (N2) pressure and the capillary line temperature, which is influenced by outer shell temperature. When the outer shell heaters came on, the capillary line temperature increased from -4°C to 0°C. Flowrate calculations predict a decrease, from 128.8 g/day to 125.3 g/day, which was the approximate flowrate shift observed.

VI. On-orbit Thermal Performance Update

With the dewar tank now approaching steady-state conditions, the heat load can be determined with better accuracy. The energy balance tool shows that the heat load will stabilize at about 473 mw, up from the previous estimate of 370 mw. The projected steady-state conditions are 166 g/day cryogen vent rate, 60.0°K cryogen temperature, and a VCS temperature of 98°K. The conductance of the VCS-N2 short is projected to be 10.7 mw/K and the cryogen lifetime is now estimated to be 1.7 years.

VII. Mega Rebound Analysis and Additional Model Enhancement Results

The model has been considerably enhanced through the efforts of Ball and Mega. However, now that the cryogen temperature is approaching 60°K, the lack of cryogen/foam properties above 58°K is a significant problem. Interpolation of existing data from 58°K to 59°K has allowed the model to be run so far, but above this temperature the change in properties is very rapid and difficult to extrapolate. Mike DiPirro will work with Richard Dame on extrapolation of nitrogen/foam material properties. Chris Miller will begin the work to get experimental data of the cryogen/foam combination in the 59°K to 61°K temperature range.

The rebound analysis indicates that the detectors can be expected to move aft 2.9 mm to 3.3 mm when 100# of nitrogen has been consumed. This may not be enough to break the thermal short or to put Camera 3 back in focus. Approximately 3.8 mm of movement is required to break the short.

The model has indicated that the cruciform forward cover has undergone elastic deformation as the coldwell has moved forward. (It is this elastic deformation that is preventing a VCS to TECI thermal short.) As the cryogen continues to sublime, the forward cover will return to its original condition. If the forward cover had undergone plastic deformation, then the forward cover would have retained the deformed condition, with a higher probability that the thermal short could be broken.

VIII. Assessment of Small but Controllable Heat Loads

Chuck Wiggins' assessment of avoidance of bright earth to reduce the thermal input to the dewar indicates that the benefit is not worth the effort. Other similar small thermal inputs that may, with considerable effort, be controlled, are also no problem.

IX. Further Estimate of Cryo Lifetime in the Presence of a VCS to TECI Short

Although we no longer expect a VCS to TECI short, a VCS to TECI thermal short will increase the Nitrogen heat load to about 780 mw. This heat load will result in a cryogen lifetime of about 1 year.

A heat load of 780 mw will not be catastrophic as it is not sufficient to cause the Nitrogen to go to a liquid state. About 1600 mw is needed to create this situation.

X. Charter Item Running Summary

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the Vapor Cooled Shield (VCS) and the cryogen tank in the area of the cold bench baffle and the VCS baffle at the forward end of the Dewar.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed to about 56°K, it expanded. This in turn pushed the coldwell (containing the detector bench) forward until the cold bench baffle contacted the VCS baffle. The thermal path was thus established. Cooling of the VCS then began as its heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps (a second order effect).

A second source of detector bench movement has been theorized. Debonding of the reticulated foam at the aft end of the coldwell has allowed the cap to cup, providing more forward motion to the detector bench. This theory is being investigated through thermal analysis of the coldwell and cruciform.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

Additional analysis indicates that the dewar heat load is approximately 473 mw versus a design condition of about 200 mw.

Should the current heat load continue throughout the mission, the cryogen lifetime is projected to be 1.7 years. If the thermal short were to be broken, then the lifetime will increase. As the Nitrogen sublimes, the thermal short contact force decreases, and the amount of heat conducted could reduce. This will increase the cryogen lifetime. Quantitative values are being determined.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

The correlation between the non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, has improved with the inclusion of lower Nitrogen shear values. Work continues in the areas of cryogen sublimation characteristics, debonding of the reticulated foam at the coldwell cap, coldwell cap contact with the cruciform, and improved knowledge of the physical properties of the nitrogen/foam between 59°K and 61°K.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected has been discussed. As the Nitrogen is used up the expansion pressure on the coldwell will decrease. This may allow the coldwell to move aft, breaking the thermal short contact. Current analyses do not support this probability.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

Total movement of the detectors at the time of the Fine alignment on Day 39 (March 27) is now 9.97 mm, an additional 0.17 mm since Day 32 (March 20). Encircled Energy and Phase Retrieval analyses on this latest data are in general agreement.

Camera data from March 28 now indicates that there has been lateral movement of the detectors, mostly in the -y direction. The pivot point is 116 mm behind the pupil plane or at about the attachment ring. Analysis is continuing.

Dewar rebound analysis indicates a recovery of 2.9 mm - 3.3 mm. This will not be sufficient to bring Camera 3 into focus.

Another long term change not related to camera focus or alignment has been identified. A greater rate of detector temperature change over life is expected due to the presence of the thermal short. Temperatures will rise to about 62°K during the first year of life with an accelerating rate thereafter until cryogen depletion. Until the last month or two this is not expected to effect performance.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any effect on the short. The combination will result in a VCS temperature of 138°K, a 40°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Further, this additional heat input will exacerbate the condition. Other options are not apparent at this time.

All controllable sources of heat input to the dewar should be reduced to a minimum. Outer shell heaters will be disabled to prevent activation in safe-mode.

XI. Action Item Summary

1. Chris Burrows to assess nominal cold mask position and a position 1mm closer to detectors. OPEN

2. Chris Miller to review VCS cooldown data prior to Day 17 to assure it was consistent with prelaunch predictions. CLOSED. Chris Miller discussed the cooldown rates. The on-orbit data compared well with the predicted values up to approximately Day 17 after installation. The heat load with curve fit shows about 370 mw of steady state load and agrees well with previous analysis.

3. Chris Miller to calculate detector temperatures after the nitrogen ice loses physical contact with the coldwell in the presence of the short and assess possibility of instability. CLOSED. Detector temperatures are not estimated to increase above 62°K in one year. After that, the temperatures are expected to rise at an increasing rate.

4. Eric Mentzell to add CDM and HOMS data to on-orbit focus data charts. OPEN

5. Glenn Schneider to provide write-up of plate scale analysis used to independently assess focus. CLOSED. Analysis write-up provided.

6. Ball to provide Dewar isotherm model. CLOSED. Chris Miller presented the isotherm model results which indicates that the Nitrogen sublimes from the coldwell

neck area first, and progresses in stages down the length of the coldwell. Approximately 90-100# of Nitrogen will have sublimed by the time the entire coldwell is exposed.

7. Mega to improve non-linear finite element model by incorporating realistic cryogen removal and breakaway shear. CLOSED. These factors have been incorporated into the current model.

8. Ball to structurally analyze forward dewar components being loaded by expansion to assess risk to filter wheel assemblies. OPEN. Analysis provided, write-up due.

9. Paul Geithner to direct the start of a TECI thermal short thermal analysis. CLOSED. Analysis has been performed by Chuck Wiggins.

10. Paul Geithner to direct the investigation of the thermal model to show the expected temperature of the detector mounting cups vs. the coldwell both in the case of the thermal short only and also with the thermal short and a collapsed coldwell cap. CLOSED. No thermal indications are expected from these conditions.

11. Mega to complete their rebound model. OPEN.

12. Chris Miller to perform a baffle thermal conductance test. OPEN

13. George Morrow to request Rodger Doxsey to change safemode to keep the dewar shell heaters off. CLOSED Done.

14. Chuck Wiggins to perform analyses on TECI shell to VCS thermal short. CLOSED. Analysis of this condition has been presented. A heat load of about 780 mw with a corresponding lifetime of about 1 year is estimated for this condition.

15. Chuck Wiggins to assess what can be done to control small external dewar heat loads. CLOSED. The amount of benefit gained is not worth the effort to implement.

16. Ball to provide a write-up of Camera 1, 2, and 3 flat field data analysis from the March 28 observations. OPEN. Analysis has begun.

17. Ball to perform structural analysis using the thermal model inputs. NEW

18. Chris Miller to provide a phase diagram of capillary tube flow rate vs temperature. NEW

19. Mike DiPirro to work with Dame on estimate of cryogen/foam material properties. NEW

20. Chris Miller to set up a test to get data on cryogen/foam in the 58°K to 61°K range. NEW

XII. Next Meeting

The next ARB meeting will be held at 10:00 a.m. EDT on April 8, 1997, at GSFC in Building 29, Room 200. Tentative agenda topics include:

- Evaluation of focus sweep/flat field data
- Update of baffle conductance test
- Update of Mega rebound model results

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ATTENDEES: George Morrow, Dave Ratzow, Frank Cepollina, Paul Geithner, Malcolm Niedner, Bill Sparks, Ethan Schreier, Rob Sticka, Glenn Schneider, Mike DiPirro, Eric Mentzell, Ed Cheng, Wayne Sours, Thomas Cygnarowicz

TELECON: Tim Kelly, Roger Thompson, John Troeltzch, Chris Miller, Rich Johnson, Laurie Furey, Richard Dame,

NEXT MEETING: Monday, April 14, 1997, 10:30-12:00, 29/200

I. General

The Agenda for today's meeting included the following items:

- Evaluation of Focus Sweep/Flat Field Data
- Update of Mega Rebound Model Results
- Update of Baffle Conductance Test
- Tank Isotherm Model Update

II. Evaluation of focus sweep/flat field data

Chris Burrows presented a summary of NICMOS focus results. NICMOS data from five separate observation sets in all three cameras have now been reduced. The results are very consistent from all images at widely different focus settings. The data have been reduced in several different ways and all give mutually consistent results. The five datasets (spaced roughly by a week in each case) give the following longitudinal detector shifts, if we assume that the detectors are parfocal at their nominal position.

Camera	1	2	3
Pre-alignment	6.79 ± 2.1 mm	5.37 ± 0.85 mm	6.49 ± 0.11 mm
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Intermed. Alignment	9.19 ± 1.78	8.74 ± 0.85	9.97 ± 0.04
Fine Alignment	12.78 ± 2.33	10.35 ± 0.96	10.14 ± 0.04
Monitor 1	NA	10.4 ± 0.61	10.15 ± 0.04

A reasonable summary is that the cameras moved by 2.5 mm in the first week, 1 mm in the second, and 0.25 ± 0.15 mm in the third. In the last week the focus has not moved within the error bars.

Lateral movement of the detectors has continued in the same general -y direction with an additional shift of about 5 pixels. This is about half the shift of the previous week, indicating that lateral movement is slowing down.

There is no indication that this lateral movement is the result of the transient heater condition postulated at last week's meeting since we continue to see movement long after the effects of the heater operation dissipated. Richard Dame felt that there may be some built up stress that is now releasing in the lateral direction.

III. Update of Mega Rebound Model Results

The rebound analysis reported at the last meeting indicated that the detectors can be expected to move aft 2.9 mm to 3.3 mm when 100# of nitrogen has been consumed, leaving Camera 3 about 1.8 mm out of focus. This will result in an ensquared energy of 45% (versus a prediction of 60%) and a Strel ratio of 60%, indicating that we will not totally recover Camera 3, but it will be close. However, we will have significant vignetting remaining and exit pupil beam alignment is also be a concern. Camera tilt is not a problem, as we can tolerate 3°-4° before degradation begins.

A more accurate rebound prediction requires measurement of nitrogen/foam properties at higher temperatures. Chris Miller is assembling the test equipment and foam samples needed to determine nitrogen/foam properties in the 59°K to 61°K temperature range. Test setup will start the week of April 14. Test temperature priorities are 60°K first, 61°K second, and finally 59°K.

Using a value for yield strength agreed to by Dave, DiPirro, and Miller, the rebound analysis still indicates the same amount of movement and no breaking of the thermal short. However, small changes in these properties can result in large changes in movement. An estimate as to when these values will be available will come in the meeting on April 14.

IV. Update of Baffle Conductance Test

The first test was performed with an unpainted baffle in full contact. The results show that, at low temperatures, the conductance is much less dependent on contact force than at higher temperatures. The next test will use a more realistic flight configuration of a painted baffle in point contact.

V. Tank Isotherm Model Update

The tank thermal model was run with the steady state heat load prediction of 470mw from the last meeting. It indicated that focal plane array temperatures will be less than

63°K until the final month (predicted to be November 1998) of cryogen life. At that time, a rapid rise in temperature is expected to end of life.

VI. Charter Item Running Summary

1. Determine the most likely cause of the increased heat flow.

The most likely source of the increased heat flow is a thermal short between the Vapor Cooled Shield (VCS) and the cryogen tank in the area of the cold bench baffle and the VCS baffle at the forward end of the Dewar.

The most likely cause of the thermal short was a result of a chain of events which began with the normal warming of the cryogen tank from its launch temperature of approximately 51°K. As the nitrogen warmed to about 56°K, it expanded. This in turn pushed the coldwell/tank head (containing the detector bench) forward until the cold bench baffle contacted the VCS baffle. The thermal path was thus established. Cooling of the VCS then began as its heat was transferred to the cryogen tank causing cryogen usage to increase. VCS cooling has been shown through modeling to exacerbate the expansion by loading the forward dewar support straps (a second order effect).

A second source of detector bench movement has been theorized. Debonding of the reticulated foam at the aft end of the coldwell has allowed the cap to cup, providing more forward motion to the detector bench. This theory is being investigated through thermal analysis of the coldwell and cruciform.

2. Estimate the cryogen lifetime assuming the heat flow remains at the higher rate.

Thermal Analysis indicates that the dewar heat load is approximately 473 mw versus a design condition of about 200 mw.

Should the current heat load continue throughout the mission, the cryogen lifetime is projected to be 1.7 years. If the thermal short were to be broken, then the lifetime will increase. As the Nitrogen sublimes, the thermal short contact force decreases, and the amount of heat conducted could reduce. This will increase the cryogen lifetime. Quantitative values are being determined through low temperature baffle conductance testing.

3. Evaluate the optical data obtained from the on-board optical alignment activities. Correlate these data with the mechanical models and attempt to reach a physical understanding of the Dewar, the cold well, and the detectors.

The correlation between the non-linear finite element model and the actual focus measurements for the NICMOS instrument, after launch, has improved with the inclusion of lower Nitrogen shear values. Work continues in the areas of cryogen sublimation characteristics, debonding of the reticulated foam at the coldwell cap, coldwell cap contact with the cruciform, and improved knowledge of the physical properties of the nitrogen/foam between 59°K and 61°K.

4. Estimate the likelihood of the heat flow returning to normal, when this might happen, and the resultant effect on cryogen life.

The possibility that the thermal short may be corrected has been discussed. As the Nitrogen is used up the expansion pressure on the coldwell will decrease. This will allow the coldwell to move aft. Current analyses indicate that this "rebound" will not be sufficient to break the short.

5. Estimate the probable long-term changes in focus and tip/tilt of the three cameras.

Total movement of the detectors at the time of Monitor 1 Alignment on Day 46 (April 3) is now 10.15 mm, essentially no change in movement since the time of the Fine Alignment on Day 32 (March 27). Encircled Energy and Phase Retrieval analyses on this latest data are in general agreement.

Camera data indicates that there has been lateral movement of the detectors, mostly in the -y direction. The pivot point is approximately 116 mm behind the pupil plane or at about the attachment ring. Total movement is approximately 15 - 16 pixels and the rate of movement appears to be decreasing. Analysis is continuing.

Dewar rebound analysis indicates a recovery of 2.9 mm - 3.3 mm over the next year. Analysis indicates that this will not be sufficient to bring Camera 3 into focus.

Another long term change not related to camera focus or alignment has been identified. A greater rate of detector temperature change over life is expected due to the presence of the thermal short. Temperatures will rise to somewhat less than 63°K until November 1998. This is not expected to effect performance, but may require more frequent calibration activities. During the last month of cryogen life, temperatures will increase dramatically.

6. Recommend options, if any, for on-orbit management of heat flow and optical alignment.

Techniques such as turning on the vacuum shell heaters and turning off the Thermal Electric Coolers (TECs) to warm the VCS are not expected to have any longterm positive effect on the short. The combination will result in a VCS temperature of 138°K, a 40°K rise from the current temperature. Analysis indicates that a rise of at least 100°K is required to break the short. Further, this additional heat input will exacerbate the condition. Other options are not apparent at this time.

All controllable sources of heat input to the dewar should be reduced to a minimum. Outer shell heaters will be disabled to prevent activation in safe-mode.

XI. Action Item Summary

1. Chris Burrows to assess nominal cold mask position and a position 1mm closer to detectors. CLOSED. This assessment is no longer needed.

2. Chris Miller to review VCS cooldown data prior to Day 17 to assure it was consistent with prelaunch predictions. CLOSED. Chris Miller discussed the cooldown rates. The on-orbit data compared well with the predicted values up to approximately Day 17 after installation. The heat load with curve fit shows about 370 mw of steady state load and agrees well with previous analysis.

3. Chris Miller to calculate detector temperatures after the nitrogen ice loses physical contact with the coldwell in the presence of the short and assess possibility of instability. CLOSED. Detector temperatures are not estimated to increase above 62°K in one year. After that, the temperatures are expected to rise at an increasing rate.

4. Eric Mentzell to add CDM and HOMS data to on-orbit focus data charts. CLOSED. This was done, but it did not add anything to the anomaly investigation.

5. Glenn Schneider to provide write-up of plate scale analysis used to independently assess focus. CLOSED. Analysis write-up provided.

6. Ball to provide Dewar isotherm model. CLOSED. Chris Miller presented the isotherm model results which indicates that the Nitrogen sublimes from the coldwell neck area first, and progresses in stages down the length of the coldwell. Approximately 90-100# of Nitrogen will have sublimed by the time the entire coldwell is exposed.

7. Mega to improve non-linear finite element model by incorporating realistic cryogen removal and breakaway shear. CLOSED. These factors have been incorporated into the current model.

8. Ball to structurally analyze forward dewar components being loaded by expansion to assess risk to filter wheel assemblies. OPEN. Analysis provided, write-up due.

9. Paul Geithner to direct the start of a TECI thermal short thermal analysis. CLOSED. Analysis has been performed by Chuck Wiggins.

10. Paul Geithner to direct the investigation of the thermal model to show the expected temperature of the detector mounting cups vs. the coldwell both in the case of the thermal short only and also with the thermal short and a collapsed

coldwell cap. CLOSED. No thermal indications are expected from these conditions.

11. Mega to complete their rebound model. OPEN. Analysis in work.

12. Chris Miller to perform a baffle thermal conductance test. OPEN. Testing is in work.

13. George Morrow to request Rodger Doxsey to change safemode to keep the dewar shell heaters off. CLOSED. Done.

14. Chuck Wiggins to perform analyses on TECI shell to VCS thermal short. CLOSED. Analysis of this condition has been presented. A heat load of about 780 mw with a corresponding lifetime of about 1 year is estimated for this condition.

15. Chuck Wiggins to assess what can be done to control small external dewar heat loads. CLOSED. The amount of benefit gained is not worth the effort to implement.

16. Ball to provide an audit of all Camera 1, 2, and 3 flat field data analyses. OPEN.

17. Ball to perform structural analysis using the thermal model inputs. CLOSED. A structural analysis was not required because the thermal data indicated stable VCS temperatures before the Fine Alignment.

18. Chris Miller to provide a phase diagram of capillary tube flow rate vs temperature. OPEN

19. Mike DiPirro to work with Dame on estimate of cryogen/foam material properties. OPEN

20. Chris Miller to set up a test to get data on cryogen/foam in the 58°K to 61°K range. OPEN

XII. Next Meeting

The next ARB meeting will be held at 10:30 a.m. EDT on April 14, 1997, at GSFC in Building 29, Room 200. Tentative agenda topics include:

- ARB Charter Review: How we stand - All
- ARB Closure Plan - Morrow
- Results of Latest Focus Run - Burrows
- Capillary Tube Flow Rate Phase Diagram - Burrows