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on Grant NCC 2-679

Scientific and Technical Support for the Galileo Net Flux Radiometer Experiment

Performance Period: 1 January 1990 through 30 November 93

Submitted by

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FINAL REPORT ON GRANT NCC 2-679

Scientific and Technical Support for the Galileo Net Flux Radiometer Experiment

Performance Period: 1 January 1990 through 30 November 93

I. INTRODUCTION

This report describes work supported by a post-launch grant (NCC 2-679) that originally covered the period from 1 January 1990 through 31 December 1992. This was extended an additional nine months at no cost until 30 September 1993, and once more until to 30 November 93. A final report on the effort from 1 January 1990 through 30 November 1993 (anticipated) is provided following the background discussion.

Tasks required during the post launch period are briefly as follows: attend PSG (Project Science Group) meetings; support in-flight checkouts; maintain and keep safe the spare instrument and GSE (Ground Support Equipment); organize and maintain documentation; finish calibration measurements, documentation, and analysis; characterize and diagnose instrument anomalies; develop descent data analysis tools; and science data analysis and publication. The following sections provide background information on the NFR instrument followed by the complete progress report.

II. BACKGROUND

The Galileo Net Flux Radiometer (NFR) is a probe instrument designed to measure net radiation flux and upward flux in five spectral bands during descent into the Jovian atmosphere. Solar energy deposition and planetary radiation losses from the 0.1 bar level to at least the 10 bar level will be measured to assess the nature of radiative drive for atmospheric motions, the location of clouds and hazes, and the amount of water vapor. Our Space Science Reviews paper (Sromovsky et al., 1993) describes the science objectives, instrument design, and expected performance of the NFR.

The 26 January 1986 Challenger explosion delayed Galileo's launch from May 1987 until October 1989. This delay provided an opportunity to correct problems with the NFR instrument, and to improve its performance and calibration. New detectors were procured and installed, motor drive digital and analog electronics were modified to improve optical chopping symmetry, the detector package was sealed in Xenon to eliminate both pressure perturbation noise and crosstalk, and a new bearing and bearing support fixture were installed. In October 1988, a reworked and re-calibrated SN02R2 instrument was delivered for probe integration. Unfortunately, the detector package seal was found to be leaking during calibration tests and just prior to delivery we discovered a problem with the front bearing. These problems were addressed by modifying the SN01R instrument, recalibrating it, and then exchanging optical heads with the SN02R instrument on 15 March 1989. This created a hybrid flight instrument consisting of the SN02R2 electronics mated to the SN01R2 optical head (that configuration was launched on 18 October 1989). For a detailed report of this work see Sromovsky and Best (1990).

Although we were able to complete enough of the calibration and characterization analysis to know that we had a generally high level of instrument performance, there remained a number of areas in which significant further effort was needed to put the characterization and calibration on a firm foundation to ensure that it will be ready for use in the analysis of descent data. The most important calibration issues were (1) calibration of reference detectors on which the NFR calibration is based; (2) extending spectral response calibration to longer wavelengths using absolute measurements; and (3) uncovering the source of temperature dependence in the spectral response and characterizing it well enough to correct for its effects on descent data. Absolute calibrations were also incomplete because they depend on spectral integrals calculated from relative response functions. In addition, there were significant anomalies in the data which needed to be investigated: (1) unexplained net flux offsets; and (2) inadequately characterized aerodynamic effects. Both effects had the potential to produce significant errors depending on how the mechanism producing them varies with temperature, Nusselt number, or Reynolds number.

In summary, significant additional work was needed (and much still is needed) to put the NFR data on solid scientific foundation. Our current state of progress and the remaining work to be accomplished is described in the following sections.

III. FINAL PROGRESS REPORT FOR NCC 2-679

Besides addressing the problem areas we also carried out the usual support functions of attending PSG meetings, analyzing in-flight checkout tests, maintenance and safekeeping of the instrument and GSE, and preparing for analysis of descent data. In the following we provide a report on progress in terms of the tasks proposed for the previous grant period.

Progress on General Science Support (Task Group A):

Participation in PSG and Project Meetings

1990 The PI attended the December 1990 PSG Meeting at JPL. NFR status summaries were prepared for presentation and transmitted to the Probe Project Scientist for both August and December PSG meetings.

We participated in an August meeting at Wisconsin with B. Chin and C. Jackson of ARC to discuss grant tasks and in-flight checkout plans. In September the PI met with Bill O'Neil to discuss NFR status and Project plans for in-flight checkouts and earth gravity assist.

Two probe instrument papers were reviewed by the PI for the Galileo Project - organized special issue of Space Science Reviews. A revised draft of the NFR instrument paper was submitted for the special issue and accepted after minor revisions. The accepted version of the paper was distributed to interested Galileo Project and NFR personnel.

At Galileo Project request, a line drawing and a photograph of the NFR were prepared for Galileo project files for use as presentation materials. We also prepared a list of candidates for group achievement awards.

1991 At the recommendation of the Galileo Probe Project Manager the PI did not attend any of the PSG meetings during 1991. NFR concerns were communicated to the Probe Scientist instead.

We participated in a June 20, 1991 meeting at Wisconsin with B. Chin and C. Jackson of ARC to discuss Project status, grant tasks, and in-flight checkout plans. We presented a progress report on all tasks, with special emphasis on calibration activities and new measurement requirements. We also discussed the need for additional support to meet task objectives.

Preparations were made for a talk by Bill O'Neil at our local Meteorology and Space Science Colloquium; but the talk had to be canceled because of Galileo Project problems. We repeated preparations for a 9 December 91 talk which did take place.

We obtained a video tape of the Galileo Pre-Launch press briefing and sent it to B. Chin for copying and distribution.

1992-3 On 30 October 1992 we hosted a talk by Bill O'Neil at the University of Wisconsin Space Science and Engineering Center.

The PI (LAS) and P.M. Fry attended the November 1992 Probe PI meeting at JPL and supported the 20 November 1992 in-flight checkout, which was a full Mission Sequence Test (MST), the first since launch. Preliminary analysis conducted as the data were being received at JPL indicated nominal NFR performance.

We also supported local press coverage of events associated with the Earth II encounter and our involvement with the mission.

The PI did not attend the 15 December PSG meeting. In support of that meeting a summary of our preliminary MST analysis was prepared and communicated to the Probe Project Manager and the Probe Project Scientist on 8 December 1992.

On 23 April 1993 we hosted another talk by Bill O'Neil at the University of Wisconsin Space Science and Engineering Center.

Participation in In-Flight Checkouts

1990 Data from the first two in-flight checkouts (26 October 1989 and 4 December 1990) were analyzed and instrument performance was evaluated. Two NFR status reports (January 1990 and December 1990) were communicated to B. Chin, Galileo Probe Manager, and R. Young, Galileo Probe Scientist.

Proper evaluation of in-flight checkout data required us to compensate for instrument spectral response changes with temperature. This was done indirectly by comparing instrument calibrations using external sources with internal instrument calibrations over a wide range of instrument temperatures and using the temperature dependent ratio between them to compensate for instrument source spectral changes following launch.

We also compiled an updated set of temperature conversion coefficients for use with the NFR flight configuration (which is a hybrid of SNO2R electronics and SN01R optical head). These were transmitted to the Probe project for implementation in ground support software.

1991 Software was written to read and analyze Galileo data tapes. This is most useful for descent sequence tests because of the relatively large quantity of data generated. We obtained checkout data on 9-track tapes for checkouts 1 and 2. The data tapes were processed to verify ingest and analysis software routines.

1992-3 The November 1992 MST (Mission Sequence Test) was supported on site as noted above. A preliminary assessment was provided at JPL during the day of the test. A more quantitative preliminary analysis was submitted on 8 December 1992. A final analysis of the MST, accounting for all of the data and making use of revised spectral response functions, was described in a detailed report submitted on 24 June 1993 (Fry and Sromovsky 1993).

Maintenance and Safekeeping of Spare Instrument.

1990 The instrument remained in its sealed container during this year.

A revised test procedure was written for annual bench tests of the spare instrument.

A large number of boxes of spare parts and miscellaneous NFR materials and equipment were received from Martin Marietta. Most of this material was turned over to stock or surplus. A small fraction of it was deemed potentially useful to the NFR project and is being stored. This includes spare filters which we used for characterizing the temperature dependence of the NFR spectral response, a spare preamp, and condenser cone samples that might also be tested.

1991 The revised bench test procedure was sent to Ames for an informal review.

The instrument also remained in its sealed container during this year. Because of the Galileo high-gain antenna deployment problems and resulting delay in the next in-flight checkout we opted to defer the functional test of the spare instrument.

1992-3 We performed bench test on the NFR spare instrument. The results were essentially as expected. A full analysis of the test is being prepared now and will be completed during the current grant period.

Organization and Maintenance of NFR Documentation.

1990 A database was established to document instrument testing which occurred on flight and spare instruments. Both calibration and diagnostic test information is now included in the database.

We completed and submitted our final report on the NFR hardware development (Sromovsky and Best 1990), an important component of NFR documentation.

1991 Results of tests to determine temperature dependence of the filter spectral responses were added to the data base.

1992-3 Results of the MST, results of the spare instrument bench test, and results of tests to determine temperature dependence of the detector spectral response were added to the data base.

Progress on Completion of NFR Calibration (Task Group B):

Reference Detector Calibration

1990 Two of the three reference detectors used in NFR spectral response calibration remained uncalibrated. Uncertainties in the calibration of the third detector caused reevaluation of our plans to procure detector calibrations from outside vendors.

1991 We developed a plan to use filters and standard sources to revise (on a low resolution basis) the spectral response of our most extensively calibrated reference detector, then run high resolution intercomparison tests between that detector and the other two detectors, as well as make independent low resolution spectral response checks of the other two detectors, to establish their calibrations.

1992-3 We surveyed several vendors and selected tentative lists of filters. The main problem we encountered was procurement of long-wavelength filters (beyond 10-15 μm). Very few stock filters are available in this range and custom filters are prohibitively expensive. An alternative approach in the long-wavelength region is to use low-cost diamond dust cut-on filters in combination with natural cutoffs of various IR optical materials to form the equivalent of a broad band-pass filter. (This is the same approach we plan to follow to establish the extreme long wave response of the NFR.) To further this analysis we have procured a computer program called OPTIMATR which is capable of computing absorption and refractive index characteristics of a wide range of optical materials. We are using this to help select materials and thicknesses to cover the spectral range needed.

Locating a suitable vendor for providing spectral transmission measurements has been a problem. Long wavelengths and the handling of diamond dust filters are the main issues. OCLI of Santa Rosa can make transmittance measurements out to 50 μm, as can OCA (Optical Corporation of America (OCA). Neither OCLI nor OCA was familiar with the diamond dust filters. OCLI may be able to do scans of diamond dust filters, but they expressed some concern regarding scattered light contaminating results (we are awaiting their technical evaluation of this concern). OCA was concerned that the polyethylene substrate of the diamond dust filters might be damaged by the hot sources of the spectrometer. Optical Filter Corp. (OFC) has yet to reply with details regarding spectral range and pricing. IR Labs may be able to offer suggestions regarding test configurations for transmittance measurements for the diamond dust filters.

Although 50 μm is more than adequate for calibrating the reference detectors, we would like to have scans out to 150-200 μm for some of the pieces that would be used in measuring the extreme long wavelength response of the NFR. We are now planning on making these measurements ourselves, using borrowed equipment (see later discussion).

We also reviewed the current spectral response calibration of our reference detector (Barnes Model T-300) with the following results: (1) the longwave falloff described by our working standard reference detector spectral response curve agrees very well with the falloff expected from the KBR window (when scaled by a factor of 0.93); (2) since the standard curve uncertainty is very noisy between 30 and 40 microns, and unknown beyond 40 microns, we replaced the detector response function from 26 microns to 46 microns with 0.93 times the window transmission (for thorium fluoride coated KBR, as provided by Barnes engineering).

Calibration of Extreme Long-Wave Spectral Response

1990 We evaluated plans for measuring the NFR spectral response at wavelengths beyond the 30 μm covered by reference detector comparisons (important for channels A and D). It appears that the most practical approach is to measure the spare NFR response to known sources filtered with well characterized bandpass filters (or equivalent). However, due to relatively poor signal to noise ratios at long wavelengths, we also considered component level measurements at these wavelengths. We have spare detectors, and some spare filters that would be relevant to this investigation. No definitive action was taken during the first year.

1991 The need for long wavelength bandpass filters, but the prohibitive cost of interference filters, forced us to consider combinations of diamond-dust long-pass filters with natural bulk absorption low-pass filters. Three diamond dust filters were procured from Infrared Laboratories, Inc. of Tucson, Arizona. These used powder sizes of 5-10 μm, 15-25 μm, and 30-40 μm. Although we requested spectral scans for all filters, we only received a partial scan of the 5-10 μm filter (the scan did not cover wavelengths beyond 40 μm). We were informed by IR Labs that their current spectrometer could not scan beyond 40 μm, but that they were procuring a Bruker spectrometer that will do cold scans out to 300 μm. IR labs offered to provide the desired scans during 1992, after delivery of their new spectrometer. These filters will be used with absolute blackbody sources to characterize the extreme long wave response of the NFR.

1992-3 IR labs was unable to provide the desired scans of their diamond dust filters during 1992 or 1993. They still do not have their new spectrometer set up for doing the desired transmission measurements. As an alternative, Peter Smith at the University of Arizona has made contact with Erick Young at Steward Observatory, who has a far IR FT interferometer that he is willing to let us use. The instrument is sensitive from 12 to 1000 microns and Young can provide a bolometer, although the detector has not been used for more than 6 months and will need to be checked out. Some reductions will have to be performed on the data to remove interference effects from the mylar beamsplitter. We are planning a week-long trip to Arizona to carry out the transmission measurements.

Calibration of Spectral Response as a Function of Temperature

The apparent temperature dependence of NFR responsivity varies from channel to channel as indicated in ***Figure 1****. These dependence curves are a function of the spectral content of the reference radiation source (especially B and E) and vary from filter to filter (compare A and C). Because both the NFR temperature and the spectral content of radiation measured during descent change with altitude, it is very important to establish in detail how the NFR spectral response depends on temperature. Because there will be a temperature gradient within the optical head during descent it is also important to establish which optical elements are individually responsible; otherwise proper corrections of descent data will not be possible.*

1990 We began our attempt to isolate the source of the temperature dependence of the spectral response of the integrated NFR instrument. Although detectors, mirrors, and the diamond window were potential contributors, spectral filters were the prime suspects, and were thus the first to be investigated. A mini environmental test chamber was needed to facilitate measurement of the *spectral response of NFR filters as a function of temperature.* The mini chamber was designed to accommodate the very small spare filters (1 mm x 2 mm) and provide thermal control of the filter in an inert gas or vacuum environment, while the filter spectral transmission was measured with our monochromator system. Software was developed to control the monochromator in concert with data readout from the lock-in amplifier we are using to record detector response (this replaced the NFR electronics/GSE system that we used during instrument spectral response measurements).

1991 The mini chamber components were installed and preliminary thermal tests were conducted. A considerable effort was made to debug thermal problems so that we could attain the desired temperature control range. After modifying the chamber to improve thermal couplings, we worked out alignment and test procedures, and carried out preliminary measurements on NFR filters.

We measured transmissions for filters B, E, and D at temperatures of -40, -10, 23, and 50°C. The largest temperature effect was found for the channel D filter, as illustrated in **Figure 2.** Only slight changes in spectral response were found in other channels, which initially raised questions about the validity of the tests. To verify that the filters actually changed temperature in accord with the temperature readouts we verified that measured temperature-dependent shift of the cut-on wavelength of the channel E filter actually moved in accord with documented characteristics of this cut-on (Kopp 1986). We also investigated the possibility that temperature dependent changes were occurring outside the primary passbands of the filters. We used long-wavelength pass filters with various cut-ons to show that there were no spectral leaks in the channel E filter within the range from 6 μm to around 40 μm. We also investigated the transmission of a

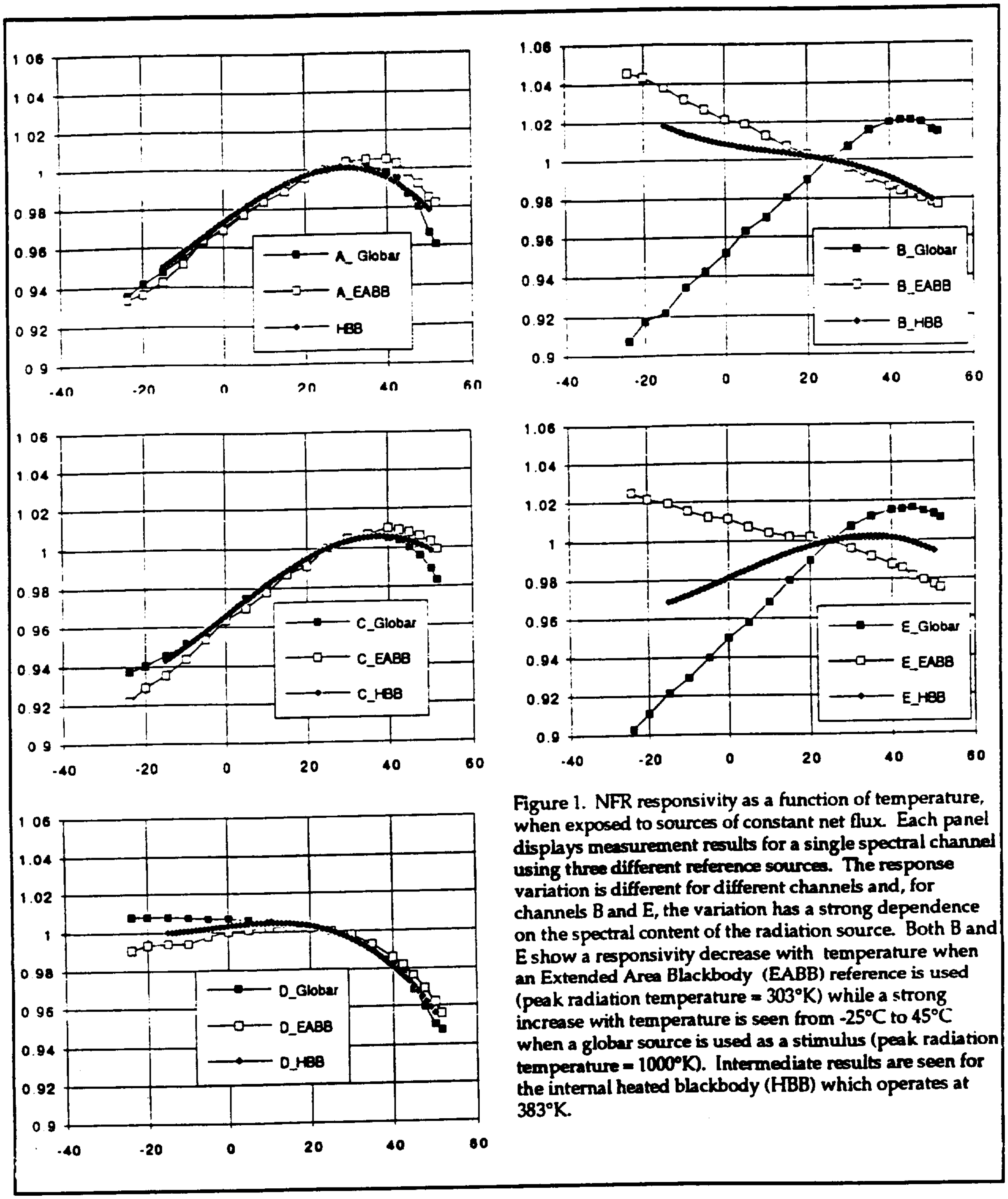

Figure 1. NFR responsivity as a function of temperature, when exposed to sources of constant net flux. Each panel displays measurement results for a single spectral channel using three different reference sources. The response variation is different for different channels and, for channels B and E, the variation has a strong dependence on the spectral content of the radiation source. Both B and E show a responsivity decrease with temperature when an Extended Area Blackbody (EABB) reference is used (peak radiation temperature = 303°K) while a strong increase with temperature is seen from -25°C to 45°C when a globar source is used as a stimulus (peak radiation temperature = 1000°K). Intermediate results are seen for the internal heated blackbody (HBB) which operates at 383°K.

thin diamond, similar to the common NFR diamond window. The diamond window showed no significant temperature dependent spectral transmission properties. These transmission measurements thus did not themselves lead to an obvious explanation of the source-spectrum variations and filter-to-filter variations in response versus temperature. We suspected that a significant role might be played by the detector, or, less likely, by the condenser cone or mirrors.

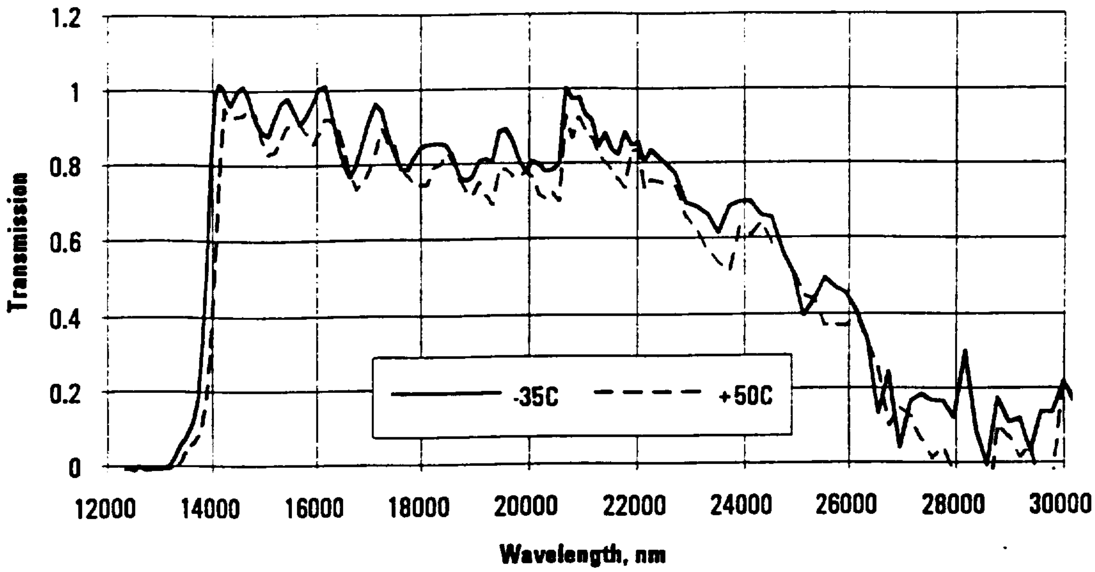

Figure 2. Effect of temperature on Channel D spare filter spectral response. The dashed line is for -35°C, the solid line for +40°C.

1992-3 During this period we began the task of measuring the *temperature dependence of the relative spectral response of the detectors*. We designed new fixtures for our miniature environmental test chamber to accommodate a spare detector assembly. This assembly was mounted on a newly designed preamp board which was also mounted within the test chamber. This chamber allowed thermal control of the detector while it is exposed to a known radiation source of controllable spectral content; it also provide a proper detector environment for ambient measurements of relative spectral response as a function of wavelength. Our existing monochromator is a useful source of a stable spectral content which can be used to explore the temperature dependence of the detectors, although the results only provide relative changes with temperature. By repeating spectral input scans at different detector temperatures, we are able to establish the ratio of detector response at T to the response at ambient. This identifies the spectral character of the temperature variation of spectral response without actually establishing the spectral response itself. The "absolute" spectral response, i.e. the relative response as a function of wavelength at a fixed detector temperature must be defined using the filter and absolute blackbody source method described elsewhere.

Our preliminary measurements of detector spectral response as a function of wavelength using this new test fixture produced two important results: (1) the detector response at a fixed wavelength is a nearly linear function of temperature from -40°C through +50°C, quite unlike the characteristic form of the NFR temperature dependence curve which shows a roll off and actual decrease near the end of this range (**Figure** 3.); (2) the temperature dependence of detector response is essentially independent of wavelength (**Figure 4**). Although detector-to-detector variations and other details remain to be resolved, it is quite clear that the temperature dependent spectral response characteristic of the integrated NFR instrument does not arise from the detectors and that there is a response falloff at high temperatures which is due neither to filters nor to detectors.

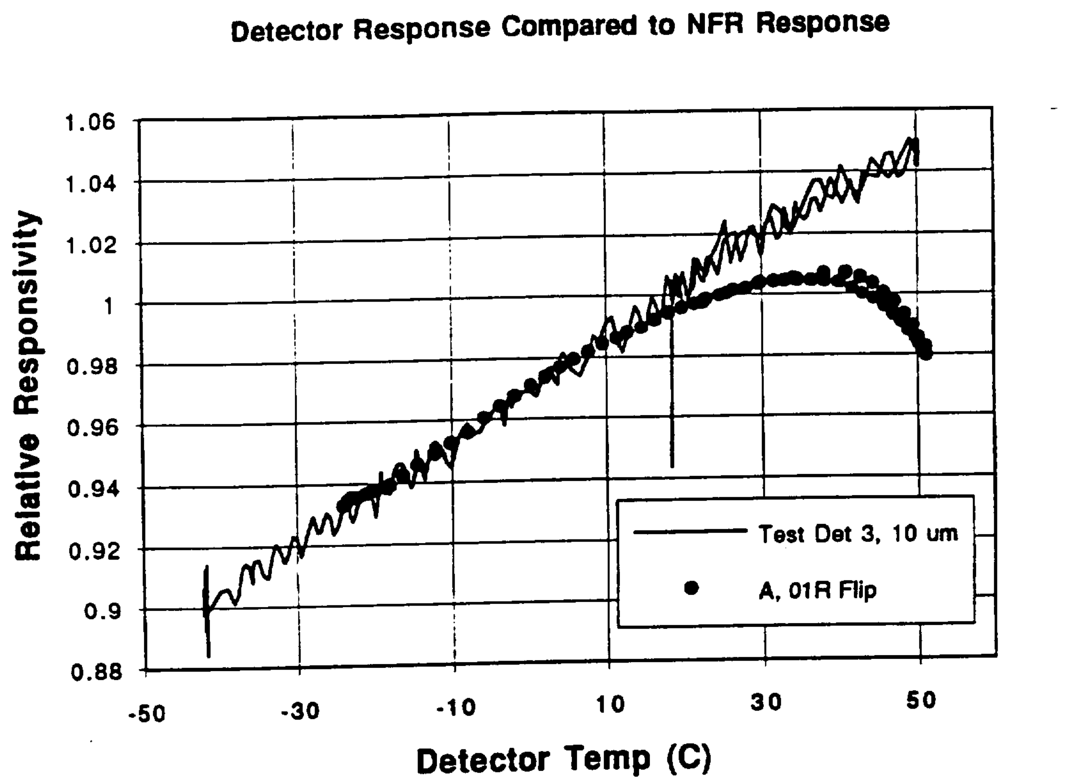

Figure 3. Response versus temperature for the NFR instrument (channel A), compared to that of a spare detector. The rolloff above 40°C seen in the instrument curve is not due to filter effects and has an unknown origin.

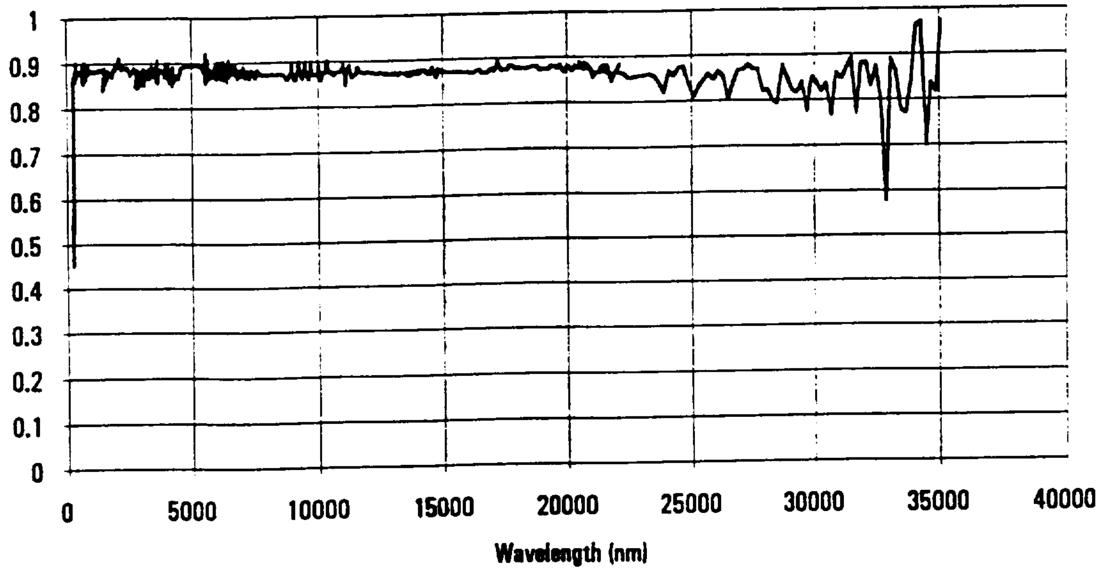

Figure 4. Spectral variation in the effect of temperature on spare detector responsivity. The plotted ratio of response at -40°C to that at +40°C is essentially independent of wavelength.

Recent analysis has resulted in an approximate explanation of the spectral variations in temperature dependence. We developed a FORTRAN computer program to integrate the Planck function over the NFR filter function, accounting for both source temperature and detector temperature. With the help of this program, called SEESR, we were able to estimate relative signal levels incident on each detector for each source configuration: a source temperature of 80°C (EABB), (2) a source temperature of 109°C (HBB), and (3) a source temperature of 1000°K (Globar). These signal levels were also computed as a function of filter temperature, using spectral response curves interpolated from measured filter data. We also computed crosstalk signals for channels B and E, based on coupling coefficients measured during the flight optical head calibration. Comparing the direct signals expected from B and E with the crosstalk signals these channels would experience, we found that crosstalk signals were comparable to the direct signals during HBB and EABB calibrations. Thus it is possible in an approximate way to explain the unusual behavior of the responsivity curves of these channels as an effect of crosstalk. A model in which response to crosstalk decreases by 17% from -40°C to +25°C, while response to direct signals increases by 10%, does a fair job of reproducing both variations due to EABB and HBB source differences, and B to E differences in response to

HBB measurements (**Figure 5.**). The channel E response to EABB measurements is not as well modeled, but this may be a result of errors in coupling coefficients or in the flux calculations. In spite of this discrepancy in channel E the case for crosstalk explaining most of the anomalous response effects in channels B and E is very strong. We do not understand why crosstalk signals should decrease with temperature. Because gas conductivity increases with temperature one might expect crosstalk to increase with temperature. However, if the thermal coupling is through the visilox detector substrate rather than via gas conduction, the temperature dependence might go the other way.

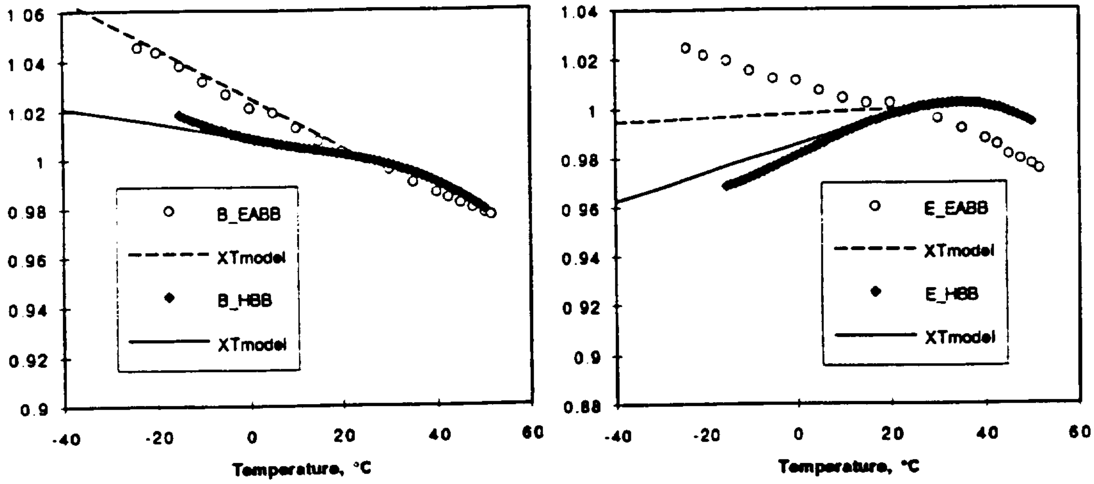

Figure 5. Models of Channel B and E responsivity variations based on crosstalk signals decreasing with temperature by 17% from -40°C to +25°C. Coupling coefficients in the model were obtained from SNO1R2 calibration data. Models are plotted as straight lines, measurements as points.

Using SEESR, we can also explain the essential difference between Channel D and Channel A responsivity curves. Computing the Channel D inband fluxes as a function of detector temperature for Globar and EABB sources, then multiplying that curve by Channel A response function (which represents the "gray" detector responsivity curve) we obtain a set of responsivity vs. temperature curves for Channel D which match the measured curves reasonably well (as shown in **Figure 6**). There are several unresolved issues concerning this model. First, as documented in **Figure 2**, our measurements of detector responsivity in isolation do not match the "gray" response curve. The rolloff beyond 40°C appears to be a spectrally independent effect and its origin is probably physically close to the detector because of its transient characteristics.

It remains to be determined whether the preamp board could produce such effects. A second unresolved issue is whether the spare D filter we measured is of the same type as used in the NFR instrument (see discussion in the following section).

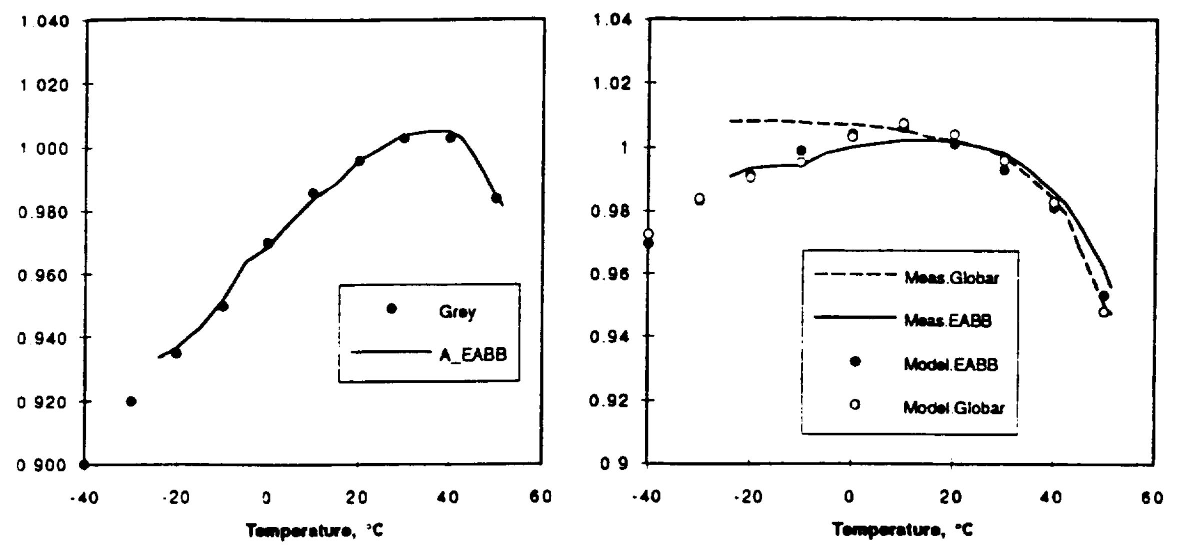

Figure 6. Models of Channel D responsivity variations with temperature, assuming an effective non-spectral (grey) response function shown on the left (which matches channel A response) to simulate detector response, and the measured spare channel D spectral transmission versus temperature. The models (points) for the two source spectra agree approximately with the observations (solid and dashed curves).

Calibration Data Analysis

1991 A gain transfer problem was identified as a result of analysis of in-flight checkout data. Prior to launch we thought that electronics gain measurements with the GSE (Ground Support Equipment) for both SN01R and SN02R electronics would provide the data needed to adjust for gain differences between the electronics used for calibration and the electronics used for flight. However, we now know that the ESU (Electronics Stimulus Unit) test is not an adequate measure of electronics gain because it fails to account for instrument-to-instrument variations in input resistor divider ratios resulting from the use of low-precision resistors in the instruments. Because these resistors were never measured it is not possible to transfer calibrations of the flight optical head using the spare electronics to the flight electronics to any better than 1-2%. However, we believe that this is not a serious problem because an adequate estimate of the in-flight gain can be obtained from internal hot blackbody calibrations.

1992-3 To improve the accuracy of our in-flight checkout analysis we developed new spectral response functions for channels A, C, and D. This was done in spite of incomplete reference detector calibrations using some new techniques which are described below. Spare filter elements were spectrally scanned using our monochromator and mini-vacuum chamber setup. We also made use of OCLI test data where available. We made use of SNO1R, SNO1R2, and SNO2R2 spectral response data to separate filter from detector effects (the SN01R2 and SNO2R2 optical heads used IR Associates detectors, while the SN01R optical head used Barnes detectors). We also reviewed grating change discontinuity adjustments and made some changes and also discovered a few procedural errors which resulted in slightly late change of order-sorting filters, invalidating a few of the data points. The revised spectral response functions, in comparison with previous functions, are shown in **Figure 7**, and discussed below.

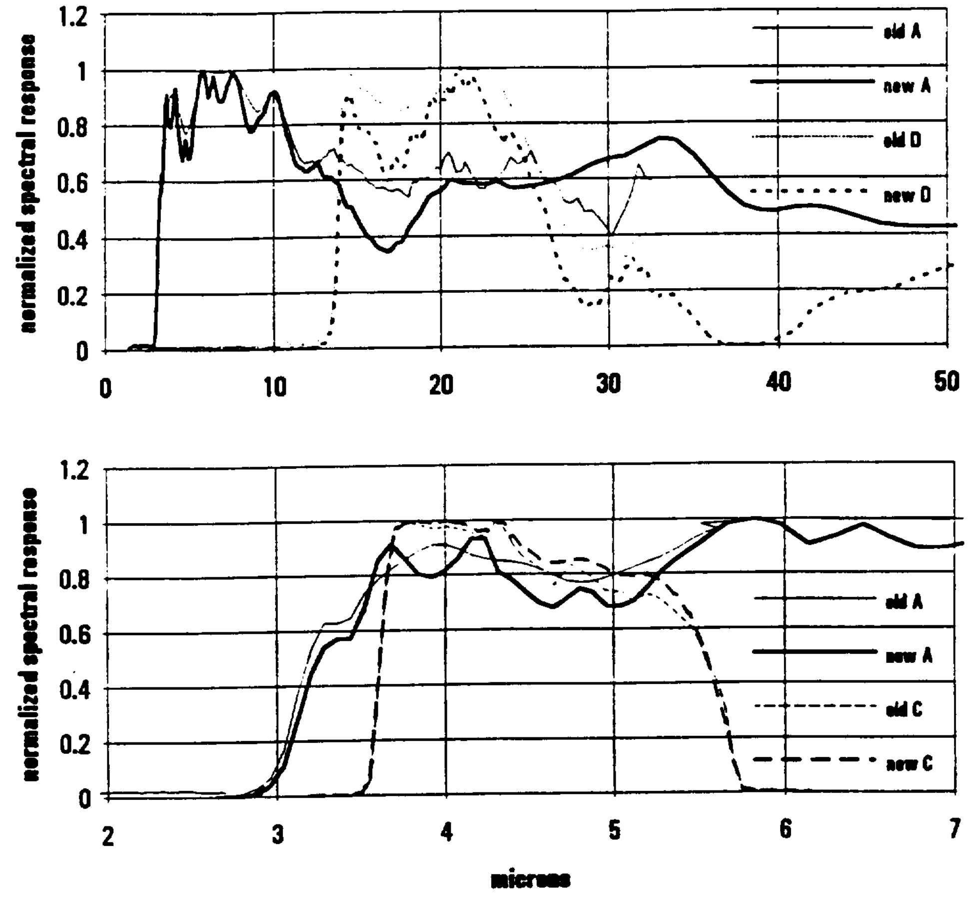

Figure 7. Revised NFR spectral response curves (heavy lines) compared to previous spectral response curves (light lines).

For channel A, our coordinated analysis of spectral response data yielded the following results: (1) channel A filter measurements obtained from OCLI agree with our own measurements of a spare filter, with both showing substantial channel spectra that are not present in measurements of the integrated instrument (this may be due to wider range of angles passing from the condenser cone through the filter); (2) our previous response function for channel A (see **Figure** 7) was too heavily smoothed and thus missed significant response variations in the 3-9 micron range; (3) channel A filter scans were found to be in good agreement with SN01R2 spectral response measurements (out to the 35 μm limit) except for a relatively low response near 5 μm (due to extra absorption in the NFR diamond window) and an even larger drop between 12 and 21 μm (believed to be a detector response feature); (4) SNO1R2 and SN02R2 spectral scans for channel A are in excellent agreement in the 3-5 μm range, but deviate by as much as 15-20% in the 12-25 μm range (a possible result of the different reference detectors used as discussed later); (5) we settled on a revised spectral response curve that uses our SN01R2 response curve from 2.7-25 μm and the OCLI scan (smoothed over channeling oscillations) from 25-50 μm, and setting the response to a constant value beyond 50 μm. In this discussion the NFR spectral response results refer to the ratio of NFR counts to reference detector counts for either DTGS T-300 (a reference detector that has been extensively characterized) or DTGS II (an uncharacterized detector of the same design), divided by the standard spectral response curve for DTGS T-300. During SN01R2 calibration the DTGS II detector was used, while the SN01R and SN02R2 calibrations used the DTGS T-300 detector.

For Channel C we obtained the following results: (1) erratic channel C response measurements in the 4-4.5 μm range were a result of small wavelength differences between instrument and reference scans in combination with very sharp and strong atmospheric absorption due to CO_2 (confirmed by LOTRAN calculations for laboratory path lengths); (2) a comparison of C/A ratios shows that the 3.5 μm cut on is 0.06 μm to the right, and the perturbation near 4.3 μm is much reduced for the ISR (Intermediate wavelength Spectral Response) test relative to the LSR (Long wavelength Spectral Response) test, presumably a result of the smaller slits used in the former; (3) our own measurements of a spare filter (Martin designation C-2-H) compared very well with an archive scan (for filter designated OCLI W04578-4) suggesting that there was only one type of filter used for channel and that the more accurate archive scan can be used to establish a better response curve for channel C; (4) we determined an improved spectral response for channel C using the archived scan of the filter multiplied by a diamond transmission spectrum $\tau_d(\lambda)^f$, where $f \approx 0.5$ was adjusted to provide a best match to the measured SN01R spectrum outside the 4.3 μm CO_2 perturbation.

For channel D our revised analysis obtained the following results: (1) the channel D spectral response curves for SNO1R2 and SNO2R2 both show the 15-20 μm dip seen in channel A scans (the dip is not seen in D/A ratios and is much smaller in SN01R scans, clearly implicating the IRA detectors); (2) the D/A ratios for SNO1R2 (flight) and SNO2R2 look very much alike and also like scans of the "spare" channel D filter (Martin designation D-2-Q) up to 22 μm, but the D/A ratios clearly do not reach zero at 28 μm as the filter scan does, implying that the "spare" filter is not the same type used in the instruments; (3) the channel D response for $\lambda < 13$ μm is about 10^{-3} down from the in-band response, which is consistent with the level of crosstalk expected from channel A; (4) based on documentation of a transmission scan for a similar filter, we believe that channel D has a long wave leak, characteristic of the Ge substrate, with a peak transmission of about 38% at about 60 μm; (5) a revised spectral response curve was obtained from the average of the measured D/A ratios of SN01R2 and SN02R2, with a long wave leak appended, then multiplied by the spectral response of channel A and normalized. We also contacted Max Lowenstein of ARC, who was involved in the original procurement of NFR filters, in an attempt to locate records of channel D filter scans, but were unable to obtain any additional documentation. We did find in our own local search a partial scan of a filter designated L13620-9, which agreed very well with our measurements of the spare D filter.

Characterization of Anomalous Effects (Task Group C)

1990 These tasks were deferred.

1991 These tasks were deferred. We had planned to carry out a circuit analysis to determine plausible sources of the Analog Zero offset anomalies so that guided tests could be conducted, but the individual who was to carry out that analysis was so heavily committed to other projects of greater urgency that he could not complete the analysis.

1992-3 A new anomaly was added to the list. The NFR temperature dependence of responsivity is anomalous in the sense that neither the detectors nor the filters can explain the falloff from linear response as temperatures approach 50°C. Remaining tasks originally proposed in this group, primarily characterization of aerodynamic perturbations and Analog Zero offsets were deferred again.

Science Data Analysis Support (Task Group D):

Signal Processing Algorithm Development

1990-1 Algorithm development was deferred.

1992-3 An algorithm to compute the temperature dependent spectral response of NFR filters was developed from the filter test data (this was implemented in the SEESR program metioned above). However, this algorithm only deals with that part of the temperature dependent spectral response arising from the filters. Most of effort has been deferred until the new grant period.

Atmospheric Modeling

1990-1 UW tasks deferred. Work was done by Martin Tomasko at the University of Arizona to model solar spectral radiation transfer. To improve the efficiency of his doubling and adding program he modified it to double only the difference between single scattered and multiply scattered radiation, thereby reducing the number of azimuthal terms that needed to be retained in the calculation. He also included the wavelength dependence of the NFR filters and set up the integration over the field of view of the NFR, but was then notified that his DISR instrument was selected for Cassini, and had to temporarily stop work on Galileo. Of $35K proposed, only $15K was spent at the University of Arizona.

1992-3 Most of the effort was deferred until new grant period.

Long-Term Behavior of the Detector Package Seal.

1990-1 The radiometric leak detection fixture has been refurbished to correct feed-through problems. It has passed leak tests and is now ready for use, except for a valve that needs to be replaced. The He saturation test set up procedure has been written, but the rest of the test procedure remains to be completed.

1992-3 The needed valve was ordered. Most of the effort was deferred until the new grant period.

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ACRONYMS

AFGL	Air Force Geophysical Laboratory
DISR	Descent Imager/Spectral Radiometer (Casssini Huygens Probe Instrument)
EABB	Extended Area BlackBody (external source used for calibration)
ESU	Electrical Stimulus Unit (ground support)
HBB	Hot BlackBody (internal NFR calibration reference target)
MST	Mission Sequence Test
NFR	Net Flux Radiometer
NOSC	Naval Ocean Systems Center (San Diego)
SN	Serial Number
SN01R	The NFR unit that was installed on the probe ready for launch in May of 1986. It was delivered to UW in December 1987 for verification of the planned NFR Calibration tests.
SN01R2	The NFR unit that was upgraded from SN01R in February 1989. The SN01R2 optical head is on the Probe in transit to Jupiter. The SN01R2 electronics are mated with the defective SN02R2 optical head and reside at UW.
SN02R	This unit is the design equivalent of the SN01R instrument. The SN02R unit was initially delivered to UW in August 1987 for verification of the planned NFR Characterization tests, then returned to Martin Marietta for upgrading to SN02R2.
SN02R2	The upgraded SN02R NFR unit. This unit was to be the flight unit and was delivered to UW for Characterization and Calibration testing on October 1988. The tests revealed a failed detector package seal. The defective SN02R2 unit was installed on the Probe in October of 1989. The SN01R2 optical head later replaced the defective SN02R2 optical head on the Probe. The flight configuration that is in transit to Jupiter is the SN02R2 electronics with the SN01R2 optical head.