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Carnarvon Trip Report — July/August 2005

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2006 January 25

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Abstract

The main aim of this trip was to get the station running again after the May floods by fitting a new rain detector and a new amplifier/V-F module for Mark V, and by trying out new detector modules in Jabba. A few other repair and maintenance tasks were also achieved.

Contents

1 Introduction

In May of 2005 the Carnarvon dome flooded — a very heavy storm hit when the rain detector wasn't working and the dome was open. Steve Hale and Ian Barnes visited soon after [1], and resurrected most of the systems but found that some aspects of the Mark V data-acquisition system, the rain detector, and the two front detectors of Jabba were faulty. Ian, Steve, and Brek Miller designed and built a new Mark V amplifier/V-F device and two new detectors for Jabba. The Mark V Photomultiplier Electronics Box (PMTEB) [2] and Jabba detectors [3], together with a replacement Lock-In Amplifier and rain detector were shipped to Carnarvon (some components were carried by Steve).

Roger was on site from July 25 to August 9. Steve arrived on July 28 and left August 9.

2 Diary

2005 July 25

Roger arrived by SkyWest at about 3.30 pm — nearly 3 hours late! Quick look at dome — seemed fine, “sleeping” with the Relay Box switched to Manual and powered off. Called Les Schultz just to let him know we were around.

2005 July 26

Checked rain detector — which always thought it was dry.

Bought ladder, finer soldering iron and spray bottle; ladder delivered by Mitre 10.

Got small, but apparently solar, signals from the Mark V amplifier and Lock-In.

Noticed that the mount slewing was uncontrolled — always driving fully to one limit or the other.

2005 July 27

Rewired the internal cable of the rain detector. Rain detector still faulty.

Found Dec servo inoperative because of broken wire at the Down limit switch. Re-soldered and servo behaved well.

2005 July 28

Steve arrived around 1pm.

Tried both new and old rain detectors in the system — wiring the new one into the connector block attached to the dome. Neither worked.

Brek reported that Mark V data were not getting through. Since the instrument appeared to be working well from the scope and meters on the 27th, it must be the V-F stage that isn’t working.

2005 July 29

Bench tested the rain detectors. Old didn’t work — new one did with external pull-up resistor, but it didn’t drive the module. Swapped the module’s input transistor in case it was faulty — no change. Realised the module was not compatible with the most recent version of output logic from Vaisala!

Quick check of new PMTEB — gave similar analogue signals to old module, but also has a 15 mV DC offset.

2005 July 30

Tried rain detector with pull-up resistor in module — didn’t work. Mocked the input circuit up on breadboard — and it worked! Finally concluded that the diagrams and notes on the connections used by the module are incorrect. Modified the wiring — rain detector worked! Moved pull-up into lower junction box so that the module responds to the MIL plug being removed by signalling “rain”.

Found polarity of final output of analogue stages of PMTEB was wrong. Need to reinstate an inverter stage, but chip has not been sent.

2005 July 31

Removed old amplifier and V-F modules and started to work in earnest on the new ones. Confirmed analogue signals from the new and old circuits are similar. Worked with no inverter stage, so jumped over the filter stage too to have the right polarity to count. Very low Sum count rate (just a few hundred Hertz). Got data sheets for ICs and considered mods to analogue gains and V-F sensitivity.

2005 August 1

Ordered INA105s from Farnell and a 1550-VA UPS from Auslec in Geraldton.

Increased sensitivity of Sum V-F converter by a factor of 20 — count rate responded as it should. Made a unity-gain inverter using an INA114 and connected filter stage. All fine — except the offsets were sizable fractions of the detected signal.

Installed the rain detector on the external boom. Confirmed operation.

2005 August 2

Tracked down faulty RA slewing to missing coupling between mount shaft and its encoder — the encoder was in a fixed position. Tried to repair but needed more work.

Modified an offset set up in the PMTEB to null the offset at the input to the Sum V-F converter. Set the "zero" to about 800 counts (600 of which comes from the gating system).

2005 August 3

Put RA encoder coupling back in after gluing it back into shape. Checked that the computer could point well enough for the coarse servo to pull in.

Worked on Mark V. After cleaning the front filter and optimising the oven power, the hot:cold increased from 8 to 15 and 50-kHz modulation was very clear at the end of the day. Not sure, but thought the Lock-In seemed to jump up and down in sensitivity.

Looked at Jabba to see how to fit new detectors. Steve wired one up in the evening.

2005 August 4

Spent most of day working on Jabba. Could not get thermal control of new detector. Output is saturated, but pulse rate only about 25 kHz.

The two detectors for the front cell in Jabba dropped to zero counts for no reason we could explain. Took quite a while testing around the V-F box in the instrument without finding anything wrong. When reconnected everything worked again!

Measured up the aft detector space and mounting to assist when making new designs.

Monitored successful automatic dawn and dusk operation. Leave on automatic from now on. Mark V seemed to work well.

2005 August 5

Ran on Mark V all day. One or two intensity/transmission steps. See if these recur on other days.

Steve replaced the weather sensor connector block.

Managed to cover the new detector well enough to check that it was sensitive to light. There was a 1 kHz oscillation; increased feedback capacitance in I-V converter. Output count tallied with expectation.

Called in to pay a courtesy visit at the Shire Office — no one relevant there. Left them my mobile number and our scheduled departure.

2005 August 6

Put the new detector into Jabba; it saturated, so we reduced the gain.

Checked Mark V for loose components. Tightened up the attachment nuts of the front beam covers and double-checked that the front filter was well-held.

Swapped the Lock-In amplifiers. The replacement from Birmingham needed to be set one lower on sensitivity — indicating the old one does have a problem. Set the output offset to ±2.499 V using a multimeter on the "Output" BNC.

Picked up the UPS and INA105s from Les. Put the UPS on charge.

Glued insulating foam back onto Mark V.

Checked operation of slew motor — fine.

2005 August 7

Ran on Mark V until the last hour or so.

Still have intensity/transmission steps — and there are smaller hints of problems in the Jabba traces too. Checked that the servo micrometers were fully locked.

Adjusted the Lock-In offset in zoo.conf file to make the ratio as close to zero as we could.

Tested the UPS — fine.

2005 August 8

Improvised an iris with tape to stop Mark V down from 50 mm to about 46 mm aperture to look for any effect on steps. Some indication at the end of the day that the steps in Mark V were smaller.

Checked rain detector — fine.

2005 August 9

Checked rain detector again — still working.

Noted electricity meter reading in bunker.

Left by SkyWest — 5 hours late!

3 Replacing the DRD 11 Rain Detector with a DRD 11A

This was a rather confusing and frustrating process not helped by our unfamiliarity with the Carnarvon weather module, the change to the output logic of the detector which Vaisala have made in revising models, and incorrect drawings and notes in the dome. Rather than spell out the gory details, here is a summary of how Carnarvon's rain detector is now configured, and some information which may help if Vaisala change yet again.

We annotated the manuals in Carnarvon both to indicate the changes we made and to correct mistakes in the allocations of wires.

3.1 Electronics

Carnarvon has now had three different models of Vaisala rain detectors (first a DPD 12 [4], then a DRD 11, and finally a DRD 11A [5]). For the convenience of the user, Vaisala change the nature of the output logic every time they change the detector design! Clive's original Carnarvon weather module requires zero volts at the input to its first OR gate to indicate “dry” and five volts for “wet”. This was exactly what the first detector in Carnarvon (the 12) did output (when connected with an external resistor as recommended by Vaisala). The 11 outputs the inverse logic levels, so a single FET inverter was put in front of the module’s first OR gate. The 11A has an open collector output, and the output floats when “dry” and conducts to ground when “wet”. With an external pull-up resistor, this behaves the same as the 11. Table 1 summarises this information and Figure 1 shows the circuit now in place.

Table 1: Rain Detector Output Logic

	Detector Dry	*Detector Wet*	*Comment*
OR Gate Input Requires:	0 V	5 V	
DPD 12 Output:	0 V	5 V	Works directly
DRD 11 Output:	5 V	0 V	Requires inversion
DRD 11 A Output:	Floating	Path to GND	Requires pull-up and inversion

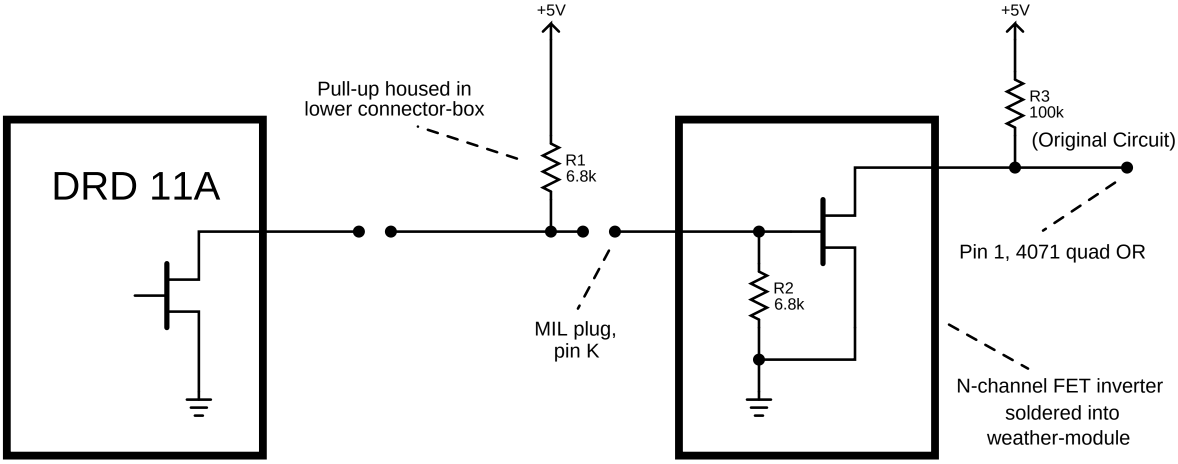

Figure 1: Weather Module Configuration

3.2 Wiring

Figure 2 summarises the wiring as we left it. As the diagram shows, there are two junction boxes for the weather cable. The first is a die-cast box about one metre along the cable from the MIL plug which connects into the Weather Module. The second is a new PCB connector block beside the dome aperture.

3.3 Mounting the Detector on the Boom

The physical structure of the DRD 11A is also different from that of the DRD 11. In particular the water-proof electrical connector protrudes further from the bottom of the detector and takes

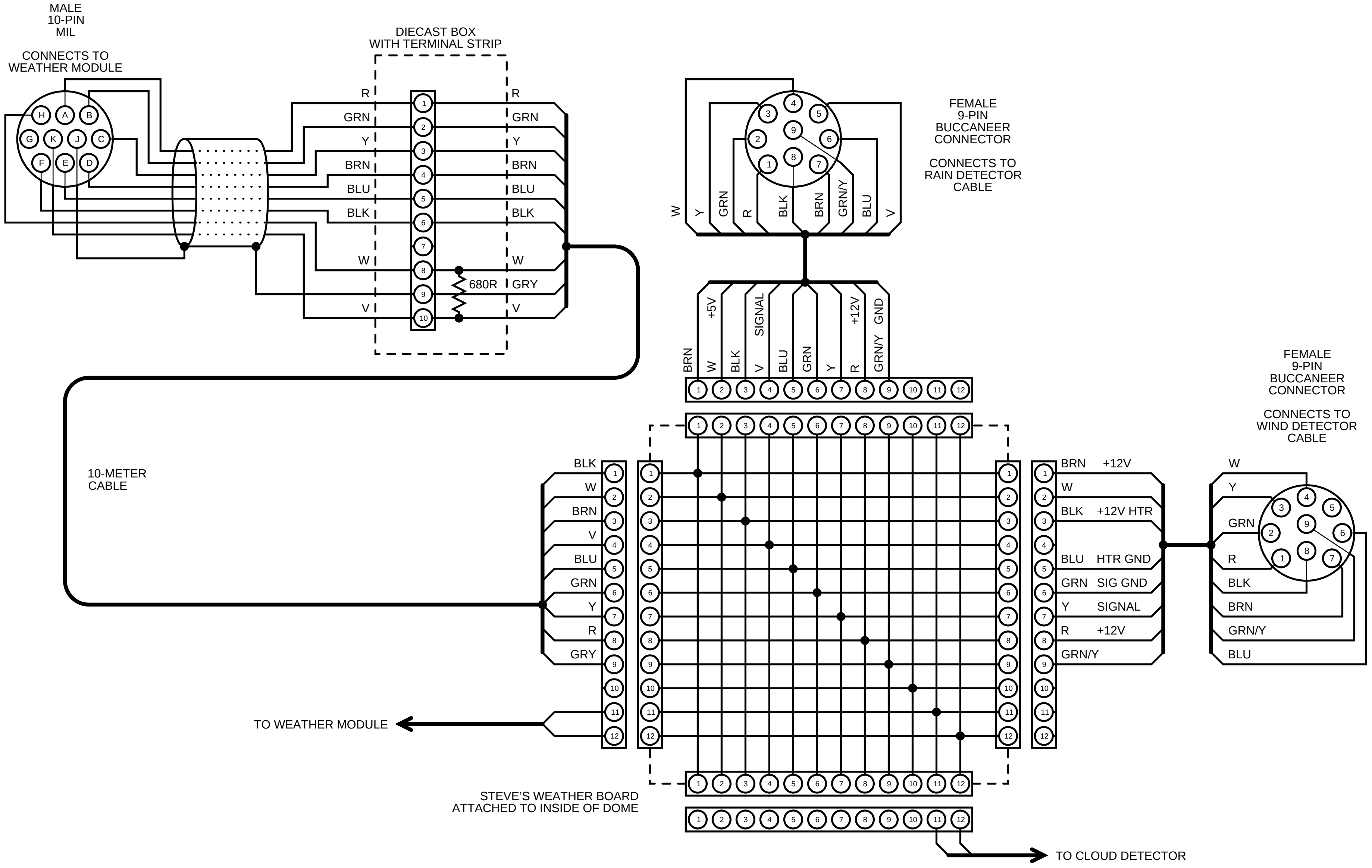

Figure 2: Weather sensor wiring. The two water-proof buccaneer connectors are meant to be connected in parallel so that you can interchange the rain and wind detectors. However, the violet wire on pin 4 needs to be disconnected from the wind detector, otherwise the rain detector stops working.

the form of a several-component feed-through and screw connector. In order to mount it, the feed-through of the DRD 11 had been cut down, allowing the head to sit almost flush to the boom and be held by a cable-tie. We did not want to cut through the feed-through on the DRD 11A for fear of losing the water seal, so it was necessary to stand the head off the boom to allow enough space for the whole feed-through assembly. We improvised two "legs" by butchering two nylon hose couplings and Aralditing them to the base of the rain-detector housing. We cut two slots in either side of the housing to allow a cable tie through both in front of and behind the detector. Figure 3 tries to show the principle — it is not to scale.

The detector was then attached to the boom by two cable ties. It passed repeated wetting tests.

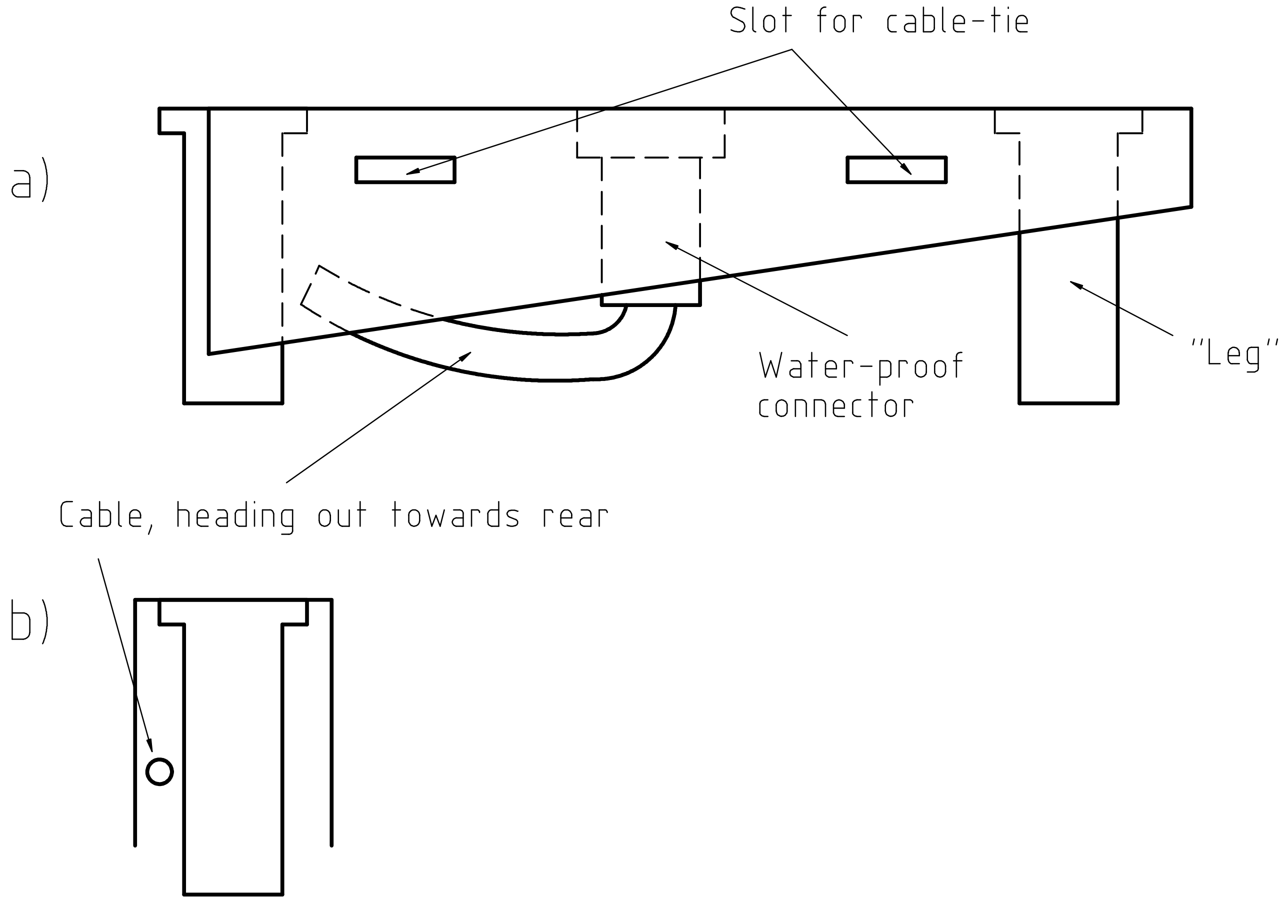

Figure 3: Rain-detector mount (a) side view and (b) rear view. In both drawings the rain-detector head has been omitted. It sits above the water-proof connector shown in (a). This drawing is not to scale.

4 Replacing Mark V Electronics with the PMTEB

The PMTEB is a single box which replaces the set of boxes previously used to I-V convert the instrument signals; integrate the photomultiplier signal to give a "Sum" output; and then V-F convert the "Difference", "Sum", and "Transmission" voltages. Due to the rush to get the trip under way, there was not time to fully bench-test the PMTEB before shipping it to Carnarvon, and a number of details had to be finalised on site. Rather than give all the details of the tests and the modifications made as a result, the following briefly summarises the state of the PMTEB as it was left, with one or two comments in explanation where necessary. The final circuit diagrams are in [2].

4.1 The Photomultiplier I-V Stage

The PMTEB was originally shipped with a 330-kΩ feedback resistor (the same as the old device). Even after optimising Mark V, this arrangement only gave about 50 mV output. We therefore increased the feedback resistor to 680 kΩ and dropped the parallel capacitor from 22 pF to 10 pF to maintain the same time-constant. The maximum output was found to be about 130 mV, and after inversion would be comfortably within the 500-mV input range we set for the V-F stage (see Section 4.3).

4.2 The Inverter Stage

The output of the I-V stage has two purposes. Its mean value represents the “Sum” signal. The amplitude of its 50-kHz component represents the “Difference”.

We have traditionally integrated the output of the I-V stage to generate the “Sum”, and the new PMTEB has an active filter capable of carrying out much the same role. This filter is, however, inverting. Since the output current of the “current-mode” (negatively biased) PMT is negative, the output of the I-V stage is a positive voltage. To be processed by our V-F stage, the signal must be positive after smoothing — but it will be inverted by the filter. There is therefore need for a further inversion stage. It is possible to configure the VFC32 to accept negative inputs, but the PMTEB adopts the approach of having an inverting stage straight after the I-V converter.

As shipped there was some uncertainty about the polarity of signals to expect, and the inverter had been “jumped” over and the chip intended to implement it (INA105) had not been sent. We used an INA114 to carry out the inversion (leaving pins 1 and 8 open circuit and grounding pins 3 and 5). The ground for pin 3 was permanent; pins 1, 5, and 8 were bent up. We bought five INA105s from Farnell; we left the INA114 in place, but it can simply be removed and replaced by an INA105 if ever needed.

The moral is — if in doubt, send the spares.

4.3 V-F Stage

The “Sum”, “Difference”, and “Transmission” V-Fs all worked straight away. The output from the “Sum” system was, however, very small. This was due to the V-F being configured for a 10-V full-scale input, when the “Sum” signal is only of the order of 100 mV. To increase the count rate, whilst keeping the other signals of recognisable sizes we increased the sensitivity of the V-F. This was achieved by dropping the input resistor to the VFC32 from 39 kΩ to 2 kΩ, decreasing the full-scale voltage to 500 mV. Due to scarcity of components, the 2-kΩ resistor was actually achieved by putting two 1-kΩ resistors in series.

4.4 Analogue Offsets

With no signal applied there were offsets of +5 mV, +3 mV, and −15 mV on the outputs of the I-V stage, the inverter, and the filter respectively. These are not insignificant compared with the "Sum" signal itself, and we wanted to reduce the offset at the input to the V-F stage as much as possible. Ideally these offsets would be lower by design or choice of components, but otherwise offset trims would be necessary.

An offset trim was designed for the inverter stage of the PMTEB, but didn't look like it would work without an additional resistor. Instead, we modified it to be able to null the offset presented to the V-F converter, needing to cancel the current driven to pin one of the VFC by the −15-mV offset voltage through the 2-kΩ input resistor. The resistor values we used were rather lower than we would have liked [2], but we had to source quite a large offset current (7.5 mA). With no input light we adjusted the "Sum" count to be about 200 above the digital offset (see the next Section). At odd times we found the dark count could fall to 600 counts. Since, however the background scattered light amounts to about 6000 counts (see Section 6), we did not feel it important to open up the PMTEB and increase the offset slightly.

Rather than simply duplicating the above in any new design, it would be better to see if the designs could be modified or higher specification chips could be used to reduce the intrinsic offsets, before considering how best to counter them.

4.5 Digital Offsets

With no input applied, the V-F converters all generate 600 counts in a "4-second" counting interval. This is because the V-F output "rests" high, and enables the scalers to count gate pulses. The remedy is to invert the output logic of the V-Fs before their respective line-drivers. While we could see how to achieve this with a FET inverter in each line, we fought shy of butchering the PMTEB further for a relatively small improvement. The correct output logic should be implemented in the next version.

4.6 Transmission Monitor

The Transmission Monitor saturated its V-F converter in its original specification. We blocked part of the input beam to get a feel for how excessive the gain was; we dropped the I-V resistor from 330 kΩ to 47 kΩ and increased the parallel capacitance from 22 pF to 150 pF.

5 Jabba Detectors

In their earlier trip, Steve and Ian found that the front detectors of Jabba were not working. They left the instrument working with the aft detectors moved to the forward cell and carried the old forward detectors back to Birmingham. Ian, Brek, and Steve designed a new detector circuit to house the detector, its cooling, and I-V and V-F conversion all on one board [3]. The aim was to test out these detectors and to see how much more room there might be in Jabba to allow a little more space in the very crowded detector boxes when future designs are drawn up.

5.1 Light Detection

By virtually blacking out the detector as originally configured (covering the diode with a black paper disc with the detector powered from a flying ±15-V supply), we were able to study its behaviour using the scope. We found that it was sensitive to light, but was prone to oscillate at about 1 kHz. We increased the parallel capacitance from 6.8 pF to 33 pF and the oscillation stopped.

In the instrument we found that with the original feedback resistor in the I-V stage the V-F converter saturated. We watched the counts from the (working) front cell as the mount pulled into servo control and compared the level with the counts from the new detector looking at the aft cell. We found that when the front cell had achieved only 1/20th of its full count level, the new detector saturated. To give us a little leeway, we dropped the new detector gain by 30×, using a 1.5-MΩ resistor in parallel with 1000 pF (two 2000-pF capacitors in series). The count rate peaked out at 105 k counts, about 10% below saturation — the aft cell seems to see more scattering than the front!

During a full day's observation on August 8, we noticed a number of apparent drop-outs of this detector. We did not have time to investigate.

5.2 Temperature Control

When first connected the detector heated quickly and we disconnected it when it reached 50°C. We found that the Peltier connections were the wrong way around. Although reversing the leads stopped the rapid runaway, the temperature controller did not function properly — the detector very slowly heated with the controller permanently indicating that balance was not achieved (the "balance" light was always on). We repositioned the sensor to try to give a better measurement of the diode can temperature — but this made no difference to the lack of temperature control.

We checked that the thermal runaway should not have damaged the Peltier (they should cope up to 85°C). We left one detector measuring the aft cell, but without temperature stabilisation, and brought the other back to the UK.

5.3 Mounting Space

The mounting brackets from the aft port position were removed and Steve carried them to Birmingham to help inform new designs. The aft starboard position is shown in Figure 4.

6 Mark V Performance

6.1 Hot:Cold Ratio

We looked at Mark V performance with a view to optimising it before we finally chose the gain resistor and V-F voltage range settings described in Sections 4.1 and 4.3. When we first

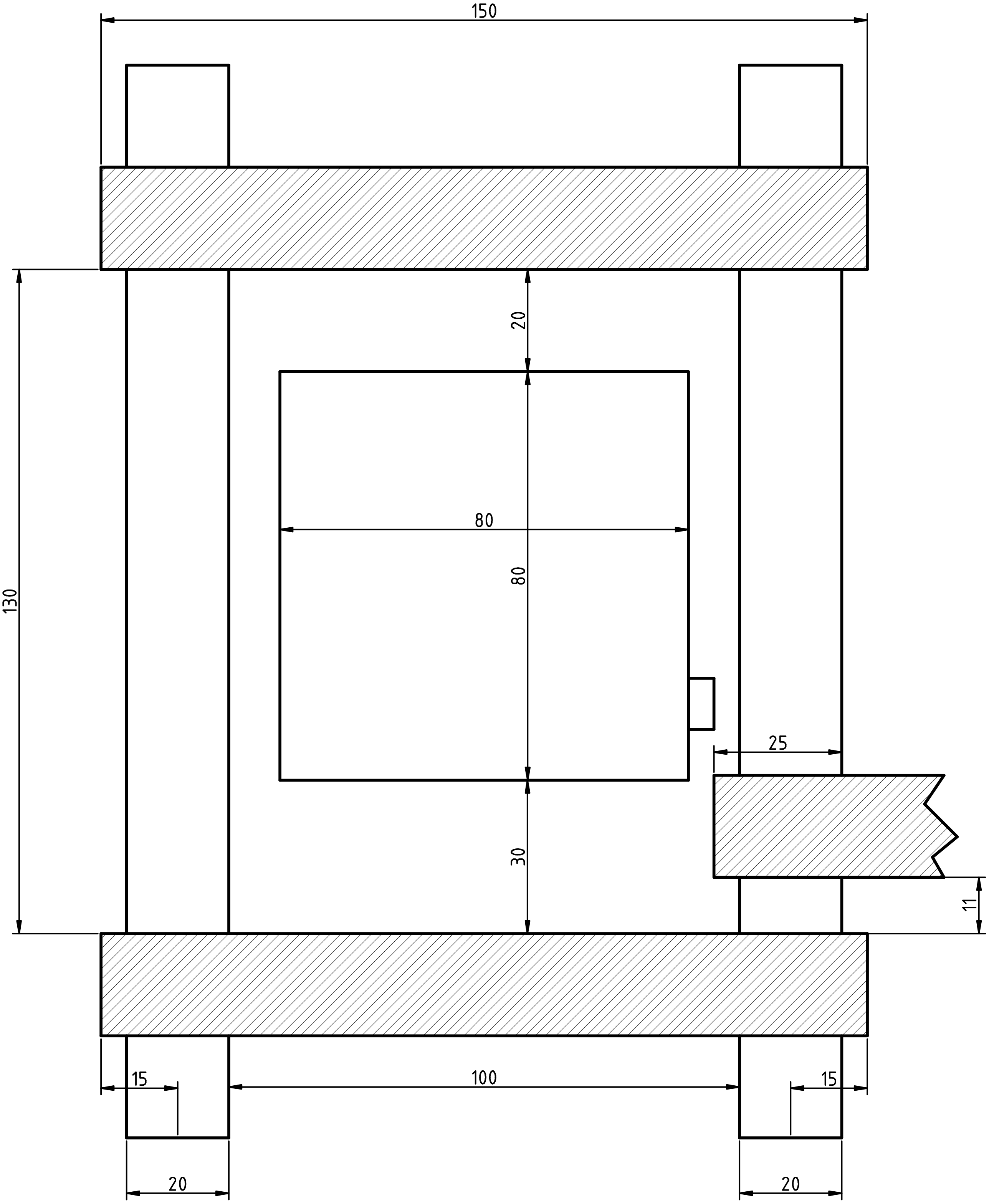

Figure 4: Jabba detector mount. All dimensions are in millimeters.

powered-off the oven to get an initial hot:cold ratio, the Sum counts went up strongly, reaching 43,600 from a start of 31,700, they then fell to give a "cold" count of 3,500. This implies that the oven was running too hot. In the end all we did was remove and clean the front filter (using running water, lens fluid, and alcohol) and optimise the oven voltage.

After cleaning the filter the cold count had dropped to 3,250, while the peak count went up to 38,500. Finally reducing the oven voltage from 12.36 V to 10 V increased the count to 53,500 and this was as close to the maximum as we could adjust the oven supply. The overall effect of cleaning and oven adjustment is to increase the hot:cold ratio from about 8 to 15.5. We did not make further adjustments.

6.2 Lock-In Settings

The three parameters required by zoo.conf were set to:

Lock-In offset:	2.50 V
V-F Gain:	20785 Hz V^{-1}
Gate setting:	3

All controls were set to their "arrowed" positions.

6.3 Steps in the Intensity Trace

On the few times when we ran for long periods we found that there were steps in the intensity trace. Typically there would be a step down sometime close to 2 pm and a step up after about one and a half hours. On August 6 we checked inside Mark V for loose components. All were firmly clamped, except for the beam covers at the front of the instrument, which had not been properly tightened when we accessed the front filter on August 3. We did tighten the covers this time and also double checked that the front filter was firmly held (by pressing a finger against a shadowed area of the filter and trying to slide it).

There were still steps in the data of August 7 — but we also noticed less dramatic ones had occurred in Jabba at about the same time. With no time left for a proper investigation of the servo, we checked that the micrometers were firmly clamped. To see if it is possible to easily remove the steps from Mark V, on August 8 we stopped down the aperture from 50 mm to about 46 mm by using black tape to make a poor man's iris. There was some indication that the steps were less severe and more like Jabba's.

It looks like the source of the steps is the fine guider, but their effect on Mark V might be reduced by stopping down the instrument a little. At present the front aperture is as drawn in Figure 5.

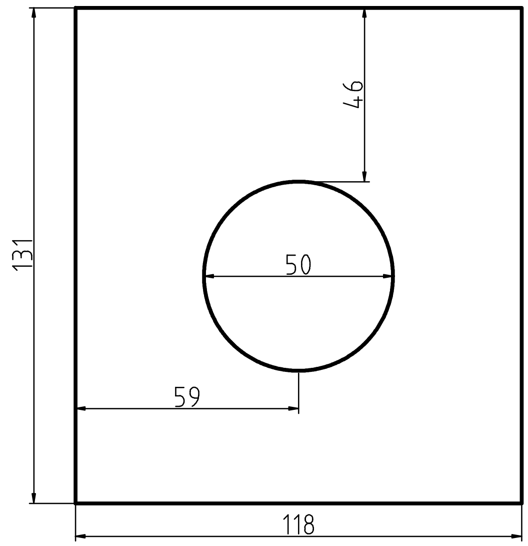

Figure 5: Mark-V front aperture. All dimensions are in millimeters.

7 Other Chores

7.1 Instrumentation

We moved the old oscilloscopes, Lock-In amplifier, and Mark V Amplifier and V-F boxes into the bunker. The new scope was very useful. We left it with one channel looking at the output of the Sum inverter, and the other at the reference from the PEM. Triggering off the reference, the scope shows the 50-kHz modulation on the PM signal later in the day.

7.2 Mount

The limits were behaving oddly when we arrived. Roger re-soldered the "Down" Dec limit switch, and Steve swapped over the definitions of the Up/Down and Left/Right limits in the software — they were the wrong way around.

The mount was clearly not under computer control in RA when we arrived. At each attempt to slew it would run to a limit. This turned out to be due to the loss of the coupling bush between the mount and encoder shafts. The encoder was very stiff when we tried to turn it by hand — we think that it had ceased and the rotation of the mount had distorted and pushed out the bush. We freed up the encoder with switch cleaner, and Araldited the bush into something like its original shape.

While this worked for the rest of our stay, the next visit should replace the encoder and coupling — and leave some spares.

The clutch did not always engage early in our stay — leaving the servo-motor to track the Sun and servo. Lubricating the clutch shaft freed it up and it worked for the rest of the stay.

We observed, but never got to the bottom of, the slew motor working well and driving the mount quickly from all positions and in either direction, during the day, but it appeared to be labouring at shut down. It did work and we couldn't track down anything obvious, so that's the way it was left. It would be sensible to introduce the ability to fall back to servo-motor driving in the software.

7.3 New Acquisitions

We are now the proud owners of a ladder (in the bunker) and a fine (but not very powerful) soldering iron.

We also bought a 1500-VA UPS. It is a Powerware 5125 Tower (*www.powerware.com*) made by:

Invensys Energy Systems Pty Ltd
119-127 Wick Road
North Ryde, NSW 2113
Australia
+61-2-9878-5000 (telephone)
+61-2-9887-2186 (fax)
1300-303-059 (repair in Australia)

Our stockist was (on the advice of Les):

Auslec
270 Place Road
Geraldton, WA 6530
Australia
+61-8-9921-2444 (telephone)

We charged it up for 24 hours. It was able to drive the shutter back from fully up (at least) twice.

If we want to, we can add up to four external battery packs to this unit.

8 Settings as We Left Them

8.1 Mark V

Lock-In Amplifier: Phase 3.7; Time Constant 1 ms; Smoothing Off; High Stab In; Zero offset +2.50 V (set using external meter); Low-pass filter max; High-pass filter 1 kHz; Sensitivity 1 mV; 5× expansion.

PEM-80 (modulator controller): Pk-pk retardation 500.

IF Temperature Controller 9.15.

8.2 Jabba

Detector Temps: Front Port 22.77°C, Front Starboard 23.17°C, Aft Port detector removed, Aft Starboard 34°C (not controlled).

Oven Temps: Front Top 119.44°C, Front Bottom 120.74°C, Aft Top −9.57°C (not connected?), Aft Bottom 120.11°C.

Pockels-cell driver 4.50 on the dial (uncalibrated).

9 Conclusions and Recommendations

9.1 Rain Detector

The DRD 11A worked well after the installation. It might be worth making a little BTR based on Section 3.1 of this report to have at all sites to help someone grappling with Vaisala's latest version.

We left the cloud detector operating. It was working well, cutting in for the first and last ten minutes or so of each day. Les can always be asked to switch it out, but we felt it was a useful back-stop for the rain detector.

9.2 Mark V and its Systems

We left Mark V in reasonable shape. The hot:cold is about 15:1 and the "steps" appear to be due to the guider. These might be reduced by stopping down the instrument. It would be worth bringing out 45-mm, 40-mm, and 35-mm apertures to help test this idea. (Or they could be shipped out and Les could try it out.)

The new PMTEB works quite well. If a new one is designed, it would be worth trying to select circuits/components with smaller intrinsic offsets. The V-F outputs should be inverted.

9.3 Jabba

The new detector systems need more bench testing to troubleshoot possible problems with temperature control and drop-outs, and also to make sure that our choice of time-constant was sensible. We did not clean the front filter of Jabba — to keep its count rate on the aft detector from saturating! It really should be done at the next visit.

9.4 Spares

There is a spare for each type of mount motor and we have a reasonable stock of and access to (via the stores in town) mechanical tools. The spares for common resistor values are getting thin and/or hopelessly scrambled. It would be sensible to re-stock with resistors and capacitors.

9.5 Software

The software worked reliably through the stay — with the exception of the detection of the mount limits mentioned in Section 7.2. It would greatly assist someone trying to optimise an instrument if a numerical and graphical running display of data was easily available, and if fitting and transform routines were available on site to aid quantitative judgments as to data quality. A one page BTR about how to run these would help.

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[2] IAN BARNES. Mark V photomultiplier electronics box (PMTEB). *BISON Technical Report Series,* Number 258, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, November 2005.

[3] IAN BARNES. The Jabba detector (JDET). *BISON Technical Report Series,* Number 257, High-Resolution Optical-Spectroscopy Group, Birmingham, United Kingdom, November 2005.

[4] Vaisala rain detector DPD 12A. BiSON Manual Collection, 1982.

[5] Vaisala rain detector DRD 11A. BiSON Manual Collection, 1996.