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TR16xx v1 **November 26, 2016**

— HANDBOOK —

ShipRad, Shipboard Radiation Package

Version 1

Three ShipRad sensor plates ready for testing. From left, GPS antenna B, Shaded SPN radiometer, PIR, Unshaded SPN radiometer, VN300 INS/GPS in weatherproof box, and GPS antenna A. Note the middle VN300 box is open and shows the small VN300 IMU. The mounting plate is fabricated from Type 5052 aluminum and hard anodized.

Abstract The ShipRad is designed to provide a precision measure of downwelling shortwave radiation, both diffuse and total irradiance, from a slowly moving platform such as a ship or buoy. The instrument combines a collection of commercial radiometers with a GPS based inertial navigation system (INS), all mounted onto a single plate (photo above). An electronic box with power control and data logger accompanies each sensor plate. The data logger, Campbell CR1000, accepts the

Acronyms and Abbreviations

CAT5	A standard ethernet cable with four twisted pairs of wires.
CR1000	The datalogger made by Campbell Scientific.
DAQ	Data Acquisition system, generic term.
DIN	A DIN rail is a metal rail of a standard type widely used for mounting circuit breakers and industrial control equipment inside equipment racks.
Ethernet	Ethernet is a family of computer networking technologies commonly used in local area networks (LANs)
GPS	Global positioning system. Also the name for the hardware/software module using the GPS receiver.
FRSR	Fast-Rotating Shadowband Radiometer (FRSR).
IMU	Inertial measurement units (IMU) is a synonym for INS.
INS	An inertial navigation system (INS) is a navigation aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate via dead reckoning the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external references.
Irradiance	The sum of radiation falling on a point from all directions in a hemisphere.
Longwave	Radiation in the wave lengths 40–50 μm.
Loggernet	A family of programs for writing and executing programs in Campbell data loggers.
MARCUS	ARM project in the Southern Ocean, scheduled for 2017–2018
PIR	The Precision Infrared Radiometer, Pyrgeometer measures the global downwelling longwave irradiance in the waveband 4–50 μm
Radiance	Radiation falling on a point from a specific spherical angle.
RJ25	A special 6-pin termination used with the A2 encoder.
RJ45	Standard 8-pin termination for the Cat5 cable.
Shortwave	Visible light approximately in the wave bands 300–3000 nm.
SPN	The Sunshine Pyranometer uses an array of seven, miniature thermopile sensors and a computer-generated shading pattern to measure the direct and diffuse components of incident solar radiation.
SPNu	An unshaded version of the SPN
VN300	The GPS enhanced INS made by VectorNav, Inc.
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Notes on this Manual

“toc” appears along the right margin throughout this handbook. These jump to the table of contents. All entries in the table of contents are links to that section. Also, all references to figures and sections are links. By using the links one can move rapidly through the handbook.

Handbooks for the VN300, SPN, PIR, and CR1000 datalogger accompany this document. These are all thorough and complete. We assume the user is familiar with these components so that this handbook can be brief and concentrate on operation of the ShipRad itself.

Contents

1 Product Information

1.1 Instrument Title

Shipboard Radiometer System (ShipRad)

The ShipRad is designed to provide a precision measure of downwelling shortwave radiation, both diffuse and total irradiance, from a slowly moving platform such as a ship or buoy. The instrument combines a collection of commercial radiometers with a GPS based inertial navigation system (INS), all mounted onto a single plate.

The basic sampling rate is 1 Hz. Raw samples are collected by the Campbell CR1000. Final estimates are computed in post-processing analysis.

1.2 Mentor Contact Information

For questions and information on ShipRad and its applications.

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Electronic circuits

2 System

2.1 System sketch

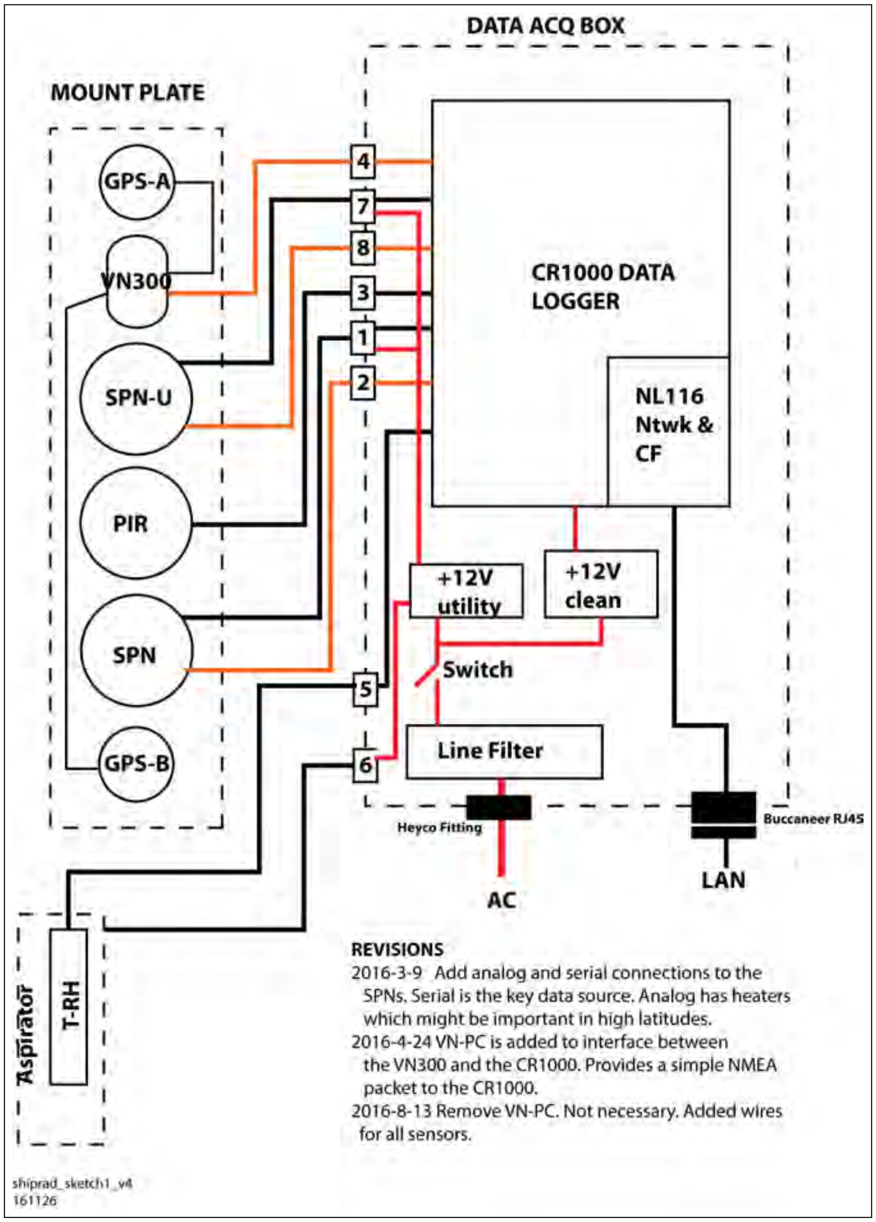


Figure 1: ShipRad system sketch. Two primary components are the sensor plate and the data acquisition box (DAQ). The radiation sensors are mounted firmly to the plate. Once the system is calibrated they cannot be moved without compromising data accuracy. The DAQ contains power control and the data logger, a Campbell CR1000.

2.2 Sensor plate

Figure 2: Sensor plates. Three plates mounted on a board for testing. From left to right are GPS antenna B, the shaded SPN, the PIR, the unshaded SPN, the VN300 IMU, and GPS antenna A. On the center plate the VN300 box is open so the IMU is visible.

Three identical sensor plates were built. Each plate was made from aluminum folded into a strong cross-section and hard anodized (See Fig. 6). When deployed one plate will be placed on the port side and one on the starboard side. A third system will be available as a spare in the event of failure.

The three systems will be calibrated for tilt and solar angle and once that “characterization” is complete it is important that no sensor of INS component be moved. Hence the third system.

2.3 Data acquisition electronics

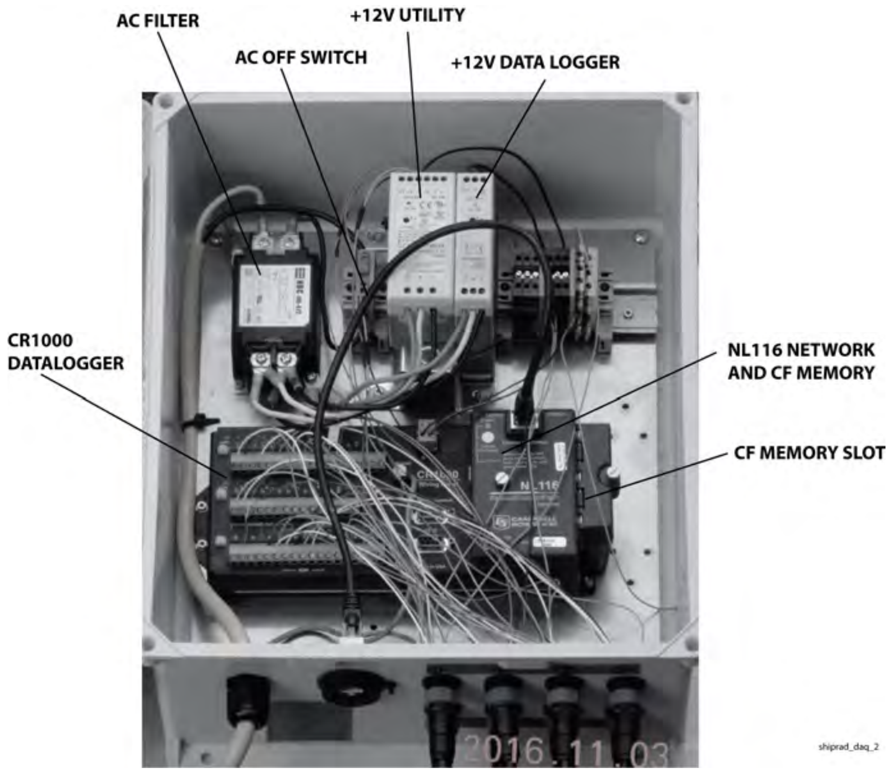


Figure 3: Data Acquisition system (DAQ).

The Data Acquisition system (DAQ) is a weathertight enclosure with the CR1000 data. All sensors on the plate and a T/RH sensor & aspirator combination plug into the box for power and data recording. A network interface allows data collection by the AMF data system.

In the event the AMF data collection fails a 2 GB compact flash (CF) card can collect up to 91 days of data.

2.4 Serial Numbers, November 26, 2016

SR1	**S/N**	**Calib**
spn	A1555	
spnu	A1567	
pir	33061F3	4.00
vn300	96	
t/rh	M1510141	
aspirator	n/a	
moxa	TAEJE1000886	
cr1000	2456	
NL116	3585	
SR2		
spn	A349	
spnu	A1565	
pir	30056F3	3.55
vn300	95	
t/rh	M1510142	
aspirator	n/a	
moxa	TAEJE1000866	
cr1000	26932	
NL116	3588	
SR3		
spn	A925	
spnu	A1566	
pir	33060F3	3.89
vn300	97	
t/rh	M1510140	
aspirator	n/a	
moxa	TAEJE1000849	
cr1000	2455	
NL116	3583	

3 Connections

Each sensor on the plate, the T/RH and aspirator connect to the DAQ with Bulgin Buccaneer Series 400 IP68 connectors. A connector catalog is included with the documents with this handbook.

The cables to the DAQ are 1.5 m long. They were made short purposely because the VN300 INS serial output is high (115200 bps) and also because ships are electrically noisy and short cables minimize radio frequency interference.

NOTE: We have found the Bulgin 400 connectors to be weak and prone to failure. When plugging in these connectors be sure to line up the keyway and avoid twisting the backshell as much as possible.

4 CR1000 data logger

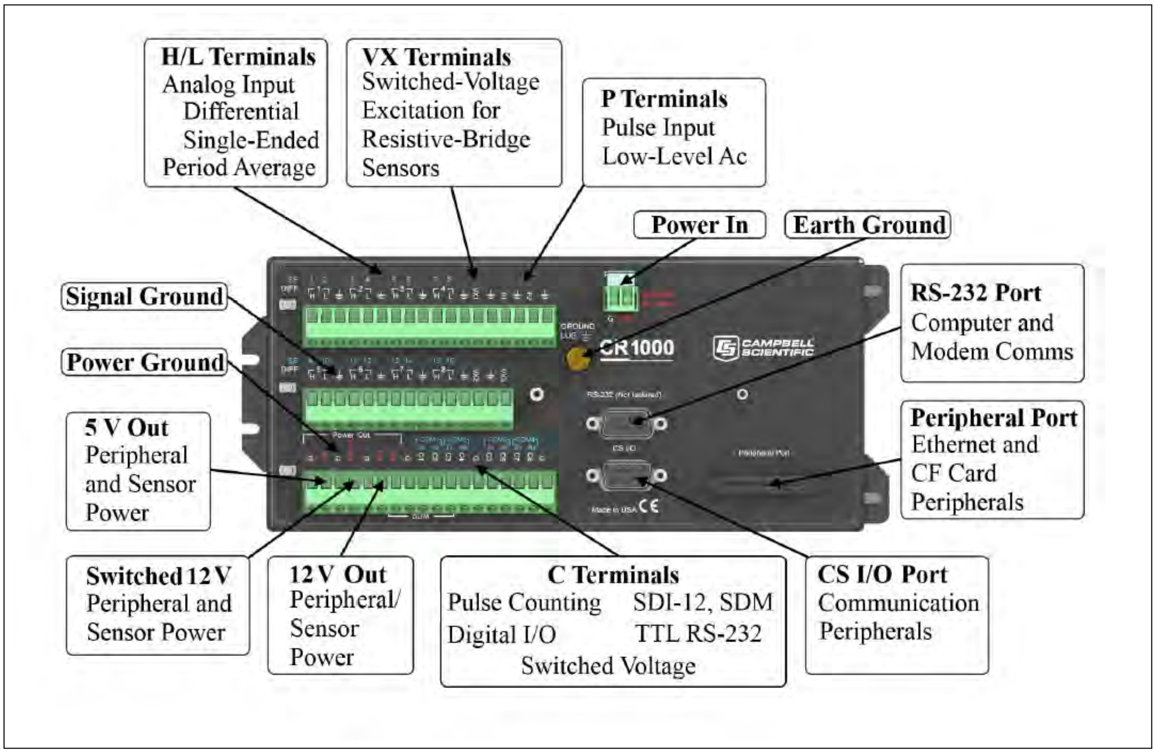


Figure 4: CR1000 panel.

5 Operation

This section provides a general guideline for connecting the system and beginning operation.

5.1 Connecting it together

• Mount the plate in its frame or test fixture. Do not connect cables until last.

• Mount DAQ and T/RH/Aspirator in a firm spot. Be sure the AC switch is off.

• Finally connect sensor cables. Be gentle and careful.

• Connect the AC power.

5.2 CF memory card

• Remove the CF card and reformat. This will remove all the data.

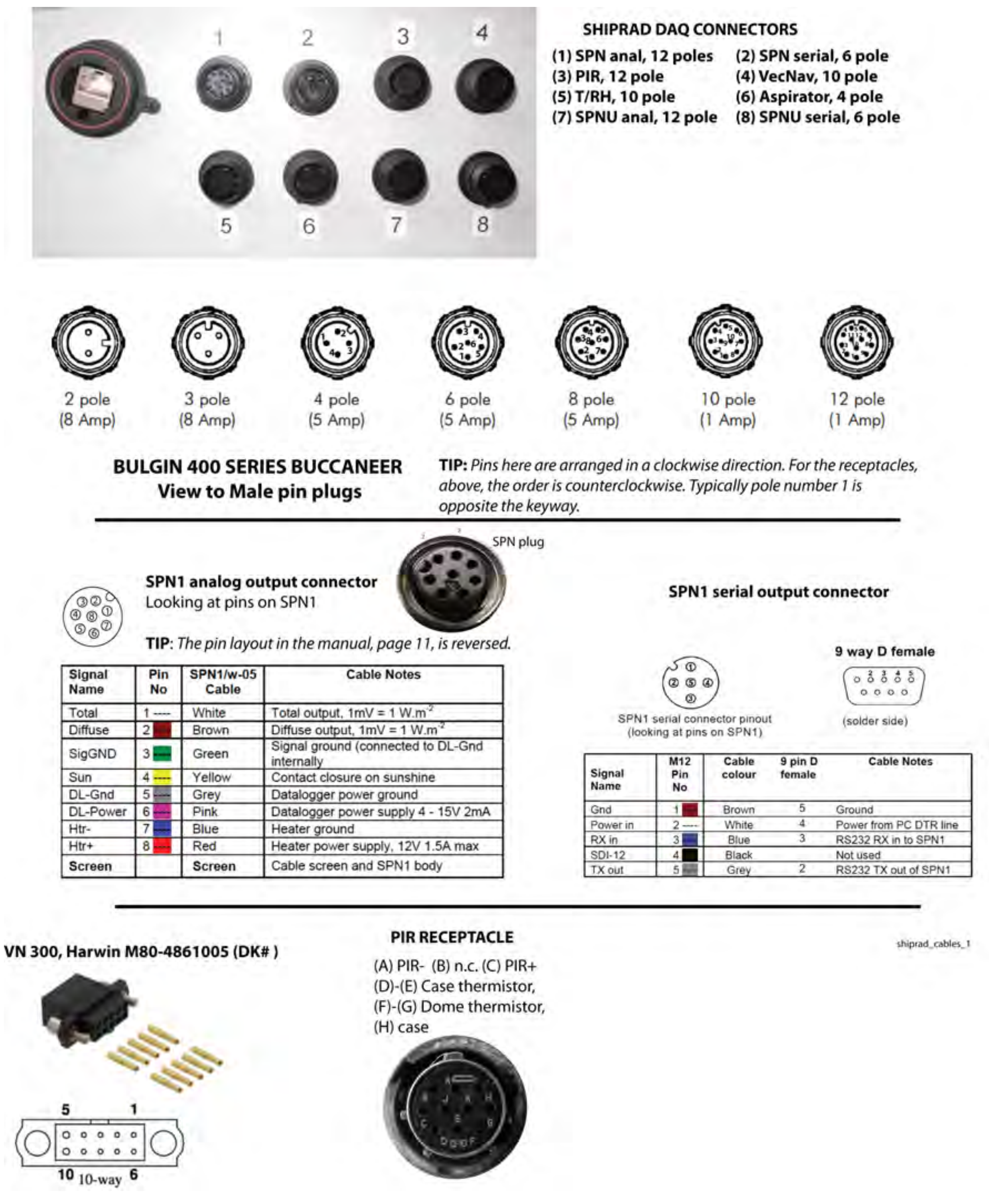
• Plug the CF card into the datalogger.

5.3 Initialization

• Turn on the AC switch. The data logger will reformat the CF card for data collection. This can take an hour or so.

APPENDICES

A Cables



Signal Name	Pin No	SPN1/w-05 Cable	Cable Notes
Total	1 ----	White	Total output, 1mV = 1 W.m^{-2}
Diffuse	2	Brown	Diffuse output, 1mV = 1 W.m^{-2}
SigGND	3	Green	Signal ground (connected to DL-Gnd internally
Sun	4	Yellow	Contact closure on sunshine
DL-Gnd	5	Grey	Datalogger power ground
DL-Power	6	Pink	Datalogger power supply 4 - 15V 2mA
Htr-	7	Blue	Heater ground
Htr+	8	Red	Heater power supply, 12V 1.5A max
Screen		**Screen**	Cable screen and SPN1 body

Signal Name	M12 Pin No	Cable colour	9 pin D female	Cable Notes
Gnd	1	Brown	5	Ground
Power in	2 ----	White	4	Power from PC DTR line
RX in	3	Blue	3	RS232 RX in to SPN1
SDI-12	4	Black		Not used
TX out	5	Grey	2	RS232 TX out of SPN1

Figure 5: Summary of connectors.

External

#1	**Cable_SPN**									
	Cable_SPN_Analog	**24.2.6**								
PATHWAY			**SPN to Bulgin (DAQ Exterior)**					**Bulgin bulkhead to datalogger**		
CONNECTORS			8-pole M12 waterproof connector using cable type SPN1/w-05				Bulgin PX0410/12P/6065	PX0412/12S		
			1	Total	Total output, 1mV = 1 W. m-2	White	1	1	White	1
			2	Diffuse	Diffuse output, 1mV = 1 W. m-2	Brown	2	2	Brown	2
			3	SigGND	Signal ground (connected to DL-Gnd internally)	Green	3	3	Green	gnd
			4	Sun	Contact closure on sunshine	Yellow	4	4	Yellow	n.c.
			5	DL-Gnd	Datalogger power ground	Grey	5	5	Grey	Power Out Gnd
			6	DL-Power	Datalogger power supply 4 - 15V 2mA	Pink	6	6	Orange	Power Out 12V
			7	Htr-	Heater ground	Blue	7	7	Blue	External -V
			8	Htr+	Heater power supply, 12V 1.5A max	Red	8	8	Red	External +V
				Shield	Cable screen and SPN1 body	Purple	9	9	Purple	Case gnd
							10	10		
							11	11		
							12	12		
#2	**Cable_SPN_Serial**	**24.2.8**								
PATHWAY			**SPN to Bulgin (DAQ Exterior)**					**Bulgin bulkhead to datalogger**		
CONNECTORS			**SPN1-RS-10 (use w/ PC or Serial Device)**				**Bulgin PX0410/06P/6(**	**PX0412/06S**		
			1	Gnd	Ground	Brown	1	1	Brown	Power Out Gnd
			2	Power in	Power from PC DTR line	White	2	2	White	Power Out 12V
			3	RX in	RS232 RX in to SPN1	Blue	3	3	Blue	C5
			4	SDI-12	Not used	Black	4	4	Black	nc
			5	TX out	RS232 TX out of SPN1	Grey	5	5	Grey	C6
			6				6	6		
#3	**Cable_PIR**	**24.2.4**								
PATHWAY			**PIR to Bulgin Plug (DAQ Exterior)**					**Bulgin bulkhead to datalogger**		
			PIR PLUG				DAQ PLUG	DAQ RECEP		
CONNECTORS			PT06W-12-10S				PX0410/08P/6065	PX0410/08S		CR1000

External

			H	Case	Shield (note: H to 1)	Black	1	1	Black	Case gnd
			A	PIR-	PIR-	White	2	2	White	3/L
			C	PIR+	PIR+	Red	3	3	Red	3/H
			D	TCase+	TCase+	Green	4	4	Green	7
			E	TCase-	TCase-	Blue	5	5	Blue	gnd
			F	TDome+	TDome+	Brown	6	6	Brown	8
			G	TDome-	TDome-	Yellow	7	7	Yellow	gnd
							8	8	-	
								10K 0.01% VX1 to 7		
								10K 0.01% VX1 to 8		
#4	**Cable_Nav**	**24.20.?**								
PATHWAY			**Internal VN300 to Bulgin Plug (DAQ Exterior)**				External VN to DAQ	**Bulgin bulkhead to datalogger**		
CONNECTORS		**24.02.01**	Harwin M80-5001042			HARWIN M80-4861005	Bulgin PX0410/10P/6065 Plug	PX0412/10S Receptacle		CN1000
			1	VCC	3.3V to +17V	red	1	1	red	12V
			2	TX1	RS-232 voltage levels data output from the sensor. (Serial UART #1).	wht	2	2	wht	com1/rx
			3	RX1	RS-232 voltage levels data input from the sensor. (Serial UART #1).	orn	3	3	ylw	com1/tx
			4	SYNC_OUT	Output signal used for synchronization purposes. Software configurable to pulse when ADC, IMU, or attitude measurements available.	tbd	4	n.c	n.c	
			5	GND	Ground	blk	5	5	blk	com1/gnd
			6	RESTORE	If high at reset, the device will restore to factory default state. Internally held low with10k resistor.	tbd	6	n.c	n.c	n.c
			7	SYNC_IN	Input signal for synchronization purposes. Software configurable to either synchronize the measurements or the output with an external device.	TBD	7	n.c	n.c	n.c
			8	TX2_TTL	Serial UART #2 data output from the device at TTL voltage level (3V).	TBD	8	n.c	n.c	n.c

			9	RX2_TTL	Serial UART #2 data into the device at TTL voltage level (3V).	TBD	9	n.c	n.c	n.c
			10	GPS_PPS	GPS pulse per second output. This pin is a TTL voltage level (3V) output directly connected to the PPS (pulse per second) pin on GPS receiver A.	TBD	10	n.c	n.c	n.c
#5	**Cable_T/RH**	**24.2.14**								
PATHWAY			**T/RH to DAQ (external)**					**Bulgin bulkhead to datalogger**		
CONNECTORS							Bulgin PX0410/10P/6065	PX0412/10S		
			1	V out 1	Temp, 0-1V, -40 to 60, T = v*100 - 40	White	1	1	White	10
			2	RS485-B		Brown	2	2	Brown	
			3	A Ground		Green	3	3	Green	Agnd
			4	V out 2	Humidity. 0-1 v RH = v * 100	Yellow	4	4	Yellow	9
			5	-	-	Grey	5	5		
			6	RS485-A		Pink	6	6	Pink	
			7	V cc		Blue	7	7	Blue	Pwr 12V continuous
			8	GND		Red	8	8	Red	Pwr GND !! Note red is ground
				SHIELD		Black	9	9	Black	
#6	**Cable_ASP**	**24.2.16**								
PATHWAY			**Aspirator to DAQ (external)**					**Bulgin bulkhead to datalogger**		
CONNECTORS							Bulgin PX0410/04P/6065	PX0412/04S		
			1	Tach		Green	1	1	Green	11
			2	Pos	14-27 VDC	Red	2	2	red	External -V
			3	Neg		Black	3	3	blk	External +V
#7	**Cable_SPNU_ analog**	**24.2.10**								
			SPN to Bulgin (DAQ Exterior)					**Bulgin bulkhead to datalogger**		
CONNECTORS			SPN1/w-05 (use w/ Datalogger)				Bulgin PX0410/12P/6065	PX0412/12S		
			1	Total	Total output, 1mV = 1 W. m-2	White	1	1	White	3
			2	Diffuse	Diffuse output, 1mV = 1 W. m-2	Brown	2	2	Brown	4
			3	SigGND	Signal ground (connected to DL-Gnd internally)	Green	3	3	Green	gnd

			4	Sun	Contact closure on sunshine	Yellow	4	4	Yellow	n.c.
			5	DL-Gnd	Datalogger power ground	Grey	5	5	Grey	Power Out Gnd
			6	DL-Power	Datalogger power supply 4 - 15V 2mA	Pink	6	6	Orange	Power Out 12V
			7	Htr-	Heater ground	Blue	7	7	Blue	External -V
			8	Htr+	Heater power supply, 12V 1.5A max	Red	8	8	Red	External +V
				Shield	Cable screen and SPN1 body	Screen	9	9	Screen	Case gnd
							10	10		
							11	11		
							12	12		
#8	**Cable_SPNU_serial**	**24.2.12**								
PATHWAY			**SPN to Bulgin (DAQ Exterior)**					**Bulgin bulkhead to datalogger**		
CONNECTORS			SPN1-RS-10 (use w/ PC or Serial Device)				Bulgin PX0410/06P/6065	PX0412/06S		
			1	Gnd	Ground	Brown	1	1	Brown	Power Out Gnd
			2	Power in	Power from PC DTR line	White	2	2	White	Power Out 12V
			3	RX in	RS232 RX in to SPN1	Blue	3	3	Blue	C7
			4	SDI-12	Not used	Black	4	4	Black	nc
			5	TX out	RS232 TX out of SPN1	Grey	5	5	Grey	C8
			6				6	6		

B CR1000 program

```
'ShipRad v3
'date: 161025
'program author:  rmrco
'all inputs

'Declare Constants
'Example:
'CONST PI = 3.141592654 or Const PI = 4*ATN(1)

Public PTemp, battv
Public pir,bc,bd,pirv
Public spnstr As String * 30, splitstrings(3) As String * 6, tot1ser, dif1ser, flag1
Public Nstr1
Public spnstr2 As String * 30, splitstrings2(3) As String * 6, tot2ser, dif2ser, flag2
Public Nstr2
Public vnstr As String * 150,  vnfield(16) As String * 16
Public Nstr
Public tot1, dif1  'shaded
Public tot2, dif2  'unshaded
Public rc,rd
Public lnr
Public d
Public tc,td, lw, C1, C2
Public tair, rh
Public tach

Const sigma=5.6704e-8
Const kpir=3.25e-6
'steinhart-hart coefs
Const a=0.001017394
Const b=0.000241046
Const c=0.000000149
Const tabs=273.15


Units battv=Volts
Units PTemp=degC
Units pirv=volts
Units bc=mV/mV
Units bd=mV/mV
Units tc=degC
Units td=degC
Units tot1=W/m^2
Units dif1=W/m^2
Units tot2=W/m^2
Units dif2=W/m^2
Units tot1ser=W/m^2
Units dif1ser=W/m^2
Units tot2ser=W/m^2
Units dif2ser=W/m^2
Units lw=W/m^2
Units tair=degC

Alias vnfield(4)=mode
```

```
Alias vnfield(5)=yaw
Alias vnfield(6)=pitch
Alias vnfield(7)=roll
Alias vnfield(8)=lat
Alias vnfield(9)=lon
Alias vnfield(10)=alt

'Declare Other Variables
'Example:
'Dim Counter

DataTable (rad,1,10000) 'Set table size to # of records, or -1 to autoallocate.
  CardOut (1,-1 )
DataInterval (0,1,Sec,10)
Minimum (1,battv,FP2,False,False)
Sample (1,PTemp,FP2)
'Sample(1,pirv,IEEE4)
Sample(1,tot1ser,IEEE4)
Sample(1,dif1ser,IEEE4)
Sample(1,tot2ser,IEEE4)
Sample(1,dif2ser,IEEE4)
Sample(1,pir,IEEE4)
Sample (1,bc,IEEE4)
Sample(1,bd,IEEE4)
Sample (1,tc,IEEE4)
Sample (1,td,IEEE4)
Sample(1,lw,IEEE4)
Sample (1,tot1,IEEE4)
Sample (1,dif1,IEEE4)
Sample (1,tot2,IEEE4)
Sample (1,dif2,IEEE4)
Sample (1,tair,IEEE4)
Sample (1,rh,IEEE4)
Sample (1,tach,FP2)
Sample (1,vnfield(4),UINT2)
Sample(1,yaw,IEEE4)
Sample(1,pitch,IEEE4)
Sample(1,roll,IEEE4)
Sample(1,lat,IEEE4)
Sample(1,lon,IEEE4)
Sample(1,alt,IEEE4)
EndTable
DataTable (spnser,1,-1)
  Sample(1,spnstr,String)
EndTable
DataTable (spnser2,1,-1)
  Sample(1,spnstr2,String)
EndTable
DataTable (vn300,1,-1)
  CardOut (1,-1 )
 Sample (1,vnstr,String)
EndTable


'Define Subroutines
'Sub
'EnterSub instructions here
```

```
'EndSub


BeginProg
  SerialOpen(Com1,115200,0,0,150)
  SerialOpen(com3,9600,0,0,20)
  SerialOpen(com4,9600,0,0,20)
Scan (1,Sec,0,0)
PanelTemp (PTemp,250)
Battery (battv)

    'PIR
VoltDiff (pirv,1,mV2_5,3,False,0,250,1.0,0)
pir=pirv / kpir / 1000
BrHalf (bc,1,mV2500,7,Vx1,1,2500,True ,0,250,1.0,0)

'steinhart-hart for case
rc=10000*(bc/(1-bc))
lnr=LN(rc)
d=a+b*lnr+c*lnr*lnr*lnr
tc=1/d
BrHalf (bd,1,mV2500,8,Vx1,1,2500,True ,0,250,1.0,0)

'steinhart-hart for dome
rd=10000*(bd/(1-bd))
lnr=LN(rd)
d=a+b*lnr+c*lnr*lnr*lnr
td=1/d

'Compute LW
C1=pir+sigma*tc*tc*tc*tc
C2=td*td*td*td - tc*tc*tc*tc
lw=C1-4*sigma*C2

    'temps in degC
    tc=tc-tabs
    td=td-tabs

    'SPN SERIAL
  SerialOutBlock(com3,"R",1)
Delay(0,10,msec)
SerialOutBlock(com3,"S",1)
Delay(0,10,msec)
SerialInRecord(com3,spnstr,0,15,13,Nstr1,01)
    SplitStr(splitstrings(),spnstr,",",3,0)
    tot1ser=splitstrings(1)
    dif1ser=splitstrings(2)
    'SPNu SERIAL
  SerialOutBlock(com4,"R",1)
Delay(0,10,msec)
SerialOutBlock(com4,"S",1)
Delay(0,10,msec)
SerialInRecord(com4,spnstr2,0,15,13,Nstr2,01)
    SplitStr(splitstrings2(),spnstr2,",",3,0)
    tot2ser=splitstrings2(1)
    dif2ser=splitstrings2(2)
```

```
'VecNav
SerialInRecord (Com1,vnstr,&h24,0,&h0D0A,Nstr,01)
SplitStr(vnfield(),vnstr,",",16,5)

'SPN1
VoltSe (tot1,1,mV2500,1,1,0,250,1.0,0)
VoltSe (dif1,1,mV2500,2,1,0,250,1.0,0)

'SPN2 unshaded
VoltSe (tot2,1,mV2500,3,1,0,250,1.0,0)
VoltSe (dif2,1,mV2500,4,1,0,250,1.0,0)

    'T/RH HMP155
VoltSe (rh,1,mV2500,9,1,0,250,.1,0)
VoltSe (tair,1,mV2500,10,1,0,250,.1,-40)

    'ASPIRATOR TACH
    PeriodAvg (tach,1,mV5000,11,1500,1,2,100,1.0,0)

CallTable rad
CallTable spnser
CallTable spnser2
CallTable vn300
NextScan
EndProg
```

C Mounting Plate

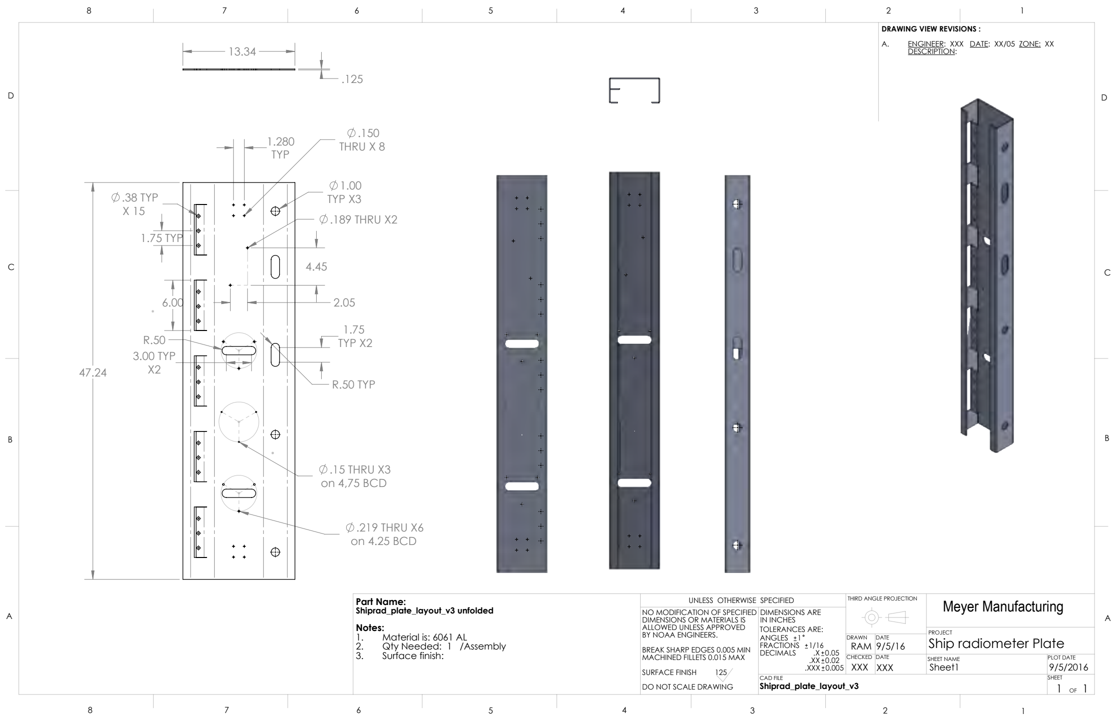


Figure 6: ShipRad plate.

D Railing Frame

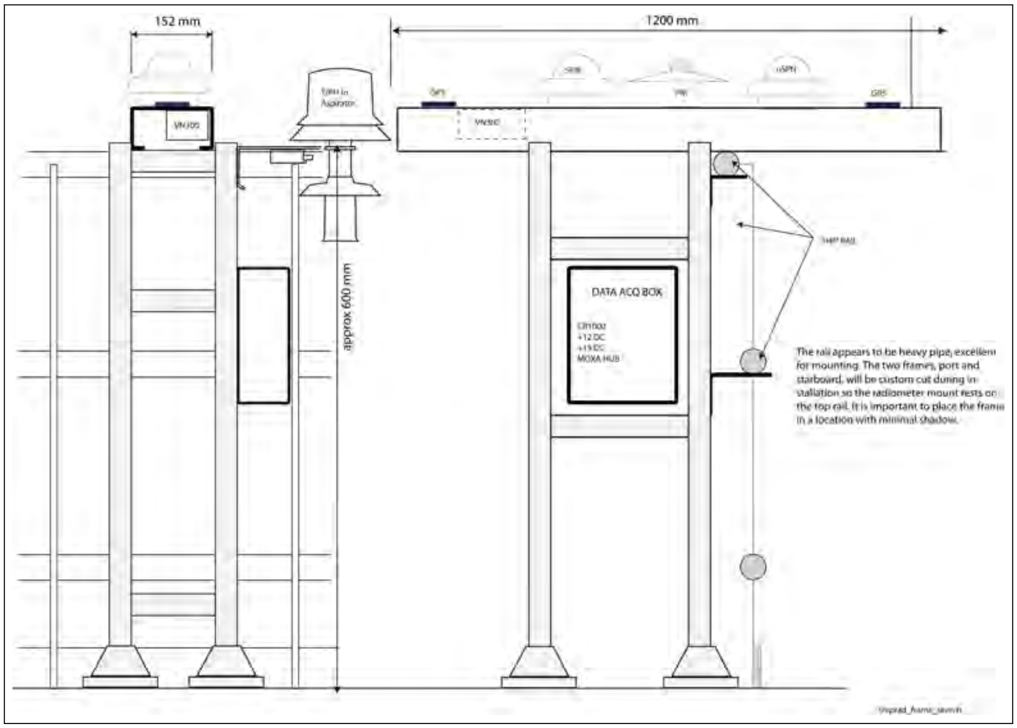


Figure 7: ShipRad frame.

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