Jet Propulsion Laboratory, California Institute of Technology

System Description Plan

Tower Instrumentation

for

Russell Ranch Site, Davis California

Prepared by: ____

Gerardo Rivera   Date

Prepared by: ____

Nathan C. Healey   Date

Copyright 2017 California Institute of Technology. U.S. Government sponsorship acknowledged.

CL#17-0875

Acknowledgement

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Change History

Revision	Date	Description	Author
Draft	9/20/2016	First Draft	N. C. Healey
Initial Release	2/7/2017	First Release	G. Rivera

Table of Contents

Table of Figures

1 Introduction

This System Description Plan (SDP) shall cover the instruments installed on the 30-foot tower at the Agricultural Sustainability Institute (ASI) facility (Russell Ranch) operated by University of California, Davis (UC Davis). The instruments represent a calibration and validation *in situ* site, which make observations of the land surface, atmospheric, and meteorological conditions. The Jet Propulsion Laboratory (JPL) has entered into an agreement with the regents of the University of California to deploy and access the site with the instruments mounted on two 30-foot (9.14 m) towers.

The Russell Ranch Sustainable Agriculture Facility is a unique 300-acre (1.2 km^2) facility near the UC Davis campus dedicated to investigating irrigated and dry land agriculture in a Mediterranean climate under different irrigation, nutrient, and crop rotation regimes.

Among Russell Ranch's ongoing experiments is a 100-year study referred to as the Century Experiment (http://asi.ucdavis.edu/programs/rr/about/century-experiment), formerly the Long Term Research in Agricultural Sustainability (LTRAS), which is comprised of a grid of 72 one-acre (4046.86 m^2) plots. LTRAS is an exploration of the long-term impacts of crop rotation, farming systems (conventional, organic and mixed) and inputs of water, nitrogen, carbon and other elements on agricultural sustainability. Sustainability is indicated by long-term trends in yield, profitability, resource-use efficiency (such as water or energy) and environmental impacts.

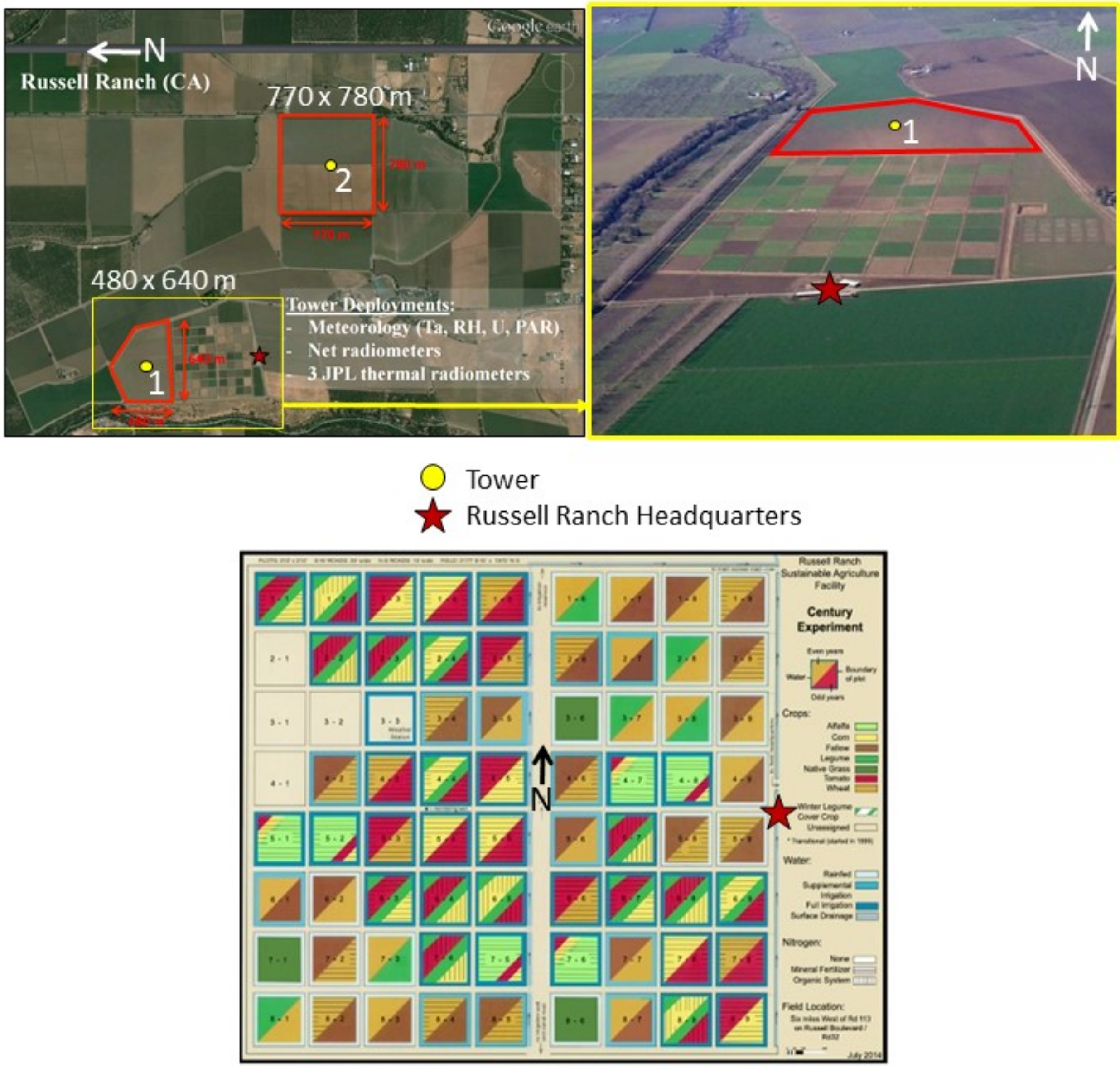
LTRAS has monitored changes in crop and soil properties, greenhouse gas emissions, exotic and invasive species (weed) ecology and economic indicators since 1993. The Sustainable Agriculture Farming Systems (SAFS) (http://safs.ucdavis.edu) project joined with LTRAS in 2003. Russell Ranch is primarily a research facility that also supports UC Davis' extension and teaching missions by hosting field days, class field trips, undergraduate interns and graduate student research.

2 Scope

This document shall cover the type of instruments deployed on the 30-foot (9.14 m) tower with the type of measurements being taken. Instrument details are not covered since this is beyond the scope of this document. However, reference documents are provided for each instrument.

NASA's JPL established two towers in 2015 to collect *in situ* data. The *in situ* data collected is displayed on the "Field Data" tab on the JPL Russell Ranch website (http://russellranch.jpl.nasa.gov/). These *in situ* data will be used for collaborative experiments between JPL and UC Davis. In addition, these data will be used by JPL for upcoming flight project instrument validations.

As see in Figure 1 below, tower 1 is located west of the main Russell Ranch facility and tower 2 is located north-east of the main facility.



Russell Ranch Sustainable Agriculture Facility Plot Crop Treatments

FIGURE 1 - SITE MAP

3 General Site Information

General information of the two sites is found below, including investigators using the site and planned use of the site by JPL researchers. The JPL Russell Ranch website provides updated information concerning the tower sites.

Site Name: Russell Ranch, Davis California, USA

<u>Tower 1 (RRT1)</u>

Latitude: 38.5424° N, **Longitude**: 121.8809° W

<u>Tower 2 (RRT2)</u>

Latitude: 38.5578° N, **Longitude**: 121.8634° W

LANDSAT TM WRS2 Path: 43 Row: 33

UTM Zone: 10

General land cover: Agricultural Crops

EOS Investigators known to be using site: A. Gillespie, K. Thome, F. Palluconi, Z. Wan

Planned field measurements: Surface skin temperature (radiometers), ground temperature (CNR4), aerosols/water (sun photometer), temperature/pressure/relative humidity profiles (radiosonde).

JPL / Russell Ranch Towers System – by Darren Drewry

As part of a recent collaborative effort between the Jet Propulsion Laboratory (JPL) and the UC Davis, Russell Ranch (RR) Sustainable Agricultural Facility, JPL has deployed two permanent 30 foot (9.14 m) tower systems at two separate locations within agricultural plots at the RR facility. The towers support a set of instruments that collect thermal properties of the surface, as well as incident, reflected, and emitted light/energy from the atmosphere, crop foliage, and soil. These measurements will be related to crop health, productivity, and water and nutrient status. The two locations will provide the necessary spatial extent for validation of satellite and airborne observations.

Website of Russell Ranch Calibration/Validation: http://russellranch.jpl.nasa.gov

The Russell Ranch website at the Jet Propulsion Laboratory (JPL) was established to act as a portal to the data and results from collaborative experiments underway at Russell Ranch between JPL and the University of California,Davis (UC Davis). The site provides access to some of the near-real time (NRT) data acquired from the site which was established by JPL in the summer of 2015.

Access to near real-time (NRT) data: http://russellranch.jpl.nasa.gov/field-data

Access to NRT weather data: http://russellranch.jpl.nasa.gov/get_met_weather

4 System Description

Each tower has a suite of instruments and sensors that are powered by solar panels and a battery bank. The data are retrieved via commercial software (Campbell Scientific, LoggerNet) every hour and sent back to JPL via a mobile data modem. A list of these instruments and sensors are listed below with a details of each instrument and sensor described in sections 5 and 6.

4.1 Power System

The power system consists of two 140-watt solar panels that provide power to four 12-volt batteries, which are controlled by the charge controller. The charge controller provides the batteries with a specific voltage and amperage so the batteries are not over or under, charge. There are a total of four 12-volt marine quality batteries stored with the charge controller inside a watertight Pelican case at each tower. The batteries supply power to the power distribution break-out bank inside the Campbell Scientific enclosure (Figure 2).

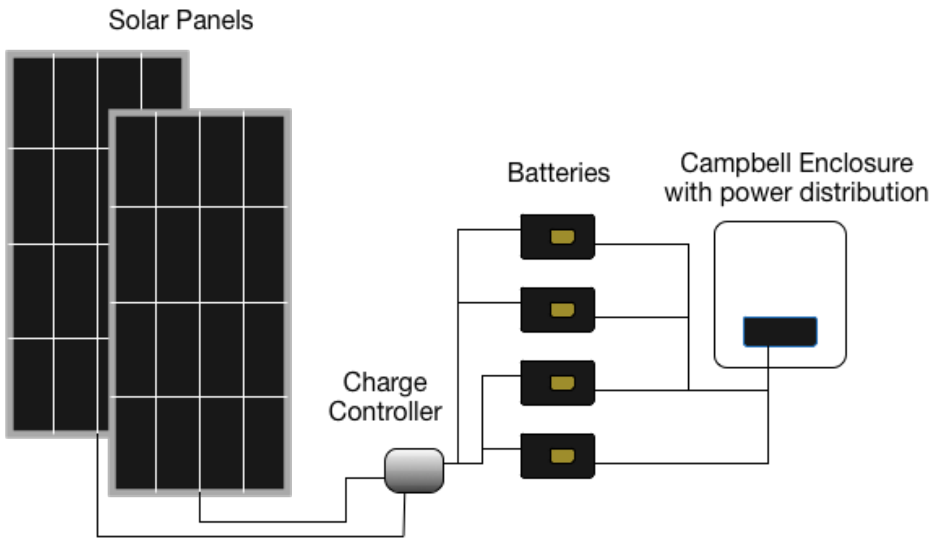


FIGURE 2 - POWER SYSTEM DIAGRAM

Mounting of the solar panels depends on the structure which you plan to mount the panel. The use of electrical tubing, clamps and pieces of Unistrut are commonly used to mount the panels (See Appendices A and B for images of our installation). UV or outdoor 8-10-gauge wire is used to distribute power from the panels to the charge controller.

Face the panels in the direction of the sun (*i.e.* South if in the northern hemisphere) otherwise the energy production of the panels diminishes and the batteries will not sufficiently recharge. For the first few months after installation, a charge meter is placed inline with the batteries to make sure sufficient daily power is being collected and stored (Figure 3).

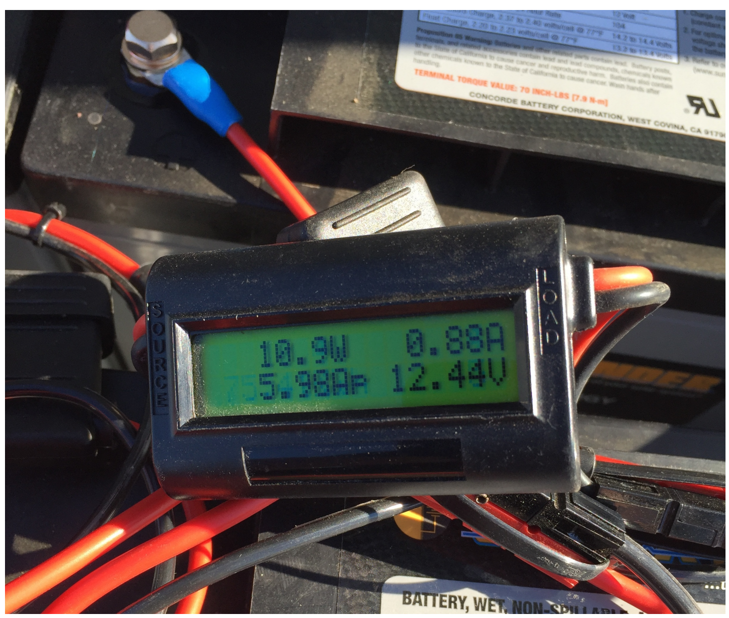


FIGURE 3 - BATTERY METER

4.2 Instrument and Sensor Suite

Instrument placement depends on the research requirements but must also provide vertical clearance for farm equipment to access the area below/around the tower. For redundancy, two sets of instruments and sensors have been installed on each tower. This provides a source for comparison between each instrument and sensor and, it also provides a backup in instances of instrument failure and/or erroneous data. Table 1 lists the core instruments and sensors mounted on each tower.

TABLE 1 - INSTRUMENTS AND SENSORS

Instrument/Sensor Description	Data Collected
Wind speed indicator (MET))	The values are in counts and are converted to meters per second (ms^{-1})
Wind direction indicator (MET)	The values are in counts and are converted to degrees with respect to magnetic north
Air Temperature with Gill radiation shield (MET)	The values are in counts and are converted to degrees Celsius (the air temperature and relative humidity sensor are integrated together)
Relative Humidity (RH) (MET)	The values are in counts and are converted to percent
Barometric Pressure with Pressure port (MET)	The values are in counts and are converted to hectopascals or millibars (hPa ormBar). The pressure port is used to prevent any errors in pressure due to wind over the sensor
Li-COR Photosynthetically Active Radiation (PAR) sensor	Sensor measures Photosynthetic Photon Flux Density (PPFD) in both natural and artificial light
Net Radiometer	Incoming solar radiation (short wave), reflected solar radiation, incoming far infrared radiation (long wave), outgoing far infrared radiation, sky temperature and ground temperature.
JPL-built Radiometer	Land surface temperature
Eddy Covariance system	Air temperature, sonic air temperature, barometric pressure, absolute carbon dioxide and water vapor densities and the orthogonal wind components (three-dimensional)

The meteorological instruments are indicated by the distinction "MET" beside the instrument. These instruments are connected using special cables provided by the manufacturer: R. M. Young. The compass, or serial box, acts as the collection point for the MET instruments. The data are transferred to the Campbell Scientific enclosure via an RS232 cable. The data cable that provides power and communication between the instruments and the RS232 communication module is custom built at JPL. Before building the cable, required length will need to be determined by taking measurements of the location where the instruments will be mounted. It is highly recommended to add two additional feet (or ~1 m) for a service loop which is needed in calibration of the compass.

An example of a complete MET station is illustrated in Figure 4 below.

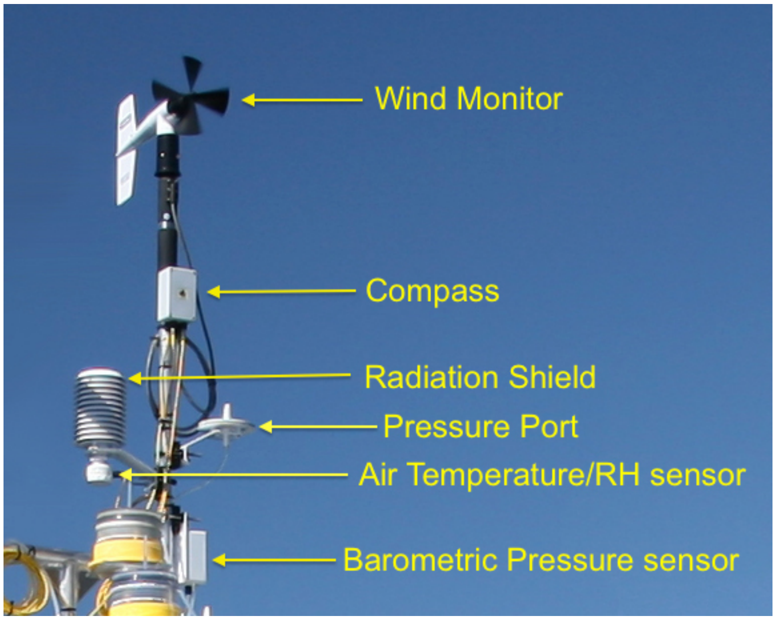


FIGURE 4 METEOROLOGICAL INSTRUMENTS

The mounts for the MET instruments are available from R.M. Young including the mounting arm used to extend the wind direction and wind speed indicators away from a tower or structure that might interfere with measurements of ambient atmospheric flow in the surface boundary layer (Figure 5).

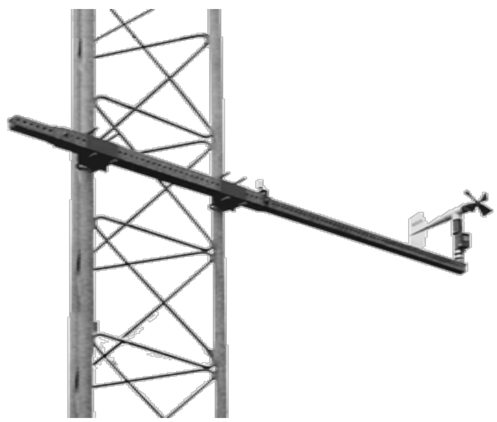


FIGURE 5 MOUNTING ARM

The LI-COR PAR sensor mounts are available from Campbell Scientific (Figure 6). This sensor has to be mounted in a location that is free from any potential shadowing, and must be leveled using the bubble level provided on the mounting stand. If the sensor is not leveled properly then incorrect data will be collected.

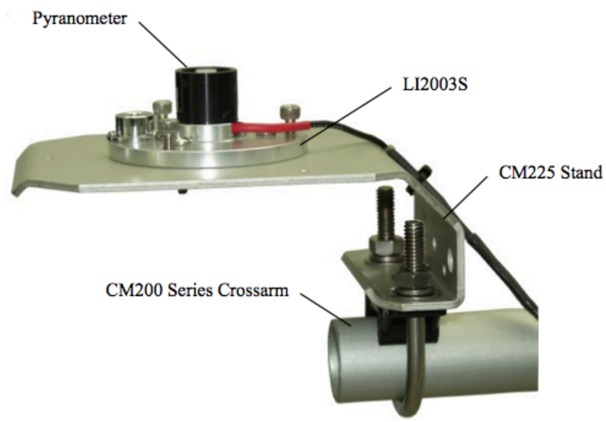


FIGURE 6 LI-COR PAR SENSOR ON MOUNTING STAND AND CROSSARM

The Kipp & Zonen CNR4 Net Radiometer comes with cable and mounting rod (Figure 7), and you must specify the length of cable you will need when ordering the instrument. The cable is wired directly to the Campbell Scientific CR3000 data logger. The Net Radiometer must have an unobstructed view of both the sky above and the measurement surface below it. There is an equation for the distance away the radiometer must be placed for every meter above the ground. The reflected shortwave radiation sensor has a footprint radius of 10 times the height. For example: if the net radiometer is positioned 1 meter above the measurement surface, the footprint radius of this sensor is 10 meters.

FIGURE 7 KIPP & ZONEN CNR4 NET RADIOMETER

The JPL Radiometers are placed in an enclosure (made by Stahlin - model J806HW), which has been customized for the type of measurements the JPL Radiometer will be performing. The initial configuration of the Russell Ranch site called for three JPL Radiometers (Figure 8). One points directly south and the other two point +/- 45 degrees from south or at southeast and southwest angles. However, due to power constraints the number of JPL Radiometers has been reduced to two: pointing south and southwest.

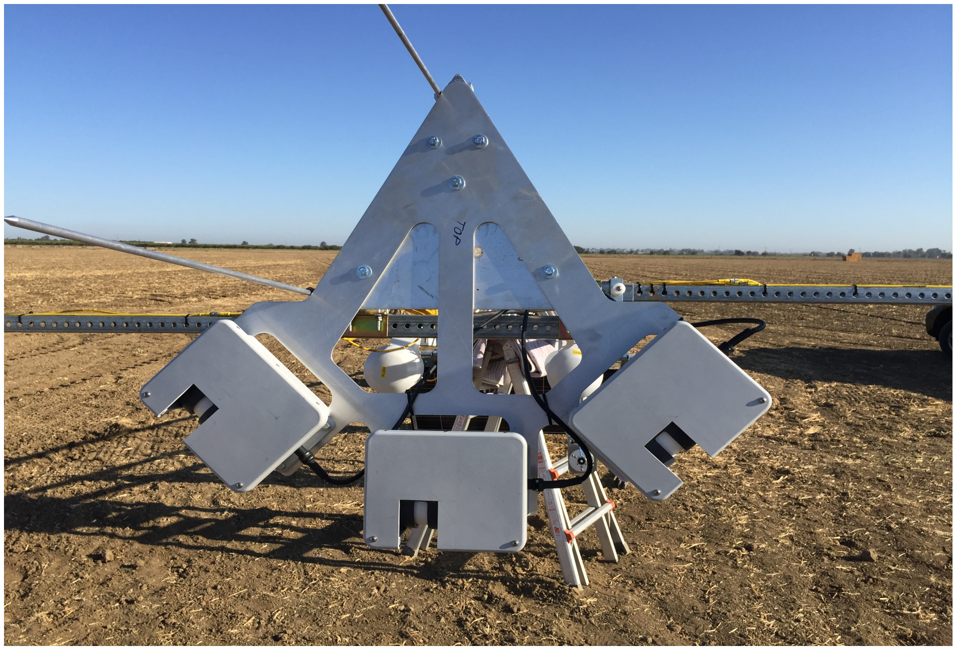


FIGURE 8 - JPL RADIOMETER MOUNT AND ENCLOSURES

Finally, the Eddy Covariance (EC) system will be stalled on one tower at a time (Figure 9). The primary focus of the EC systems is to monitor plant physiological dynamics in conjunction with meteorological phenomena, so when a particular field (i.e. tower location) is scheduled to be left fallow, the system will be transported from the tower in the fallow field to the tower in a field with a crop planted. The EC system will make observations of air temperature, sonic air temperature, barometric pressure, absolute carbon dioxide (CO_2) and water vapor densities and the orthogonal wind components (three-dimensional).

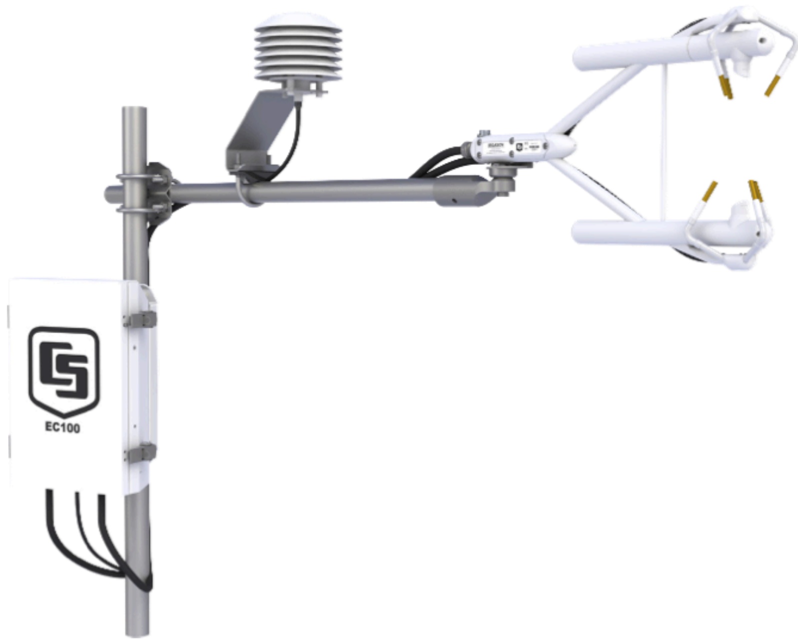


FIGURE 9 CAMPBELL SCIENTIFIC EDDY COVARIANCE SYSTEM

4.3 Data Logger, Communication, Power Distribution

All the instruments are connected to the Campbell Scientific CR3000 data logger that controls the operational software and communications between the instruments and the data modem, which relays the data back to JPL. The instruments are supplied power via the RIGRunner power distribution break-out bank which will detect any over voltage conditions and sound off an audible alarm if such a condition is reached (Figure 10). The bank also has a fuse if any of the instruments draw too much current. The Net Radiometers and the PAR sensor are wired directly to the Campbell Scientific CR3000 data logger since they draw very little current. A diagram of the enclosure's components is illustrated in Figure 10 below.

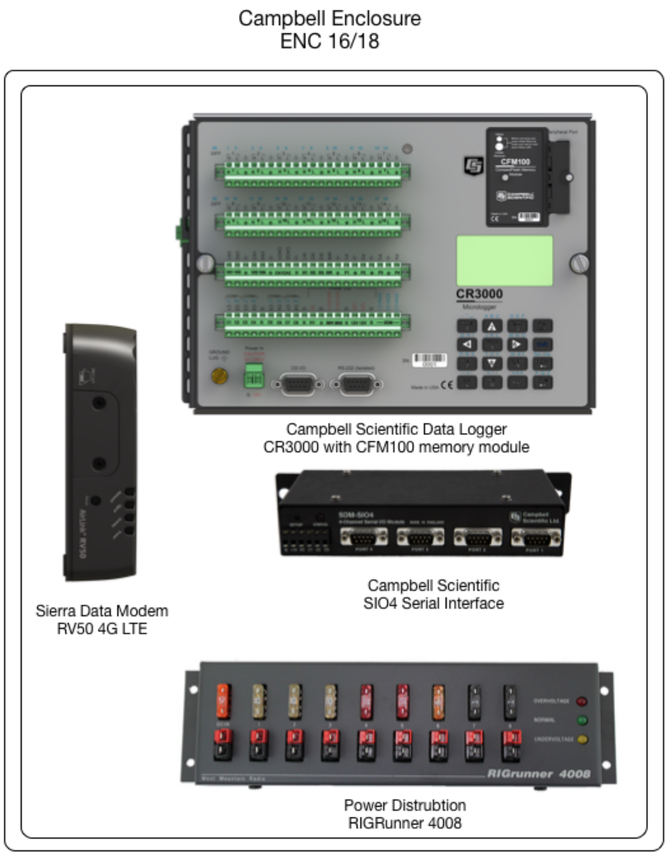


FIGURE 10 – CONTENTS WITHIN THE CAMPBELL SCIENTIFIC ENCLOSURE

5 Power System And Energy Storage

Depending on the power requirements for the installation, a set of solar panels is needed to power the instruments. The number of panels requires a balance between the number of batteries used and the number of amp-hours drawn by the instruments on a daily basis. Knowledge of the current collected on representative clear and cloudy days is required. Adjustments to the charge controller are then made to maintain proper power and energy storage. The following sections (Sections 5 and 6) describe the chosen power components for the Russell Ranch site.

5.1 Photovoltaic Systems
(Model: KYOCERA KD140GX-LFBS)

Product Information: https://www.solar-electric.com/kyocera-kd140gx-lfbs-140-watt-polycrystalline-solar-panel.html
Manual: https://www.solar-electric.com/lib/wind-sun/KD140GX-LFBS.pdf
Installation: https://www.solar-electric.com/lib/wind-sun/Kyocera-LPU-LPB-install.pdf

FIGURE 11 - SOLAR PANEL

Specifications:

Max Rated Power (Pmax)	140 Watts
Voltage at Max Power (Vmpp)	17.7 Volts
Current at Max Power (Impp)	7.91 Amps
Open Circuit Voltage (Voc)	22.1 Volts
Short Circuit Current (Isc)	8.68 Amps
Length x Width x Depth (inches)	59.06 x 26.3 x 1.8
Weight of Panel (Pounds)	28.4
Connector Cable Type	MC4 Latching Cables

5.2 Charge Controller

(Model: MORNING STAR SUN SAVER SS-20-L-12V)

Manual: http://www.morningstarcorp.com/wp-content/uploads/2014/02/SS3.IOM_.Operators_Manual.01.EN_.pdf

FIGURE 12 - CHARGE CONTROLLER

Features & Attributes

- Dimensions (LxWxH): 2.2 × 6 × 1.3 inches
- Weight: .9 lbs
- 100% slid state
- Series design (not shunt)
- True 0 to 100% PWM duty cycle
- Setpoint accuracy to 35 mV
- Marine rated terminals/ anodized case
- Temperature compensation
- Sealed/flooded battery select
- Rated to 25% overloads
- No need to derate
- Fully encapsulated in epoxy potting
- Parallel for 40 amps or more
- Green charging/ Red LVD indicators

5.3 Batteries

(Model: SUN EXTENDER PVX 1040-T)

Product Information: http://www.sunxtender.com/solarbattery.php?id=8

FIGURE 13 - MARINE BATTERY

Voltage			12 Volts		
BCI Group Size			27		
Ampere Hours @ 24 Hour Rate			104 Ah		
Weight			66 lb / 30.0 kg		
Length		Width		Height	
in	mm	in	mm	in	mm
12.01	305	6.60	168	8.93	227

- Designed for photovoltaic applications for superior & reliable solar power
- "T" terminals are copper alloy with silicon bronze bolts, nuts, & washers
- Low impedance design
- Maintenance free
- Constructed with non removable vent valves - no addition of electrolyte or water required
- Non-spillable in any attitude
- Shipped fully charged and ready to install
- Manufactured with absorbed glass mat separators (AGM)
- Sun Xtender® Series batteries ship non-HAZMAT

6 Data Logger And Communications System

6.1 Enclosure And Tripod Mast Mounting Kit (Model: CAMPBELL SCIENTIFIC RJ1816HPL and 19002)

Product Information: https://www.campbellsci.com/enc-16-18

Product Information: https://www.campbellsci.com/p19002

FIGURE 14 - CAMPBELL SCIENTIFIC ENCLOSURE

Enclosure comes with a back plane and you must order with the brackets
Order with these options:
-DC 2 CONDUITS FOR CABLES
-MM (19002) TRIPOD MAST MOUNTING
-DESICCANT & DOCUMENT HOLDER, USER INSTALLED

Specifications:

Color	White
Construction	Fiberglass-reinforced polyester enclosure with door gasket, external grounding lug, stainless-steel hinge, and lockable hasps
Enclosure Classification	NEMA 4X (before being modified for cable entry)
Dimensions	45.7 x 40.6 x 22.9 cm (18 x 16 x 9 in.) internal 43.82 x 38.74 x 25.22 cm (17.25 x 15.25 x 9.93 in.) internal under the lid space 49.53 x 44.4 x 26.98 cm (19.5 x 17.48 x 10.62 in.) external
Weight	7.7 kg (17 lb)

6.2 Data Logger
(Model: CAMPBELL SCIENTIFIC CR3000)

Product Information: https://www.campbellsci.com/cr3000
Manual: https://s.campbellsci.com/documents/af/manuals/cr3000.pdf

FIGURE 15 CAMPBELL SCIENTIFIC CR3000 DATA LOGGER

Specifications:

Maximum Scan Rate	100 Hz
Analog Inputs	28 single-ended or 14 differential (individually configured)
Pulse Counters	4
Switched Excitation Channels	4 voltage, 3 current
Digital Ports	Certain digital ports can be used to count switch closures. 3 SDM and 8 I/Os or 4 RS-232 COM I/O ports can be paired as transmit and receive for measuring smart serial sensors.
Continuous Analog Outputs	2
Communications/Data Storage Ports	1 CS I/O 1 RS-232 1 parallel peripheral
Switched 12 Volt	2
Input Voltage Range	±5 Vdc
Analog Voltage Accuracy	±(0.04% of reading + offset) at 0° to 40°C
Analog Resolution	0.33 µV
A/D Bits	16
Power Requirements	10 to 16 Vdc
Protocols Supported	PakBus, Modbus, DNP3, FTP, HTTP, XML POP3, SMTP, Telnet, NTCIP, NTP, SDI-12, SDM
CE Compliance Standards to which Conformity Is Declared	IEC61326:2002
Warranty	3 years

Dimensions	24.1 x 17.8 x 7.6 cm (9.5 x 7.0 x 3.0 in.) with low-profile base 24.1 x 17.8 x 11.9 cm (9.5 x 7.0 x 4.7 in.) with alkaline battery base 24.1 x 17.8 x 11.9 cm (9.5 x 7.0 x 4.7 in.) with rechargeable battery base
Weight	1.6 kg (3.6 lb) with low-profile base 3.8 kg (8.3 lb) with alkaline battery base 4.8 kg (10.7 lb) with rechargeable battery base

6.3 Compact Flash Module
(Model: CAMPBELL SCIENTIFIC CFM100)

Product Information: https://www.campbellsci.com/cfm100
Manual: https://s.campbellsci.com/documents/us/manuals/cfm100.pdf

FIGURE 16 - CAMPBELL SCIENTIFIC CFM100 COMPACT FLASH MEMORY MODULE

Specifications:

Typical Access Speed	200 to 400 kbits s^{-1}
Memory Configuration	User selectable; ring (default) or fill-and-stop
Power Requirements	12 V supplied through the datalogger’s peripheral port
CF Card Requirements	Industrial-grade
Dimensions	10.0 x 8.3 x 6.5 cm (4.0 x 3.3 x 2.6 in.)
Weight	133 g (4.7 oz)

6.4 Serial Expansion Ports
(Model: CAMPBELL SCIENTIFIC SDM-SIO4 SERIAL I/O INTERFACE)

Product Information: https://www.campbellsci.com/sdm-sio4
Manual: https://s.campbellsci.com/documents/us/manuals/sdm-sio4.pdf

FIGURE 17 - CAMPBELL SCIENTIFIC SERIAL I/O EXPANSION MODULE

Specifications:

Communication Rate	Speed at which data is transferred is controlled by the datalogger and can vary with the microprocessor activity as well as the length of the SDM cables.
Typical Transfer Rate	One byte per millisecond
Power Supply	Unregulated 12 V supply, 9 to 18 Vdc
Internal Battery	Retains configuration information only. (Lithium battery has an estimated life of 10 years.)
Number of Ports	4 (independently configurable for different serial data formats)
Serial Ports Baud Rate	25 to 115,200 bps
Port Output	0 to 5 V logic ±5 V for RS-232 (switchable)
Port Configuration	9-pin D connectors
Data Flow Control	By datalogger or SDM-SIO4, if required, using hardware or software protocols
Onboard Diagnostics	Built-in system watchdog resets the processor in the event of a crash caused by transients and a built-in LED gives an indication of SDM-SIO4 status on power-up.
Input Voltage Limits	±25 V
Operating Temperature Range	-25° to +50°C
Dimensions	18.3 x 8.9 x 3.6 cm (7.2 x 3.5 x 1.4 in.) 22.4 x 8.9 x 3.6 cm (8.8 x 3.5 x 1.4 in.) with mounts
Weight	499 g (1.1 lb)

6.5 Power Break Out

(Model: WEST MOUNTAIN RADIO RIGRunner 4008)

Product Information:
http://www.westmountainradio.com/product_info.php?products_id=rr_4008_c
Manual: http://www.westmountainradio.com/pdf/RRmanual.pdf

FIGURE 18 – WEST MOUNTAIN RADIO RIGRUNNER POWER BANK

Specifications:

Overall Dimensions (maximum, w/o cables)	1.4” H x 9” W x 3.0” D
Weight	11 ¼ oz.
Maximum total current	40 amps
Maximum single individual outlet current	40 amps (fuse protected)
ICAS current rating (fuse limited)	37 amps
Precision comparator window points.	11.5,15.0 Volts
Metering Accuracy	Better than 2% @ 25 deg.C.
Audible alert SPL output	~ 60dB SPL @ 1 meter
Maximum voltage (meter circuit)	32 volts
Reverse polarity protection (meter circuit)	Yes

6.6 Cellular Antenna

(MODEL: LAIRD TECHNOLOGIES 32262)

Product Information: https://www.campbellsci.com/32262

FIGURE 19 - 4G LTE ANTENNA ON MOUNTING BRACKET

Specifications:

Type	Omnidirectional, multiband
Use	4G/3G cellular, outdoor or indoor, fixed location or mobile
Frequency Range	698 to 960 MHz 1710 to 2700 MHz
Nominal Peak Gain	1.4 dBd (@ 698 to 960 MHz) 3.3 dBd (@ 1710 to 1990 MHz) 2.4 dBd (@ 2100 to 2700 MHz)
VSWR	< 2.5:1
Radome Material	High heat ABS
Polarization	Vertical
Impedance	50 ohm
Maximum Input Power	100 W
Input Connection	Type N, threaded, female
Operating Temperature	-40° to +85°C
Dimensions	8.38 x 3.66 cm (3.3 x 1.44 in.)

6.7 Mobile Modem

(MODEL: SIERRA WIRELESS RV50)

Product Information: https://source.sierrawireless.com/devices/rv-series/rv50/
Manual: https://s.campbellsci.com/documents/us/manuals/rv50.pdf

FIGURE 20 - SIERRA WIRELESS RV50, 4G LTE DATA MODEM

Features and Benefits:

- 4G (with automatic fallback to 3G and 2G)
- Very Low Power Consumption
- Compatible with Campbell Scientific Data loggers
- High-Speed 2-way Data
- 10/100/1000 Ethernet RJ45, Serial and USB Port 2.0 Micro-B
- Machine Protocols

Bands

- LTE – 1900(B2), AWS(B4), 850(B5), 700(B13), 700(B17), 1900(B25)
- WCDMA – 2100(B1), 1900(B2), AWS(B4), 850(B5), 900(B8)
- EV-DO/CDMA – 800(BC0), 1900(BC1), 1700(BC10)
- GSM/GPRS/EDGE – Quad-band

Carrier Approval – North America

- Verizon, AT&T, Sprint, T-Mobile USA,
- Rogers, Bell, Telus

Environmental

- Operating Temperature: · -30° to 70° C
- Storage Temperature: · -40° to 85° C

Power Consumption: (@12V DC)

- Typical Active, 250/300 mA
- Typical Idle, 65/95 mA
- Input Current 40 mA to 120 mA
- Input Voltage 7 – 36V DC

7 Instrumentation and Sensors

7.1 JPL Radiometers

Product Description: http://calval.jpl.nasa.gov/radiometers
Manual: Contact Simon J. Hook at JPL: *Simon.J.Hook@jpl.nasa.gov*

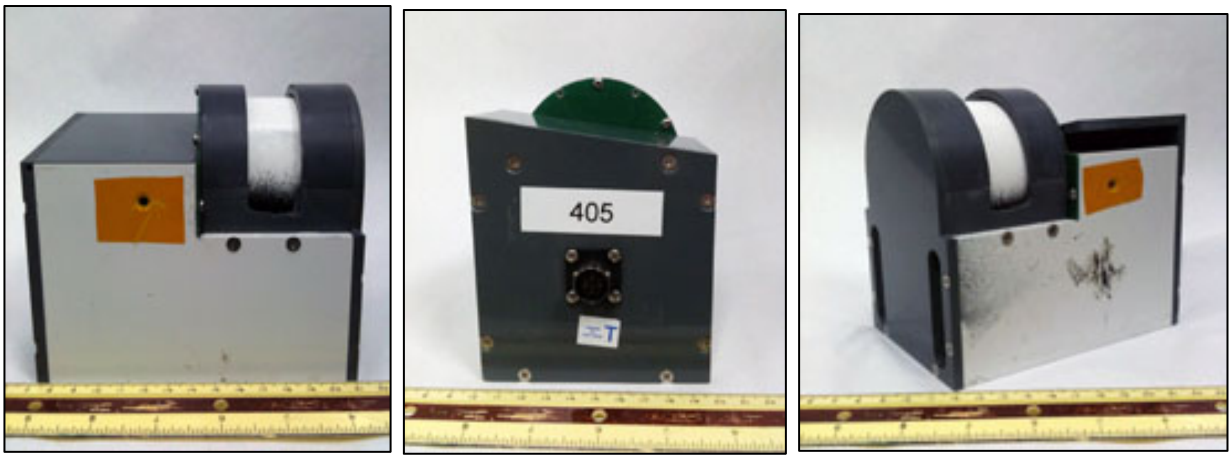


FIGURE 21 – JPL RADIOMETER

Specifications:

Length	5.625 inches (143 mm)
Width	4 inches (102 mm)
Height	5.25 inches (133 mm)
Weight	4 lb 3 oz (1.845 Kg)
Voltage/Current	12V, draw up to 2.92A depending on environment
Current Draw	25Ah per day
Voltage Range	11.2V stops working, 16V short durations only
Communication	RS232 at 2400 baud N 8 1 with no flow control
Total Field of View	200 series=44 degrees; 400, 500 series= 36 degrees
Wavelength range	8-14 micrometers

7.2 Laboratory Calibration Of The JPL Radiometers

Calibration of the radiometers deployed at Russell Ranch is undertaken at JPL and the facilities are summarized below. The manufacturer calibrates other equipment such as the CNR4 Net Radiometer.

The radiometers are calibrated using a laboratory blackbody. The systems are NIST traceable. In addition, JPL has developed a portable cone blackbody for field calibration. The specifications for the NIST traceable laboratory cone blackbody and readout system are:

- NIST designed cone in a 44 liter temperature controlled bath. Stability at 25 C: +/- 0.0007 C (7008-IR)

- Thermistor standard probe with an accuracy specification of 0.0015 °C over 0-60 °C and stability/yr of 0.005 °C. (Model 5643-R) and Secondary PRT.

- Readout system with an accuracy of 0.0025 °C at 25 °C and resolution of 0.0001 ° (Chub E4)

Calibration of the radiometers is performed in a ramp and soak mode where the blackbody or water-bath temperature is increased by a set interval and allowed to soak for several minutes and then the temperature is measured. The measured temperatures are then compared to the standard probe temperatures to derive calibration coefficients for the radiometers. After calibration the radiometers have accuracies of ± 0.1 °C.


Perturbation	Kinetic Temperature (degrees C)		Difference from no perturbation (degrees C)	
None	5.634	20.762	0	0
90% Water Vapor	5.640	20.767	0.006	0.005
110% Water Vapor	5.628	20.758	-0.006	-0.005
-1 deg C	5.640	20.767	0.006	0.005
+1 deg C	5.628	20.758	-0.006	-0.005
Ozone Factor 50%	5.640	20.767	0.006	0.005
Ozone factor 150%	5.629	20.759	-0.005	-0.004
-0.5 um SRF shift	5.561	20.717	-0.073	-0.045
+0.5 um SRF shift	5.673	20.815	0.039	0.053

Rice, J. P., J. J. Butler, B. C. Johnson, P. J. Minnett, K. A. Maillet, T. J. Nightingale, S. J. Hook, A. Abtahi, C. J. Donlon and I. J. Barton, 2004. The Miami2001 Infrared Radiometer Calibration and Intercomparison: 1. Laboratory Characterization of Blackbody Targets. Journal of Atmospheric and Oceanic Technology, vol. 21, pp. 258-267.

7.3 Net Radiometers

(Model: KIPP & ZONEN CNR4)

Product Description: http://www.kippzonen.com/Product/85/CNR4-Net-Radiometer
Manual: http://www.kippzonen.com/Download/354/Manual-CNR-4-Net-Radiometer-English

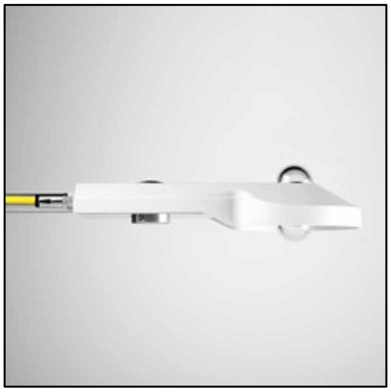
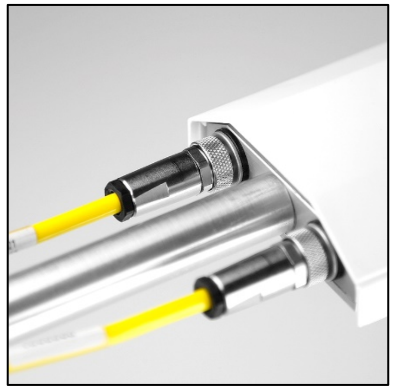



FIGURE 22 – KIPP & ZONEN CNR4 NET RADIOMETER

Order Cable at different lengths 10meter, 25meter is option.

Spectral range (50% points)	0.3 to 2.8 µm = 300 to 2800 (short wave) nm
Spectral range (50% points)	4.5 to 42 µm = 4500 to 42000 (long wave) nm
Sensitivity	5 to 20 µV/W/m²
Temperature dependence of sensitivity (-10 ºC to +40 ºC)	< 4 %
Response time	< 18 s
Non-linearity	< 1 %
Operating temperature	-40 to 80 °C
Ventilation power	(of the optional CNF 4 ventilation unit) 10 W

7.3.1 Kipp & Zonen Drying Cartridge (Model: 4250024)

The silica-gel desiccant regulates the humidity level inside the pyranometer. Initially the desiccant will have an orange color. After some time it becomes saturated with moisture and the color will change to become clear (transparent).

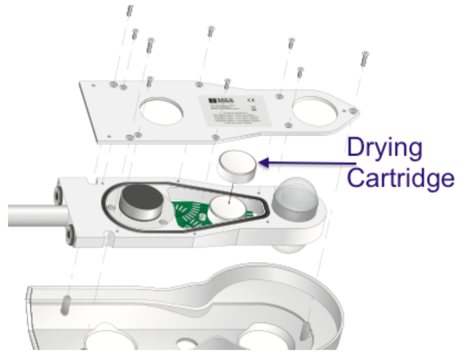


FIGURE 23 – KIPP & ZONEN DRYING CARTRIDGE

7.4 Wind Monitors
(Model: RM YOUNG 05106)

Product Description: http://www.youngusa.com/products/11/8.html
Manual: http://www.youngusa.com/Manuals/05106-90(K).pdf

FIGURE 24 – WIND MONITOR

The Wind Monitor-MA measures horizontal wind speed and direction. Originally developed for ocean buoy use, it is rugged and corrosion resistant yet accurate and lightweight. The main housing, nose cone, propeller, and other internal parts are injection molded U.V. stabilized plastic. Both the propeller and vertical shafts use stainless steel precision grade ball bearings. Bearings have light contacting Teflon seals and are filled with a low torque wide temperature range grease to help exclude contamination and moisture.

Specifications:
Range:
Wind speed: 0-100 m/s (224 mph)
Azimuth: 360° mechanical, 355° electrical (5° open)

Accuracy:
Wind speed: ± 0.3 m/s (0.6 mph) or 1% of reading
Wind direction: ± 3 degrees

Threshold:* Propeller: 1.1 m/s (2.4 mph) Vane: 1.1 m/s (2.4 mph)

Signal Output:
Wind speed: magnetically induced AC voltage, 3 pulses per revolution. 1800 rpm (90 Hz) = 8.8 m/s (19.7 mph).
Azimuth: analog DC voltage from conductive plastic potentiometer – resistance 10K Ω, linearity 0.25%, life expectancy – 50 million revolutions.

Power Requirement:
Potentiometer excitation: 15 VDC maximum

Sensor Cable:
A 3-meter (9.8 ft) pigtail cable is supplied for electrical connections.
For longer cable lengths a user supplied junction box or connector may be used.

Dimensions:
Overall height: 37 cm (14.6 in)
Overall length: 55 cm (21.7 in)
Propeller: 18 cm (7 in) diameter
Mounting: 34 mm (1.34 in) diameter (standard 1 inch pipe)

Weight:
Sensor weight: 1.0 kg (2.2 lbs)
Shipping weight: 2.3 kg (5 lbs)

7.5 Compass / Serial Interface
(Model: RM YOUNG 32500)

Product Information: http://www.youngusa.com/products/9/51.html
Manual: http://www.youngusa.com/Manuals/32500-90(S).pdf

FIGURE 25 – ELECTRONIC COMPASS AND SERIAL INTERFACE

The Model 32500 Electronic Compass measures magnetic heading, wind speed and direction signals from YOUNG sensors, and signals from four general-purpose voltage inputs. Wind direction input may be combined with compass measurements to obtain true direction. Voltage inputs may be used with YOUNG temperature, humidity, barometric pressure, and other sensors. One voltage input may be configured for connection to a tipping bucket precipitation gauge.

Specifications:
Size: 4.75 in (12 cm) H 2.87 in (7.3 cm) W 2.12 in (5.3 cm) D
Resolution: 1 degree azimuth
Accuracy: ±2 degrees RMS
Inputs: YOUNG wind sensors 2 channels, 0-1000 mV 2 channels, 0-5000 mV
Outputs: Serial RS232 / RS485
Selectable formats: ASCII Text, NMEA, RMYT compatible with 06201 display.
Operating Temperature: -50˚C to +50˚C
Power: 10 to 30 VDC, 30 mA
Mounting: 1” IPS (1.34” actual diameter)
Other: Self-calibration mode for compass

7.5.1 Retractable Mounting Arm
(Model: RM YOUNG 16106A)

Product Information: http://www.youngusa.com/products/5/36.html
Manual: http://www.youngusa.com/Manuals/16106A.pdf

FIGURE 26 - MOUNTING ARM

Used to mount the wind indicator and compass. The factory poles must be replaced with poles that 12 inch poles.

Specifications:

Length: 6 ft
Tubing size: 1.5 in
Max tower width: 20 in
Tower leg dia. (max.): 2 in
Weight (34pprox..): 20 lb

7.6 Temperature And Relative Humidity Probes

(Model: RM YOUNG 41382VC)

Product Information: http://www.youngusa.com/products/2/15.html

Manual: http://www.youngusa.com/Manuals/41382VC-90(E).pdf

FIGURE 27 – AIR TEMPERATURE AND RH SENSORS

The Model 41382VC Relative Humidity/Temperature Probe combines high accuracy humidity and temperature sensors in a single probe. The output signal is 0-1 V (standard) or 0-5 V (user selected option) for both relative humidity and temperature. RH range is 0-100%. Temperature range is -50 to +50°C.

Specifications:

Power Required:	**41382 (V –Voltage, L – Current Options)**
V Option: 10-28 VDC	8 mA
L Option: 10-28 VDC	40 mA

RELATIVE HUMIDITY: (41382)
Measuring Range: 0-100 %RH
Accuracy at 23°C: ±1%RH,
Stability: Better than ±1%RH per year
Response Time: 10 seconds (without filter)
Sensor Type: Rotronic Hygromer™
Output Signal: V option: 0-1 VDC, L option: 4-20 mA

TEMPERATURE: (41382, 41342)
Calibrated Measuring Range: -50 to 50°C (suffix C) -50 to 150°F (suffix F)
Response Time: 10 seconds (without filter)
Accuracy at 23°C: ±0.3°C /optional ±0.1°C NIST calibration – 41342 only
Sensor Type: Platinum RTD
Output Signal: V Option: 0-1 VDC, L Option: 4-20 mA, 4 wire RTD (41342 only

7.7 Multi-Plate Radiation Shield
(Model: RM YOUNG 41003)

Product Information: http://www.youngusa.com/products/2/11.html
Manual: http://www.youngusa.com/Manuals/41003-90(C).pdf

FIGURE 28 – RADIATION SHIELD

The Multi-Plate Radiation Gill Shield protects temperature and relative humidity sensors from error-producing solar radiation and precipitation.

Specifications:

Radiation Error:
@ 1080 W/m^2 intensity- Dependent on wind speed
0.4 ˚C (0.7 ˚F) RMS @ 3 m/s (6.7 mph)
0.7 ˚C (1.3 ˚F) RMS @ 2 m/s (4.5 mph)
1.5 ˚C (2.7 ˚F) RMS @ 1 m/s (2.2 mph)

Construction:
UV stabilized white thermoplastic plates, aluminum mounting bracket, white powder coated Stainless steel U-bolt clamp

Dimensions:
13cm (5.1 in) diameter x 26 cm (10.2 in) high
Mounting fits vertical pipe 25-50 mm (1-2 in) diameter

Weight:
Net weight: 0.7 kg (1.5 lb)
Shipping Weight: 1.4 kg (3 lb)

7.8 Barometric Pressure Sensor (Model: RM YOUNG 61302V)

Product Information: http://www.youngusa.com/products/3/22.html
Manual: http://www.youngusa.com/Manuals/61302V-90(h).pdf

FIGURE 29 – R. M. YOUNG BAROMETRIC PRESSURE SENSOR

Model 61302V provides a calibrated 0-5 VDC analog output. Analog current consumption is less than 3 mA. A special “sleep” mode further reduces current to about 1 μA.

Specifications:

Pressure Range:	500-1100 hPa
Operating Temperature:	-40 to +60°C
Digital Accuracy*:	0.2hPa (25°C) 0.3 hPa (-40 to +60°C)
Analog Accuracy:**	0.05% of analog pressure range
Analog Temperature Dependence:	0.0017% of analog pressure range/°C (25°C reference)
Long Term Stability:	0.2% FS per year
Update Rate:	1.8 Hz max
Serial Output:	Full duplex RS-232 – 9600 baud Polled or Continuous ASCII text or NMEA format Half duplex RS-485 (61302L only)
Analog Output:	0 to 5000 mV (Model 61302V) 4 to 20 mA (Model 61302L)
Resolution:	Analog 0.025% of scale Serial 0.01 hPa
Power:	Model 61302V (7 to 30 Vdc) Vout Mode = 2.8 mA Sleep Mode = 1.4 uA RS232 Mode = 7 mA
Dimensions:	90mm (3.6 in) x 60 mm (2.4 in) x 20 mm (0.8in)
Weight:	Net 44 g (1.5 oz)

7.8.1 Pressure Port
(Model: RM YOUNG 61002)

Product Information: http://www.youngusa.com/products/3/20.html
Manual: None

FIGURE 30 – R. M. YOUNG PRESSURE PORT

The Pressure Port minimizes dynamic pressure errors due to wind.

Specifications:
Dynamic Pressure Error: 0.5 hPa maximum @ 20 m/s

Dimensions: 11.5 cm (4.5 in) H x 13 cm (5.1 in) Dia.

Mounting: Offset bracket with U-bolt for 25 - 50 mm (1-2 in) pipe

Weight: 0.2 kg (0.5 lb)

Shipping Weight: 0.8 kg (1.8 lb)

7.9 Photosynthetically Active Radiation (PAR) Sensor
(Model: LI-COR LI190SB)

Product Information: https://www.campbellsci.com/li190sb-l
Manual: https://s.campbellsci.com/documents/us/manuals/li190sb.pdf

FIGURE 31 - LI-COR, PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR) SENSOR

Specifications:

Absolute Calibration: ± 5% traceable to the National Institute of Standards and Technology (NIST).
Light Spectrum Waveband: 400-700 nm
Sensitivity: Typically 5 µA to 10 µA per 1000 µmol s-1 m-2.
Linearity: Maximum deviation of 1% up to 10,000 µmol s-1 m-2.
Stability: Typically < ± 2% change over a 1 year period.
Response Time: 10 µs.
Temperature Dependence: 0.15% per °C maximum.
Cosine Correction: Cosine corrected up to 80° angle of incidence.
Azimuth: < ± 1% error over 360° at 45° elevation.
Tilt: No error induced from orientation.
Operating Temperature: -40 to 65°C.
Relative Humidity: 0 to 100%.
Detector: High stability silicon photovoltaic detector (blue enhanced).
Sensor Housing: Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.
Size: 2.38 Dia. × 2.54 cm H (0.94” × 1.0”).
Weight: 28 g (1 oz).

7.9.1 Millivolt Adapters For PAR Sensors
(Model: LI-COR 2290/LI-190SA or LI-190R-SMV-15)

Product Information: https://www.licor.com/env/products/light/accessories.html

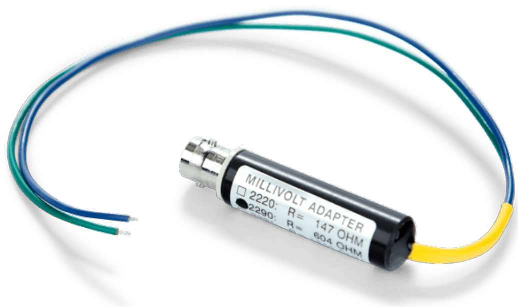


FIGURE 32 - MILLIVOLT PAR SENSOR ADAPTER

Millivolt adapters are used for connecting sensors to other manufacturers' data loggers or data acquisition systems; they are not needed with the LI-1400, LI-1500 or other LI-COR readout devices.

Li-COR provides two types of millivolt adapters: 1) a "matched" adapter that features a standardized 0-10 mV output (part numbers 2319, 2320, and 2321), and 2) an “unmatched” type that has a fixed resistor to convert the sensors' output to millivolts (part numbers 2220, 2290, and 2291). The standardized (matched) millivolt adapters are paired with a specific sensor and individually adjusted to standardize the sensor output. This eliminates the need to enter unique calibration constants or multipliers for each sensor.

The fixed resistor type millivolt adapters (unmatched) can be used with any compatible sensor to convert the sensors' output to millivolts; they require that a unique calibration constant or multiplier for each sensor be entered into the logging device to convert the output into the units of measurement.

7.9.2 PAR Sensor Mounting Plate
(Model: LI-COR LI2003S)

Product Information: https://www.licor.com/env/products/light/accessories.html

FIGURE 33 - MOUNTING PLATE WITH BUBBLE LEVEL

Size: 7.6 cm diameter (3.0”)

Weight: 95 g (0.21 lbs)

7.9.3 PAR Sensor Crossarm Mounting Kit with Bracket
(Model: LI-COR CM202 and CM225)

Product Information: https://www.campbellsci.com/cm202
Product Information: https://www.campbellsci.com/cm225-solar-mount
Length: 2 feet (0.61 m).

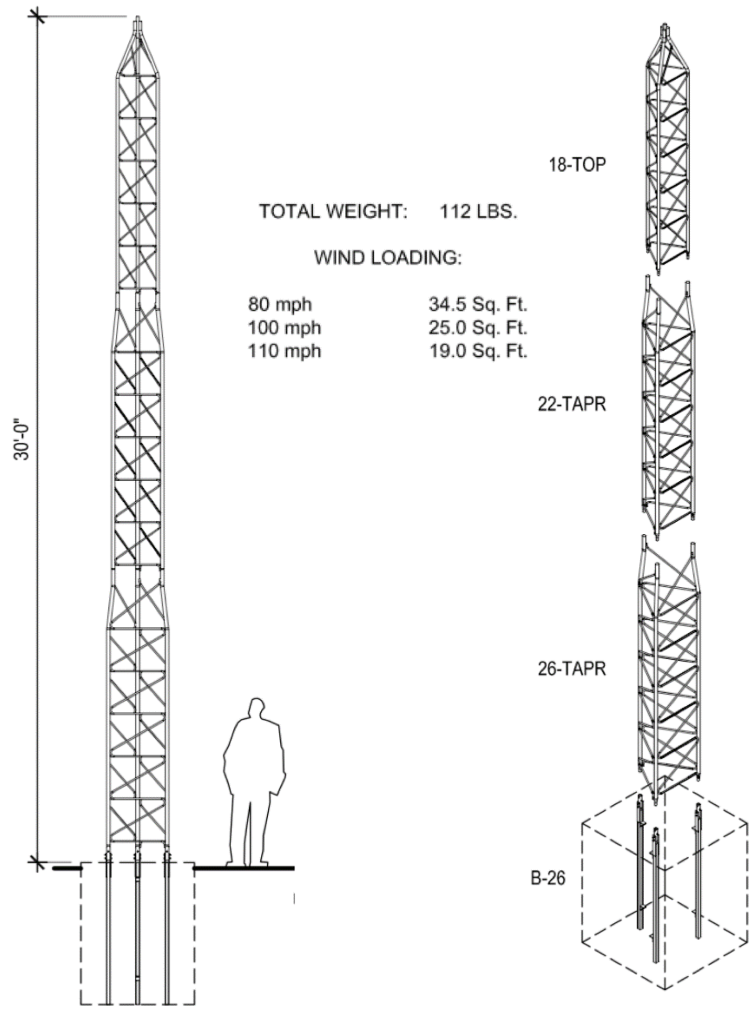
FIGURE 34 - CROSSARM MOUNT

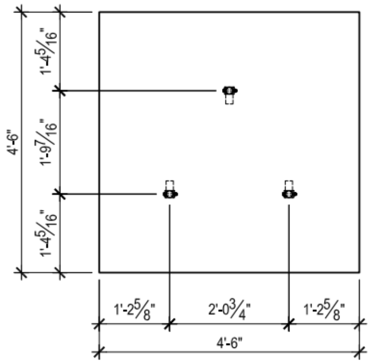
FIGURE 35 - MOUNTING BRACKET

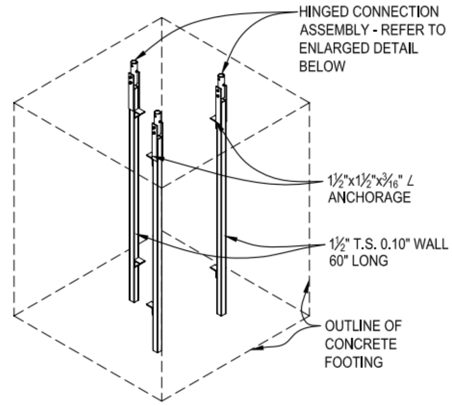
8 Tower Details

(Model: Universal Manufacturing Corporation, Universal Tower Model #35-30)

Manual: http://universaltowers.com/pdf/standard_models/06-model-35-30.pdf







Specifications:

Description	UT Model #35-30
Height	9.1 m (30 ft)
Shipping Weight	50.8 kg (112 lb)
Material	hardened drawn 6063-T832 aluminum
Vertical Pipe Outer Diameter	3.97 cm (1.56 in)
Cross Support Pipe Outer Diameter	1.43 cm (0.56 in)
Required Concrete Foundation Dimensions for B26 Concrete Mounting Base (see note 1)	137.16 L x 137.16W x 152.4 D cm (54 x 54 x 60 in)
Maximum Wind Load Recommendations (see note 2)	110 mph (B26 base unguyed)
Maximum Vertical Static Loading	(See manufactures letter)

Notes:

1. The concrete foundation requirements assume heavy soil; light, shifting, or sandy soils require a wider and deeper concrete pad.

2. The recommended wind load assumes proper installation, proper anchoring, and total instrument projected area of less than two square feet.

Loading Weights:

Item	Quantity	Weight (lbs.)	Total weight
Radiometer	2	4.1	8.2
Rad cables	3	1	3
Rad Case	3	1.5	4.5
Rad mount	2	15	30
CNR4	2	1.87	3.74
CNR4 pole	2	0.5	1
CNR4 mounting	2	0.85	1.7
CNR Boom	2	10	20
PAR	1	0.0625	0.0625
PAR mount	1	0.21	0.21
PAR cable	1	0.2	0.2
MET - Compass	2	1.5	3
MET - Wind indicator	2	2.2	4.4
MET- Pressures sensor	2	0.51	1.02
MET - Pressure sensor port	2	1.8	3.6
MET - Temp/RH	2	0.31	0.62
MET - Temp/RH Shield	2	1.5	3
MET - Mounting Brackets	2	5	10
Solar panels	2	30	60
Solar panel mounting brackets	2	15	30
Solar power cable	2	2.5	5

Total Overall Weight (lbs) **189.35**

9 Appendix A - Russell Ranch Servicing Plan

In order to service the instruments at the Russell Ranch site with restricted access during the year, this servicing plan will provide the options selected to service the tower while the crops are growing. JPL safety will also need to approve the option we select.

There are some unknowns that need to be resolved before we can implement the option: permission to use scaffolding on the property; any training classes required by safety.

9.1 Option During Growing Season

Maintain the instruments at the current height on the tower but purchase **internal staircase** scaffolding that can be assembled at site with adequate support and approval from safety to reduce any risk of injury. The company has OSHA Safety Documents available for reference. The internal staircase reduces the risk versus the ladder-scaffolding model. This configuration includes the stabilizers (outriggers) for vertical support.

This option will require assembly and disassembly of the scaffolding every time it is used. This will add additional time to the service activity. We also need to obtain JPL Safety approval before the tower can be erected.

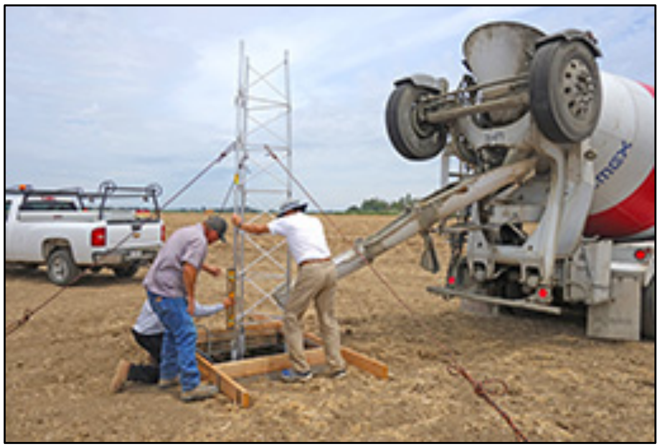
FIGURE 36 - SCAFFOLDING WITH INTERNAL STAIR

9.2 Option During Fallow Conditions

When the sites have fallow conditions then a man-lift can be used to service the tower. This option is a time-saving solution compared to assembling the scaffolding.

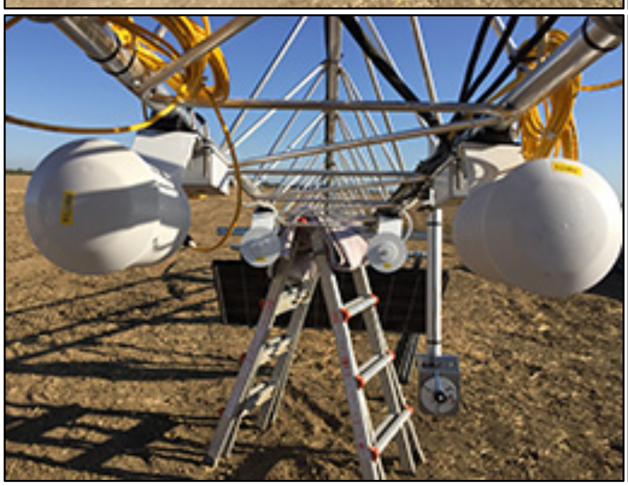
Figure 37 - Man-Lift Option

10 APPENDIX B – Images of Tower Installation and Operation

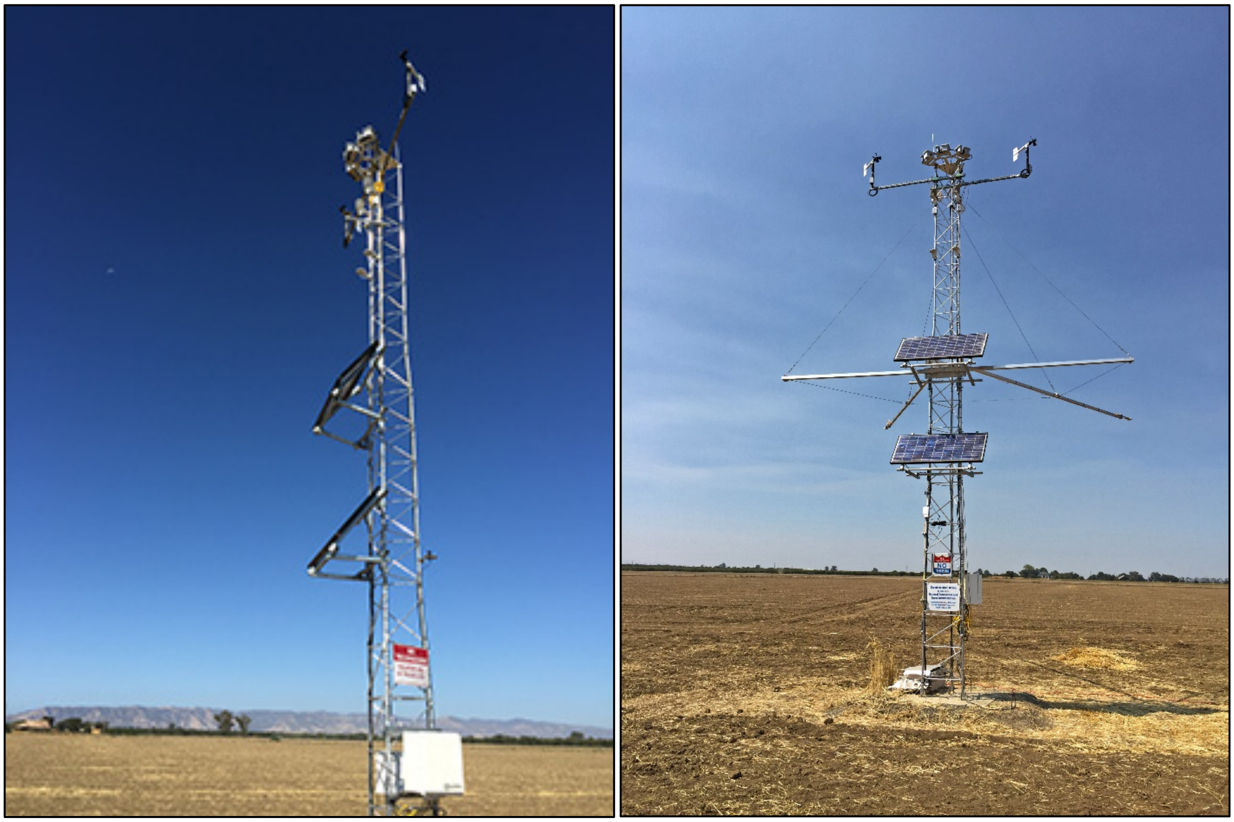


Images of tower base/footing installation, construction, erection, and grounding.

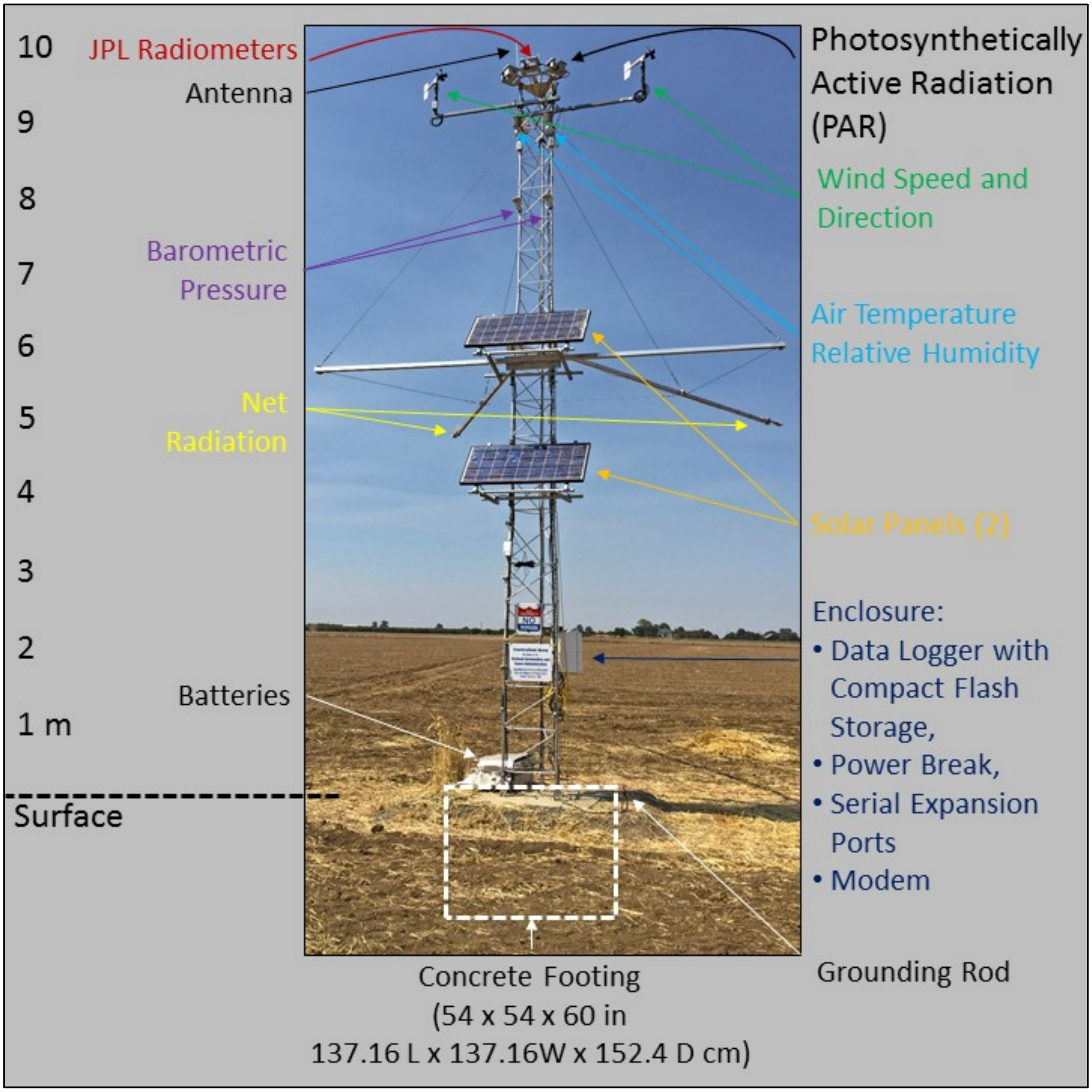





Images of adding instrumentation.



Images of scaffolding and final product.


10
9
8
7
6
5
4
3
2
1 m
Surface
JPL Radiometers
Antenna
Barometric Pressure
Net Radiation
Batteries
Photosynthetically Active Radiation (PAR)
Wind Speed and Direction
Air Temperature Relative Humidity
Solar Panels (2)
Enclosure:
• Data Logger with Compact Flash Storage,
• Power Break,
• Serial Expansion Ports
• Modem
Concrete Footing (54 x 54 x 60 in 137.16 L x 137.16W x 152.4 D cm)
Grounding Rod

11 CONTACT INFORMATION

Gerardo Rivera

Scientific Applications Software Engineer
NASA Jet Propulsion Laboratory,
California Institute of Technology
4800 Oak Grove Dr.
MS T1721-123
Pasadena, CA 91109
Email: Gerardo.Rivera@jpl.nasa.gov
Phone: 818.354.9803

Nathan C. Healey, Ph.D.

Postdoctoral Scholar
NASA Jet Propulsion Laboratory,
California Institute of Technology
4800 Oak Grove Dr.
MS 183-501
Pasadena, CA 91109
Email: Nathan.C.Healey@jpl.nasa.gov
Phone: 818.393.5358

Point of Contact: **Simon J. Hook, Ph.D.**
NASA Jet Propulsion Laboratory,
California Institute of Technology
4800 Oak Grove Dr.
MS 183-335
Pasadena, CA 91109
Email: Simon.J.Hook@jpl.nasa.gov
Phone: 818.354.0974