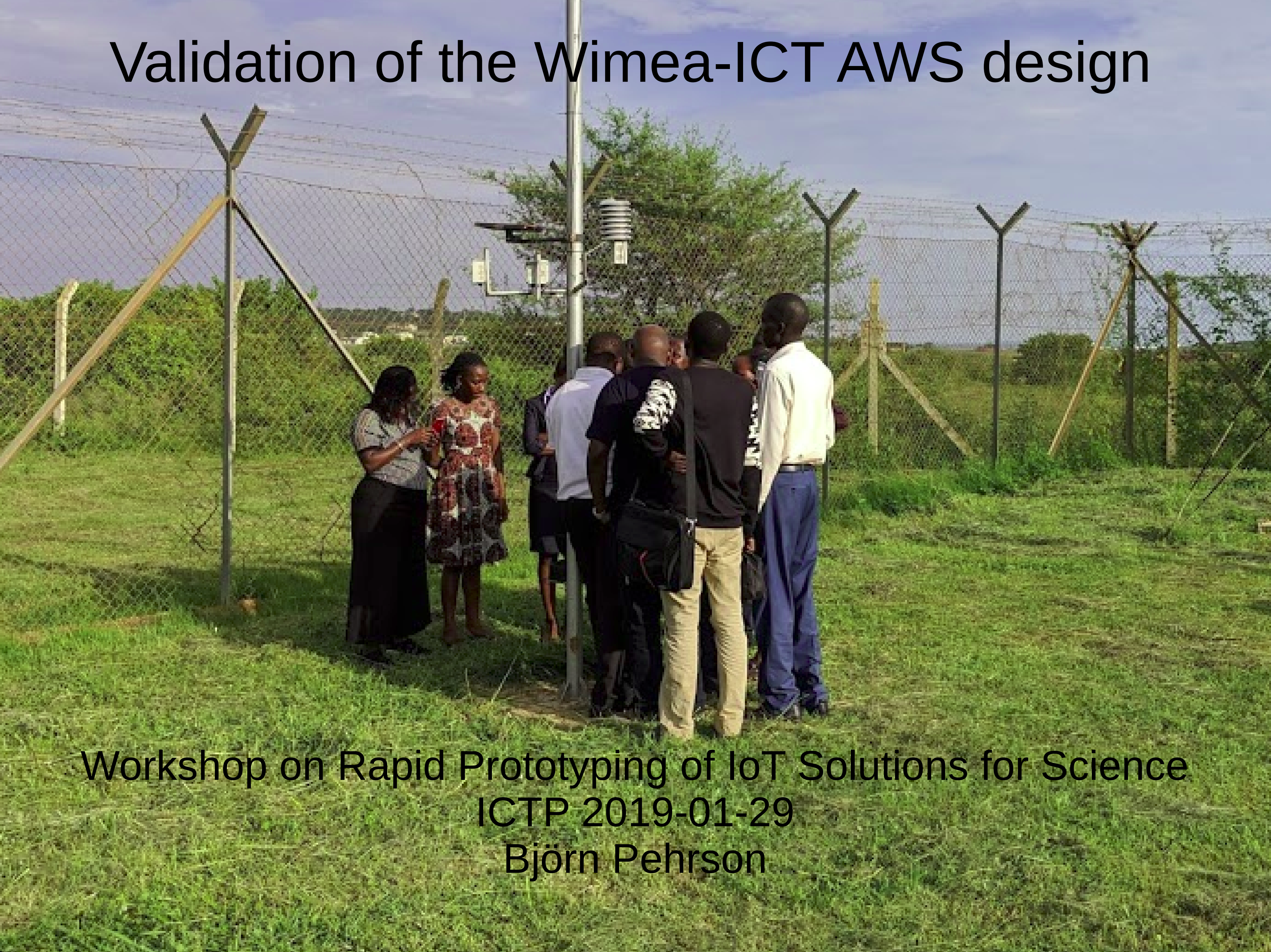
Validation of the Wimea-ICT AWS design



Workshop on Rapid Prototyping of IoT Solutions for Science
ICTP 2019-01-29
Björn Pehrson

WIMEA-ICT

Improving weather information management in East Africa using ICT

- Involving 8 PhD- and many Msc-students, their advisors and teachers
- Research components
  - Automated Weather Station
  - Weather Data Repository
  - Numerical forecasting (WRF)
  - Dissemination to End-Users

Project manager is Dr. Julianne Sansa Otim, Makerere University
Web-site is https://wimea-ict.net   Supported by NORAD

Considerations to decide whether to buy or design an own AWS?

- Surveys told: Commercial systems either
  - expensive and accurate in controlled environments
    - Vaisala, Casella, Davis...... vs
  - or cheap and not accurate enough consumer products
- Few of them robust enough to resist
  - Continuous heat, moisture and weather hazards
  - Termites, elephants, vandals
- Poor uplink communication to repositories
- Capacity building

Decisions taken

- Own design
  - Ambition to lower cost and increase robustness
  - if nothing else, to understand the challenges as a capacity building exercise
- Design goals
  - < 2000 USD per station
  - WMO compliant
  - Prototype series
    - 1 unit 1st gen in Bergen
    - 4 units 2nd gen in Bergen, Dar, Juba, Kampala
    - 70 units 3rd gen in two batches (25+45), 10 in SS, 30 each in Tz, Ug

Validation

- Validation Criteria?
  - Benchmarking, calibration
- Certification?
  - Nah…
- Supervision and periodical re-validation!
  - calibration

Rapid prototyping, why?

- Initial focus on fuctionality rather than performance
- Catch mistakes early
  - ASAP id errors, mis-specifications, new insights
- Identify and involve (end-)users asap
  - Stakeholder analysis
- Scenarios - seeing is believing
- The proof of the pudding is in the eating ()
- Think even more before….

Who are the wimea-ict (end-)users? How to involve them?

Needs and Requirements Analysis

- Food security - farming and fisheries - and others
  - More crop per drop,
  - Early warning (stormy weather, lightning, flooding)
- National Meteorological Agencies
  - From data to forecasts
  - UNMA, TMA, SSMS
- Manufacturers, custodians, etc
  - Procurement of components, assembly, testing, deployment, maintenance, recycling

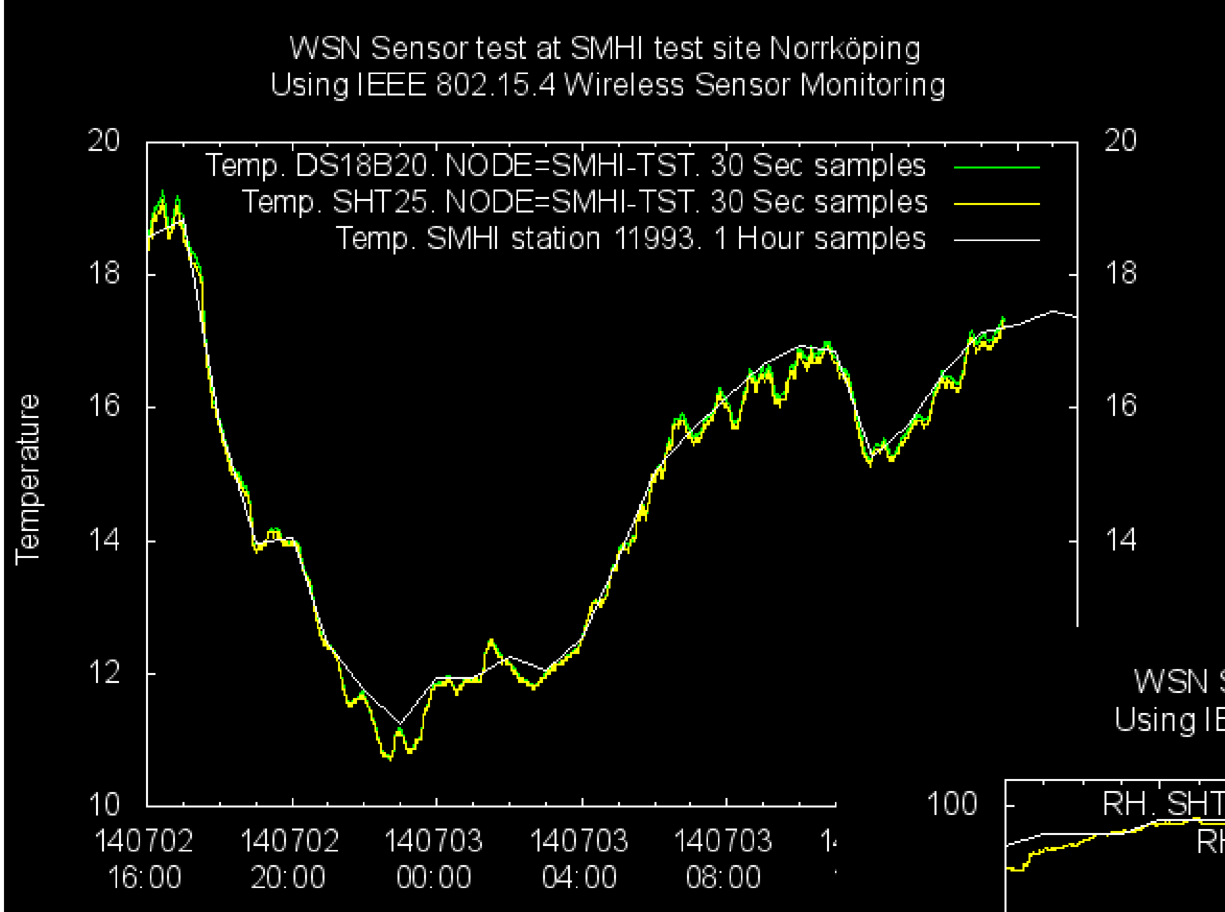
User requirements

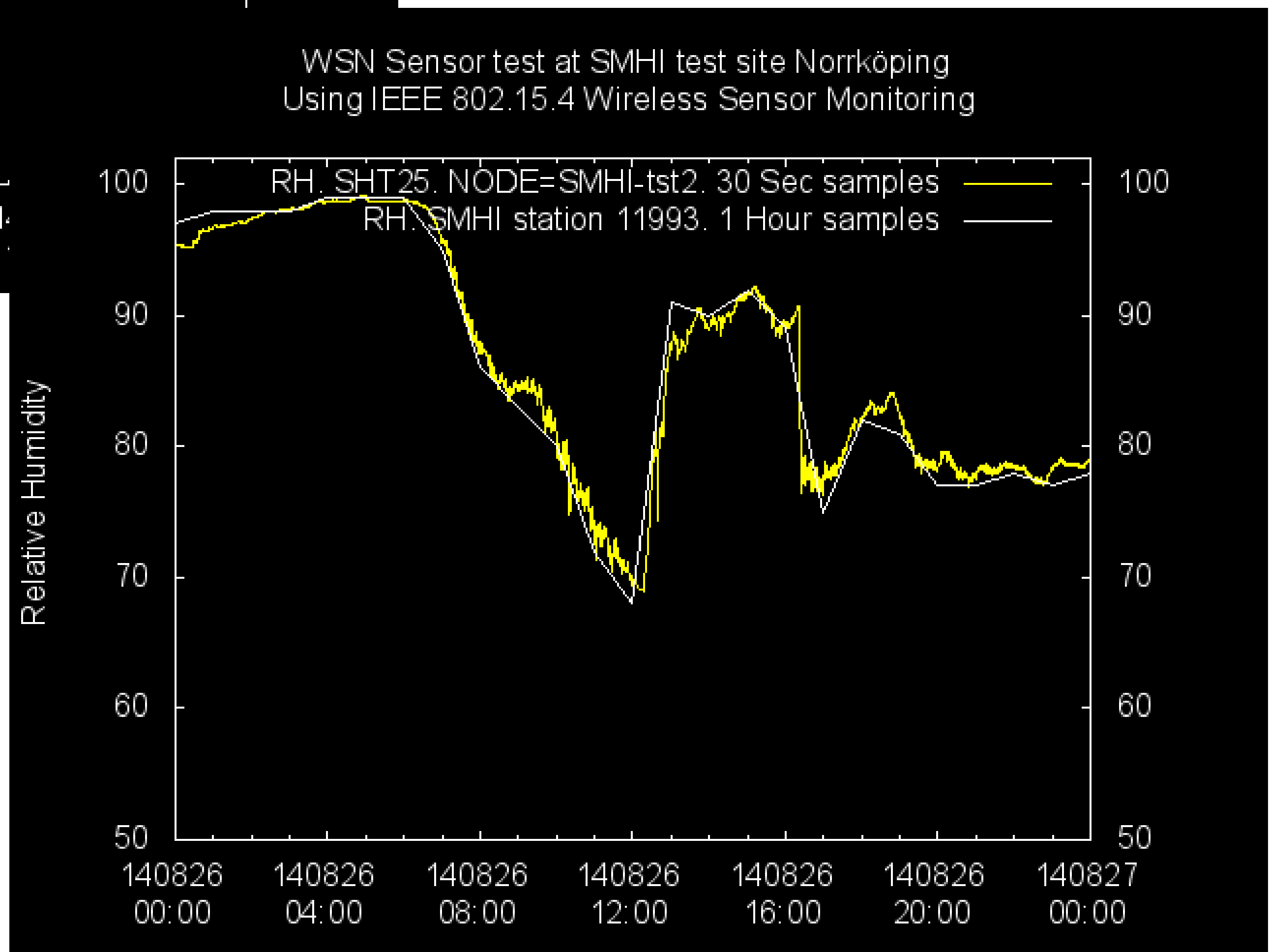
- Sensors
  - Precipitation, soil temperature and moisture
  - Air temperature and humidity
  - Wind, Insolation, Atmospheric pressure
- WMO standards
  - How, where and when to measure
  - Resolution, calibration
- Robustness and Security
  - Harsh weather, wasps/termites/elephants, vandals
- Sampling per minute
  - or even more often if possible

Choices of sensors made

- Sensors
  - Precipitation Davis 7852, 0.2 mm
  - Soil temperature DS18B20 and moisture Vegetronix VH400
  - Air temperature and humidity Sensirion SHT25
  - Wind: Inspeed e-vane and Vortex anemometer
  - Insolation Hamatsu S1223 with 3mm diffusor
  - Atmospheric pressure MS5611, BME280
- WMO standards
  - How to measure: sink, gnd, 2m 10m

Benchmarking air temperature and humidity sensors





Connectivity

- Wire
  - Copper, fibre
- Terrestrial wireless
  - Commercial cellular
  - LPWAN
  - Dedicated shf/uhf/vhf/hf
- Satellite SBS
- Sneakernet
  - Delay Tolerant Networks
  - USB-sticks
- Community Networks
- AMPRNet volunteers www.ampr.org

Design alternatives

- Traditional systems are centralized and wired
  - cpu, sensors, logger, uplink, management software,
- Innovative systems are distributed and wireless
  - independent power-lean sensor nodes
  - sink node, gateway
- Challenges
  - Uplinks, Sensors, Power consumption, robustness, security

Wimea-ict AWS design decisions

- Distributed autonomous sensor nodes
  - Gnd: precipitation, soil moisture
  - 2m: air temperature and humidity
  - 10m: wind, insolation
  - gateway/sink: Atmospheric pressure
  - 1 minute sampling interval
- Sink/gateway always on vs radio duty cycling
- Considerations
  - Power consumption, location flexibility, redundancy, maintainability,...

Implementation requirements

- Open standards
- Free Open Source SW with supporting communities
- HW Manufacturer independent platforms

WIMEA-ICT AWS Prototype Technology choices

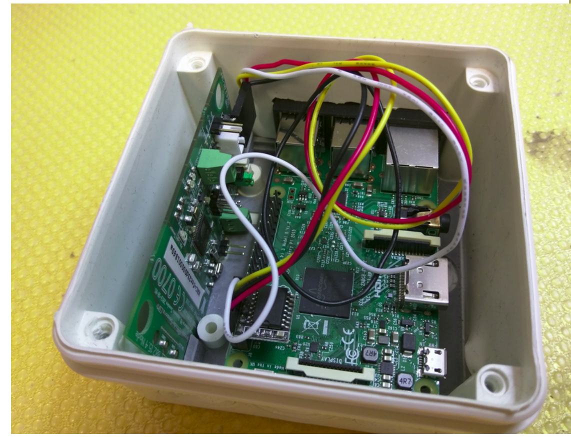
- WSN Nodes:
  - Contiki-OS, RIME platform
  - hardware http://radio-sensors.com
  - Open source firmware https://github.com/wimea-ict
  - Proprietary fw available to allow parallel development
  - Wimea-ICT open hw daughter card for sensors
- Gateway alternatives
  - Raspberry Pi/Raspbian lite
  - Low power sink node extension plus link modem
- Linux based development environment and tool chain

Radio-Sensors mote

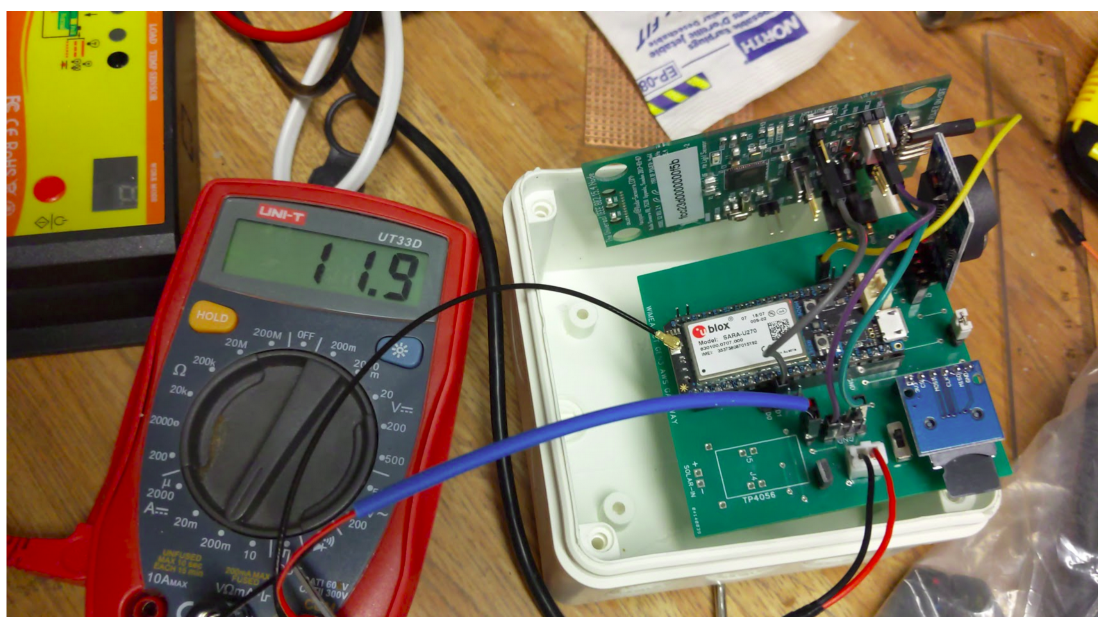
http://www.radio-sensors.com/

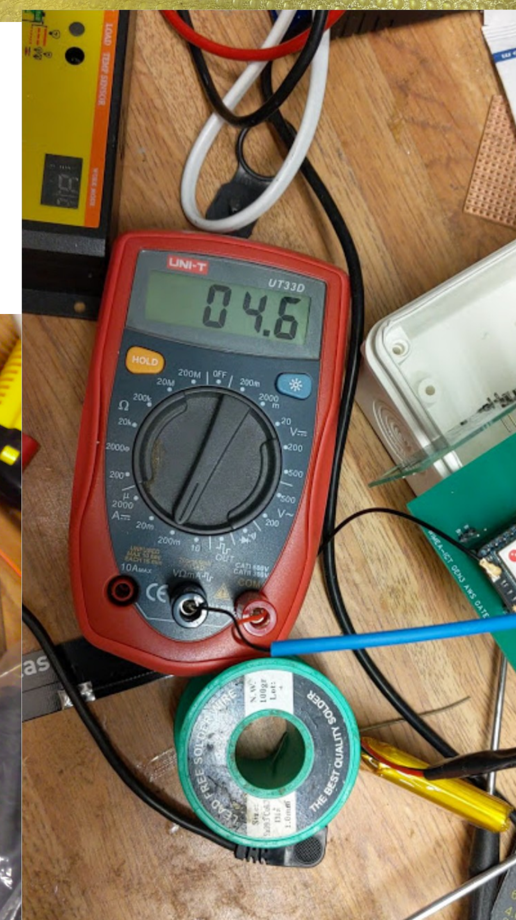
- ATMega256/128RF integrates MCU, ieee802.15.4 transceiver and an 8 channel 10bit ADC
- 1.8-3.6V operating voltage 250nA@25C in deep sleep
- Analog and pulse inputs with feed
- DS18B20 and Ambient light sensors on board
- Daughter cards with other sensors
- Connectors to SPI, I2c, ow-buses
- ContikiOS-based firmware
- Rev 2.4 with BME280 saves one daughter card

Gateway/sink-node

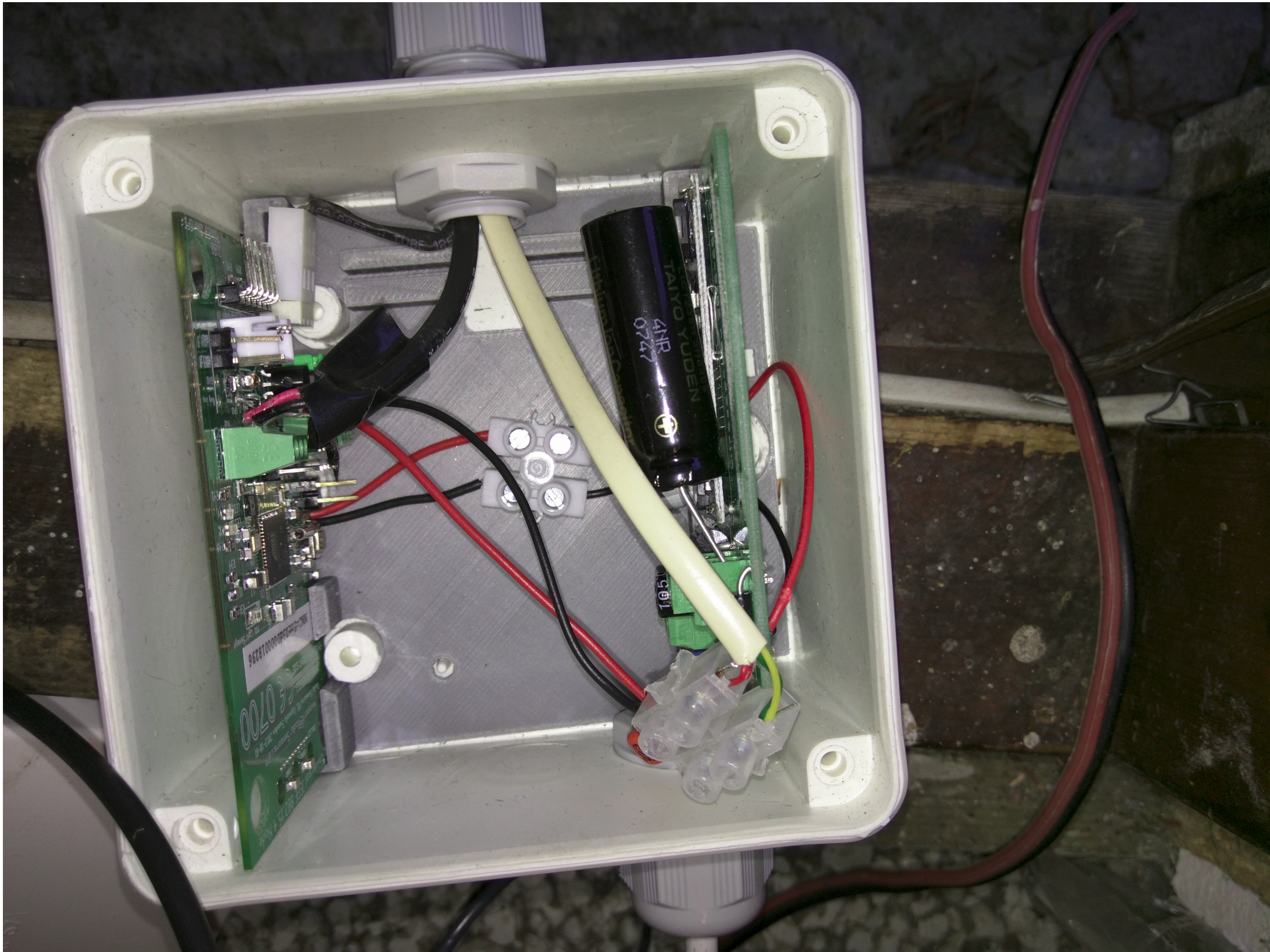


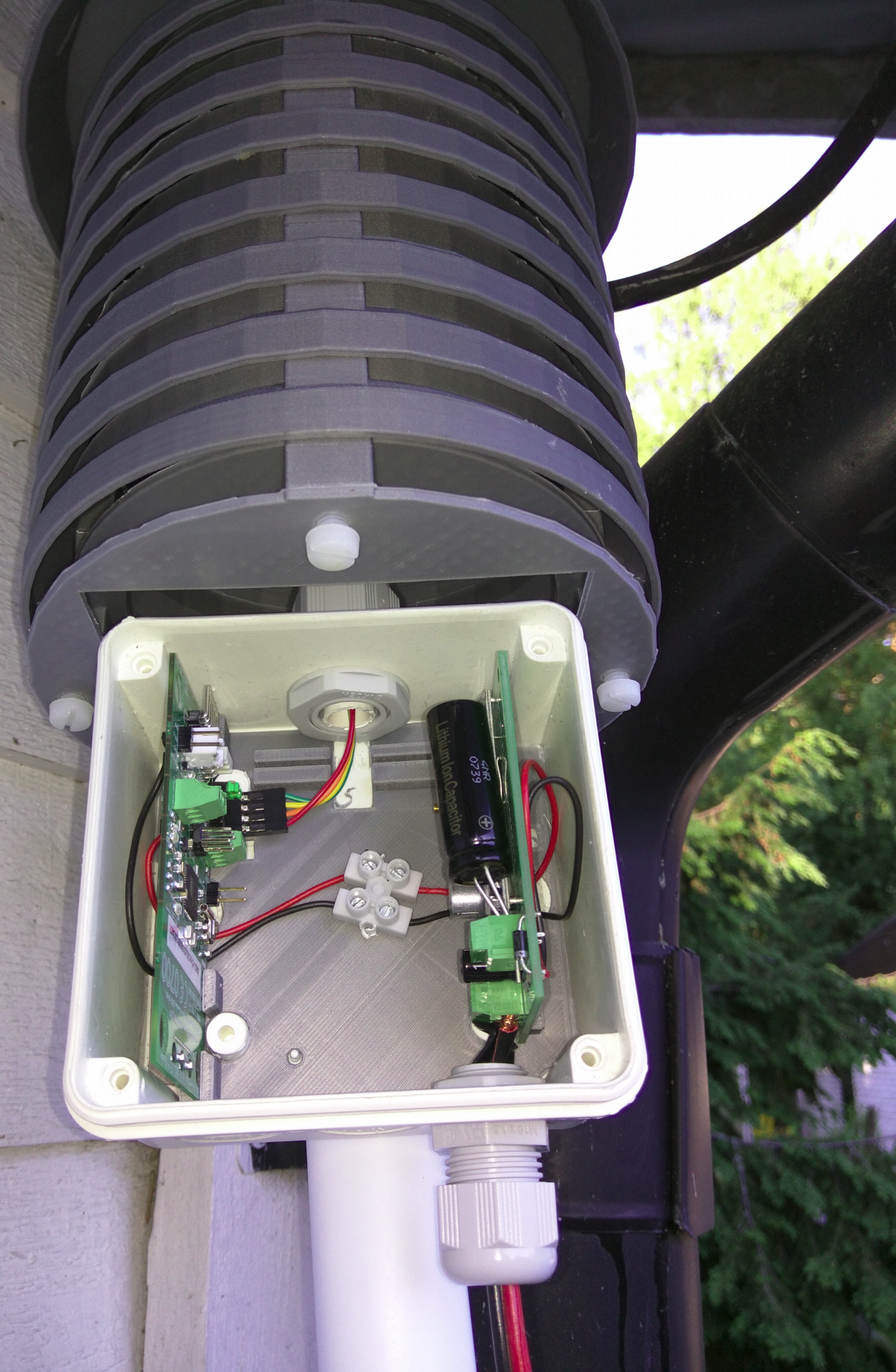
- Sink Rpi gwy
  - several uplinks
  - 5V ~200mA ~ 1W
- Sink fw gwy extension + gprs modem
  - 3.3V ~ 4-20 mA ~ 15 – 60 mW

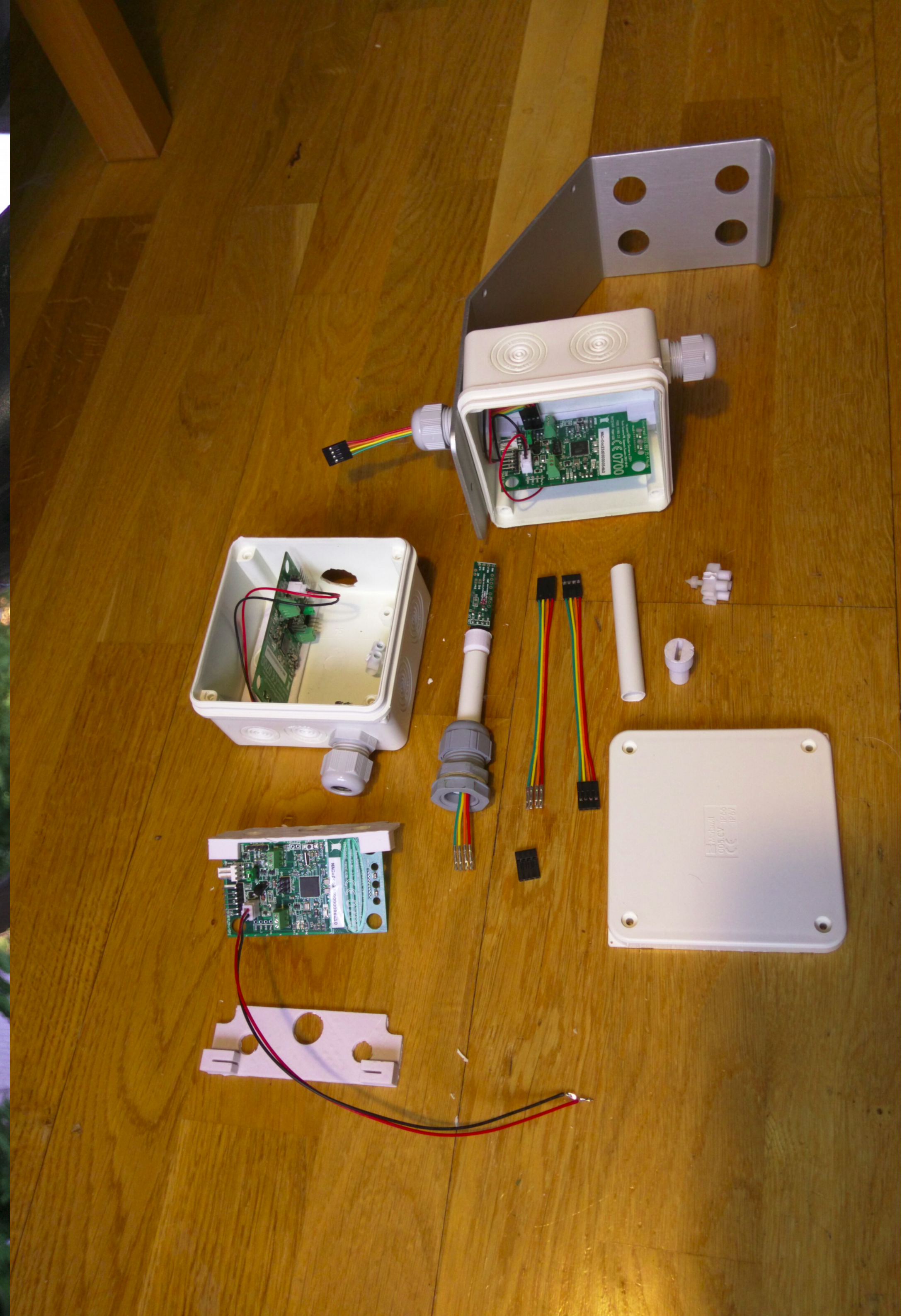




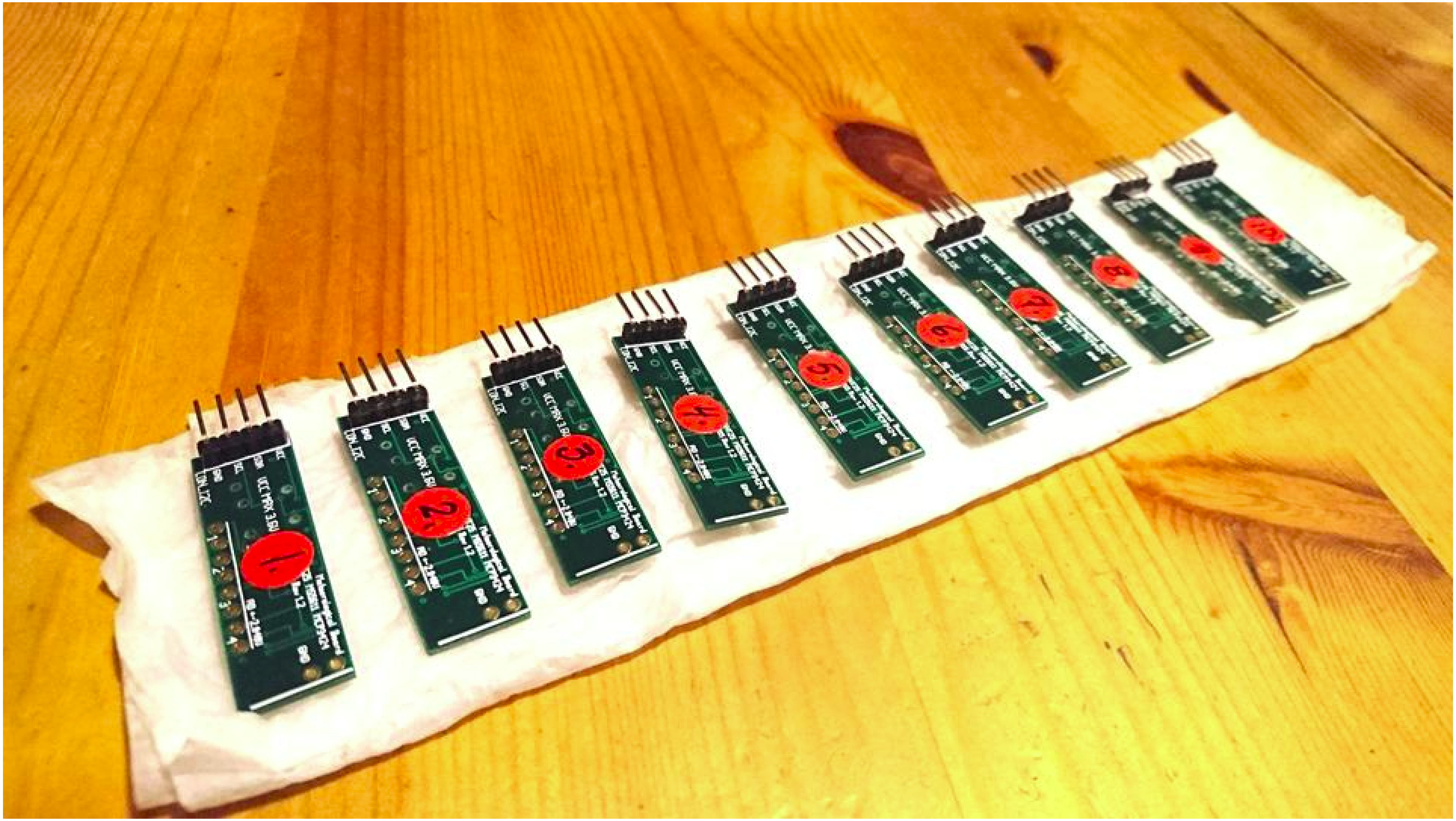
Ground node (gnd)

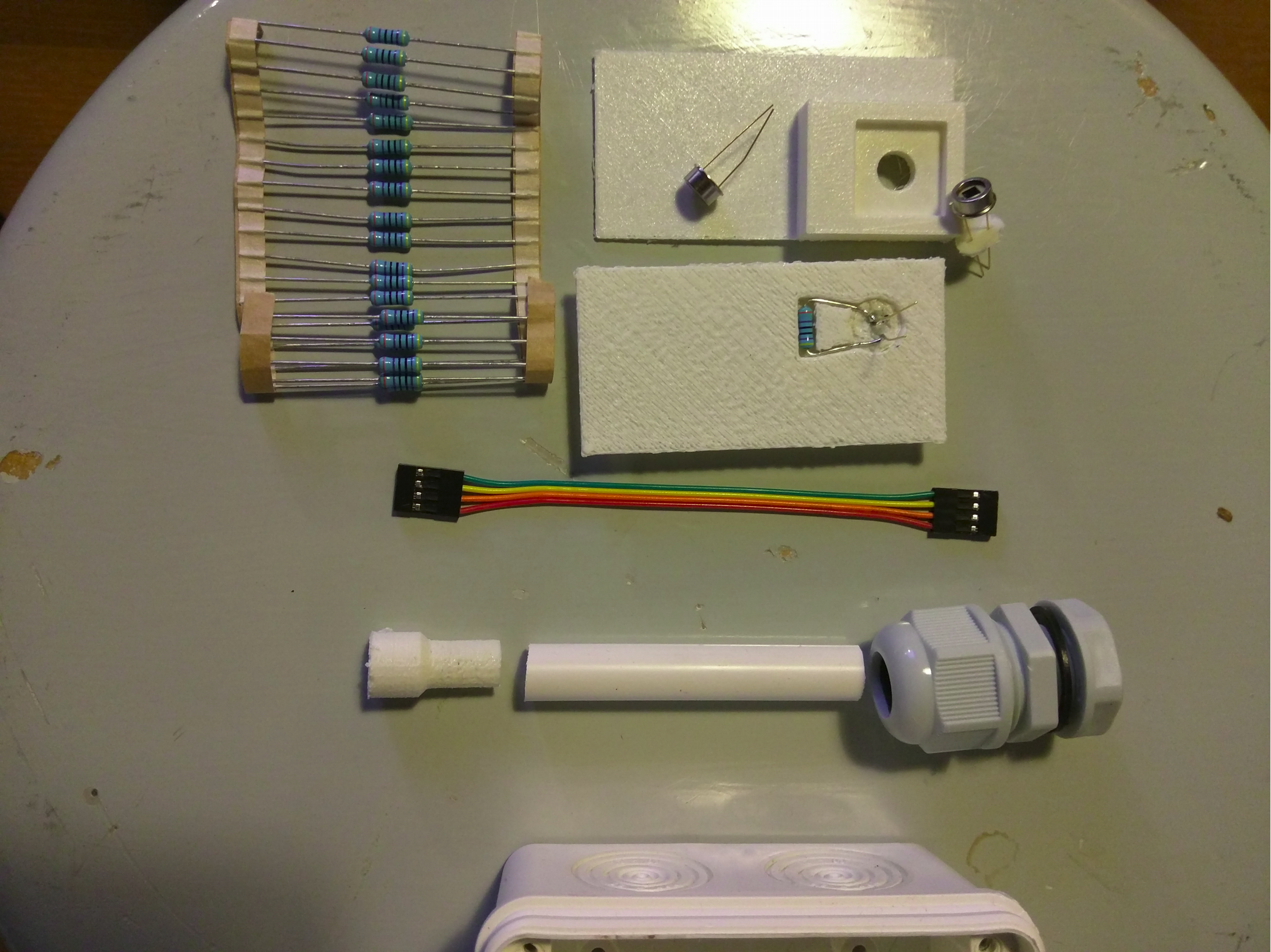


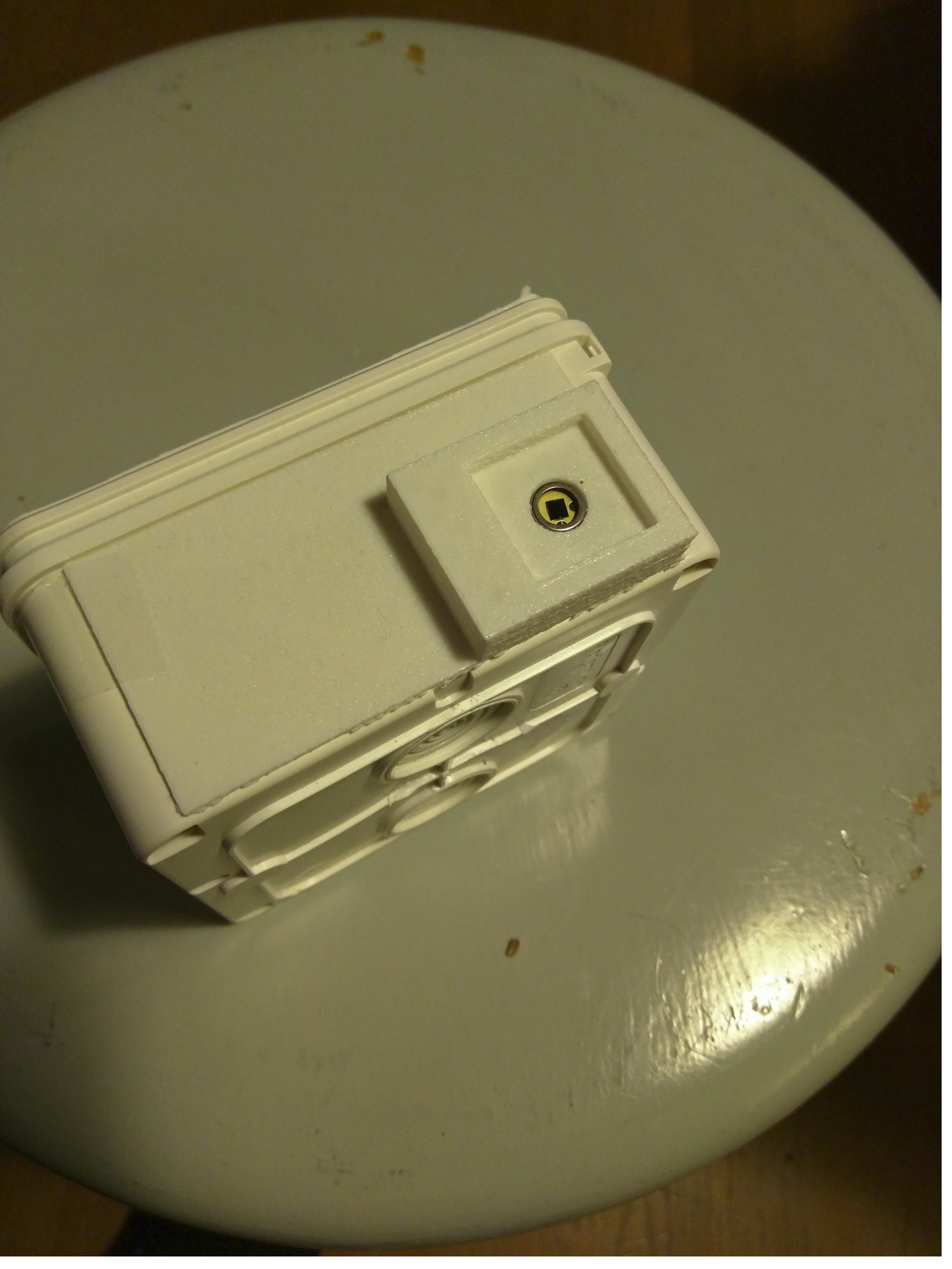

LithiumIonCapacitor



Daughter cards with SHT25







Diffusors

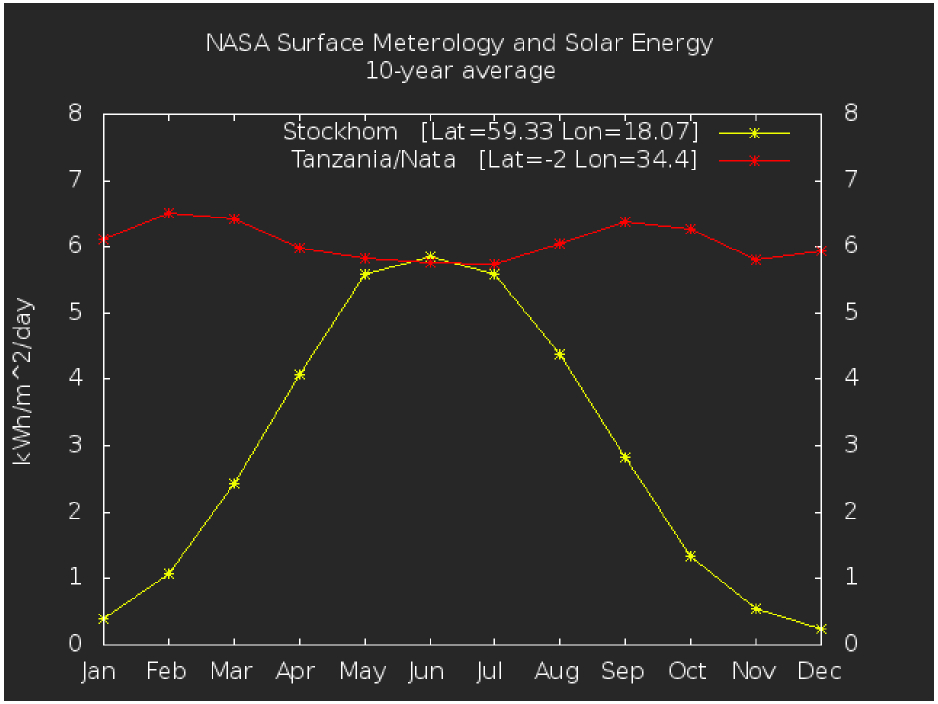
- Used to maintain linearity of measurements

Power consumption

- Load: power lean design (sleep states?)
- Sources: grid, solar, wind, fuel cell, fossile
- Storage: batteries of cells
  - chemical: alkali, lead acid, lithium, ...
  - physical: caps, ultracaps
  - Hybrid: LIC,….
- Regulator:
  - Surge protection
  - Dedicated charging cycles per cell type
  - Status monitoring
  - LVD

Power

NASA 22 year averages



https://eosweb.larc.nasa.gov/cgi-bin/sse/global.cgi

- Sources
  - solar
  - Wind
  - grid
- Storage
  - Lead Acid
  - LiFePO4
  - Ultracaps
- Regulator

Batteries with chemical cells

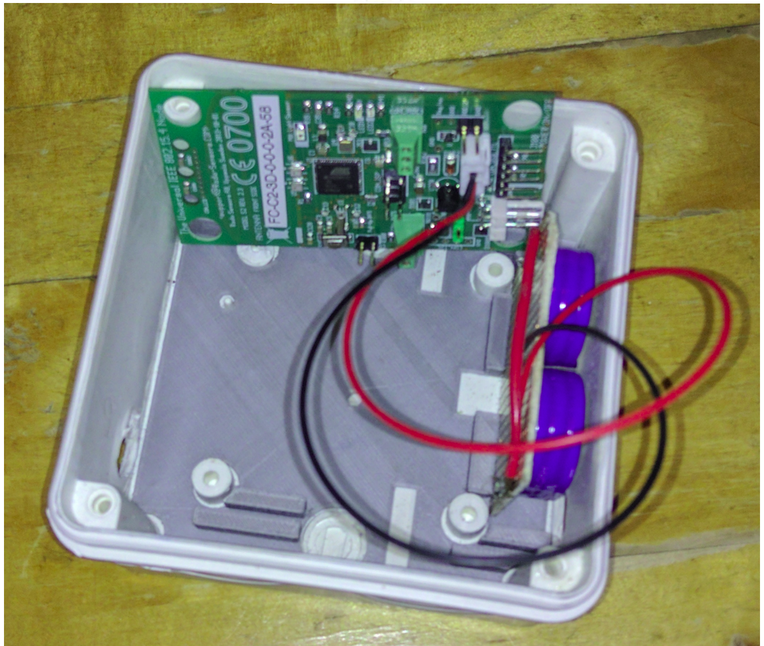
- Lead Acid 6 or 12V
  - Slow chemical chrging process
  - Charge, float, desulphatization
  - pwm,mppt algorithms, temperature-dependent
  - Do not go under 6/12V and keep the batteries cool (<25C)
  - Requires monitoring
- Non rechargable Alkali batteries
  - 3*1.5 AAA in 2m node > 1 year

Batteries with physical/capacitor cells

- Ultracaps (EDLC 2.7V)
  - Fast physical self-regulating charging process
  - Almost no internal resistance
  - Self-discharge
  - Current limitation required

Batteries with hybrid cells

- Taiyo Yuden, Vinatech LIC (1.8-3.8)
  - https://se.farnell.com/taiyo-yuden/lic2540r3r8207/lithium-ion-cap-200f-3-8v-20-150mohm/dp/1853631?st=LIC
- Vishay Enicap HVC
  - https://se.farnell.com/search?st=vishay%20hvc



Charge regulators

- Lead Acid
- LiFePO4
- Capacitors

- Balancing
- Current limitation

Robustness and Security

- Harsh weather
  - Selection of material and encapsulation
- Termites – Elephants
- Vandals
  - Minimize attraction
  - Custodians, Neighbourhood watch
- System failures
  - Redundancy, maintenance, recalibration

Production plan

- Prototype generations
  - Gen1: 2014 Evaluation of components
  - Gen2: 2016-2017 Systems level validation
  - Gen3: 2017-2018 final validation and production
- Production and deployment 2018-2019 in two batches of (25+45) using student teams and custodian communities
- Production of last batch completed, deployment halfway
- Discussions about a crowd-funding program to involve more user communities

Discussion ?

References available at https://wimea-ict.net/