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MAGIS-100 bakeout control system prototype test

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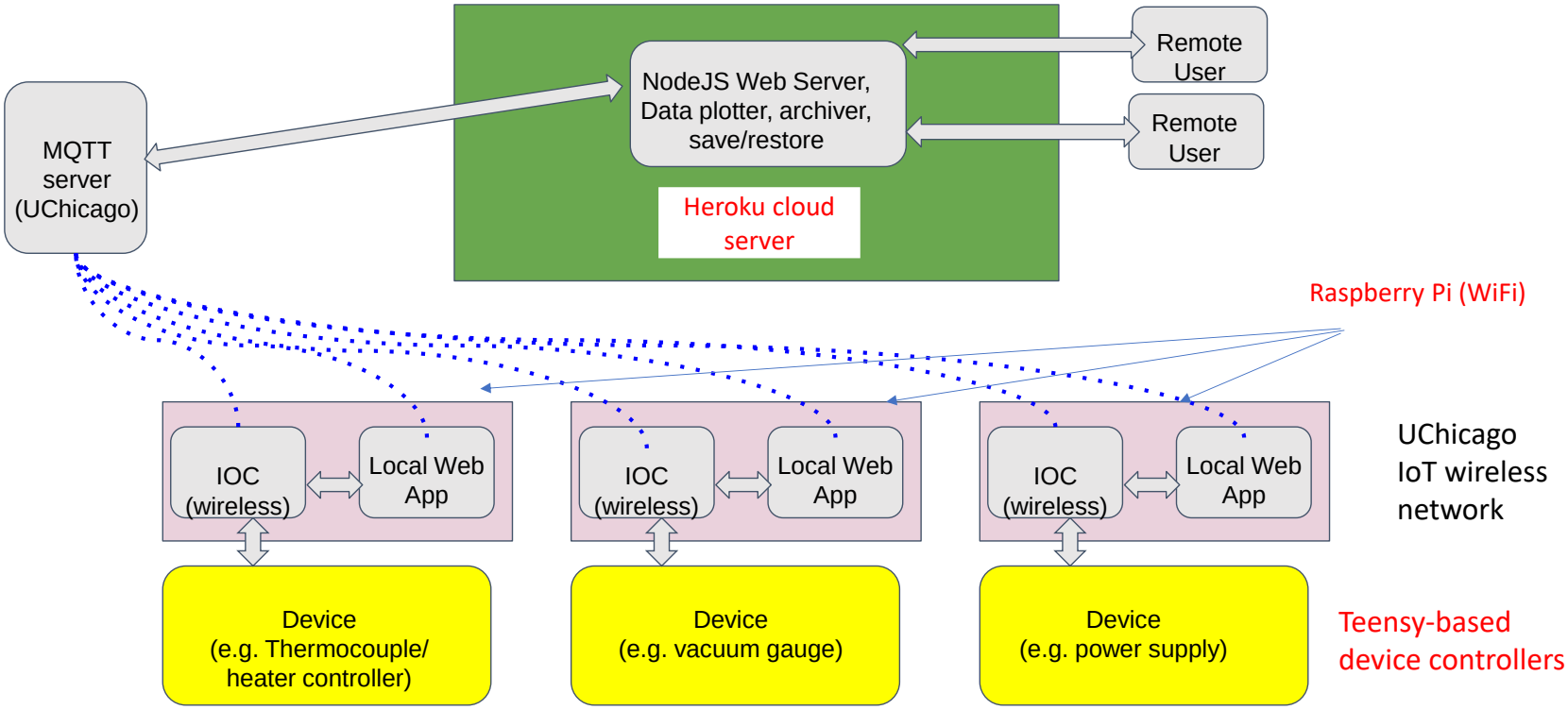
Henry Hunt, Cici Hanna (U.Chicago)

Ron Kellett, Lucy Nobrega (Fermilab)

Nov 23, 2021

Introduction: the WiDAQ project at UChicago



Wi-DAQ project is funded by 2019 UChicago College Innovation Grant S. Nagaitsev (PI) and by 2021 UChicago EFI summer research grant

See also: widaq.io

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Some definitions

- IOC – input/output controller
- IoT – Internet of Things
- MQTT (Message Queuing Telemetry Transport) is an open OASIS and ISO standard (ISO/IEC 20922) lightweight, publish-subscribe network protocol that transports messages between devices. The protocol usually runs over TCP/IP;
- Node.js is an open-source, cross-platform, back-end JavaScript runtime environment that runs on the Chrome V8 engine and executes JavaScript code outside a web browser.
- Node-RED is a flow-based development tool for visual programming developed originally by IBM for wiring together hardware devices, APIs and online services as part of the Internet of Things.

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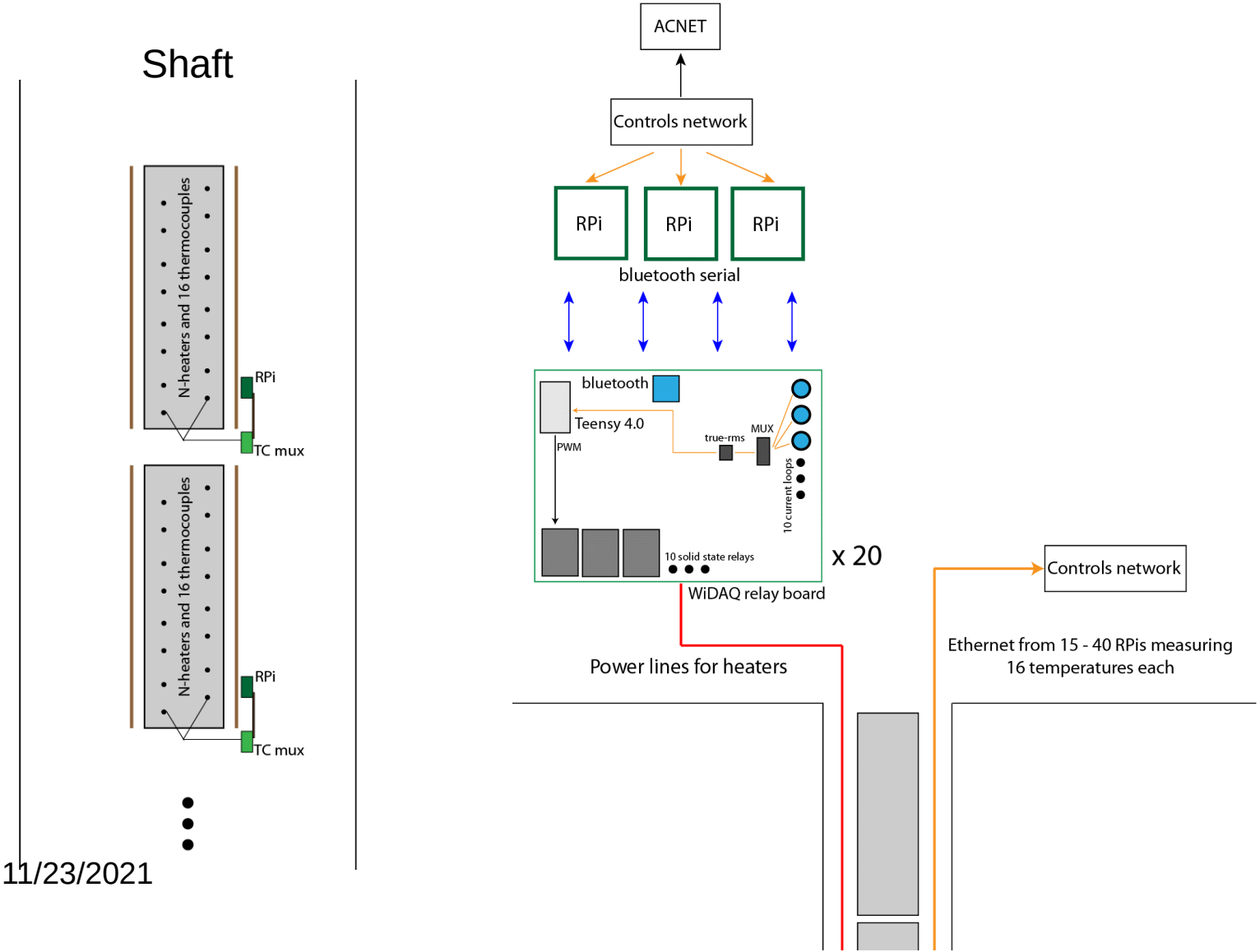
MAGIS bakeout concept

- This is a Fermilab-specific use case of Wi-DAQ.
  - The existing ACNET accelerator controls system (user interface with data logging, alarms, plotting, etc)
  - ACNET uses the so-called “controls network”, behind the Fermilab Firewall. The Controls network presently does not allow wifi devices.
  - We are proposing to use “wired” RPi’s on the Fermilab controls network with static IP addresses.
    - May need ~40 Raspberry Pi’s equally spaced along the 100-m vacuum pipe
    - Each RPi can read 16 type-T thermocouples and post it using an FTP service

Diagram of shaft and surface boards



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Proposed hardware

- Temperature module (shaft):
  - Raspberry Pi 3B+ (or 4B)
  - 16-channel multiplexer board via an SPI interface
  - 16 T-type TC’s
- Heater power controls module (upstairs)
  - RPi 3B+
  - Teensy 4.0 with a 5Hz PWM capability
  - 10-A SSR
  - …

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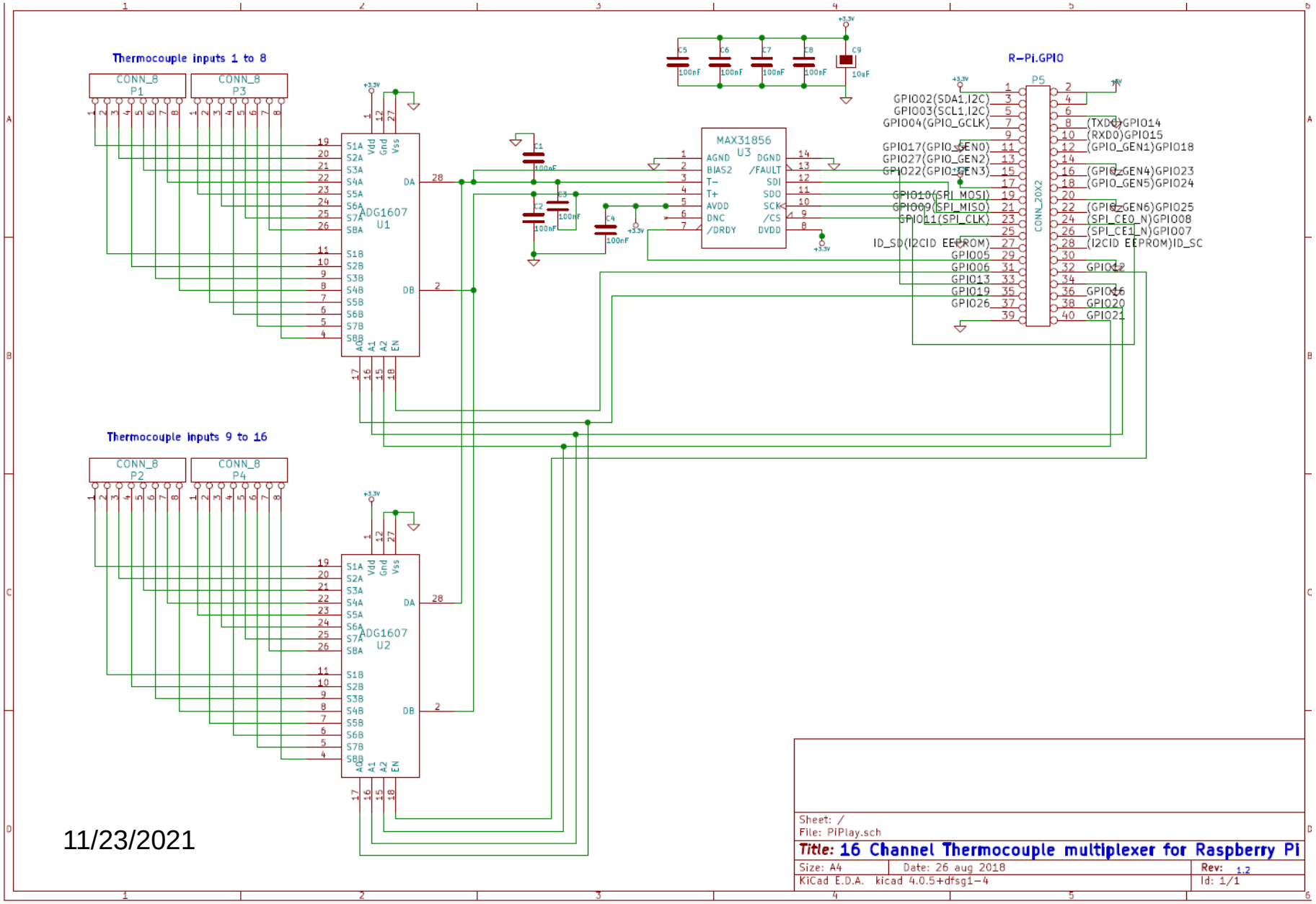
16-channel TC board



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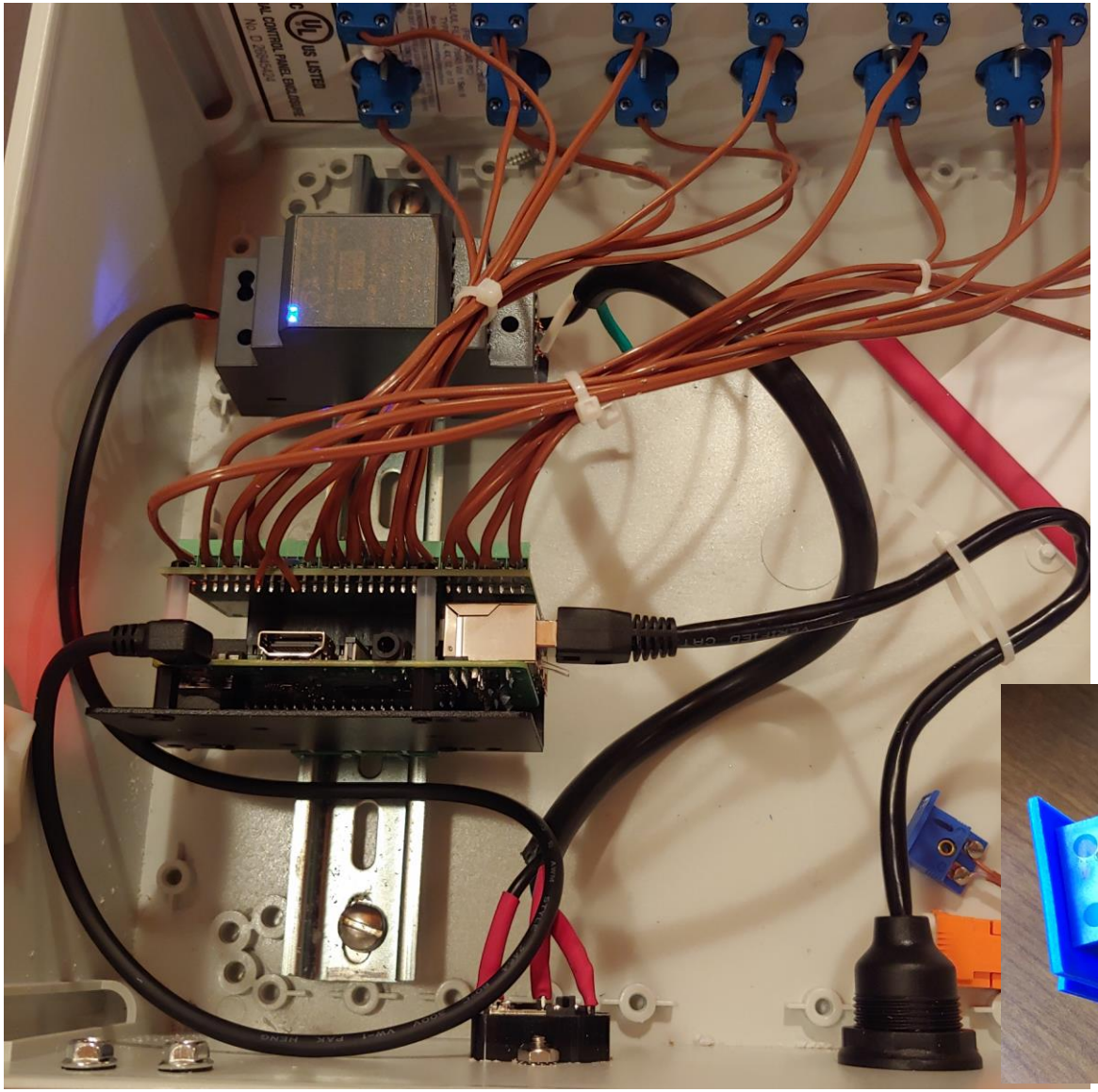
16-channel multiplexer

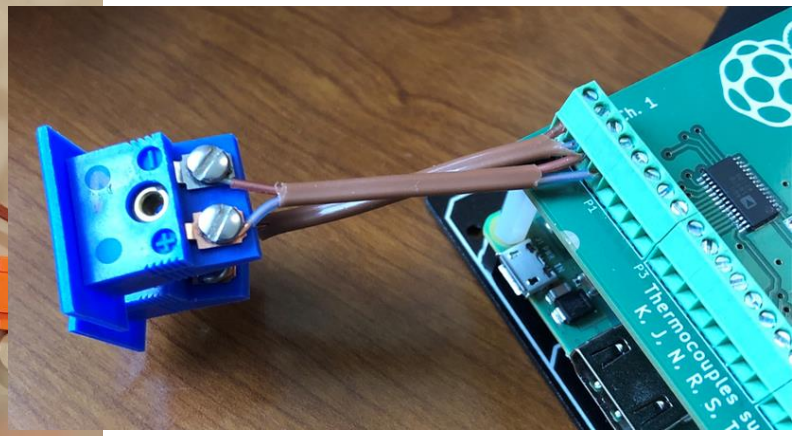
- 3 devices have been procured
- 2 are operational (one at UChicago and one at Fermilab)

Presently designing a box to mount these two boards and 16 TC sockets

16-channel TC box

Presently connected to the Fermilab Controls Network as “magis01-rpi.fnal.gov”

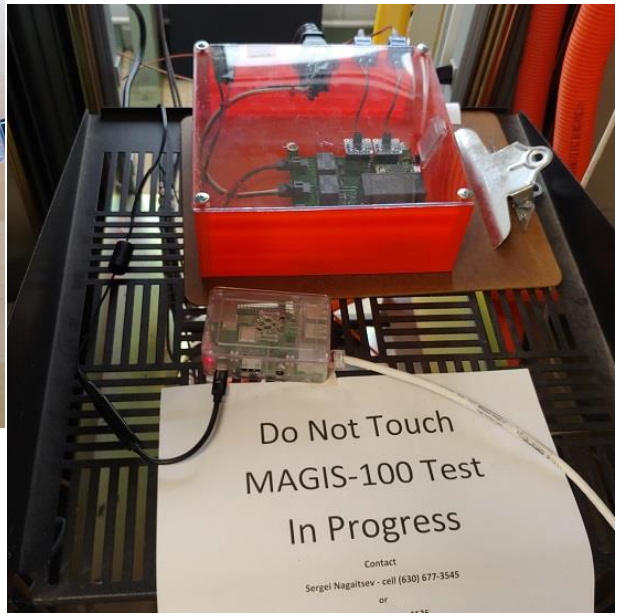




Bluetooth heater controller

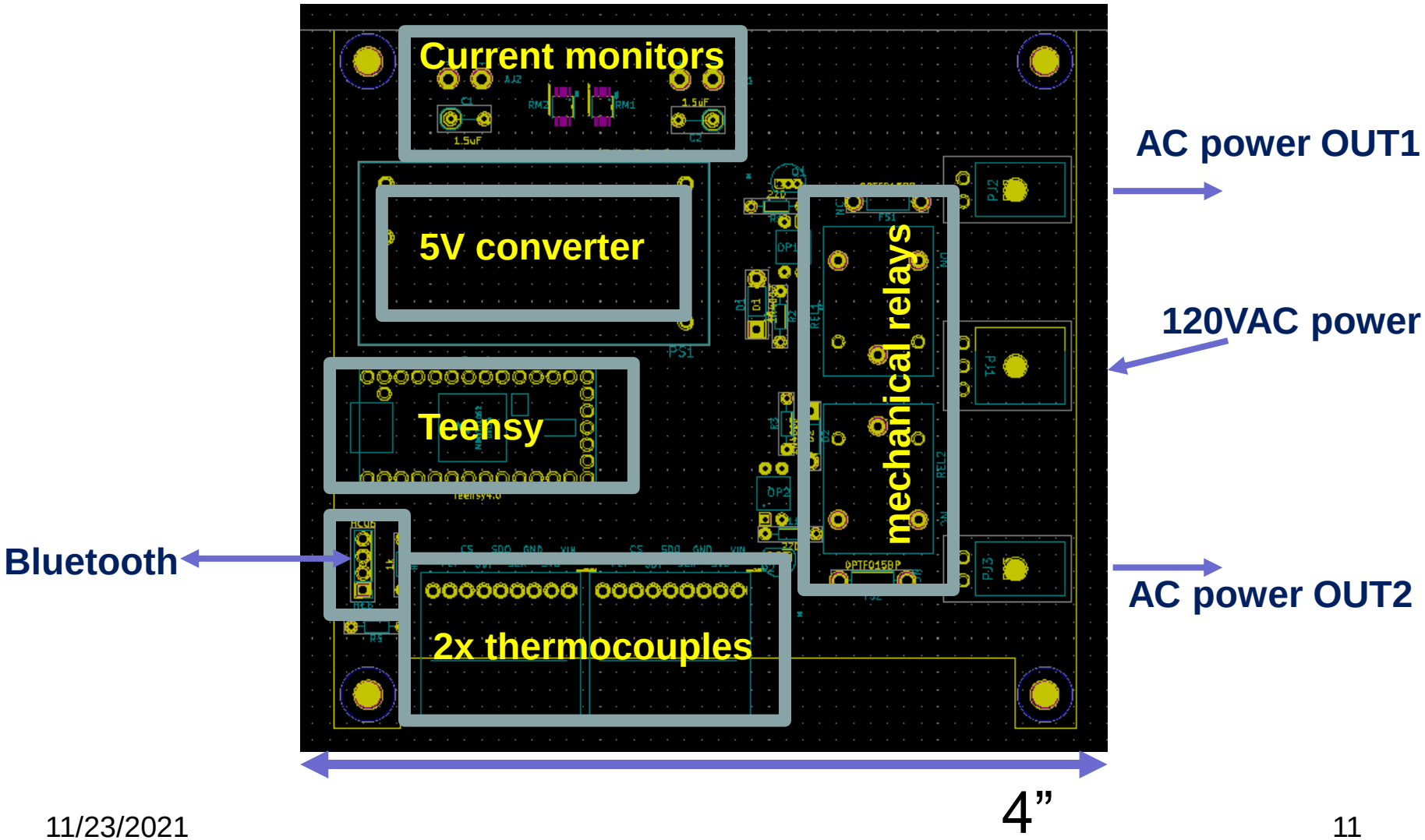
Controller:
2 Type T thermocouples
2 mechanical relays
Teensy 4.0 controller
Bluetooth HC06 serial port

Raspberry Pi 3B+



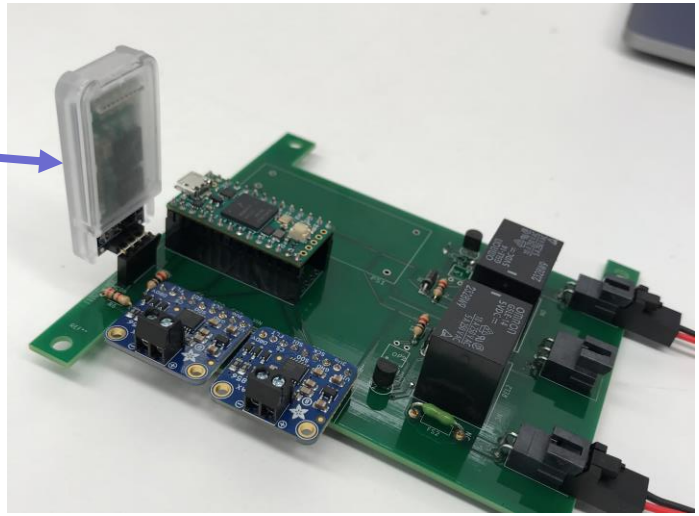
Presently connected to the Fermilab Controls Network as “magis-rpi.fnal.gov”
Being tested at Fermlab’s CMTF building with a 1-kW heat tape

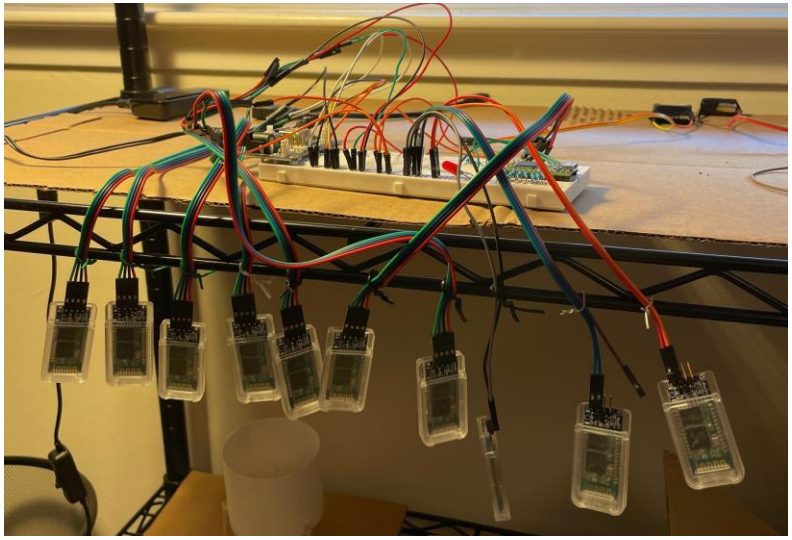
Heater controller (2-channel)



Bluetooth heater controller

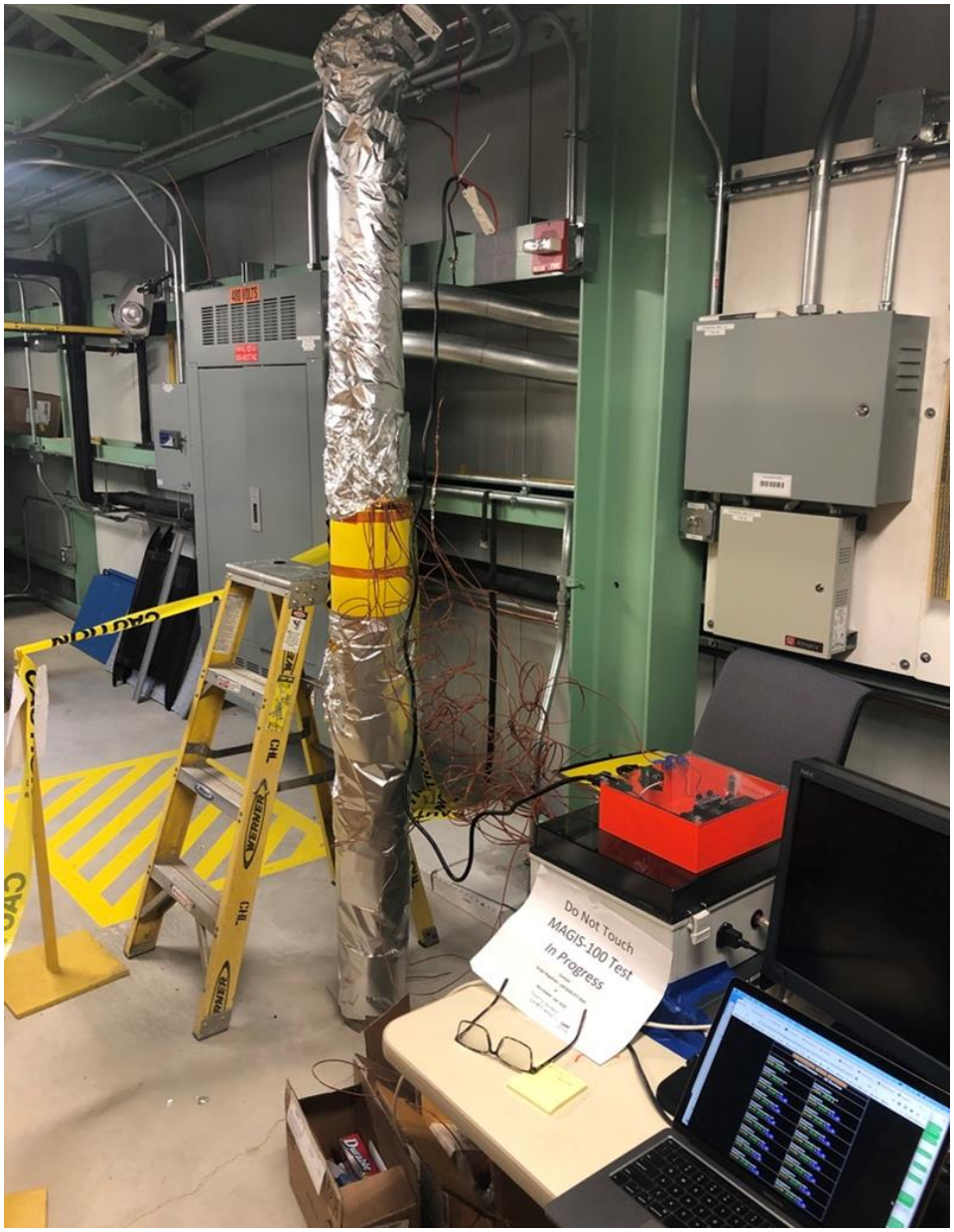
Bluetooth transceiver





Tests performed with full capacity of 7 Bluetooth serial connections per raspberry pi

Test setup at Fermilab



Proposed SSR

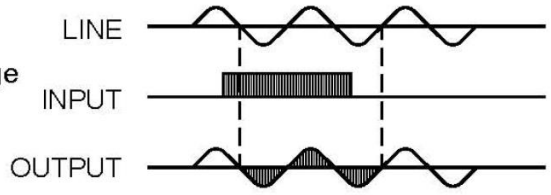
- Fotek SSR 10-DA

★High Reliability by S.M.T. & TQC.
(Surface Mounting Technology)
★High Isolation over than 50MΩ/ 500VDC
★High Dielectric over than 2.5KV
★Low Enable Current less than 7.5mA / 12VDC
C MOS IC or TTL Compatible.
★Low EMI / EFI & Surge by Zero Cross Trigger Method.
★High Surge Current Duration Over 10 Times of Rated Current / One Cycle
★High Surge Voltage Duration by Snubber Circuit.
★表面貼焊技術及全面品管，提供最可靠的 SSR
★高絕緣阻抗超過 50MΩ / 500VDC
★高耐壓超過 2.5KV
★低觸發電流小於 7.5mA / 12VDC，可與 CMOS IC及 TTL 匹配
★零點觸發方式避免電磁 / 高頻干擾
★高耐過電流，超過10倍額定電流/一週期
★具緩衝迴路可吸收瞬間突破

Control Method

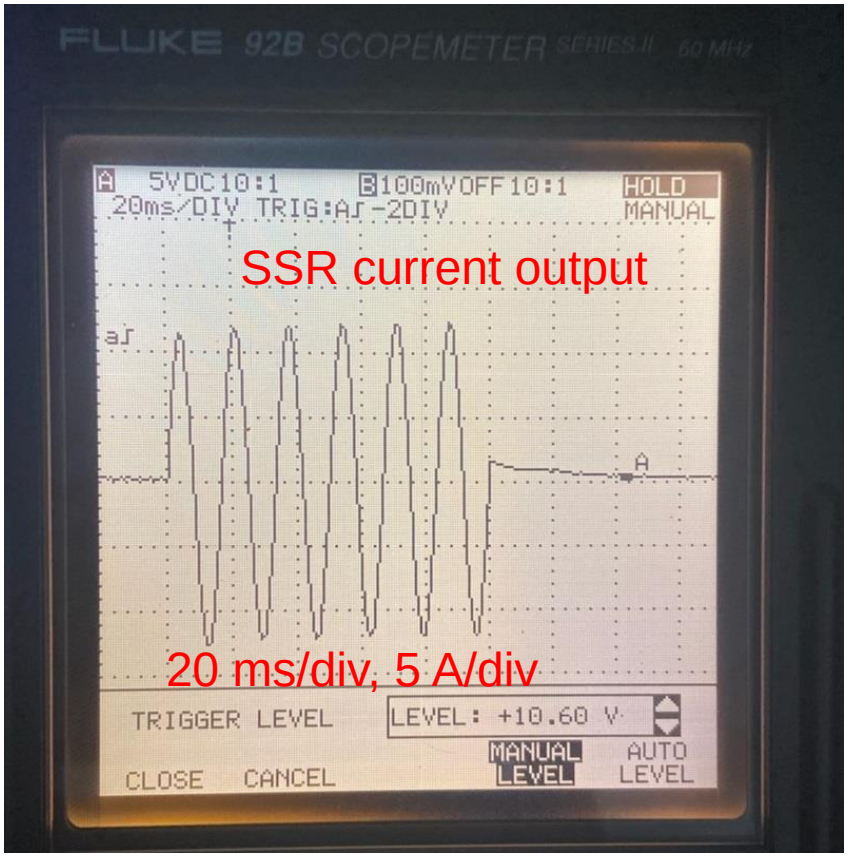
Zero Cross Trigger Method

Output TURN ON or TURN OFF
only on Zero Cross Point of sine wave , may avoid surge
or EMI / RFI occurring.
Specially suited to control resistive , capacitive and
Non - saturated inductive loads.



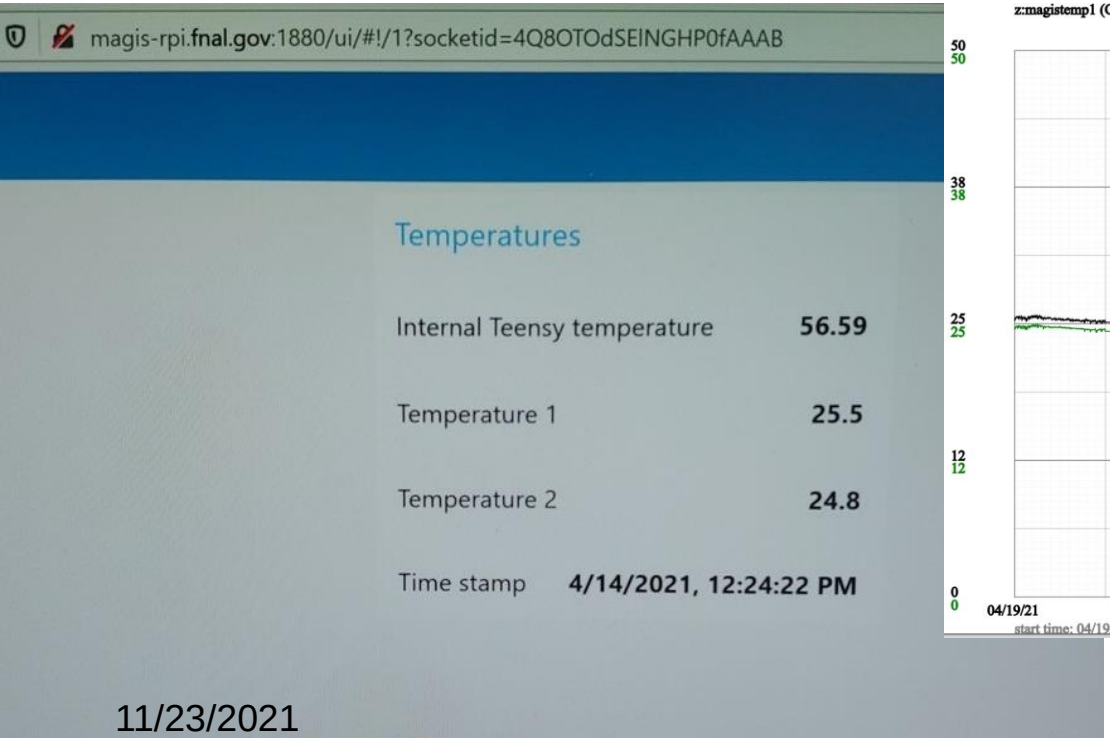
SSR test

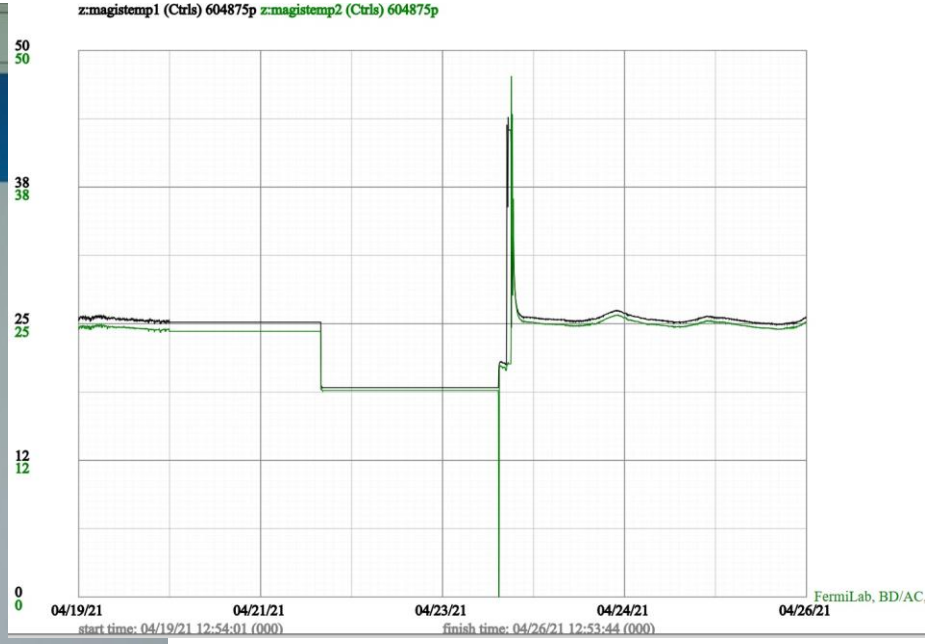
- Tested SSR with a 3.3 V direct output from Teensy 4.0
  - PWM: 5 Hz, ~50% duty factor

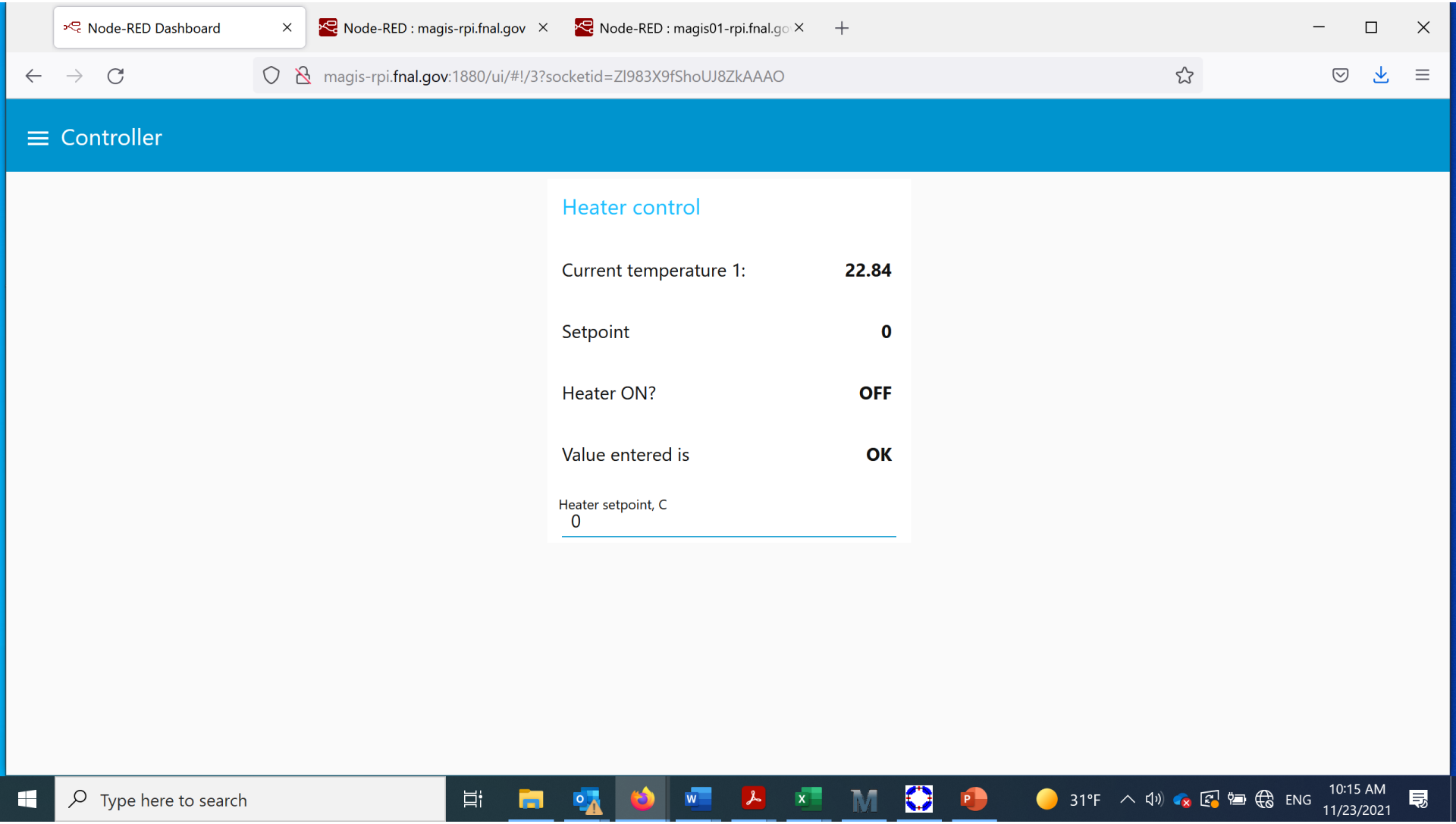


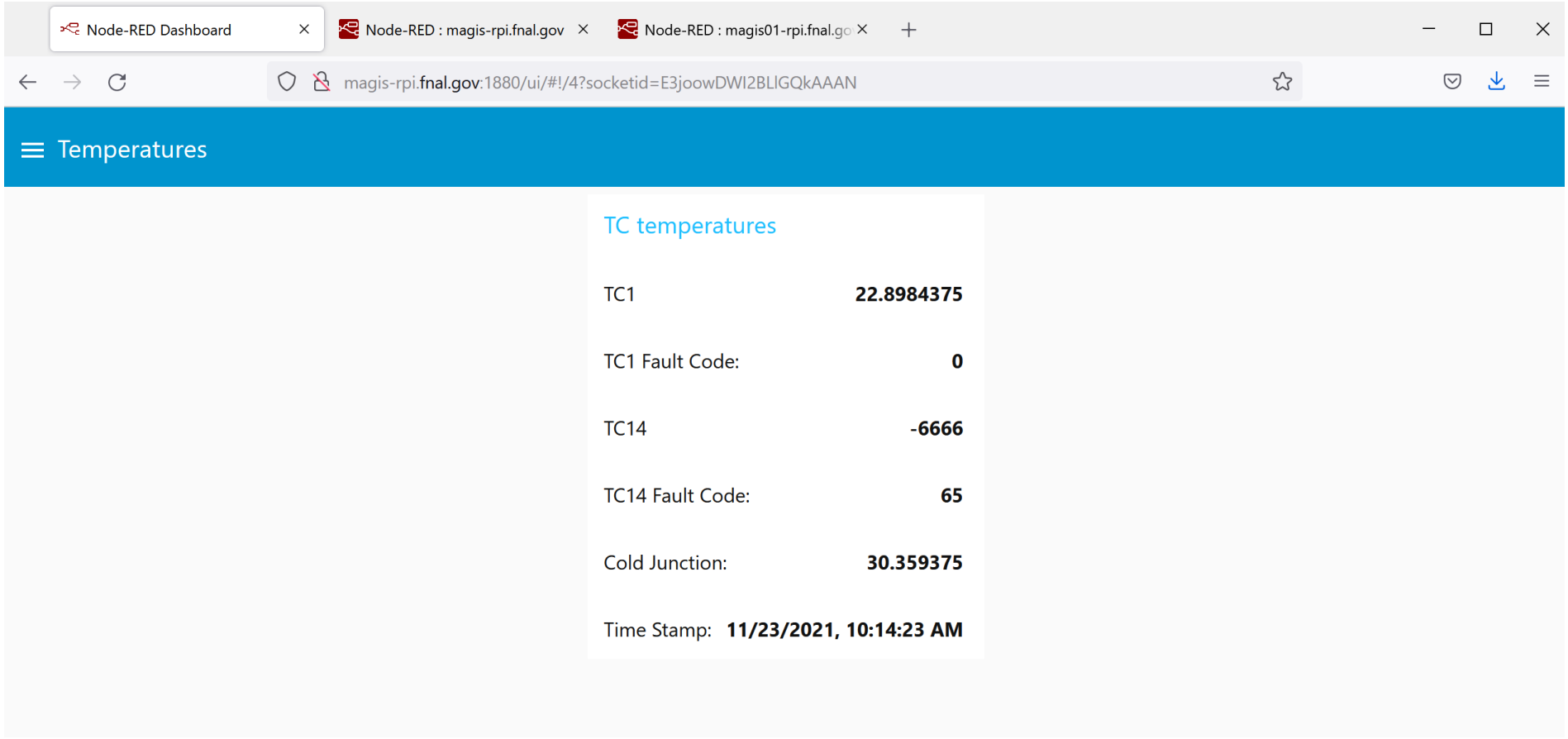
User interface

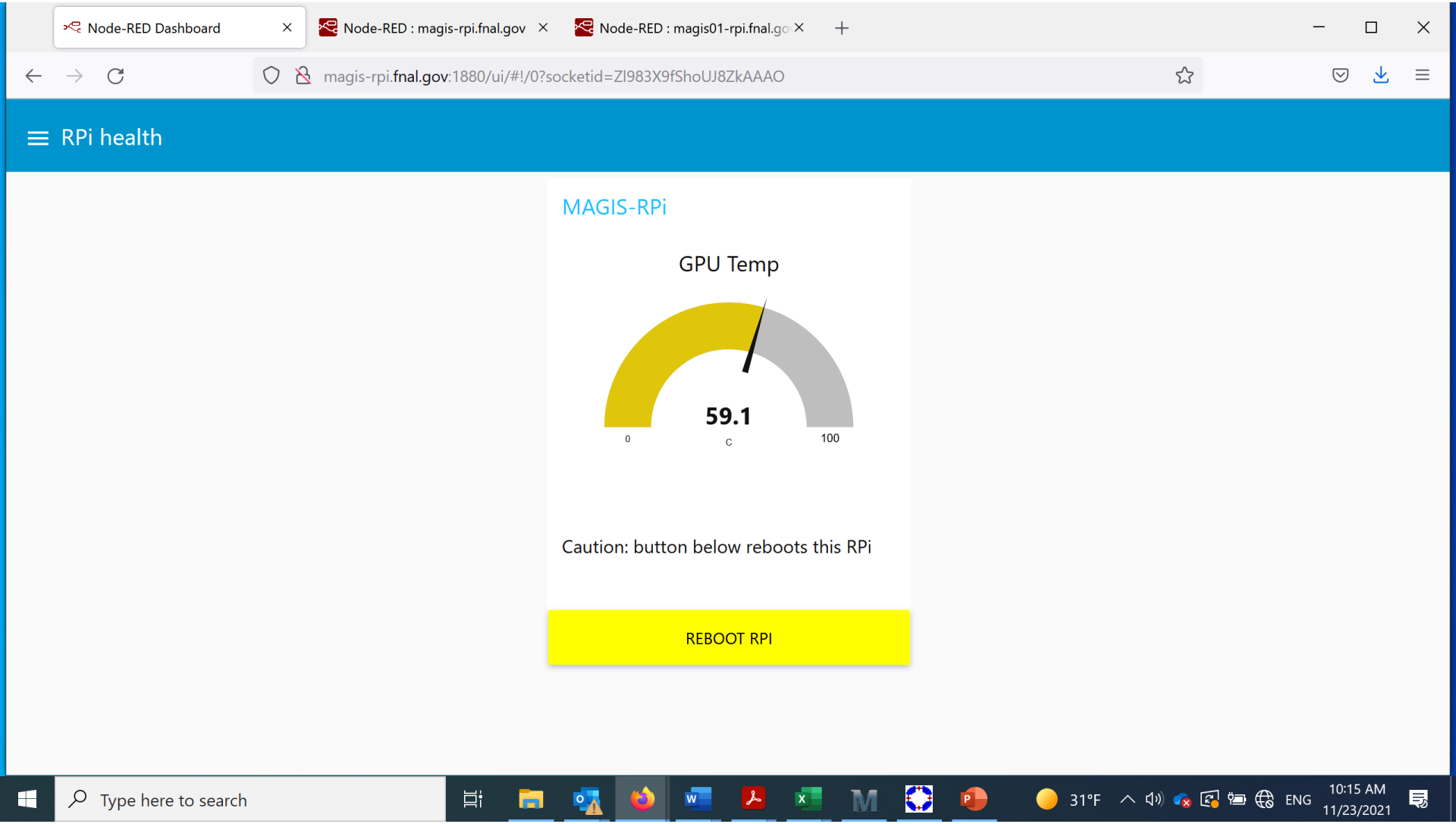
- Each RPi is running a Node.js web server via a Node-Red UI utility
- It also posts data to Fermilab ACNET (1 Hz rate)
  - ACNET provides datalogging capability

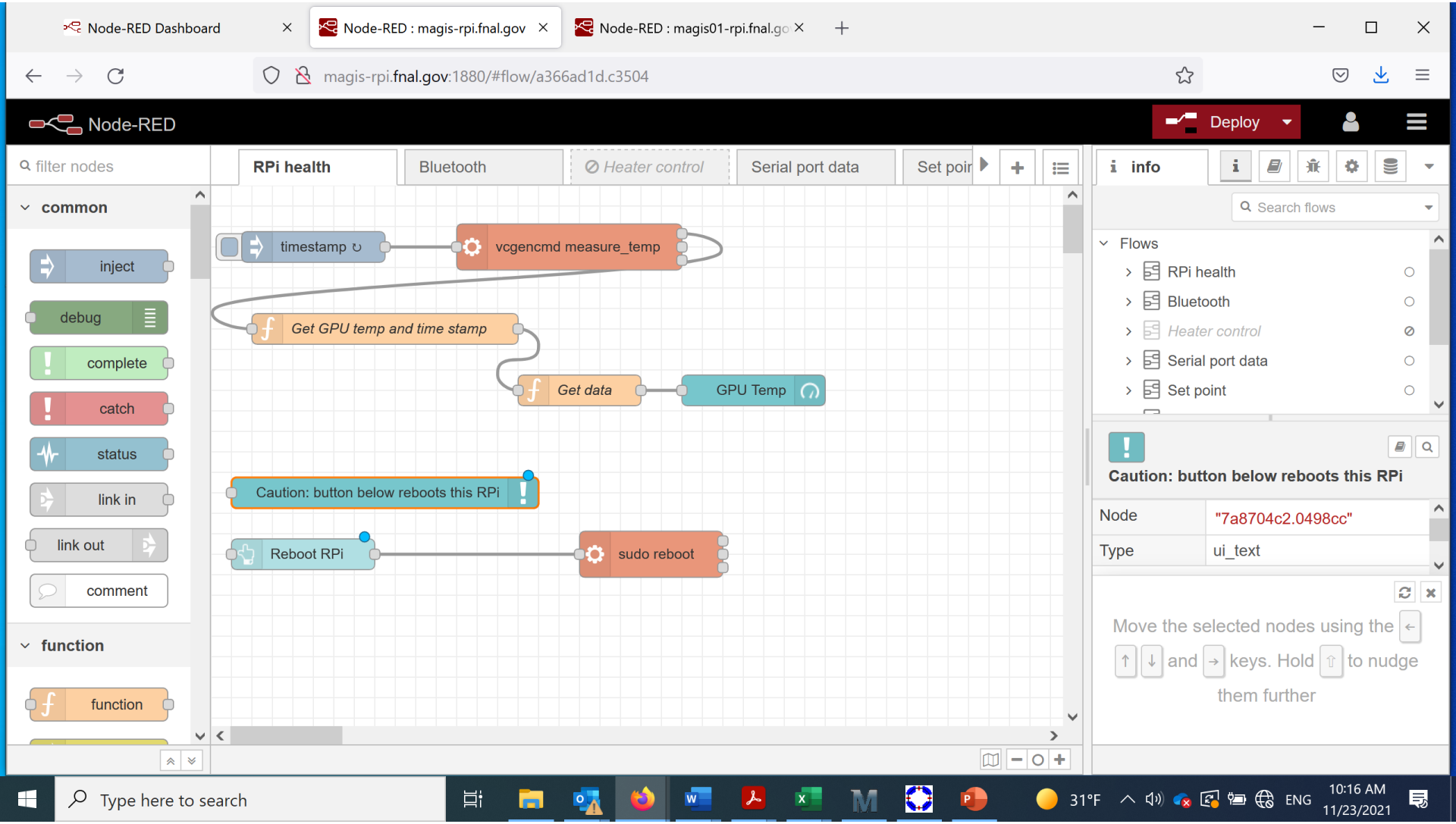


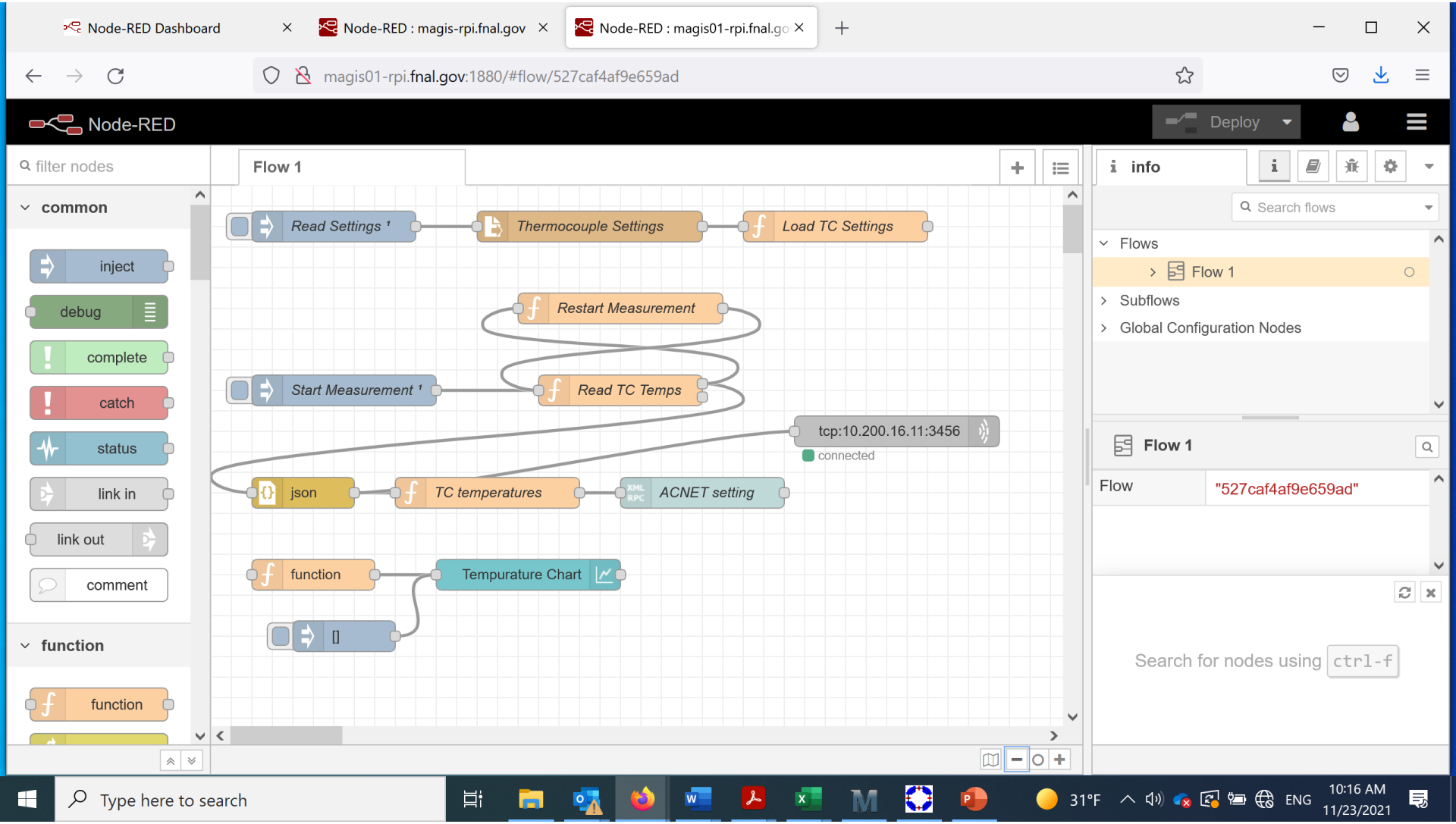


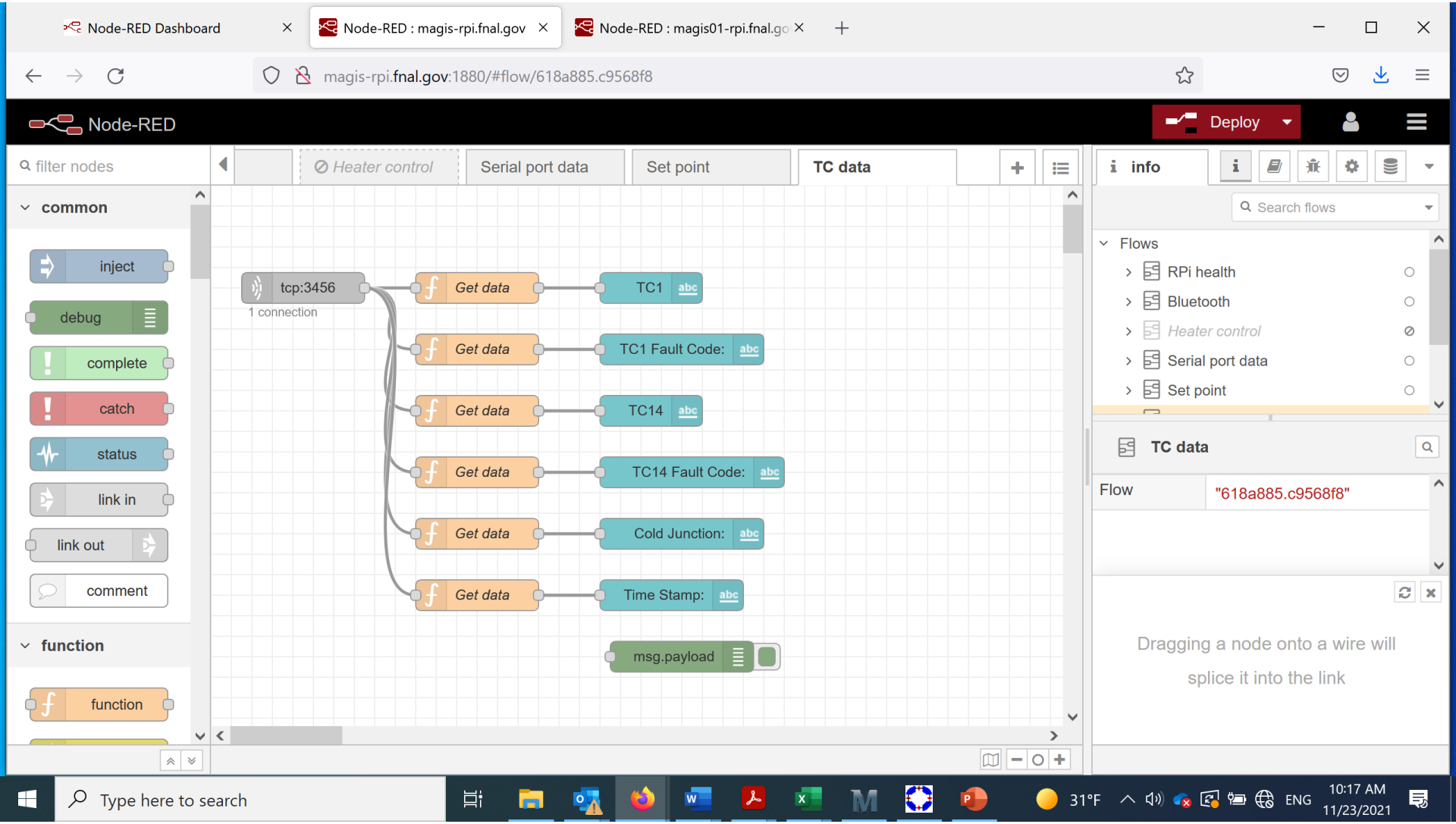

Node-RED Dashboard
Node-RED : magis-rpi.fnal.gov
Node-RED : magis01-rpi.fnal.go
magis-rpi.fnal.gov:1880/ui/#!/3?socketid=ZI983X9fShoUJ8ZkAAAO
Controller
Heater control
Current temperature 1:
22.84
Setpoint
0
Heater ON?
OFF
Value entered is
OK
Heater setpoint, C
0
Type here to search
31°F
ENG
10:15 AM
11/23/2021


Node-RED Dashboard
Node-RED : magis-rpi.fnal.gov
Node-RED : magis01-rpi.fnal.go
magis-rpi.fnal.gov:1880/ui/#!/4?socketid=E3joowDWI2BLIGQkAAAN
Temperatures
TC temperatures
TC1 22.8984375
TC1 Fault Code: 0
TC14 -6666
TC14 Fault Code: 65
Cold Junction: 30.359375
Time Stamp: 11/23/2021, 10:14:23 AM


Node-RED Dashboard
Node-RED : magis-rpi.fnal.gov
Node-RED : magis01-rpi.fnal.go
magis-rpi.fnal.gov:1880/ui/#!/0?socketid=ZI983X9fShoUJ8ZkAAAO
RPi health
MAGIS-RPi
GPU Temp
59.1
C
0
100
Caution: button below reboots this RPi
REBOOT RPI
Type here to search
31°F
ENG
10:15 AM
11/23/2021

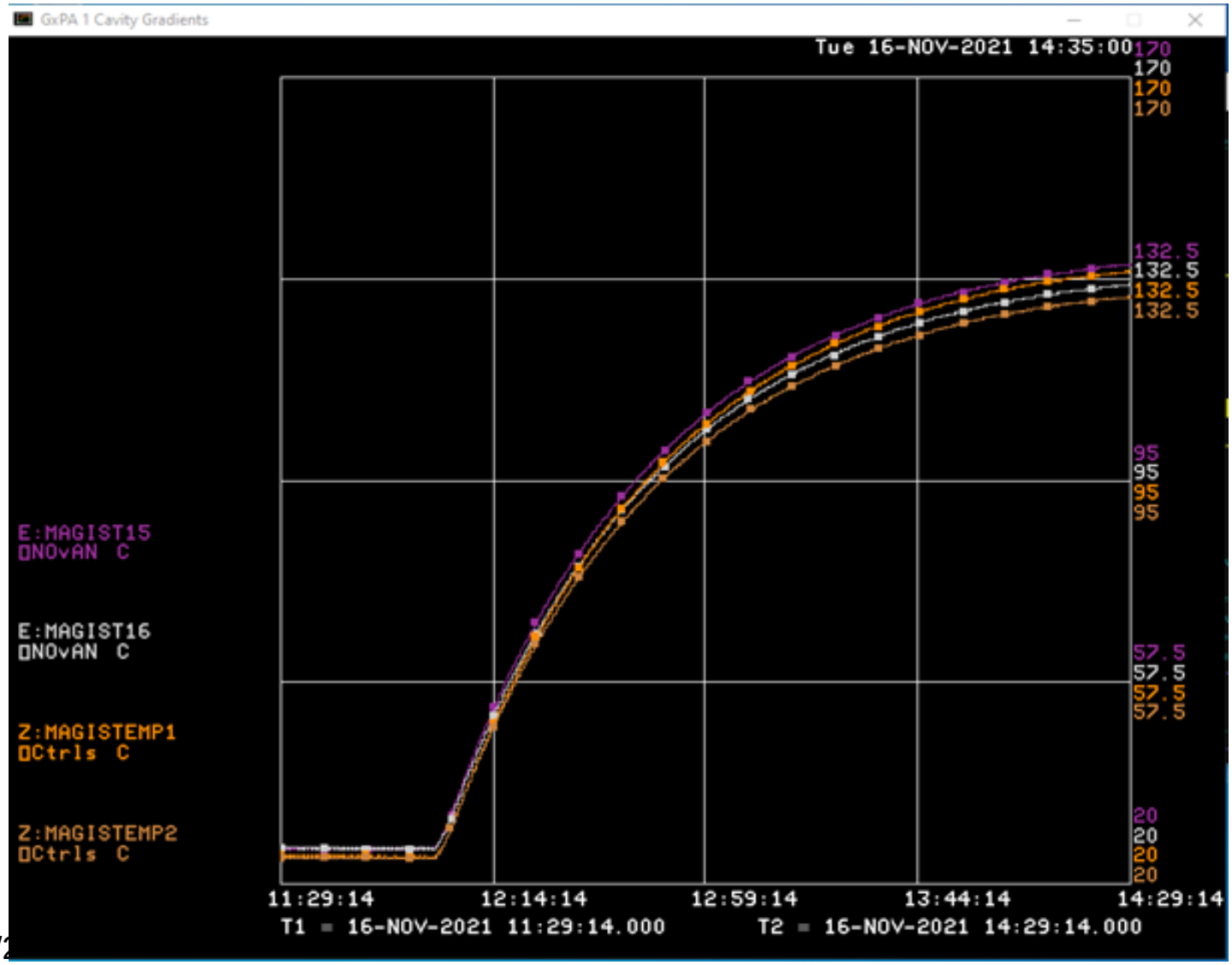

Node-RED Dashboard
Node-RED : magis-rpi.fnal.gov
Node-RED : magis01-rpi.fnal.go
magis-rpi.fnal.gov:1880/#flow/a366ad1d.c3504
Node-RED
Deploy
filter nodes
RPi health
Bluetooth
Heater control
Serial port data
Set poir
info
common
inject
debug
complete
catch
status
link in
link out
comment
function
function
timestamp
vcgencmd measure_temp
Get GPU temp and time stamp
Get data
GPU Temp
Caution: button below reboots this RPi
Reboot RPi
sudo reboot
Search flows
Flows
RPi health
Bluetooth
Heater control
Serial port data
Set point
Caution: button below reboots this RPi
Node
"7a8704c2.0498cc"
Type
ui_text
Move the selected nodes using the
and
keys. Hold
to nudge
them further
Type here to search
31°F
ENG
10:16 AM
11/23/2021


Node-RED Dashboard
Node-RED : magis-rpi.fnal.gov
Node-RED : magis01-rpi.fnal.go
magis01-rpi.fnal.gov:1880/#flow/527caf4af9e659ad
Node-RED
Deploy
filter nodes
Flow 1
common
inject
debug
complete
catch
status
link in
link out
comment
function
function
Read Settings ¹
Thermocouple Settings
Load TC Settings
Restart Measurement
Start Measurement ¹
Read TC Temps
tcp:10.200.16.11:3456
connected
json
TC temperatures
ACNET setting
function
Tempurature Chart
[]
info
Search flows
Flows
Flow 1
Subflows
Global Configuration Nodes
Flow 1
Flow
"527caf4af9e659ad"
Search for nodes using ctrl-f
Type here to search
31°F
ENG
10:16 AM
11/23/2021


Node-RED Dashboard
Node-RED : magis-rpi.fnal.gov
Node-RED : magis01-rpi.fnal.go
magis-rpi.fnal.gov:1880/#flow/618a885.c9568f8
Node-RED
Deploy
filter nodes
Heater control
Serial port data
Set point
TC data
info
common
inject
debug
complete
catch
status
link in
link out
comment
function
function
tcp:3456
1 connection
Get data
TC1
TC1 Fault Code:
TC14
TC14 Fault Code:
Cold Junction:
Time Stamp:
msg.payload
Search flows
Flows
RPi health
Bluetooth
Heater control
Serial port data
Set point
TC data
Flow
"618a885.c9568f8"
Dragging a node onto a wire will splice it into the link
Type here to search
31°F
ENG
10:17 AM
11/23/2021

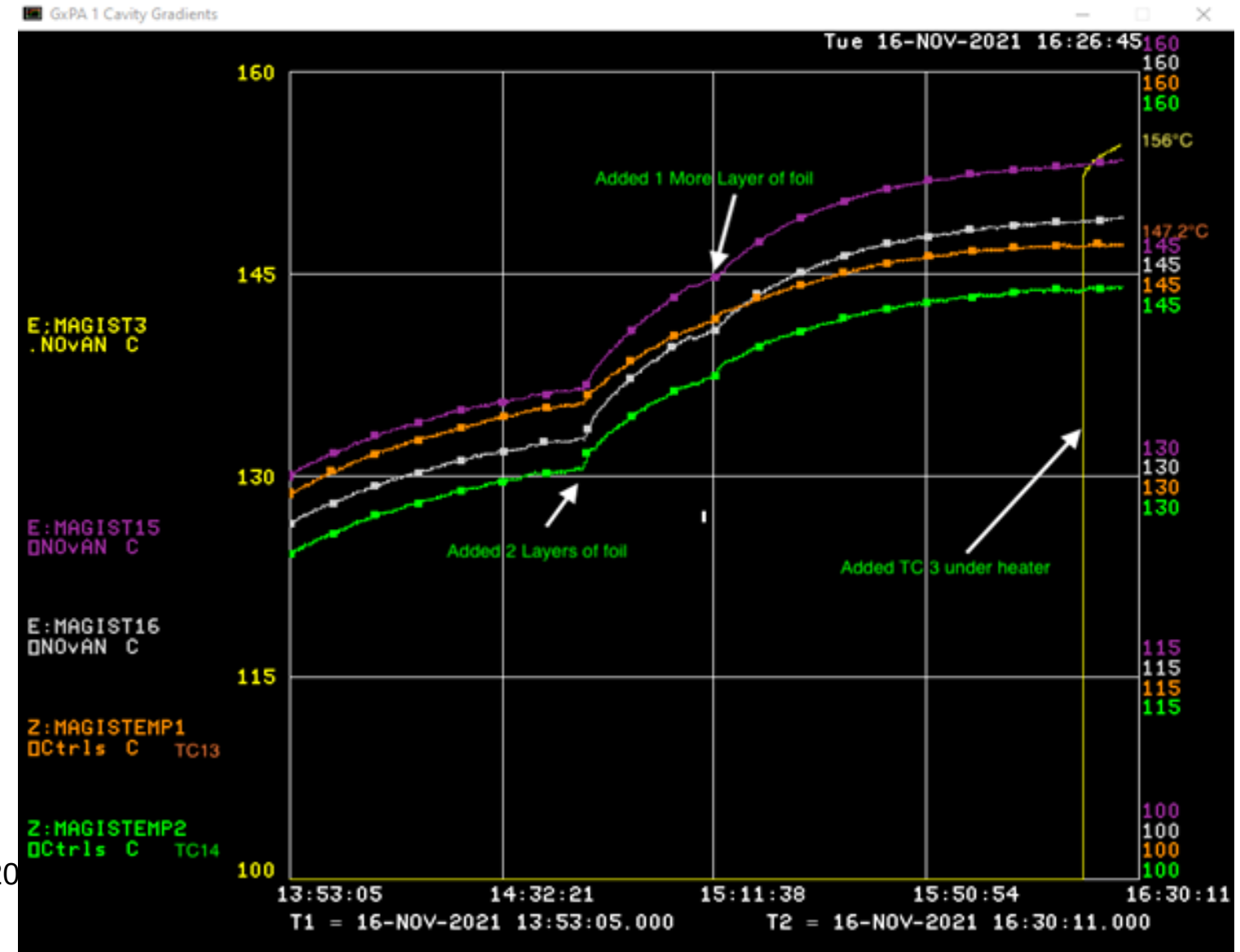
Temperature ramp (heater on)

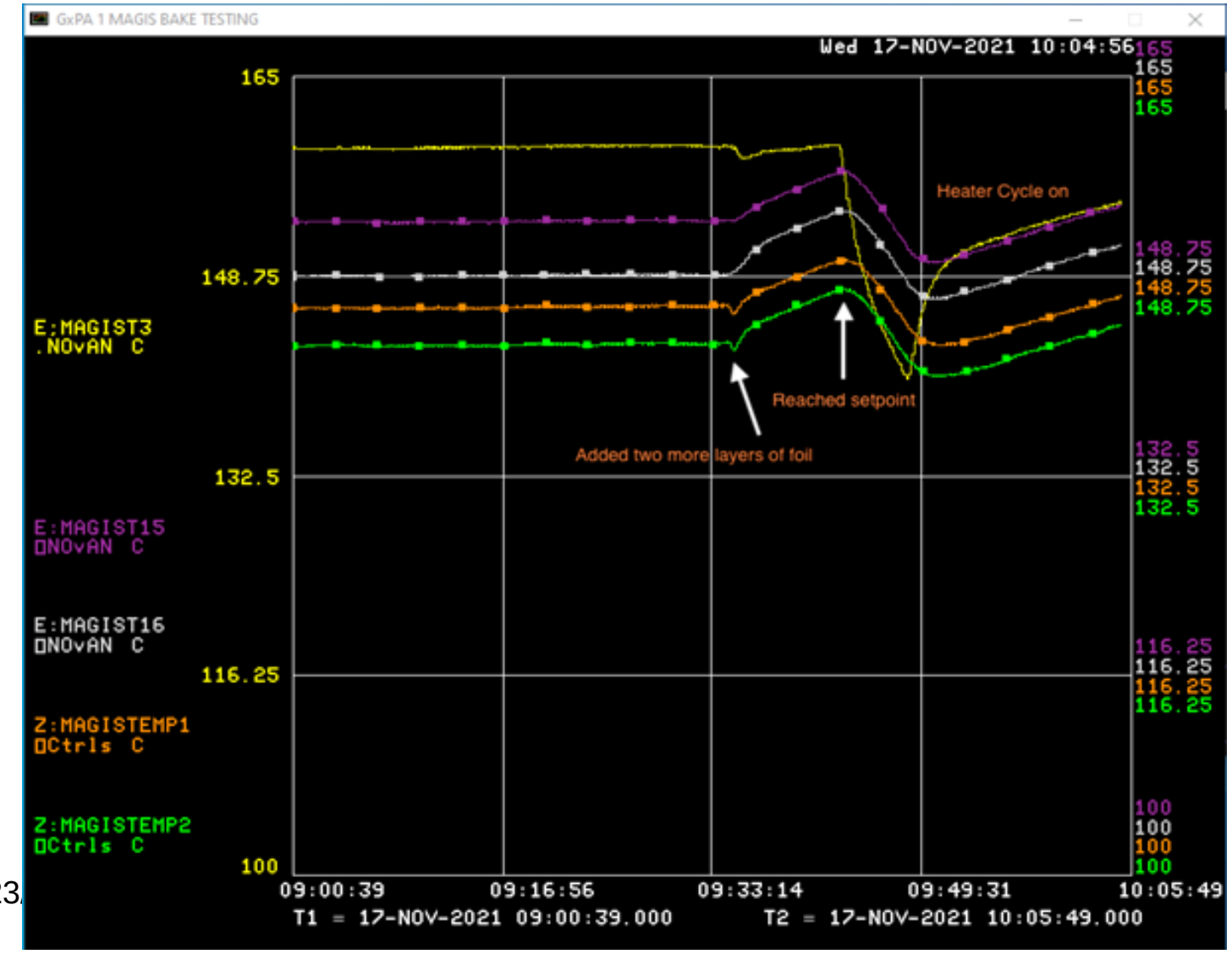
The ramp up rate of (~1.1°C/min) shown is the result of the heater being on constantly



Temperature tests

Shows adding foil & temp under heater vs between heaters



Temperature tests

Shows reaching set point with 10 layers of foil