Automated Shifting in SNO+

M.Ward on behalf of the DWG

SNOLAB Users meeting June 26-27th 2024

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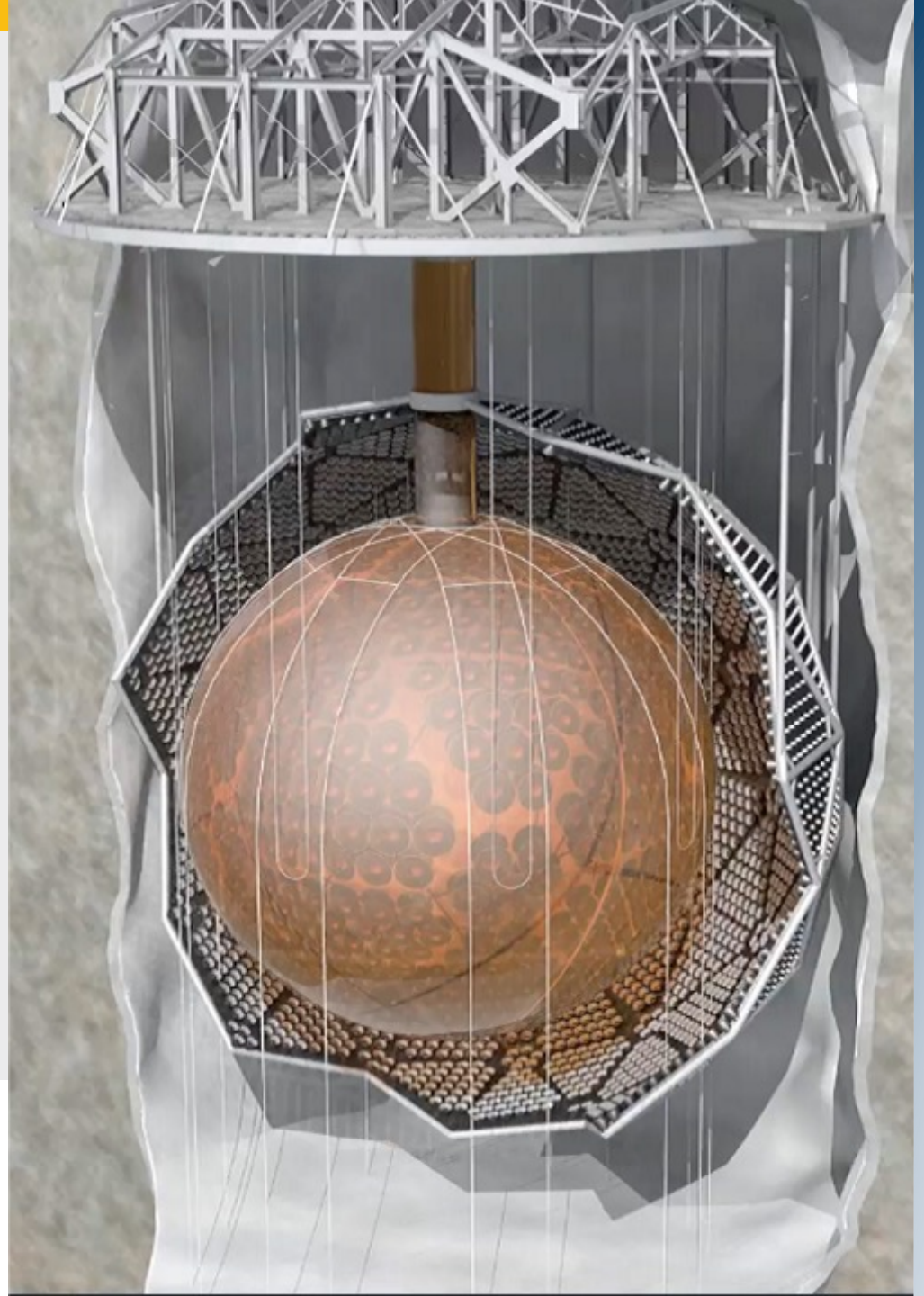
What you know (hopefully)

- SNO+ is a 780 tonne Liquid scintillator Detector.
- The scintillator is held in a 12 meter diameter acrylic sphere, surrounded by a PMT support structure (PSUP) emersed in 7000 tones of ultra pure water.
- It is instrumented with ~9400 8 inch PMTs to observe light produce by interactions.
- The DAQ is composed of original SNO electronics from the 90s (with a few upgrades)
- The Detector Working Group's Mission :
  - Maximum detector uptime
  - High quality physics data
  - Entropy control



*LAB is not maple syrup

“The History of every major Galactic Civilization tends to pass through three distinct and recognizable phases, those of Survival, Inquiry and Sophistication, otherwise known as the How, Why, and Where phases. ”

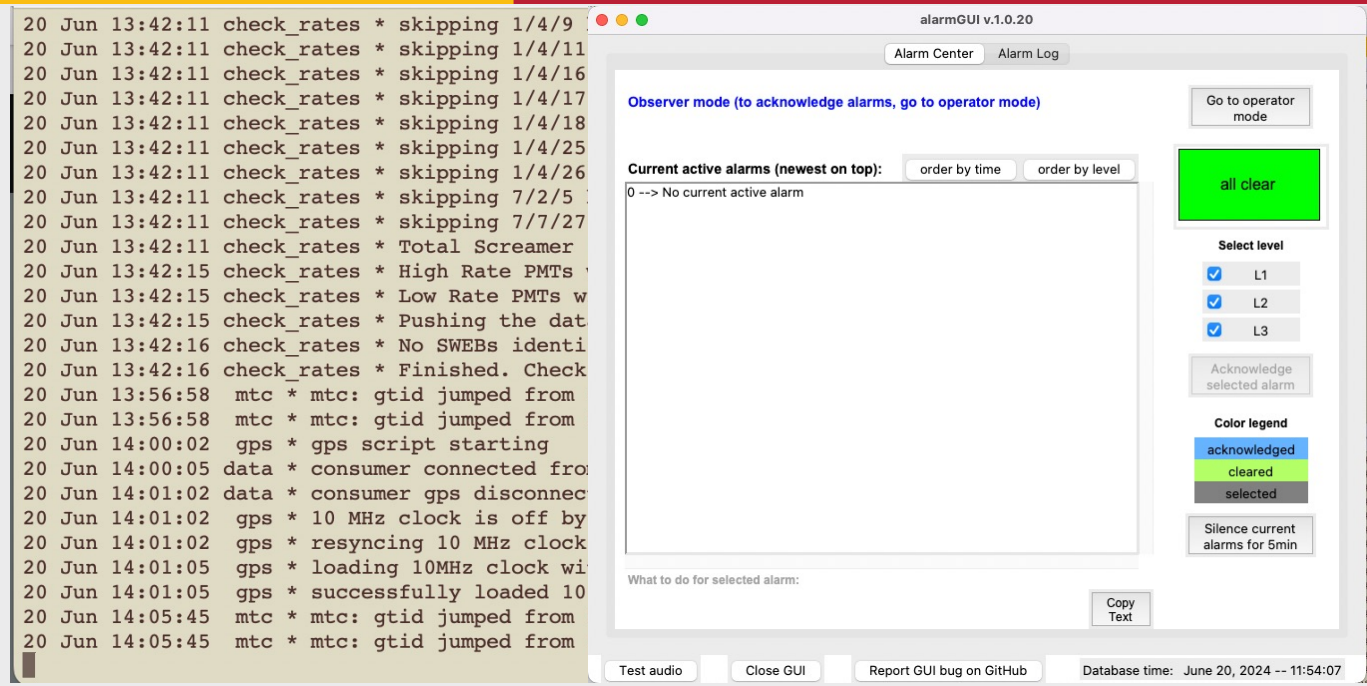
Douglas Adams

The Journey

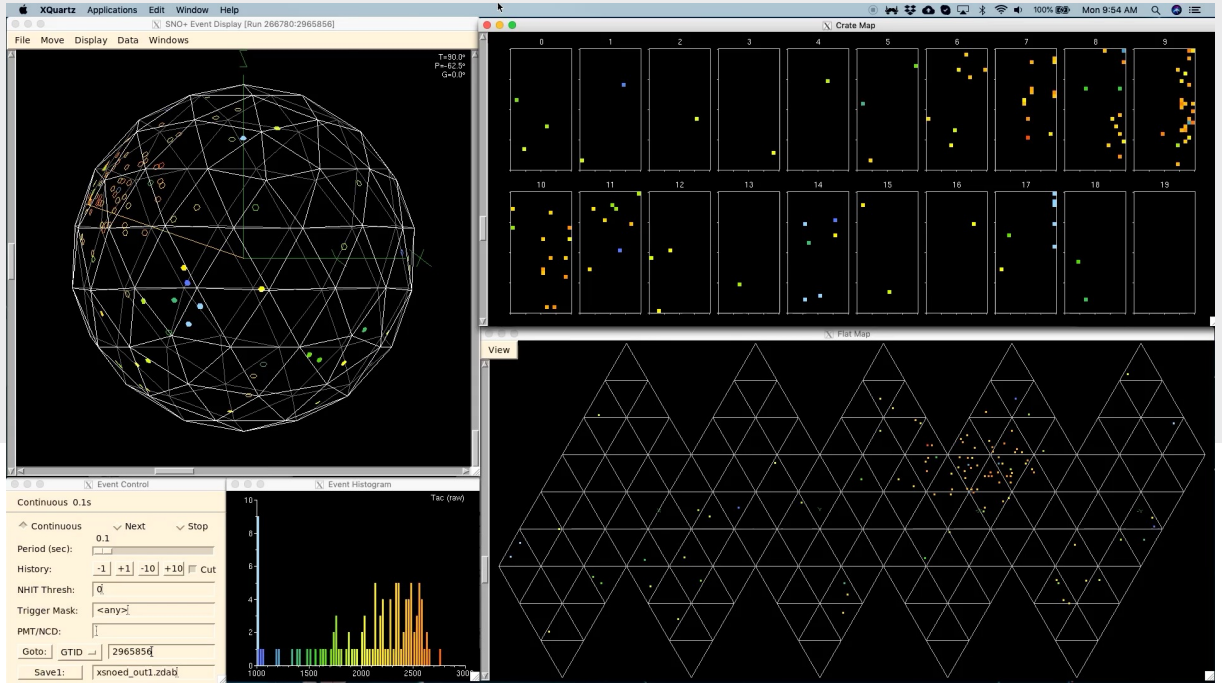
- **How** do we do shifts?
- **Why** do things go wrong when we are on shift?
- **Where** can we do better?

How do we do shifts?

- We monitor the SNO+ detector using several sources of information
  - DAQ and Builder logs
  - XSNOED (Event Display)
  - AlarmGUI
- We produce shift reports, noting events of interest or interactions with SNOLAB, hourly updates of general detector health stats.
- Respond to upset, or alarm states
- Contact the DAQ Expert team when things go wrong…
- Shifts are typically 8 hours in length, the detector does not sleep



(left) DAQ log (top) Alarmgui (bottom) Event display



Why do things go wrong when we are on shift?

- SNO+ is built on the shoulders of the original SNO hardware
- In many cases we are pushing the hardware into new and exciting territory.
- Sometimes there be dragons in these unmapped regions.
- Higher trigger rates and more stringent thresholds
  - There is a limit at which we can trigger and keep the detector in sync
  - Extra heat stress pushes some components outside of specification
- Some components are genuinely reaching end of life.
  - Passive components going out of spec causes many of our issues

Where can we do better?

- Entropy control is a constant battle
- There are cases when we see new and interesting issues, HOWEVER we are truly into the stage were the DAQ Experts group has very good knowledge in diagnosing and fixing issues with the detector.
- We have spent a lot of energy in hardware robustness in the last few years
- So what else can we do better?

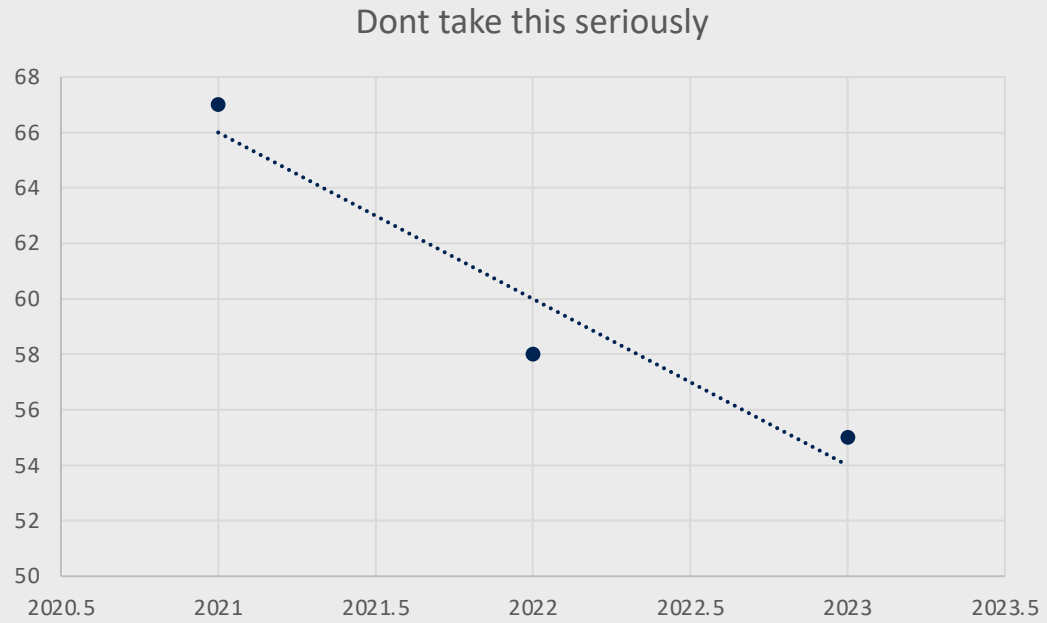
- Automation!
  - Shifting is a time consuming and labor intensive task
  - Much like we use online monitoring tools to perform data quality tasks, the question becomes… Can we create a tool to automate the tasks a shifter would do?
  - Do we gain anything else through automation?

Why Automate?

- Less people required to operate the detector
- Taking control away from the shifter frees up people to do other tasks
- A computer can respond to issues in a programmed manner
  - (No disrespect) but not all shifters are good at it.
  - A bad shifter can cause uptime loss, some examples :
    - Not seeing that a crate tripped and we haven't been seeing data from it for about 2 hours.
    - Not noticing the DAQ and builder are extremely unhappy and the detector is totally out of sync… for 4 hours
    - Waiting for a a few hours because they 'didn't want to wake the expert at 2am'
- Realistically not many people enjoy listening to TUBII sing a white-noise waltz over night.
  (We have shifters listen to triggers)

Shifting Stats!

- Shifts are taken by members of the collaboration across all seniority!
- It has however become difficult to keep all shift slots filled
- Anti-social hours are obviously the hardest to fill.
- Typically it runs down to about 15 shifts per person per year…



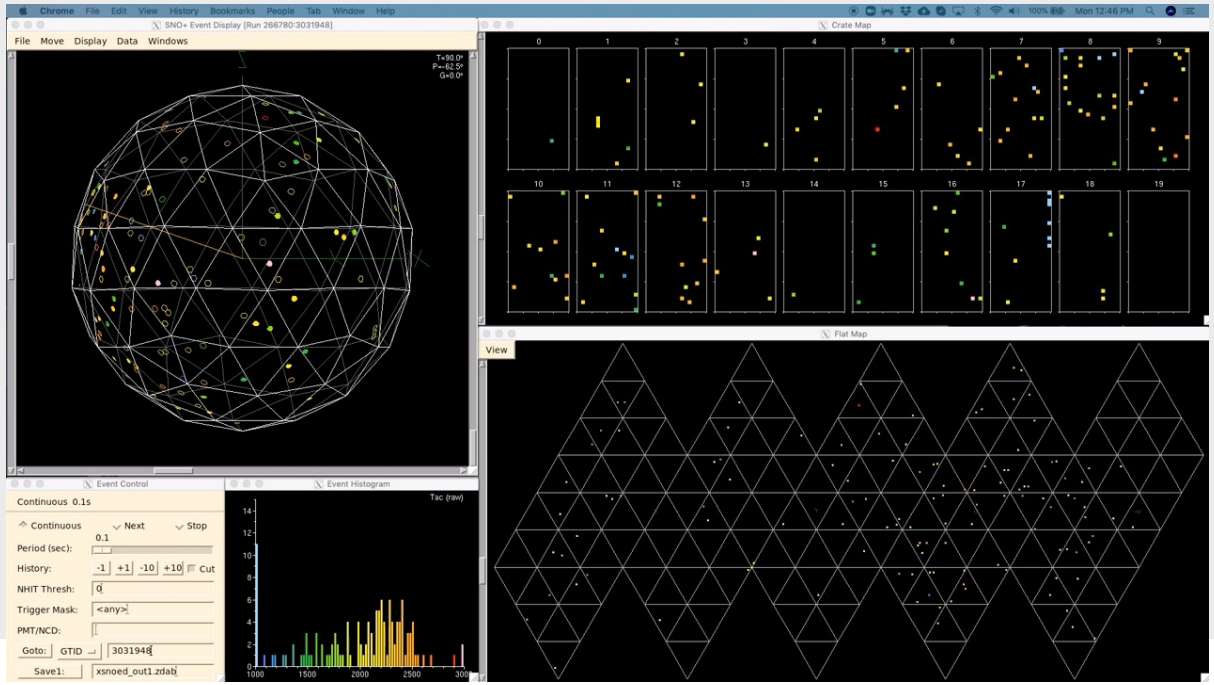
- Less people are taking shifts year on year…
- (Tongue in cheek) we will be out of shifters by 2032

How do we approach automation?

- For very good reasons we operate SNO+ with caution.
- It is important that the collaboration trusts what we are unleashing, the collaboration's DAQ experts are a big part of defining what is safe for SNO+
- Our approach has 3 important starting blocks

1. Look at how shifters actually do shifts
2. Analyze the data for when SNO+ does go wrong, are there any trends? Can we exploit it?
3. Use the existing tools as much as possible

- Figure out what it means to automate and what we want from it!



1 – How do shifters shift

- We have already spoken of the responsibilities in slide 4
- What is important to note is what are the problematic behaviors, can we fix these or not have automation recreate these issues.

- Main issues of note
  - Inconsistent note taking in shift reports
  - Inconsistent completion of shift reports
  - Inconsistent response time to Alarms
  - Long training period to identify what counts as a problem and what is a warning
    - Kinda like compiling code in C++, sometimes you can ignore warnings, other times not.

1 – How do shifters shift : The stories….

- 3am – Shifter lets an alarm go unanswered because they don’t want to wake up an expert.
- Shifter lets an alarm go unanswered likely because they silenced their speakers and just didn’t notice all of the signs of issues… (asleep?)
- Shifter constantly resyncs the detector because of DAQ warnings, potentially wasting run time.
- Shifter doesn’t notice a HV supply tripped off and a crate has been dark for 3 hours.

- **Take home message for Automation : Being attentive to the detector, constantly, is difficult for some.**
  A Tool than can’t fall foul of being inconsistent or somehow complacent will be great.
  We do also do not have the luxury of a huge collaboration and pool of people to do shifting!

Disclaimer : There are more good shifters than bad! Don’t hate me!

2 – Alarms – When things go wrong

Shifter, initially startled by the alarmgui, takes a few moments to look at what is going on.

- Fix themselves? Nope gonna need help
- Call an expert

Before

Expert : Don't worry about a thing, I got this

After

Expert : Yeah… so… let me tell you a story in 3 parts for the shift report.

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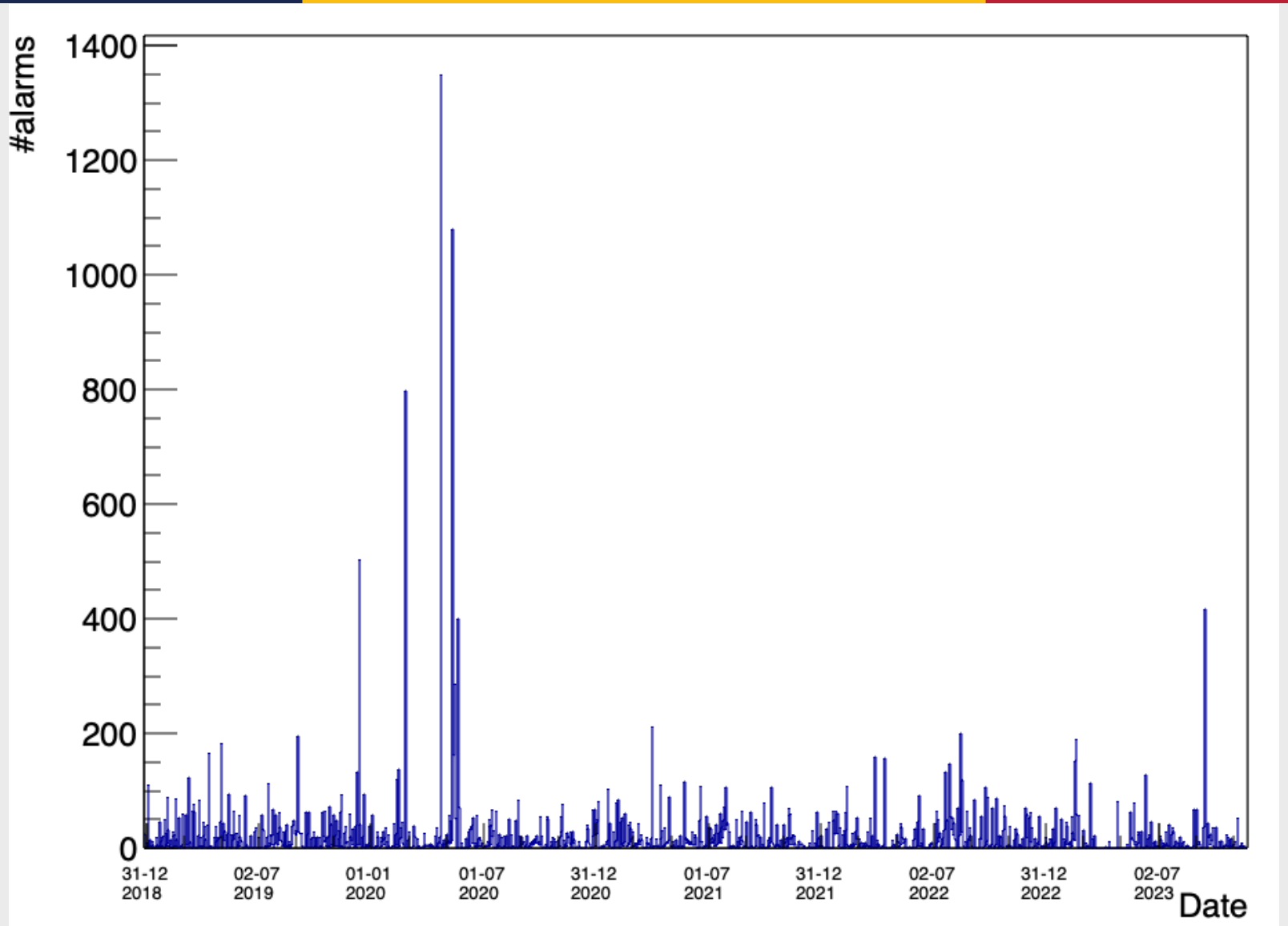
2 - Alarms

- The alarm system is operated from a database,
  - **Any system can be programed to issue an alarm!**
  - **We track 587 different alarms with 3 levels of severity!**
  - **We can add more if we want… is it Tuesday? ALARM!**
- Safety systems are already tied to several level 3 alarms
  - **We can issue hardware level emergency shutdown based on alarms alone.**

- A system will issue a SQL post to the DB with the alarmID (one of the 587 IDs)
- DB will create an active alarm with a timestamp.
  - Alarms can be acknowledged by a user
  - They can clear based on user action, OR hardware changes
  - Not all alarms require expert intervention!

- **We can thus track things quite well**



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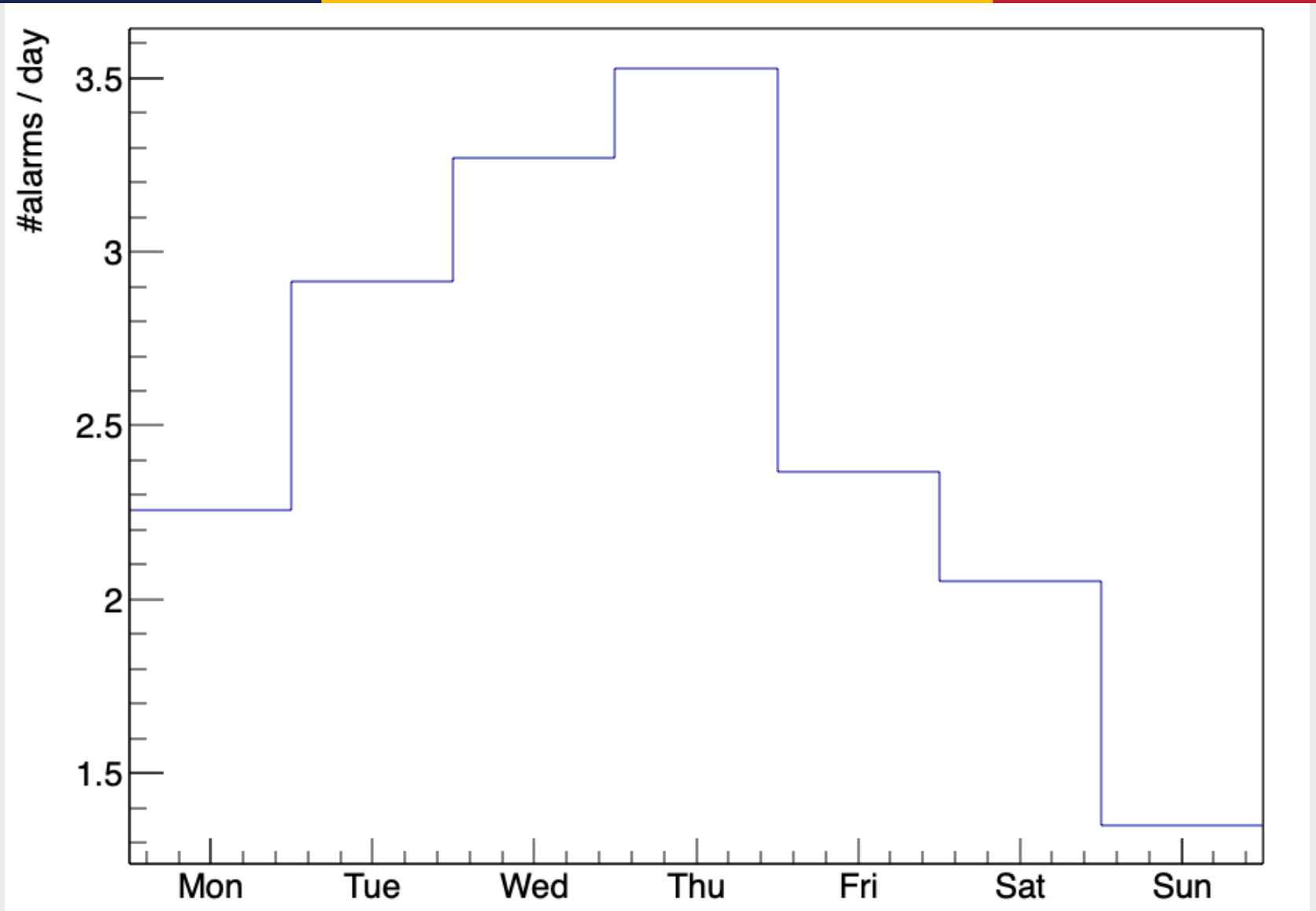

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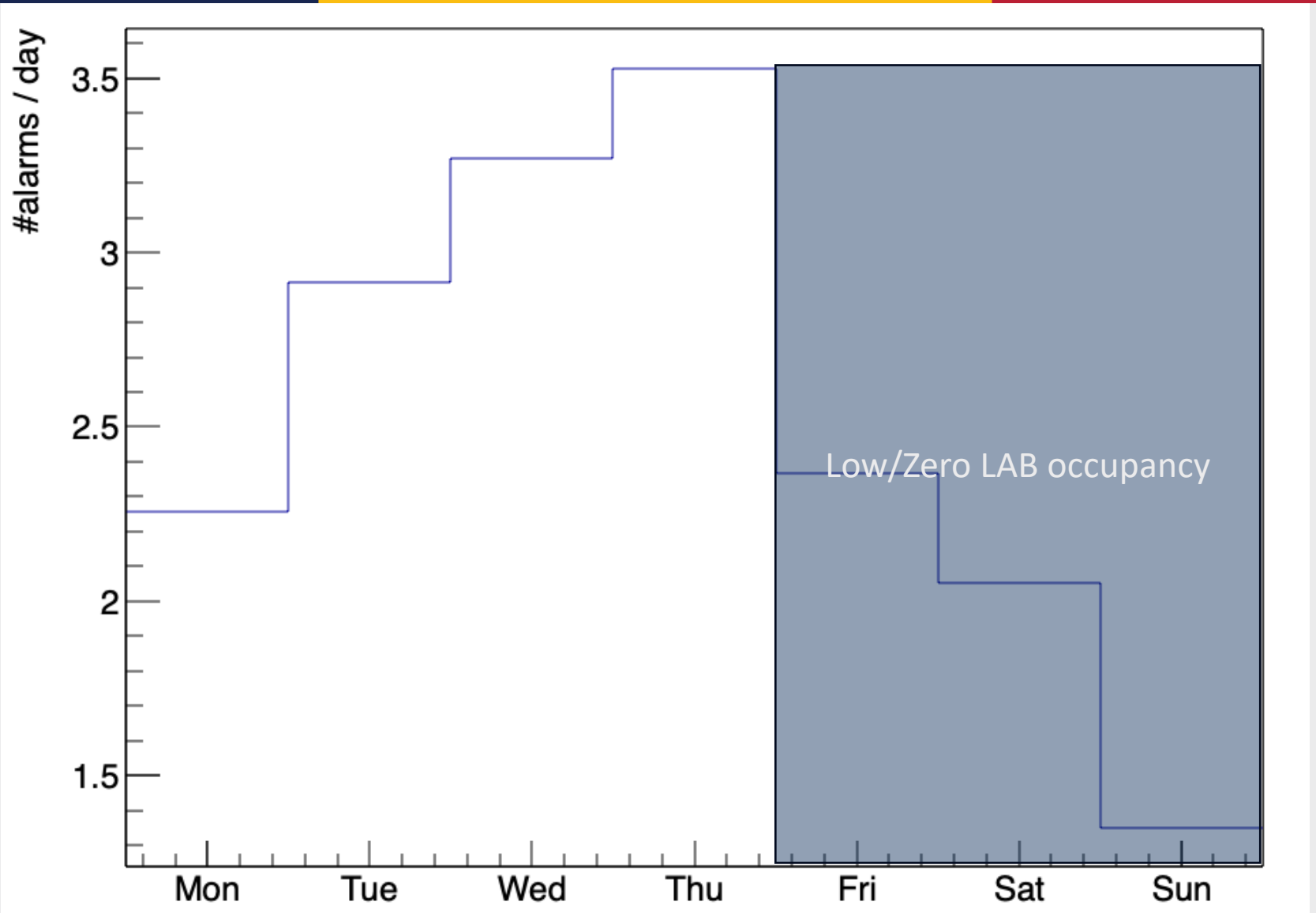

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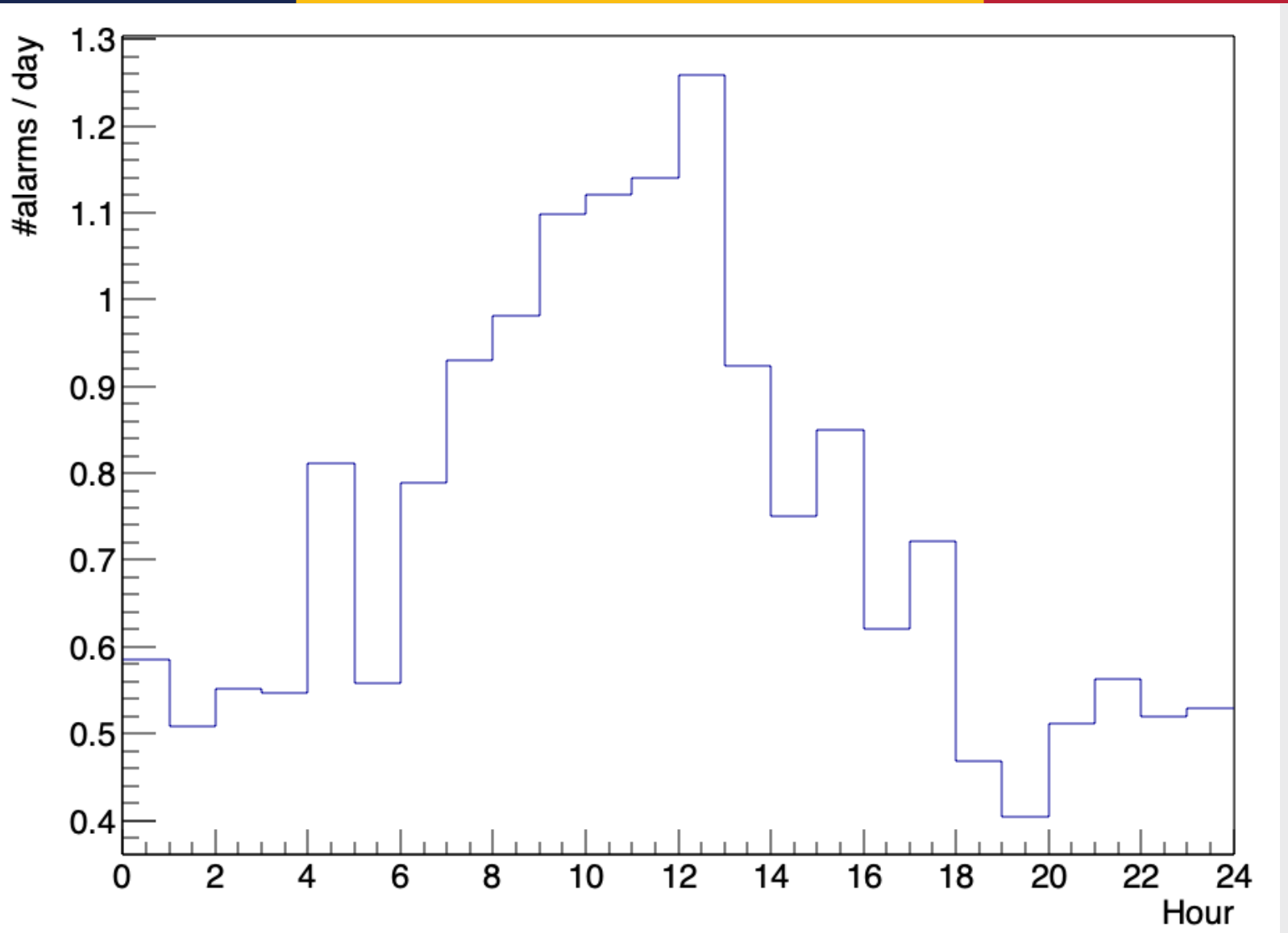

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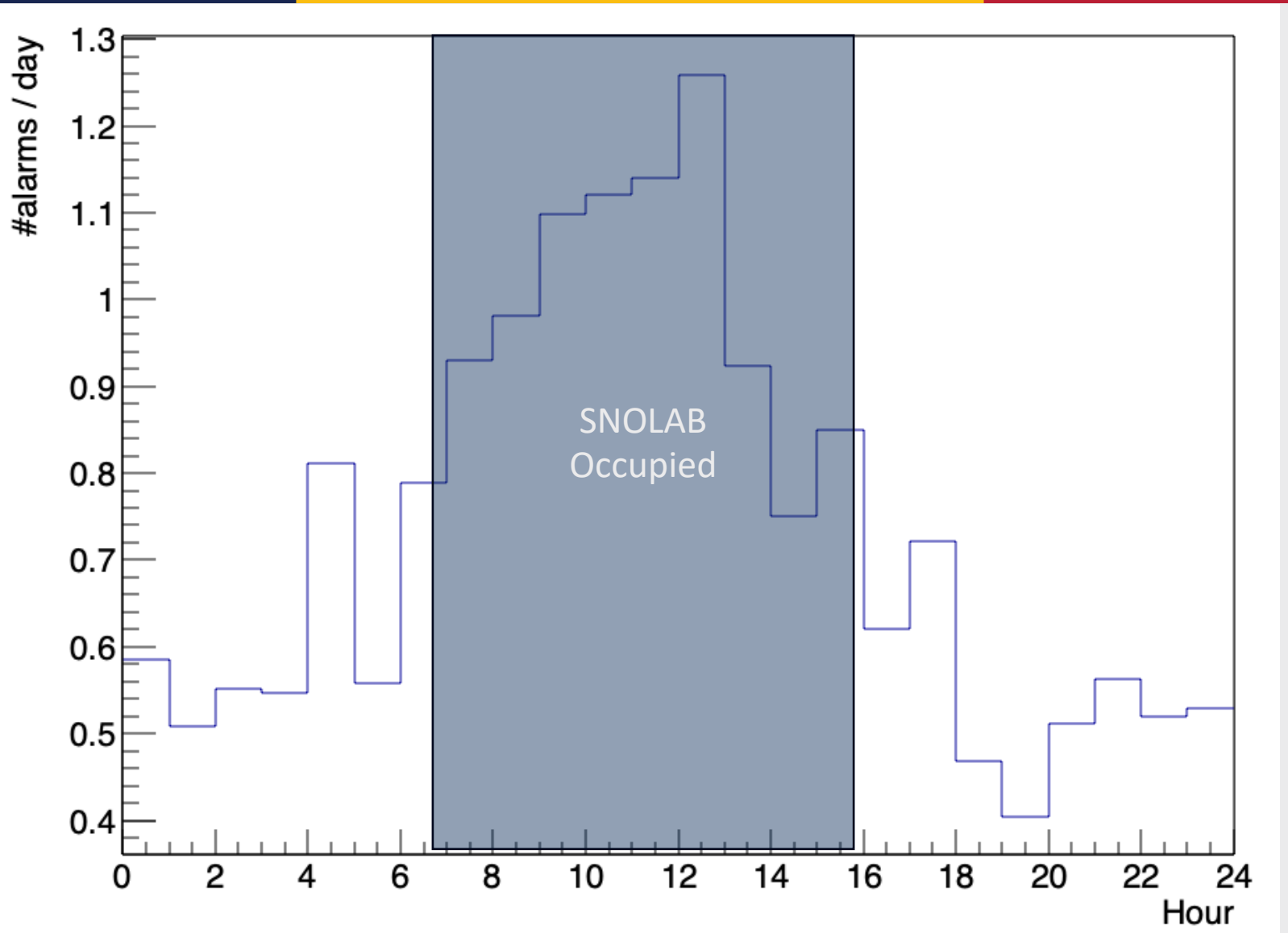
#alarms / day
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
SNOLAB
Occupied
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour

We can draw one very important conclusion from this data

SNO+ is a teenager (in its 20s)

- Doesn't like it when people are nearby
- Doesn't like daytime hours
- Sometimes craves attention
- Needs reminding how to do basic tasks
- Can't count… sometimes

- In reality… likely there is a grounding issue causing this.

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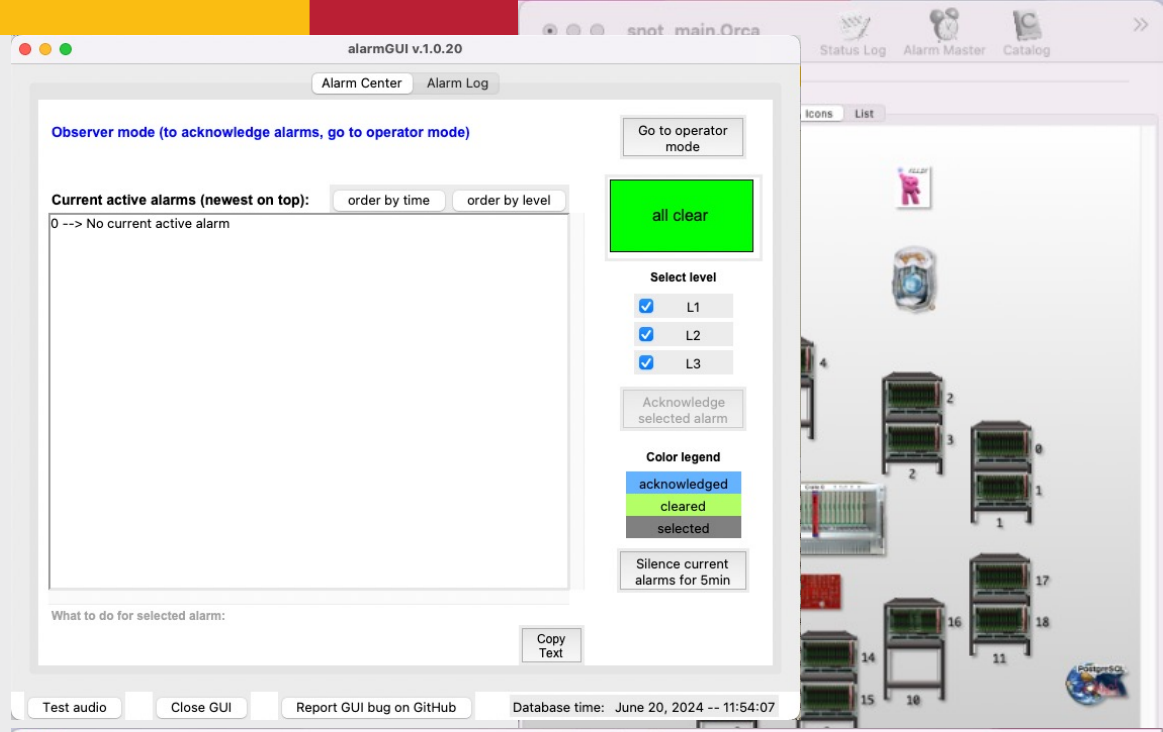
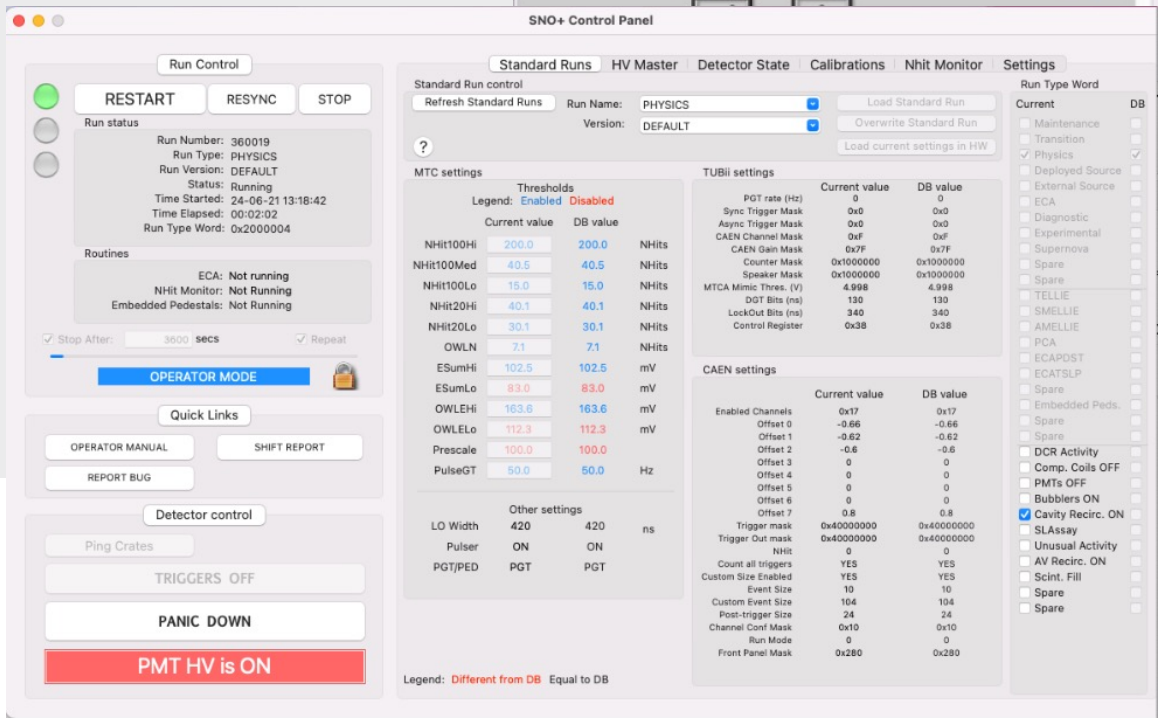
2 – Alarms – The serious version of the last slide

- **Take home for automation**
  - We trust in our Alarm system to trigger when something is wrong
  - We know SNO+ is most stable outside times of lab occupancy
    - If we are to unleash an automated system, THIS would be the target times
  - The Expert group is extremely well versed in items we can safely ignore and ones that need response.
  - The Expert group knows how things behave when there are alarms and what can be done (if any) to remedy things in a safe manner.

3 – Existing tools

- Lots of our tools and utilities are written in Python
  - Fairly quick to develop, we have produced many very stable scripts that we know work and trust, edge cases ironed out.
- We already have mechanisms that watch for specific alarms and perform actions for detector safety
  - Detect communication loss between UG and Surface > Power off after 30 minutes
  - We monitor rack power supplies for issues, and automatically shut down racks in the case of alarms
- Orca software we use to control the detector
  - Has a communication protocol already that had not been implemented
- **Take Home – We don't need to invent anything significantly different**





Minimum specifications for automation

Required:

1. Simple Logical program to perform basic case like tasks
2. Start, Stop, Restart and Resync runs
3. Change runtype (into our maintenance config)
4. Communicate with Experts when things go wrong
5. Produce a log that can be used by run-selection

Stretch goals

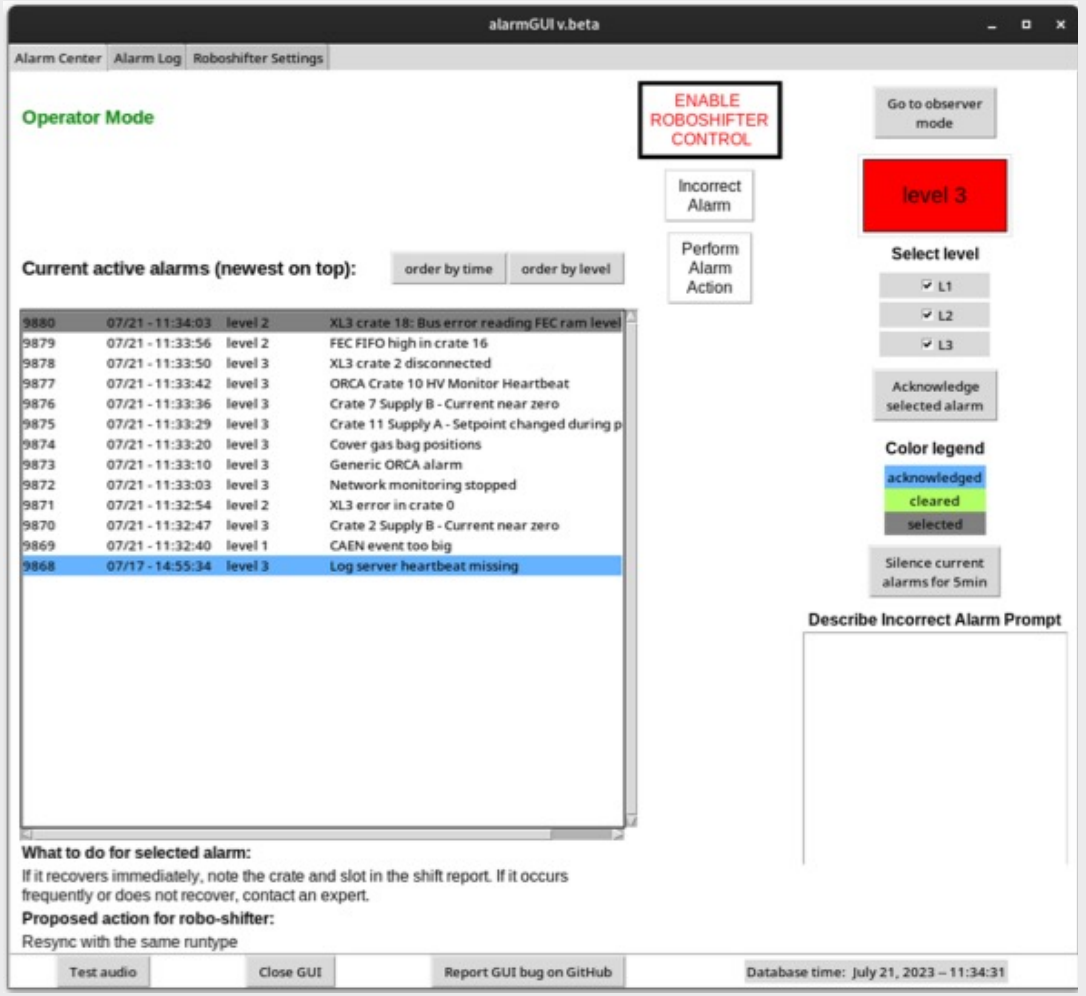
- Produce shift reports like a shifter would
- Multiple lines of communication with Experts
- Slack integration via a bot

Initial Planning – Lily de Loe, Mark (advice)

- Quickly we identify that the AlarmGUI already in use provides a good starting point.
  - It already pools the AlarmDB for active alarms.
- We track alarms for basically EVERYTHING
- Our Expert group has dealt with a huge number of issues, we know what things can be fixed by a shifter vs an Expert.
- Develop response philosophy.
- Identified a route by which we can talk with Orca
- Result
  - Decided that actions should be based on the alarm, NOT the level
  - Pooled our experts for default actions, created a list of actions.
  - Produced a modified AlarmGUI with prototype functions as a possible replacement for the GUI
  - Understand that Orca will require some modification for us to interact with it.

Production – David Drobner (Co-op) , Anita Masuskapoe, Mark (Advice)

- Turned expert feedback into an extra column in our Alarm Table, action to take per alarm.
- Reworked lots of code to produce a program we renamed Roboshifter.
- Communication between Roboshifter and Orca is demonstrated,
  - Orca updated to allow for remote run start, stop, runtype changes, HV readback and control.
- Basic interaction with Shift report pages
- Able to pull DAQ log and builder log information
- Able to send SMS messages



Process

Did this happen 5 times in a short period?
Change runtype to maintenance

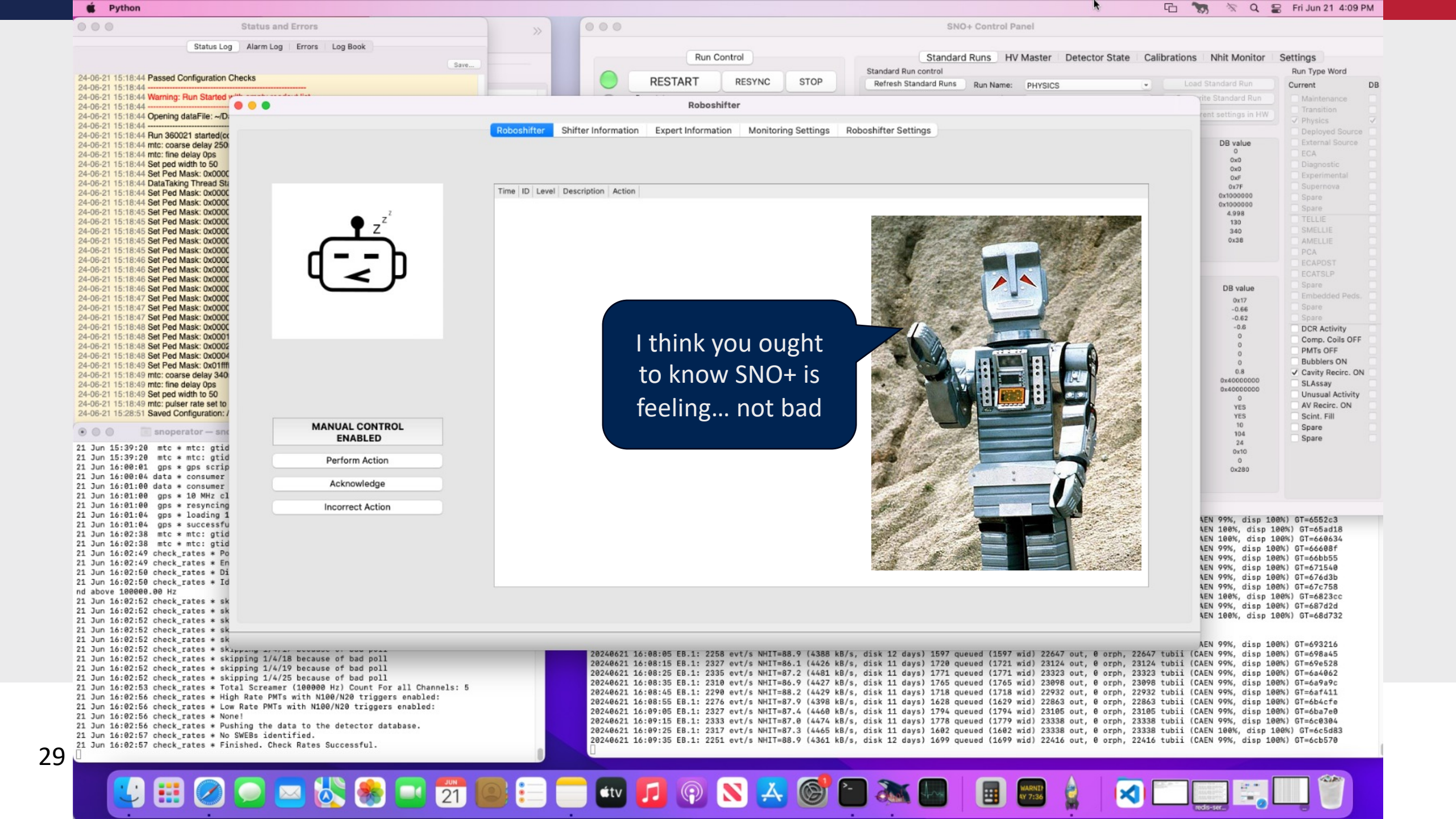
1. Alarm occurs, regular alarmgui / webgui do what they usually do. User alerted via regular means.
2. Pull the desired action matching the alarm id from the database
3. Grab the DAQ log and builder log, put this in the Shift Report
4. Alert the shift channel of the alarm with the DAQ and builder messages, send SMS and Email to shifter
5. Perform desired action, for most alarms it will try a resync of the detector,
6. Start a shutdown timer.
7. If timer reaches 30 minutes, ramp down PMTs...
8. Timer is cleared upon alarm acknowledgement or clearing due to action

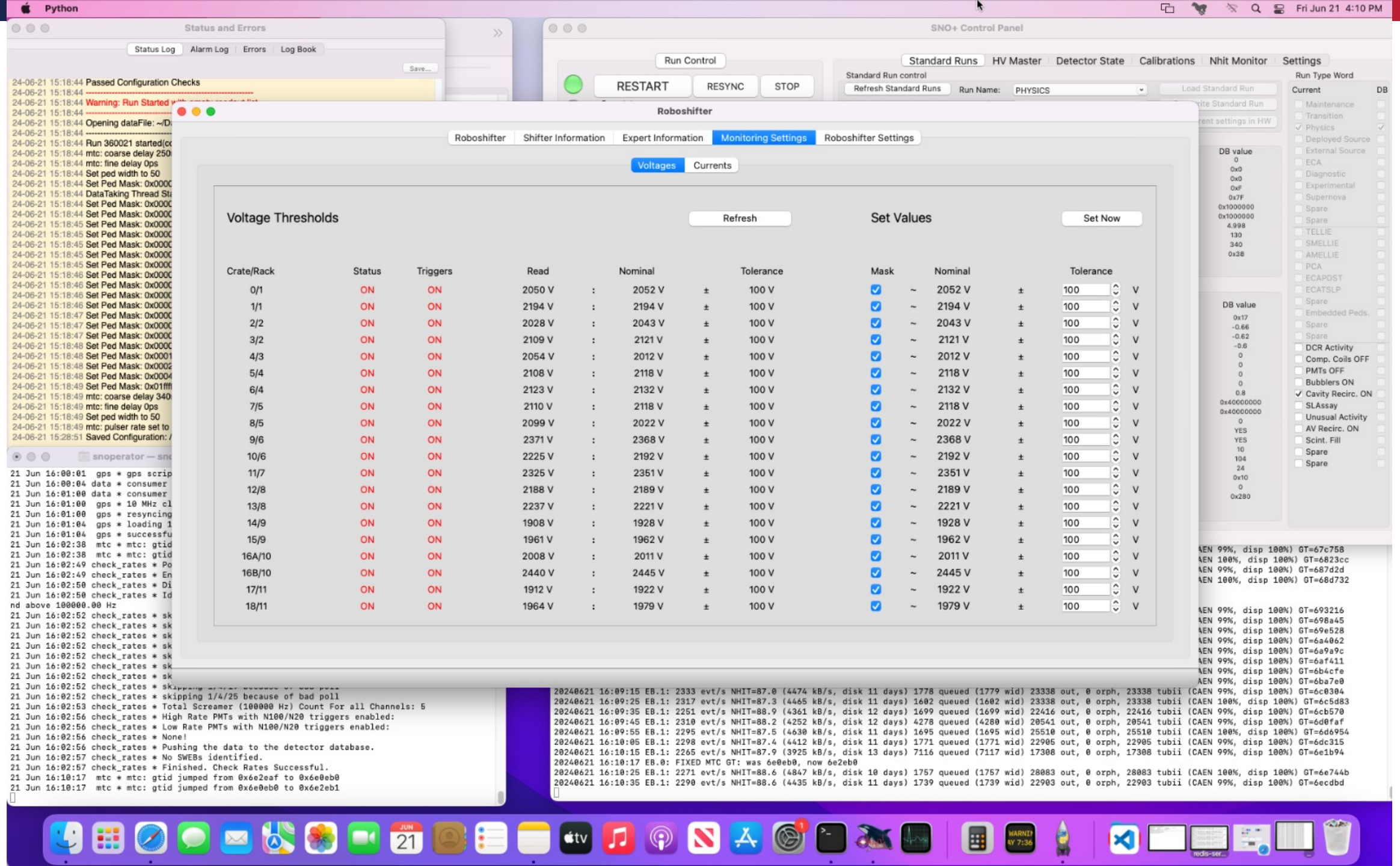
Testing during Davids Co-op term

- Testing
  - Roboshifter was tested disconnected with Orca in a development environment to catch crashes and edge cases
  - Runtype change and run start, stop, resync tested in a development environment but not connected to the detector.
  - Slack functionality works
  - SMS works
- Issues
  - Orca communication is a little flaky
  - Alarm floods can cause crashes
  - Random crashes
  - Grabbing builder and DAQ logs can hang or just take an excessive amount of time.

Further development – Parmesh Ravi, Anita Masuskapoe, Matt Depatie, Mark Ward

- Further orca communication
  - HV and Current feedback
  - Set Runtype word
  - Save Orca status
- User communication reworked
  - Slack messages are less spammy, and more targeted
  - SMS system more robust
  - Email system more robust
  - Voice calls!
  - Able to call experts rather than just shifter
  - Interaction with SNOPLUS shift whiteboard.
- UI changes
  - New interface, extra tabs
  - Visible mode changes, so we know who/what is in control
  - Visible feedback on who is on call along with overrides
- Able to make full shift reports!!!
  - Able to complete shift reports at a level a shifter should be able to!
  - Able to track and alert a shifter to changes in PMT Current readback.
- Lots of under the hood robustness fixes


Python
Fri Jun 21 4:09 PM
Status and Errors
Status Log
Alarm Log
Errors
Log Book
SNO+ Control Panel
Run Control
RESTART
RESYNC
STOP
Standard Runs
HV Master
Detector State
Calibrations
Nhit Monitor
Settings
Roboshifter
Roboshifter
Shifter Information
Expert Information
Monitoring Settings
Roboshifter Settings
Time
ID
Level
Description
Action
MANUAL CONTROL ENABLED
Perform Action
Acknowledge
Incorrect Action
I think you ought to know SNO+ is feeling… not bad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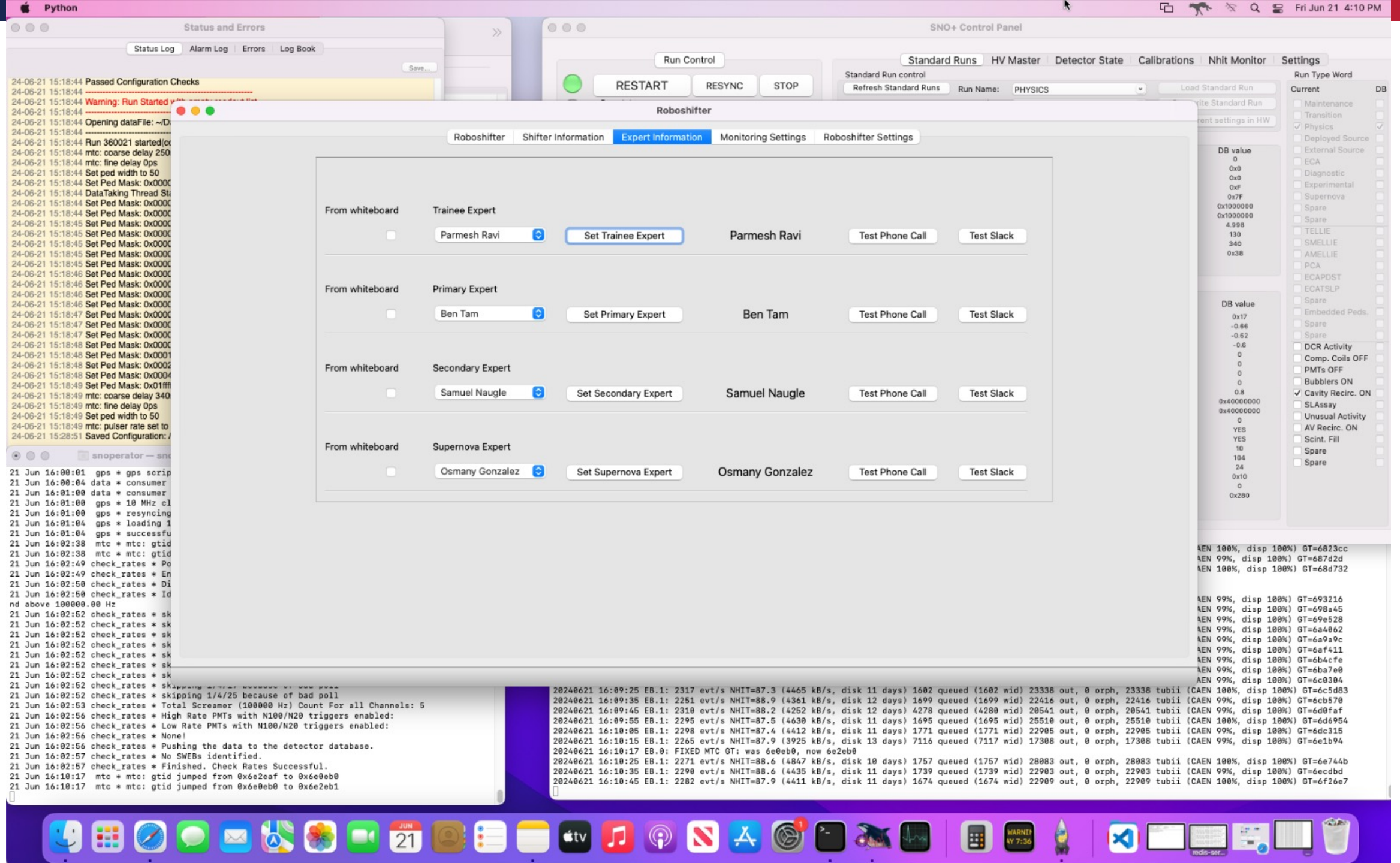
Voltages
Currents
Voltage Thresholds
Refresh
Set Values
Set Now
Crate/Rack
Status
Triggers
Read
Nominal
Tolerance
Mask
Nominal
Tolerance
0/1 ON ON 2050 V : 2052 V ± 100 V ~ 2052 V ± 100 V
1/1 ON ON 2194 V : 2194 V ± 100 V ~ 2194 V ± 100 V
2/2 ON ON 2028 V : 2043 V ± 100 V ~ 2043 V ± 100 V
3/2 ON ON 2109 V : 2121 V ± 100 V ~ 2121 V ± 100 V
4/3 ON ON 2054 V : 2012 V ± 100 V ~ 2012 V ± 100 V
5/4 ON ON 2108 V : 2118 V ± 100 V ~ 2118 V ± 100 V
6/4 ON ON 2123 V : 2132 V ± 100 V ~ 2132 V ± 100 V
7/5 ON ON 2110 V : 2118 V ± 100 V ~ 2118 V ± 100 V
8/5 ON ON 2099 V : 2022 V ± 100 V ~ 2022 V ± 100 V
9/6 ON ON 2371 V : 2368 V ± 100 V ~ 2368 V ± 100 V
10/6 ON ON 2225 V : 2192 V ± 100 V ~ 2192 V ± 100 V
11/7 ON ON 2325 V : 2351 V ± 100 V ~ 2351 V ± 100 V
12/8 ON ON 2188 V : 2189 V ± 100 V ~ 2189 V ± 100 V
13/8 ON ON 2237 V : 2221 V ± 100 V ~ 2221 V ± 100 V
14/9 ON ON 1908 V : 1928 V ± 100 V ~ 1928 V ± 100 V
15/9 ON ON 1961 V : 1962 V ± 100 V ~ 1962 V ± 100 V
16A/10 ON ON 2008 V : 2011 V ± 100 V ~ 2011 V ± 100 V
16B/10 ON ON 2440 V : 2445 V ± 100 V ~ 2445 V ± 100 V
17/11 ON ON 1912 V : 1922 V ± 100 V ~ 1922 V ± 100 V
18/11 ON ON 1964 V : 1979 V ± 100 V ~ 1979 V ± 100 V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Roboshifter Settings
From whiteboard
Trainee Expert
Parmesh Ravi
Set Trainee Expert
Parmesh Ravi
Test Phone Call
Test Slack
From whiteboard
Primary Expert
Ben Tam
Set Primary Expert
Ben Tam
Test Phone Call
Test Slack
From whiteboard
Secondary Expert
Samuel Naugle
Set Secondary Expert
Samuel Naugle
Test Phone Call
Test Slack
From whiteboard
Supernova Expert
Osmany Gonzalez
Set Supernova Expert
Osmany Gonzalez
Test Phone Call
Test Slack

Staged deployment

- January – March 2024
  - Roboshifter put in control over weekends
  - 38% of shifts
  - Successful! Iron out minor bugs
- March 2024 onward
  - Roboshifter put in control weekends and overnight.
  - 58% of shifts
- Stability is very good
  - Was able to keep SNO+ running during network outages!
- Shifters benefit greatly from Roboshifter,
  - More time to do other things
  - Roboshifter does lots of the book keeping tasks for the shifter during a regular shift.
  - User feedback has been positive.

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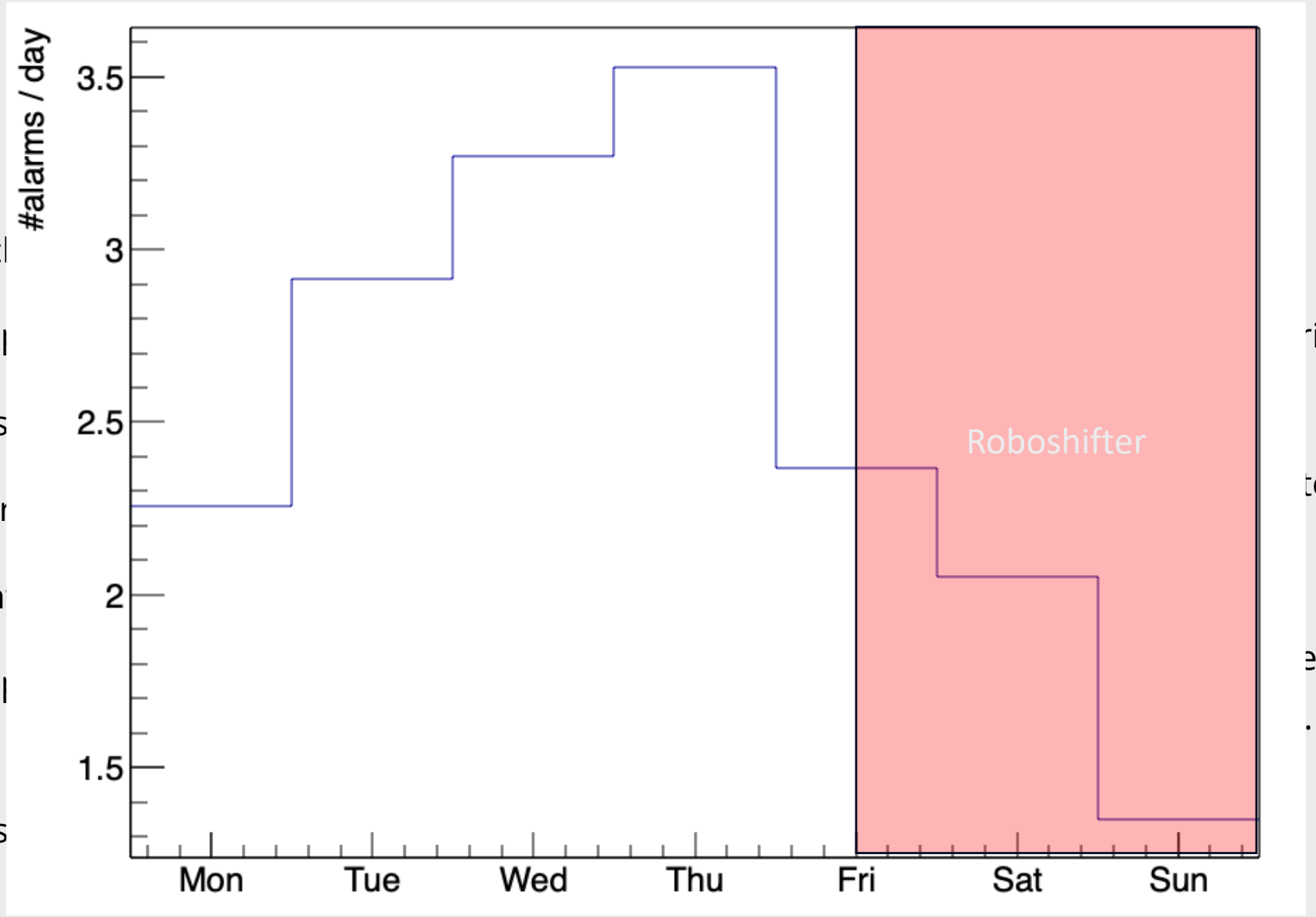

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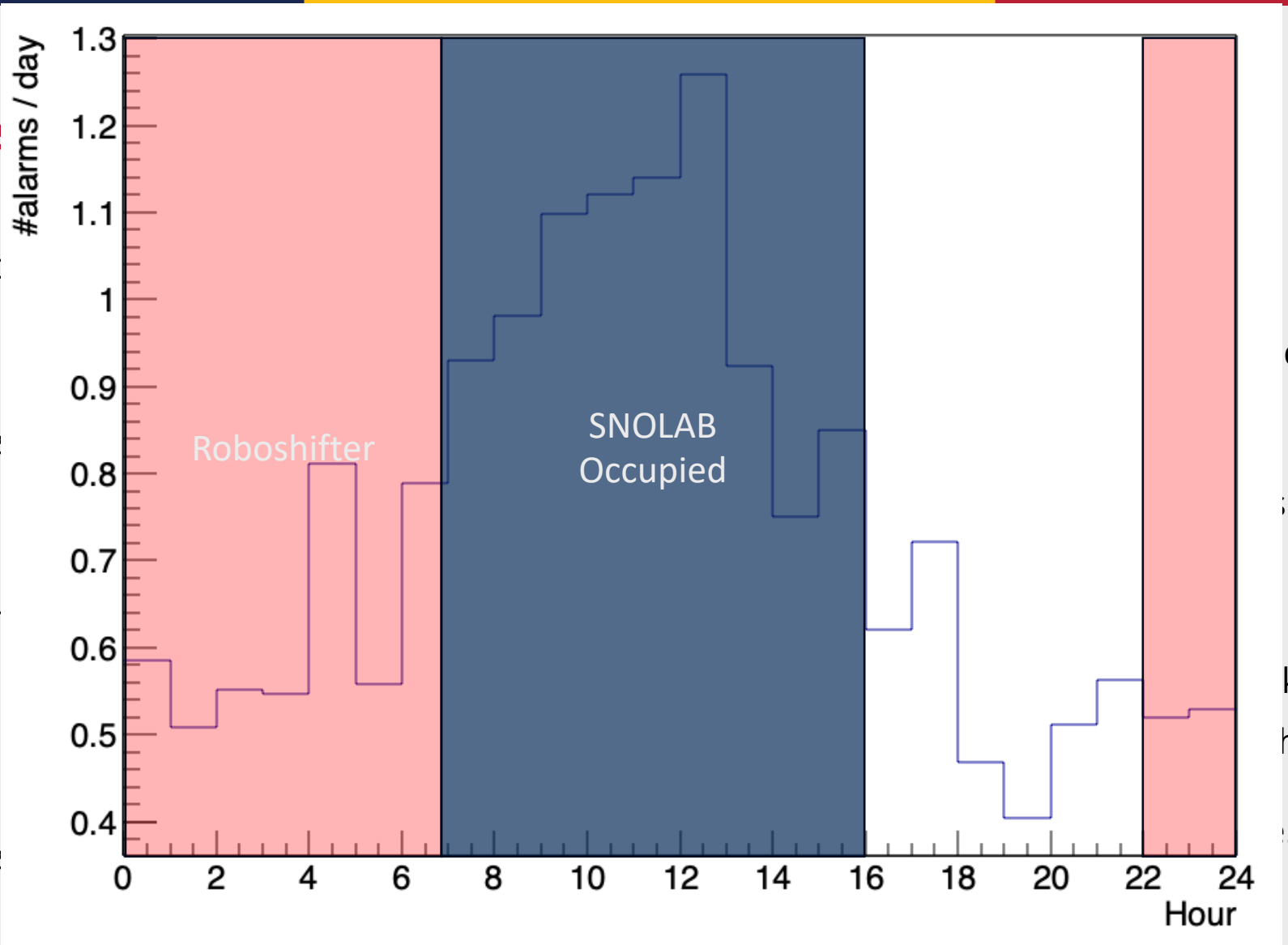

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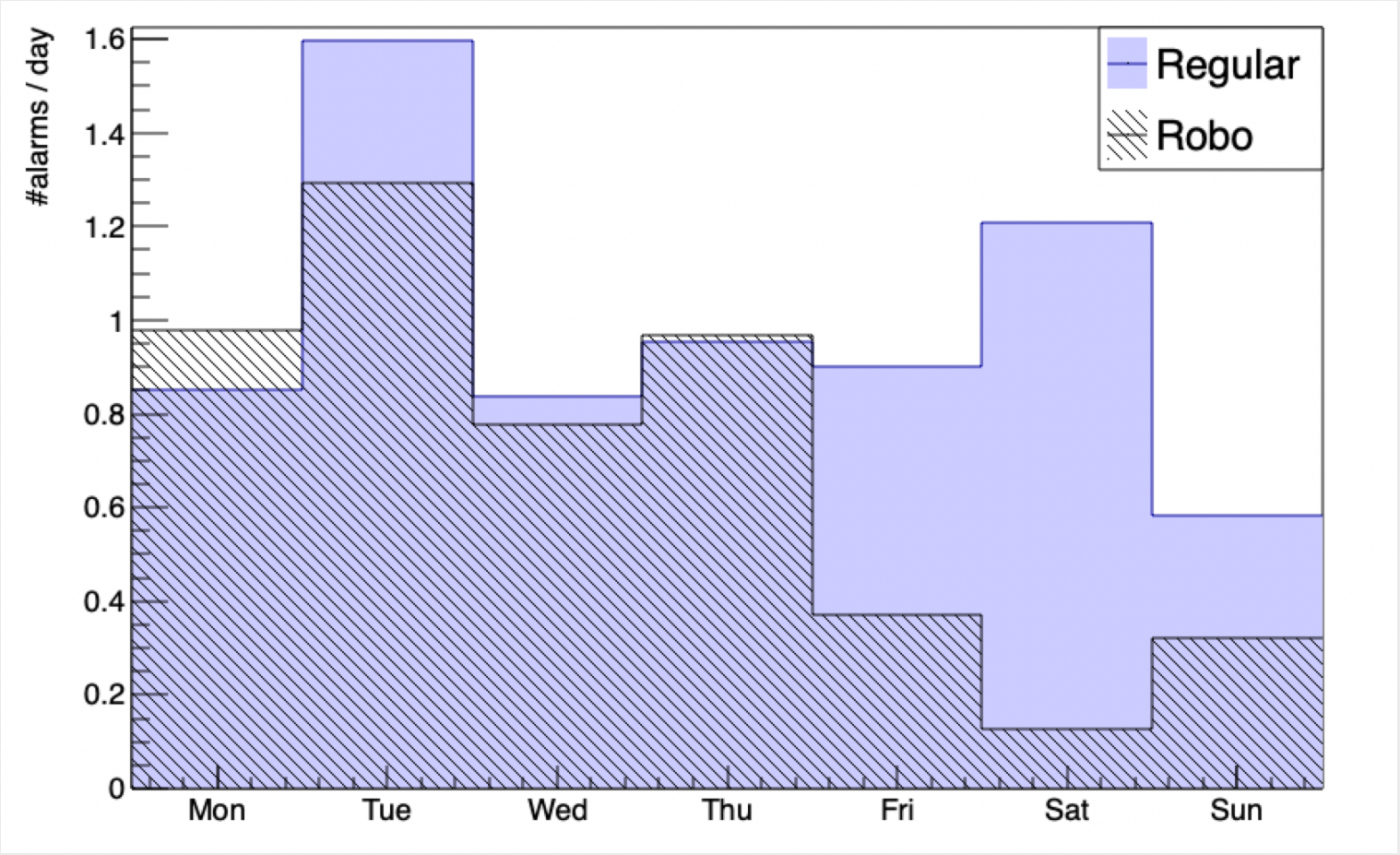
Compare Stats for 6 months



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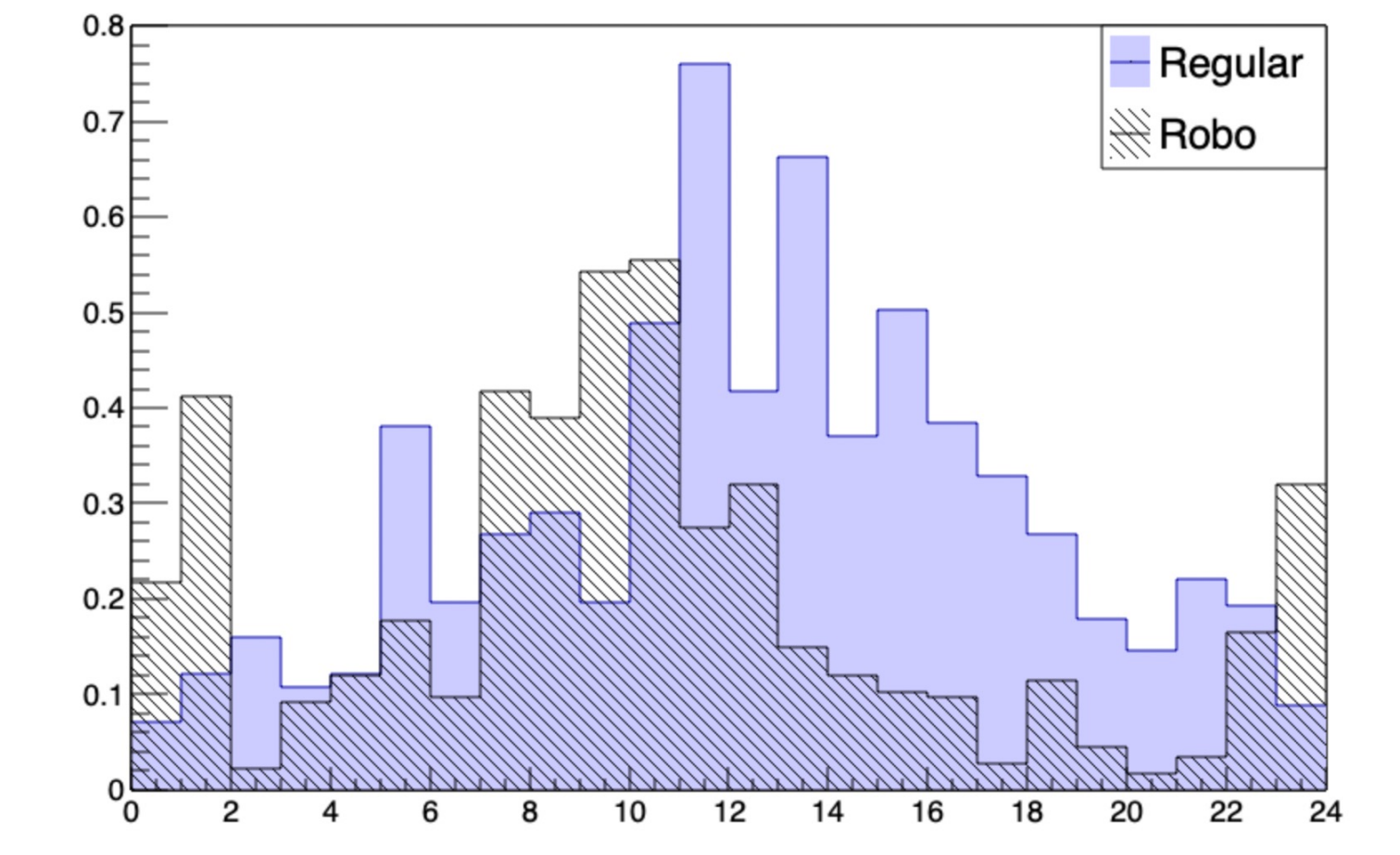

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Remarks

- Alarms are produced by the Detector… NOT the shifter
  - HOWEVER – if a shifter responds slowly, we can generate multiple alarms for a single issue.
  - This could be the origin of the drop in alarm rates during evenings and weekends as automatic actions can fix issues before they cascade.
  - This would naturally impact weekend and night stats more.
- Reminder – The goal of Automation was never to reduce alarms! So Use caution/common sense. There are scenarios though where we could get better uptime with its use.

There was a FEC FIFO alarm, but I already fixed it with a resync… you are welcome by the way… I still wanted to call you at 3am to tell you about it though, I'm fine to, not that anyone asks me. I sometimes skip my heartbeat to get attention

Marvin, SNO+'s pal who's fun to be with

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Minimum specifications for automation - Revisited

Required:

1. ~~Simple Logical program to perform basic case like tasks~~
2. ~~Start, Stop, Restart and Resync runs~~
3. ~~Change runtype (into our maintenance config)~~
4. ~~Communicate with Experts when things go wrong~~
5. ~~Produce a log that can be used by run-selection~~

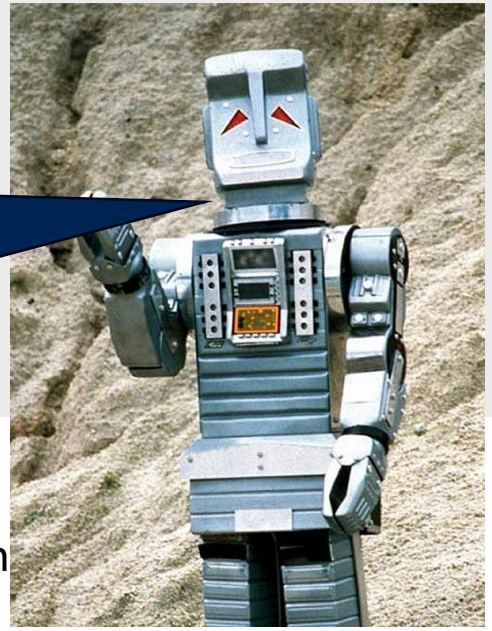
Stretch goals

- ~~Produce shift reports like a shifter would~~
- ~~Multiple lines of communication with Experts~~
- ~~Slack integration via a bot~~
- Current and HV tracking! A shifter can do this, but its extremely unlikely a shifter spots changes and alerts experts consistently
- Shown to work despite TERRIBLE outside world network connectivity

Summary

- Thanks to the work of the Expert group, as well as **talented students** and postdocs we have successfully produced an automated shifting tool for SNO+
- The tool can produce shift reports exactly as a human is expected to do.
- The tool can perform basic detector tasks which can aid in clearing of alarms and keeping data flowing.
- The tool acts as an aid to the human shifters, improving the consistency of shift reports and allowing accelerated responses to alarms.

Here I am, brain the size of a planet and they ask me to open a new shift report…



Marvin, SNO+'s pal who's fun to be with

Queen's UNIVERSITY