Green Mining and the Perils of Mining Energy Profiles

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with
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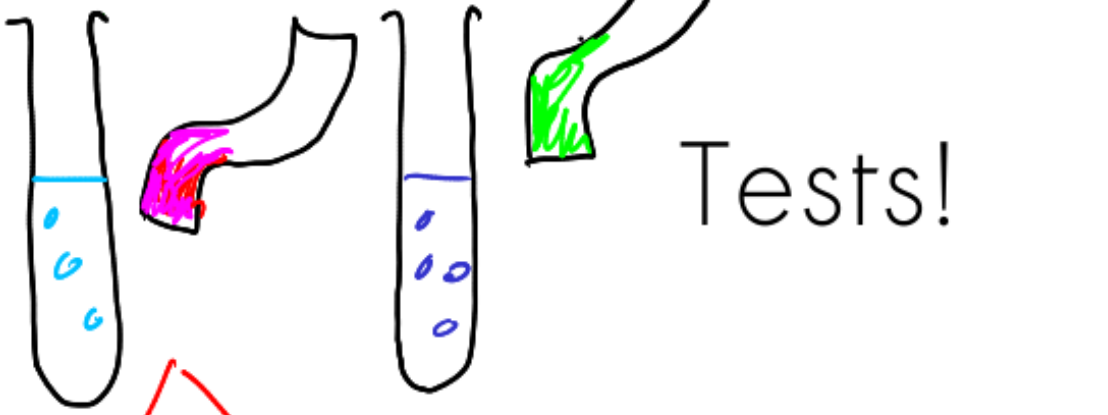
What is Green Mining?

Static Analysis



Tests!

Software Change

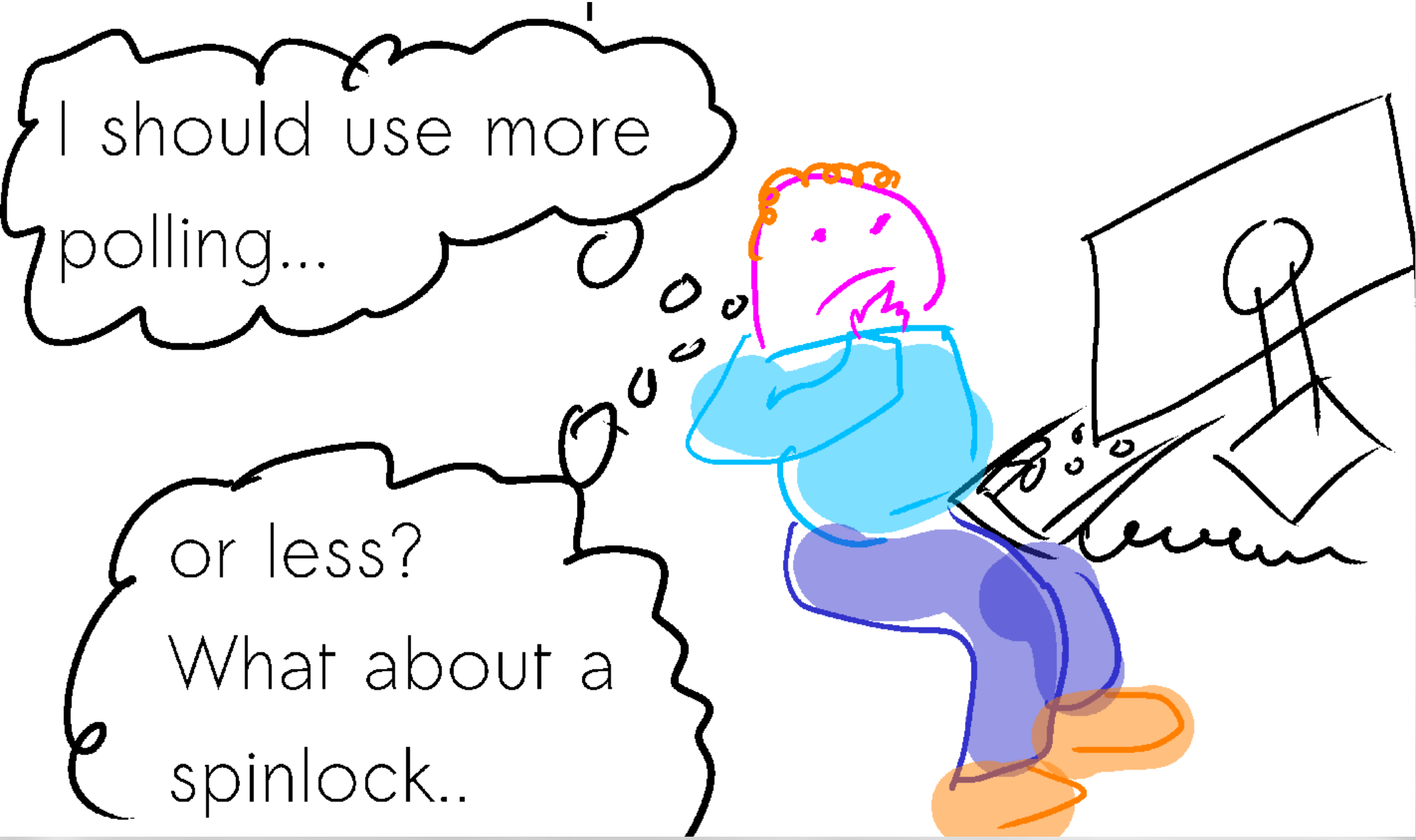
Corpus of test runs related to software changes

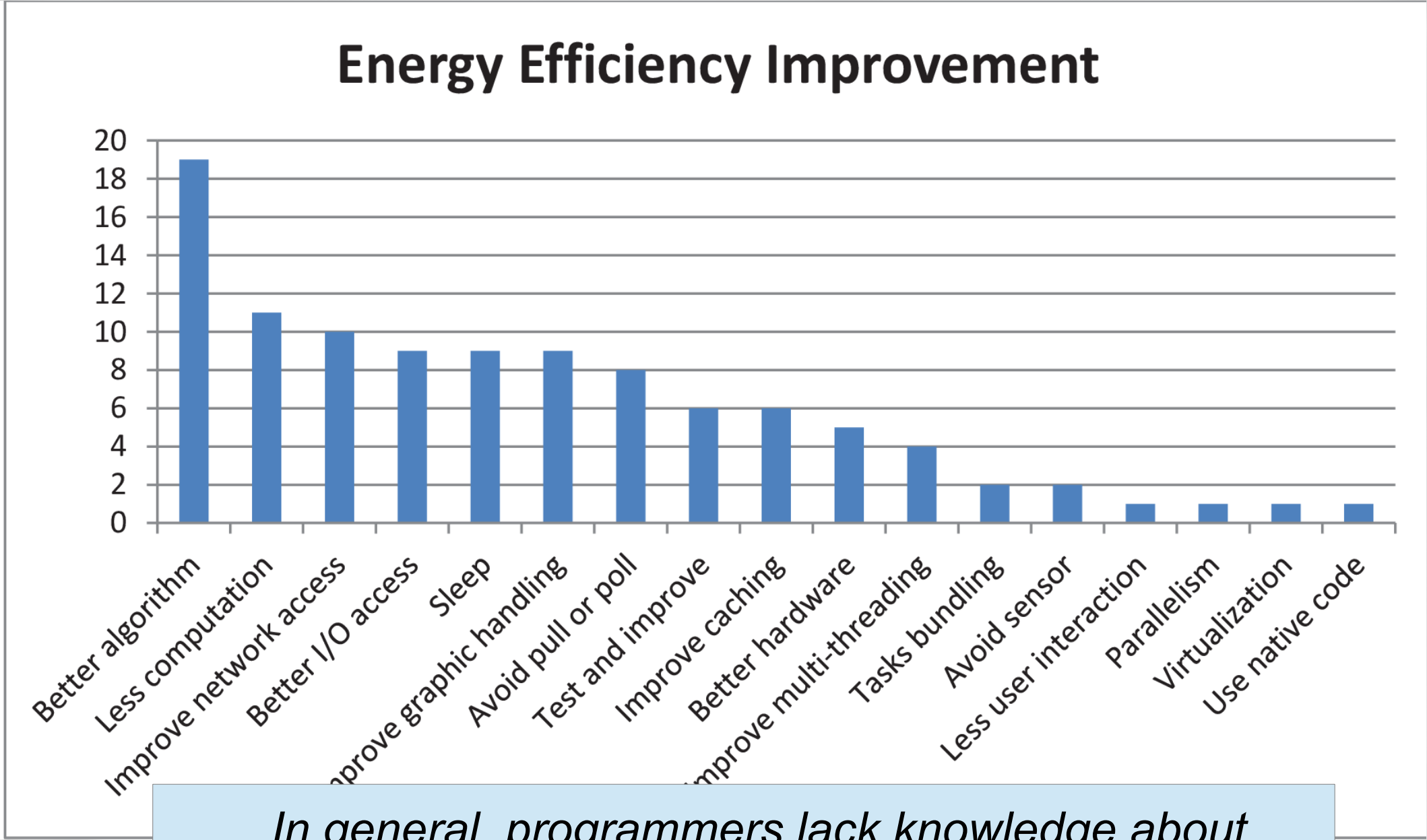
Dynamic Analysis

Green Mining's Goal

To reason about the **energy** consumption of source code changes based on a corpus of power regression tests.

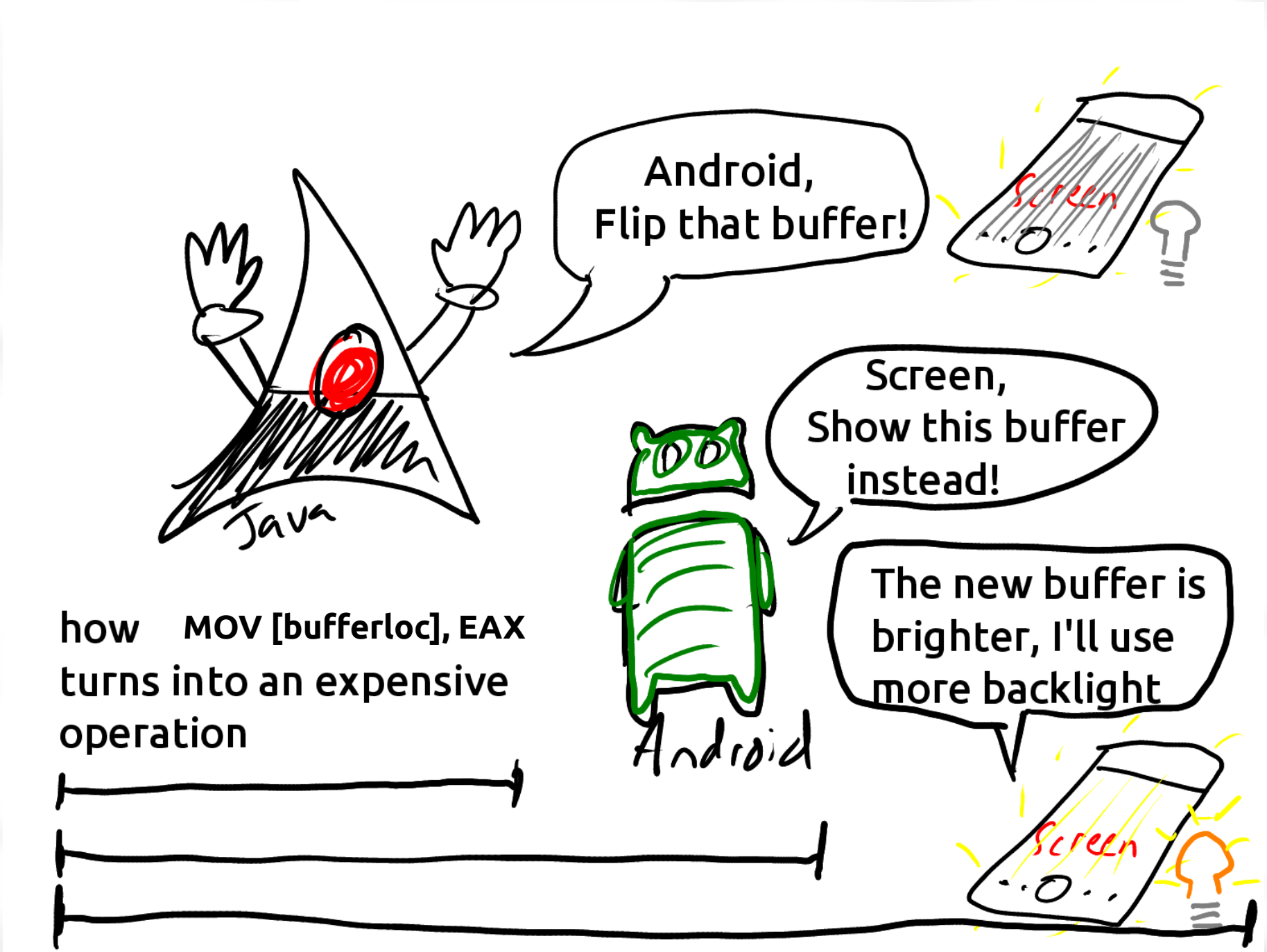
Programmers are responsible for Software Power Use!

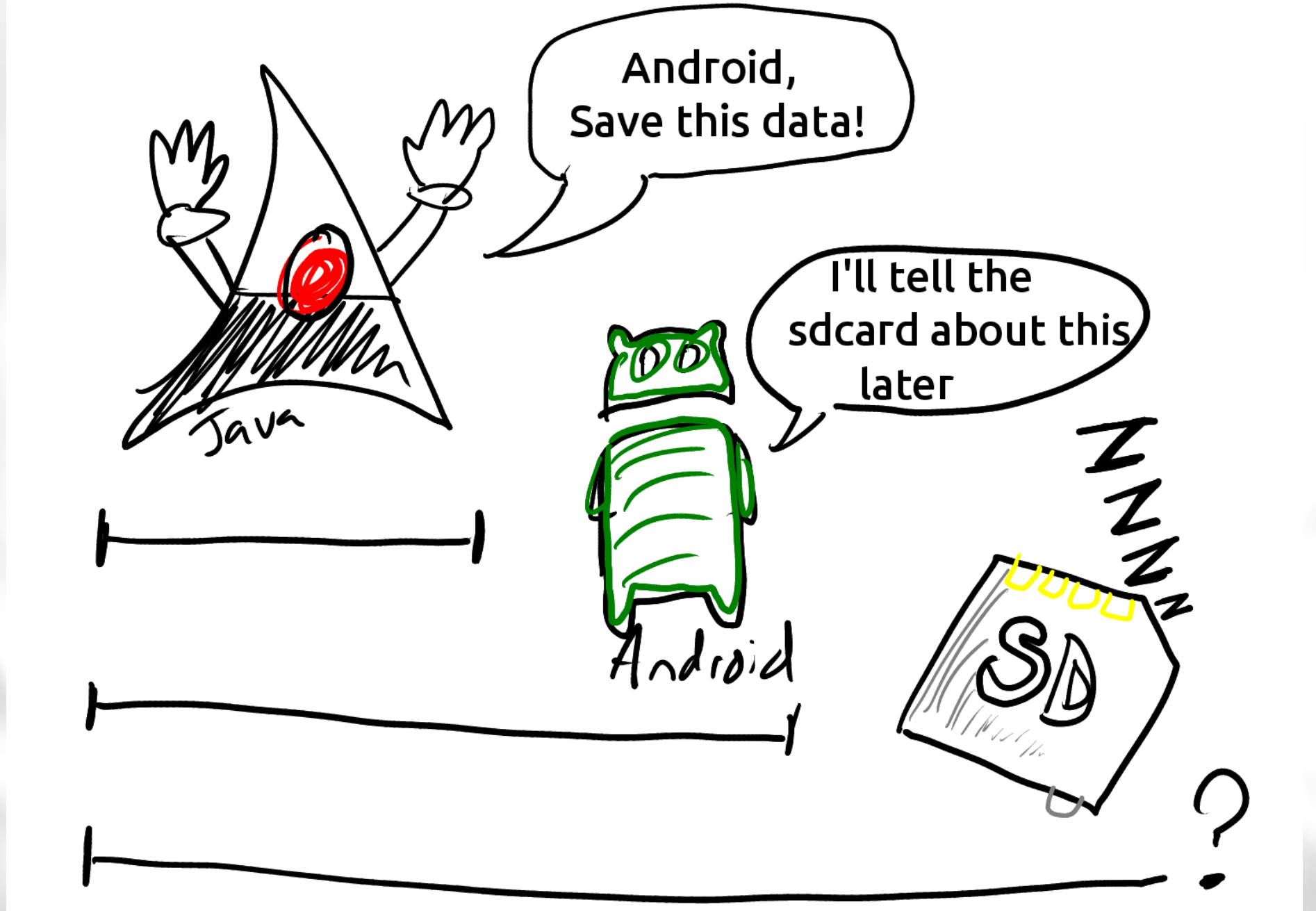


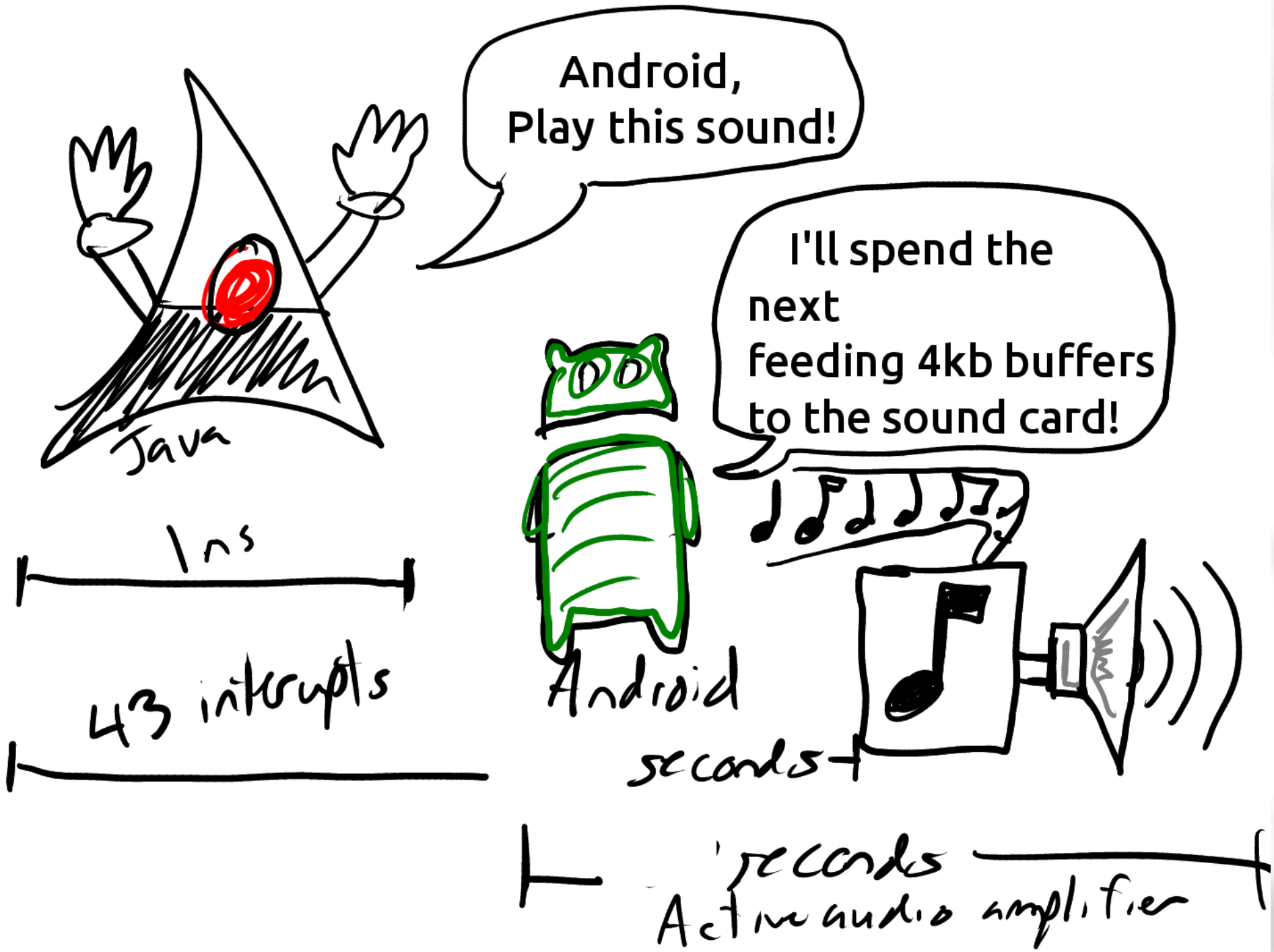


In general, programmers lack knowledge about software energy consumption, but they are more knowledgeable about software energy consumption on mobile devices than on desktop computers.

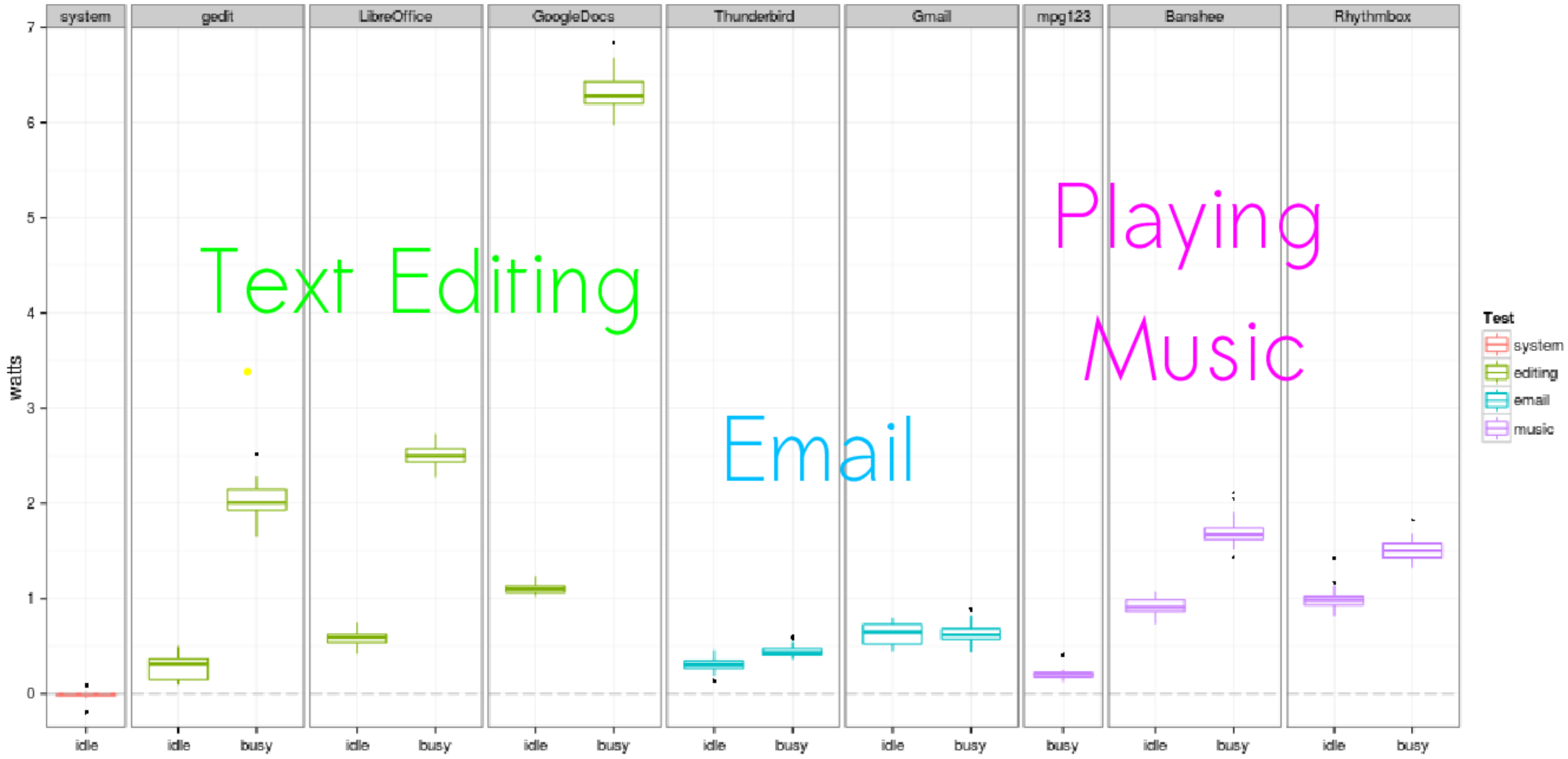
http://webdocs.cs.ualberta.ca/~hindle1/2014/green-programmers/ [Pang et al.]


Android,
Flip that buffer!
Screen
Java
Screen,
Show this buffer
instead!
Android
The new buffer is
brighter, I'll use
more backlight
Screen
how MOV [bufferloc], EAX
turns into an expensive
operation


Android,
Save this data!
Java
I'll tell the
sdcard about this
later
Android
SD
?

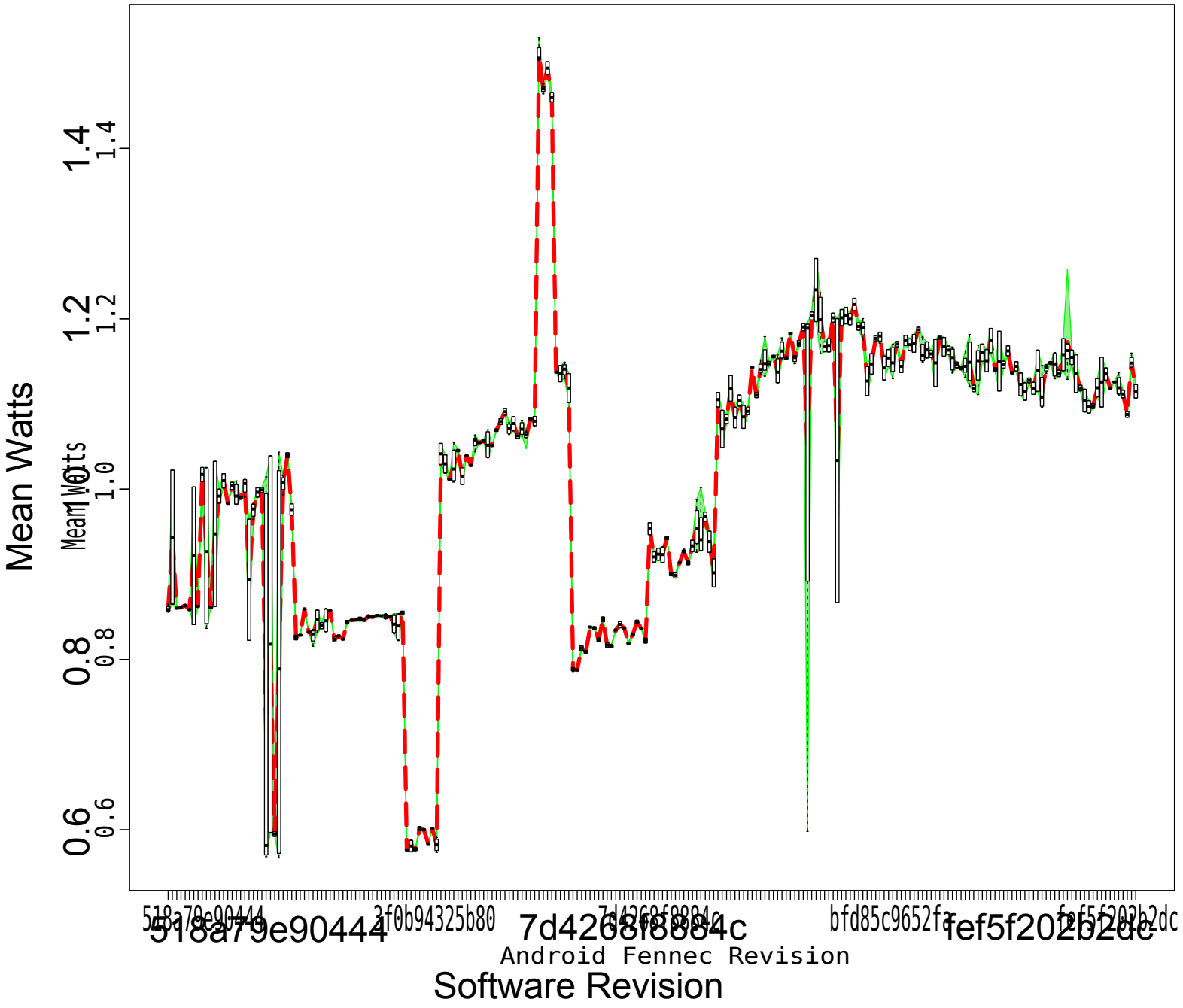

Android,
Play this sound!
I'll spend the next
feeding 4kb buffers
to the sound card!
Java
1ms
43 interrupts
Android
seconds
seconds
Active audio amplifier

Energy Profile of Single Versions

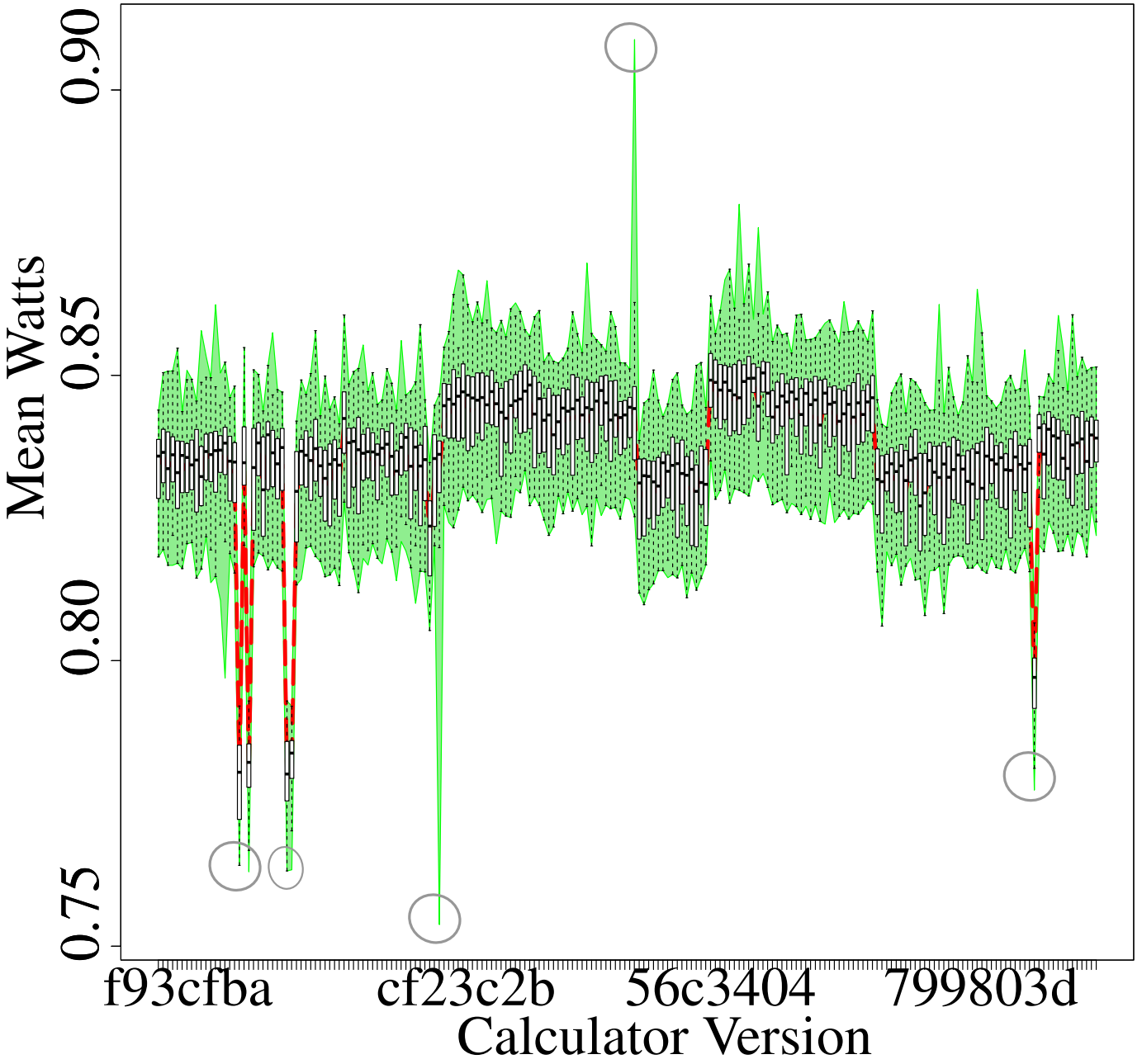


Chenlei Zhang and Daniel German

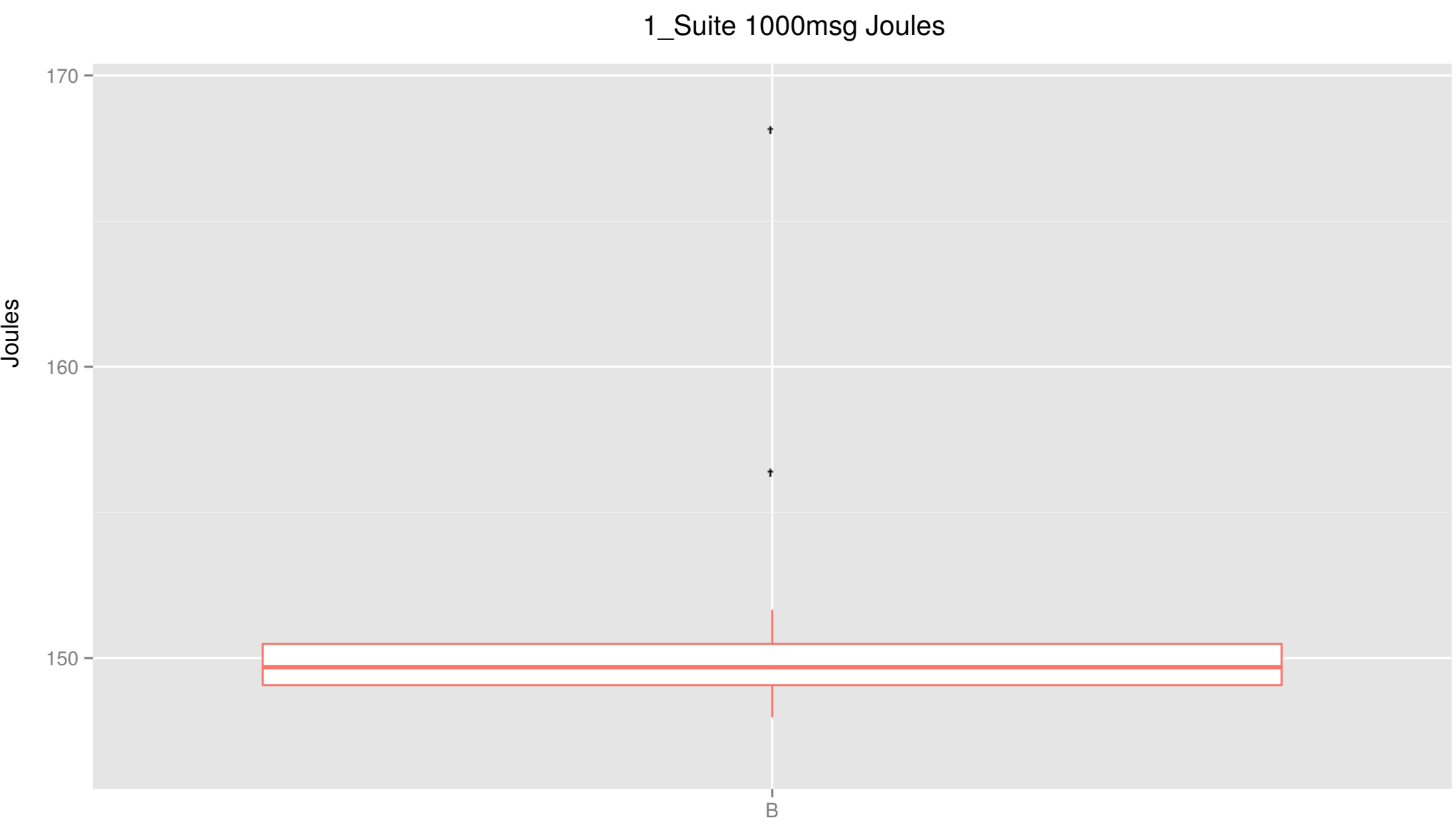
Android Firefox Energy Profile



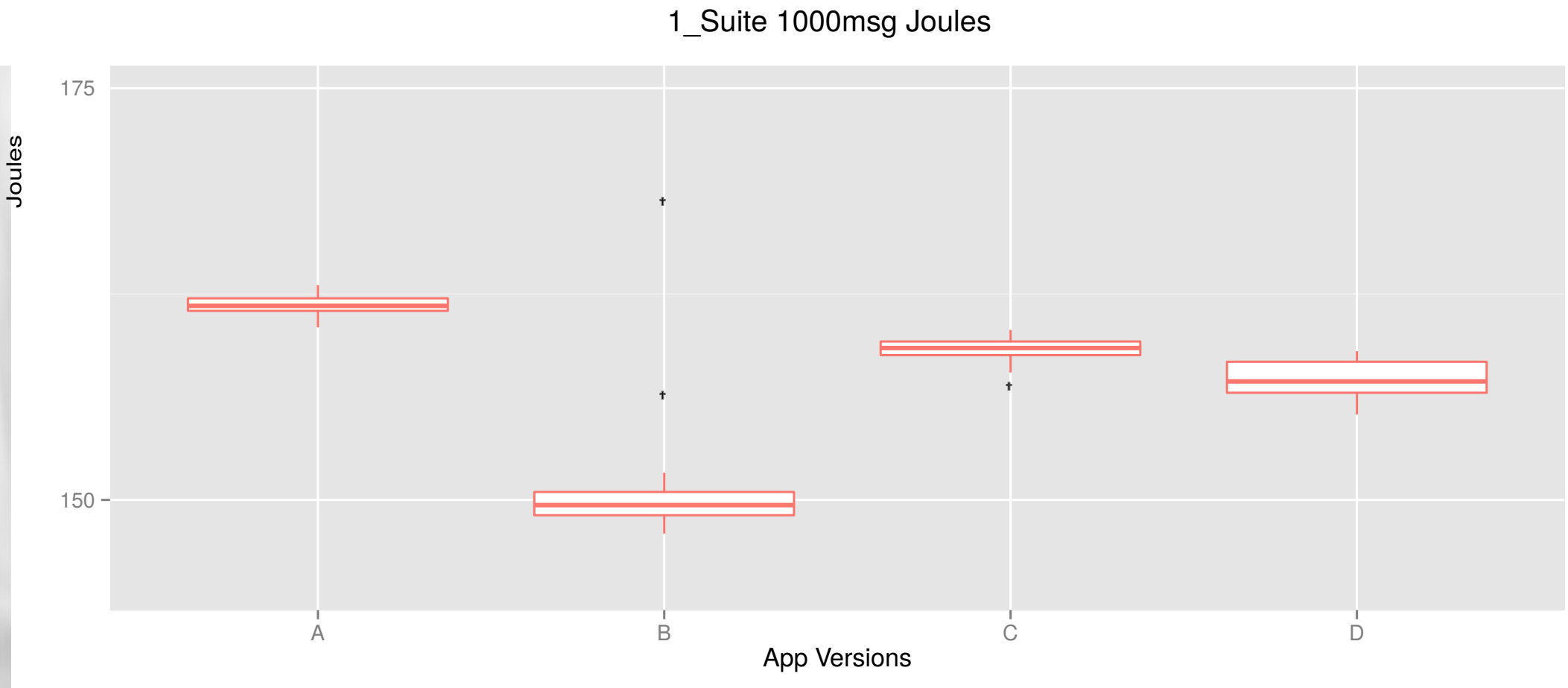
Android Calculator Energy Profile

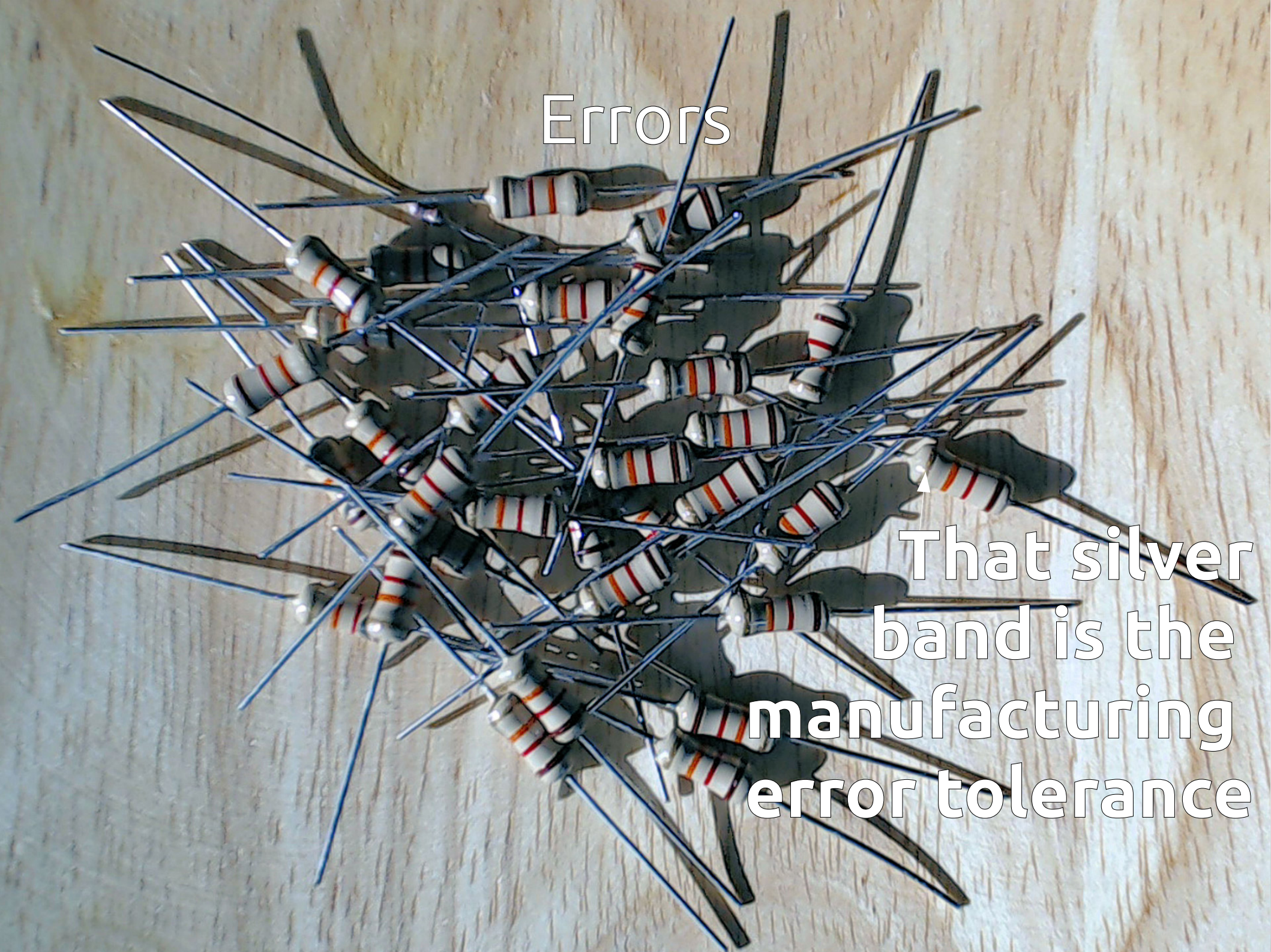


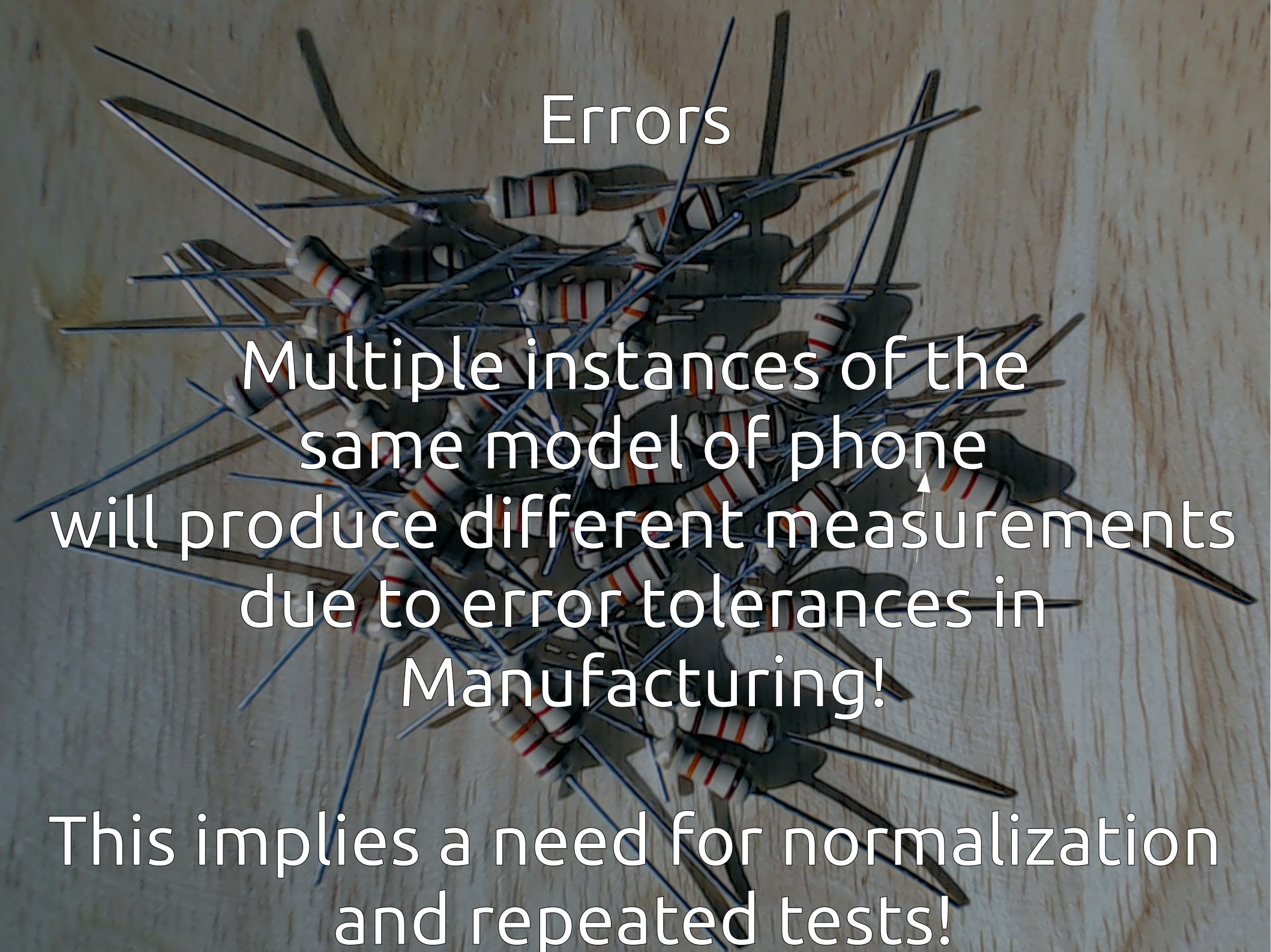
Energy Profile: Same test, Same Device



Energy Profile: Different device, different response



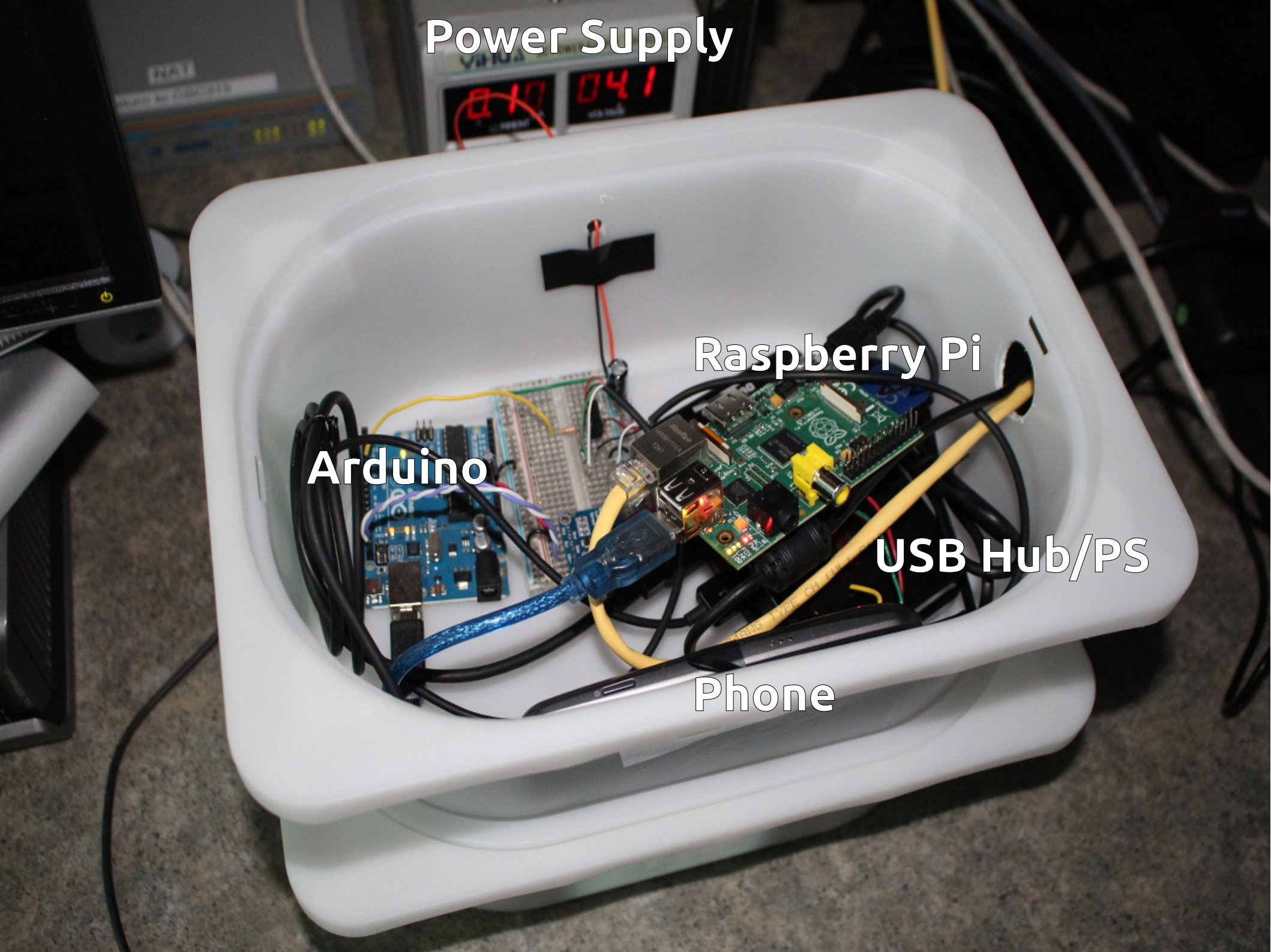

Errors
That silver band is the manufacturing error tolerance



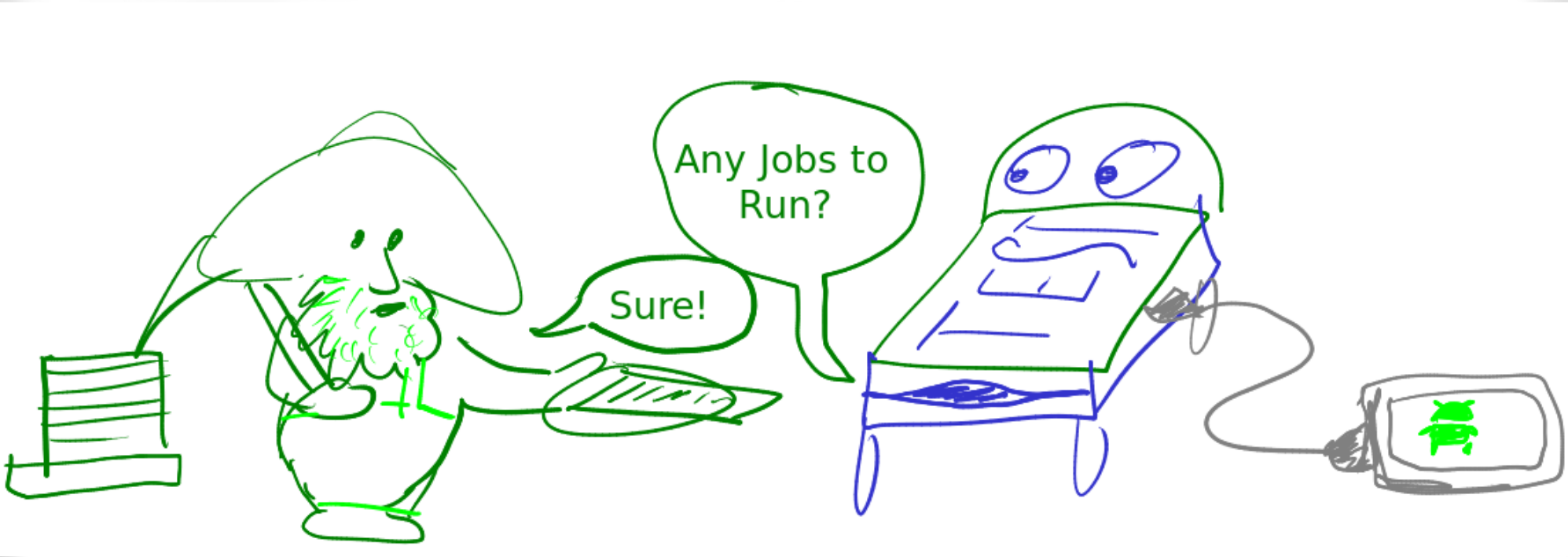
Errors

Multiple instances of the same model of phone will produce different measurements due to error tolerances in Manufacturing!

This implies a need for normalization and repeated tests!

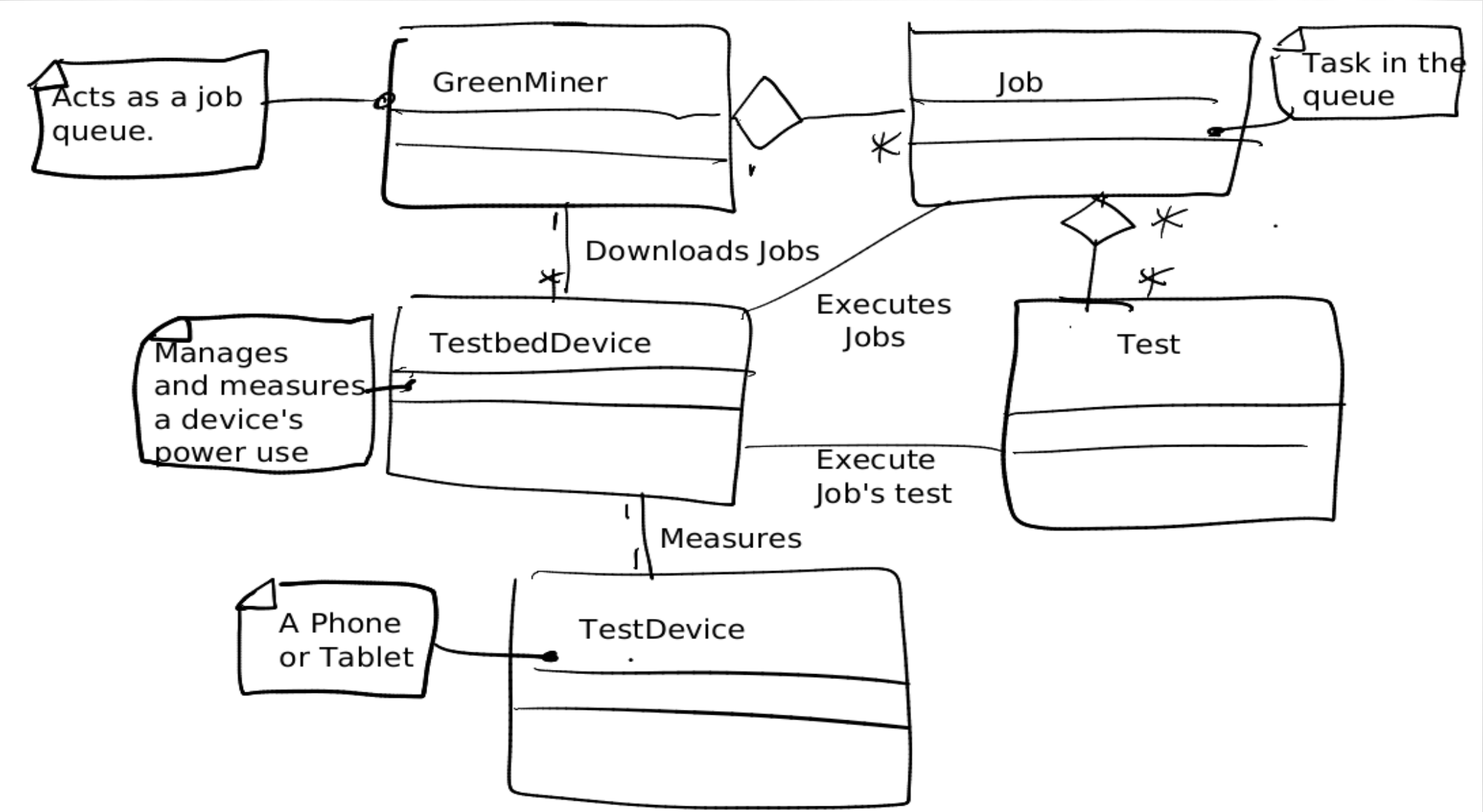

Power Supply
Raspberry Pi
Arduino
USB Hub/PS
Phone

Elaborate Job Queue

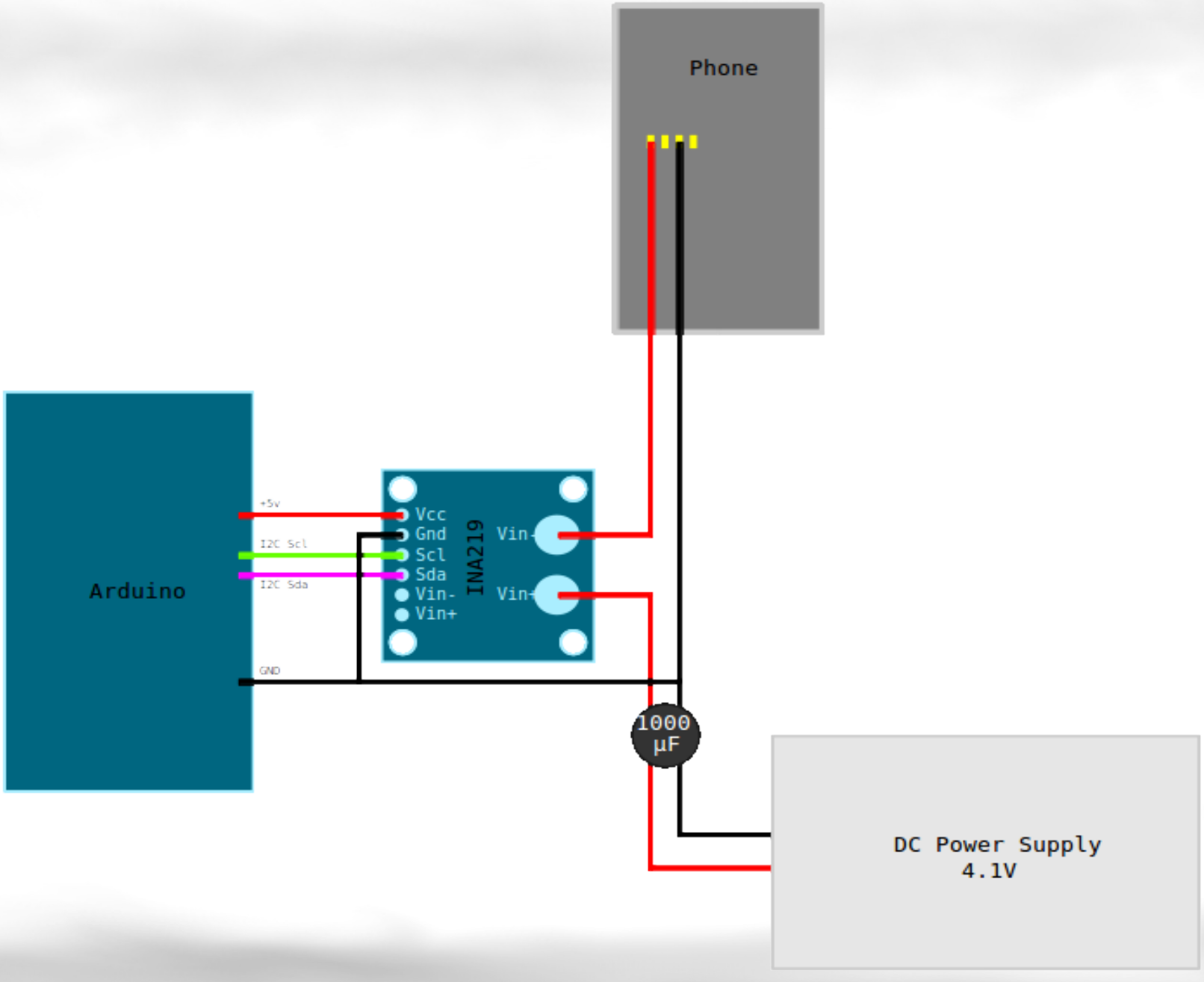


[MSR 2014]

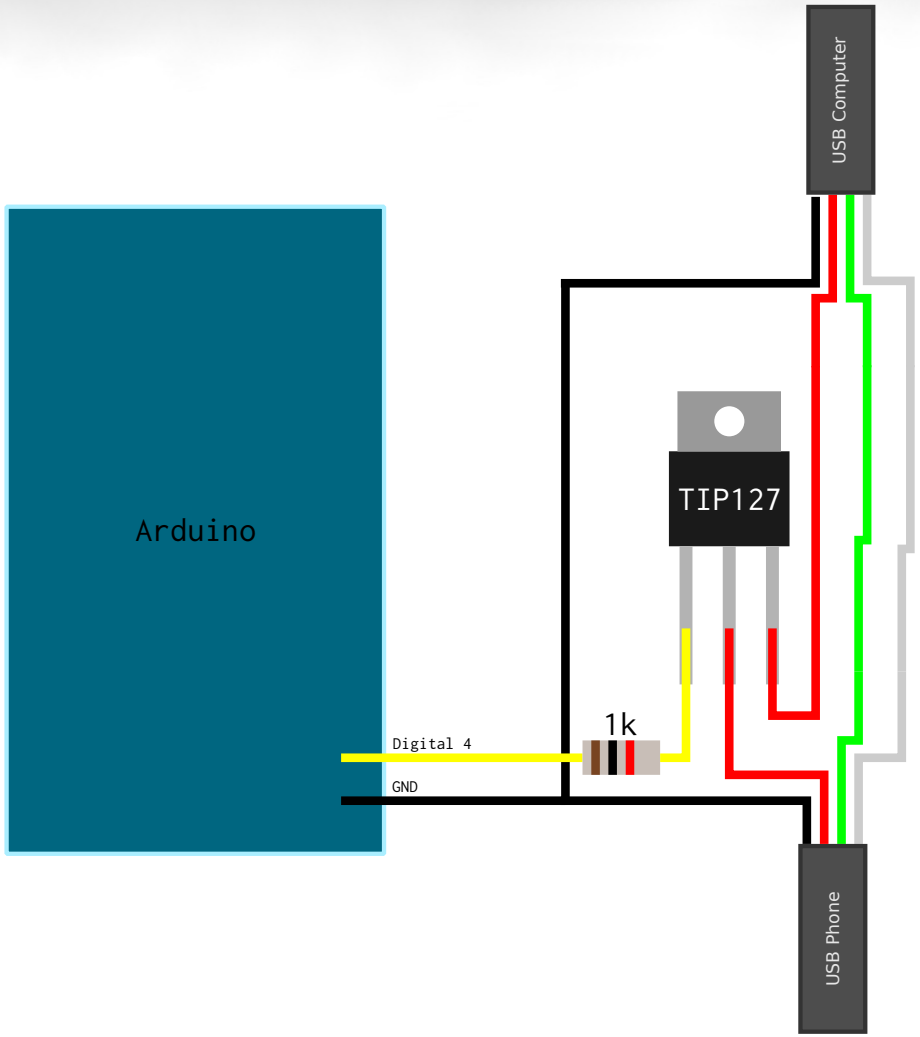
How does it work?



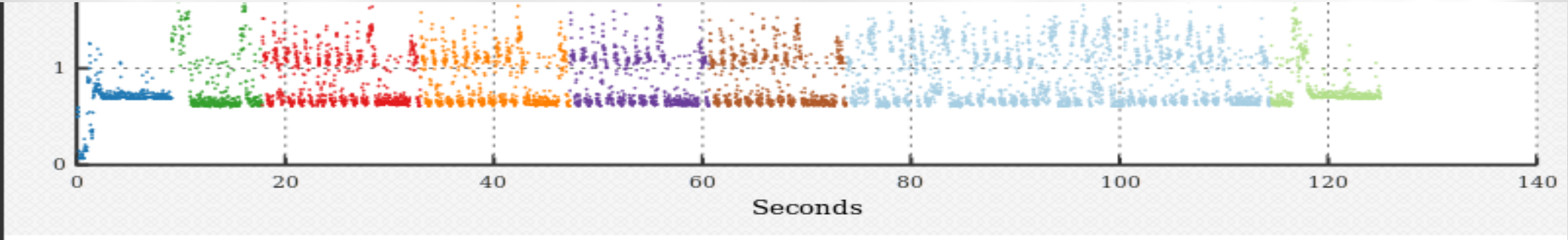
Fake the Battery

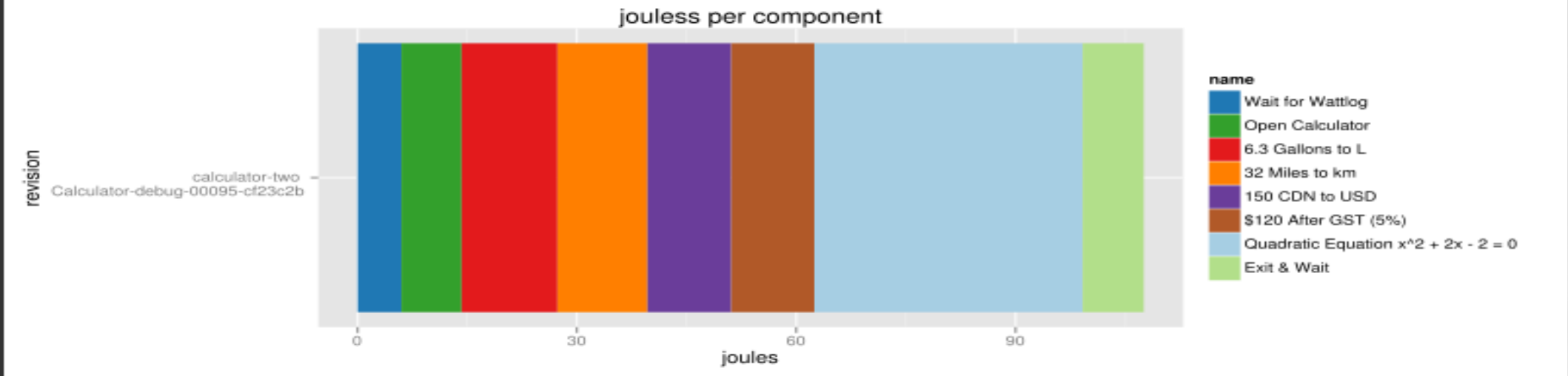


Control the USB Connection



Timeseries graph and Component Breakdown

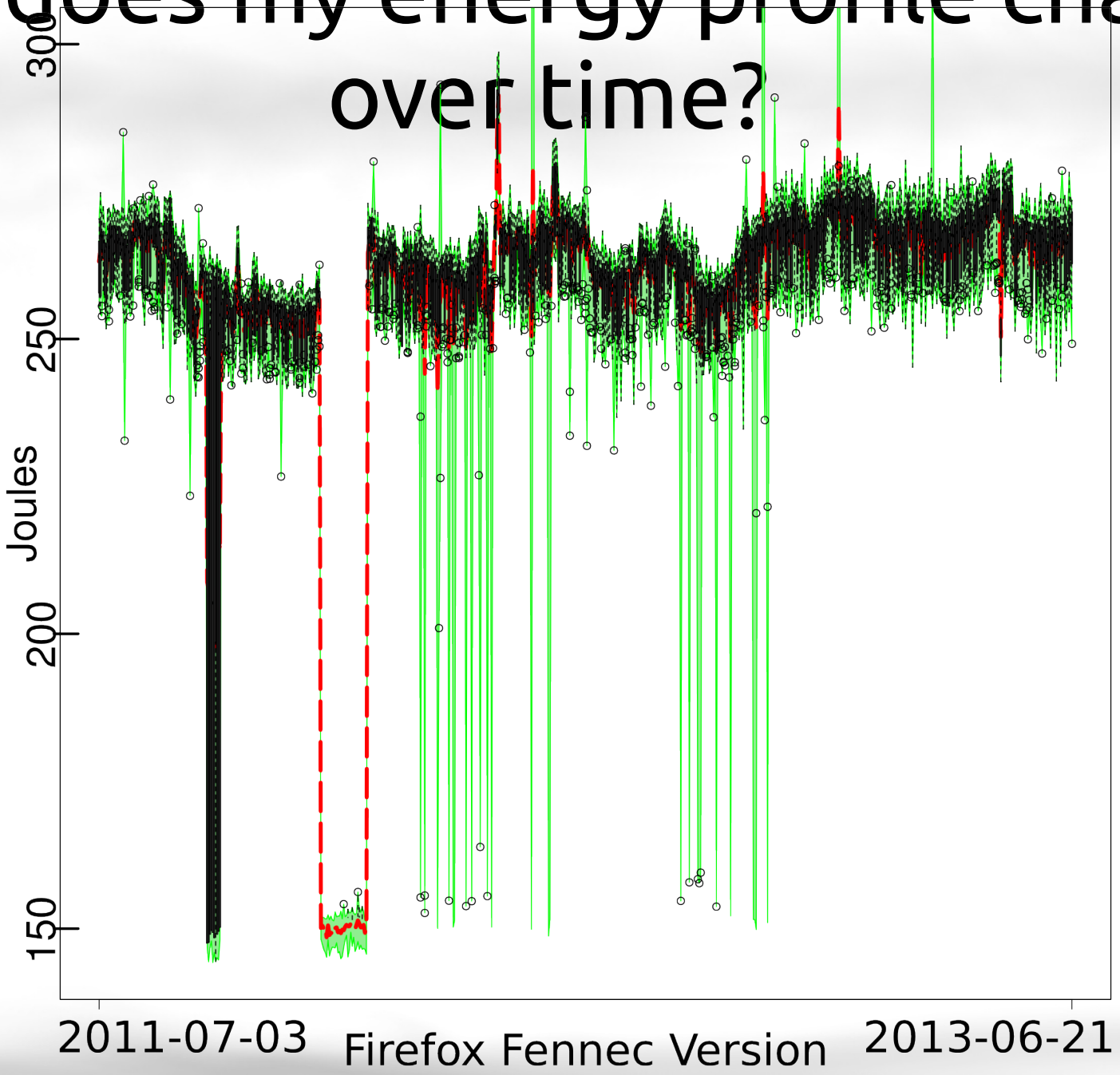




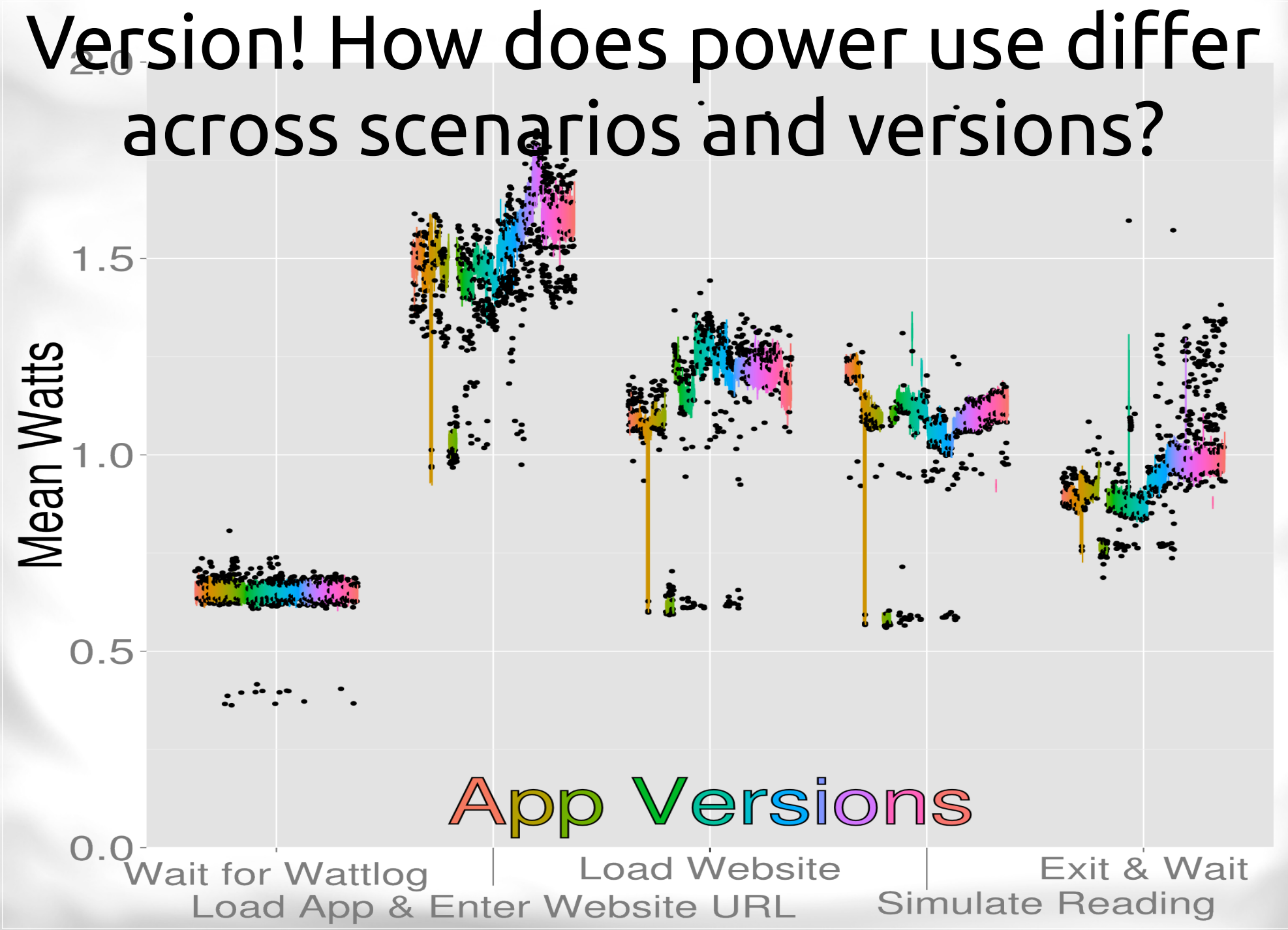
- Wait for Wattlog
- Open Calculator
- 6.3 Gallons to L
- 32 Miles to km
- 150 CDN to USD
- $120 After GST (5%)
- Quadratic Equation x^2 + 2x - 2 = 0
- Exit & Wait

Power Consumption for Test: 107.53J
Average Power Use (Entire Test): 0.860W
Maximum Power Consumption: 2.705W at 9.610s
Minimum Power Consumption: -0.215W at 0.019s

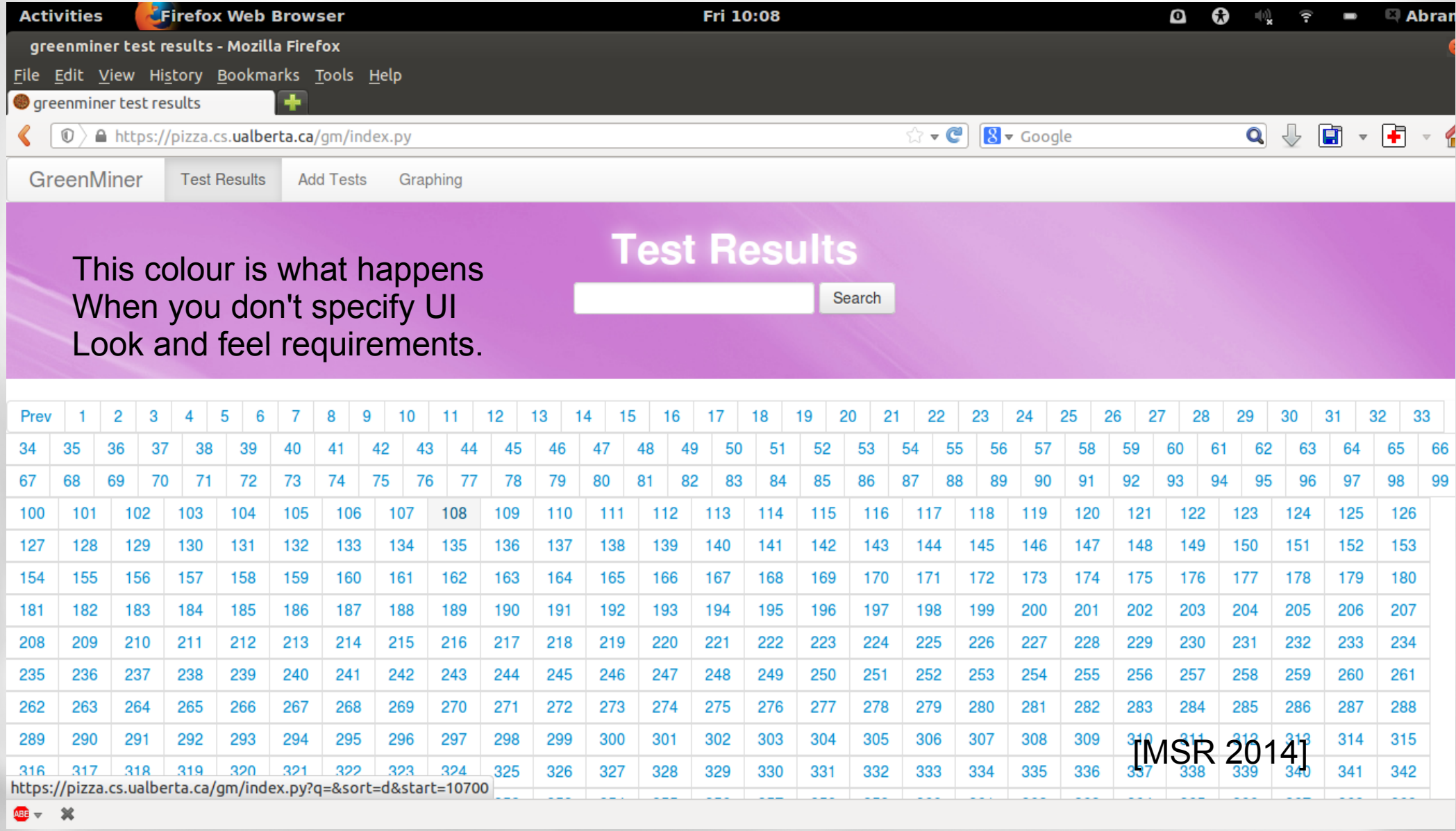
Aggregate Plotting
How does my energy profile change over time?



Aggregate by Component and Version! How does power use differ across scenarios and versions?



Green Miner



[MSR 2014]

Per Component Breakdown

Partition	Time	Joules	Average	Maximum	Minimum
Wait for Wattlog	9.08s	5.99J	0.659W	1.260W at 1.218s	-0.215W at 0.019s
Open Calculator	8.70s	8.23J	0.946W	2.705W at 9.610s	0.601W at 14.732s
6.3 Gallons to L	15.18s	13.12J	0.864W	1.638W at 28.346s	0.606W at 18.593s
32 Miles to km	14.33s	12.30J	0.859W	1.645W at 42.333s	0.607W at 47.201s
150 CDN to USD	13.34s	11.47J	0.860W	1.655W at 55.831s	0.608W at 60.579s
$120 After GST (5%)	13.16s	11.37J	0.864W	1.564W at 64.794s	0.610W at 62.529s
Quadratic Equation x^2 + 2x - 2 = 0	40.68s	36.71J	0.902W	1.693W at 106.599s	0.598W at 76.831s
Exit & Wait	10.55s	8.36J	0.792W	1.761W at 116.764s	0.612W at 116.251s

Info	Description
Power Source	Power Supply
Current Sense	ina219

Statistic	Before	After
Battery Charge	86	86
Battery Health	2	2
Battery Temperature	33°C	33°C
Airplane Mode	On	

Sometimes we need to debug the tests with some context

$120 After GST (5%)	13.16s	11.37J	0.864W	1.564W at 64.794s	0.610W at 62.529s
Quadratic Equation x^2 + 2x - 2 = 0	40.68s	36.71J	0.902W	1.693W at 106.599s	0.598W at 76.831s
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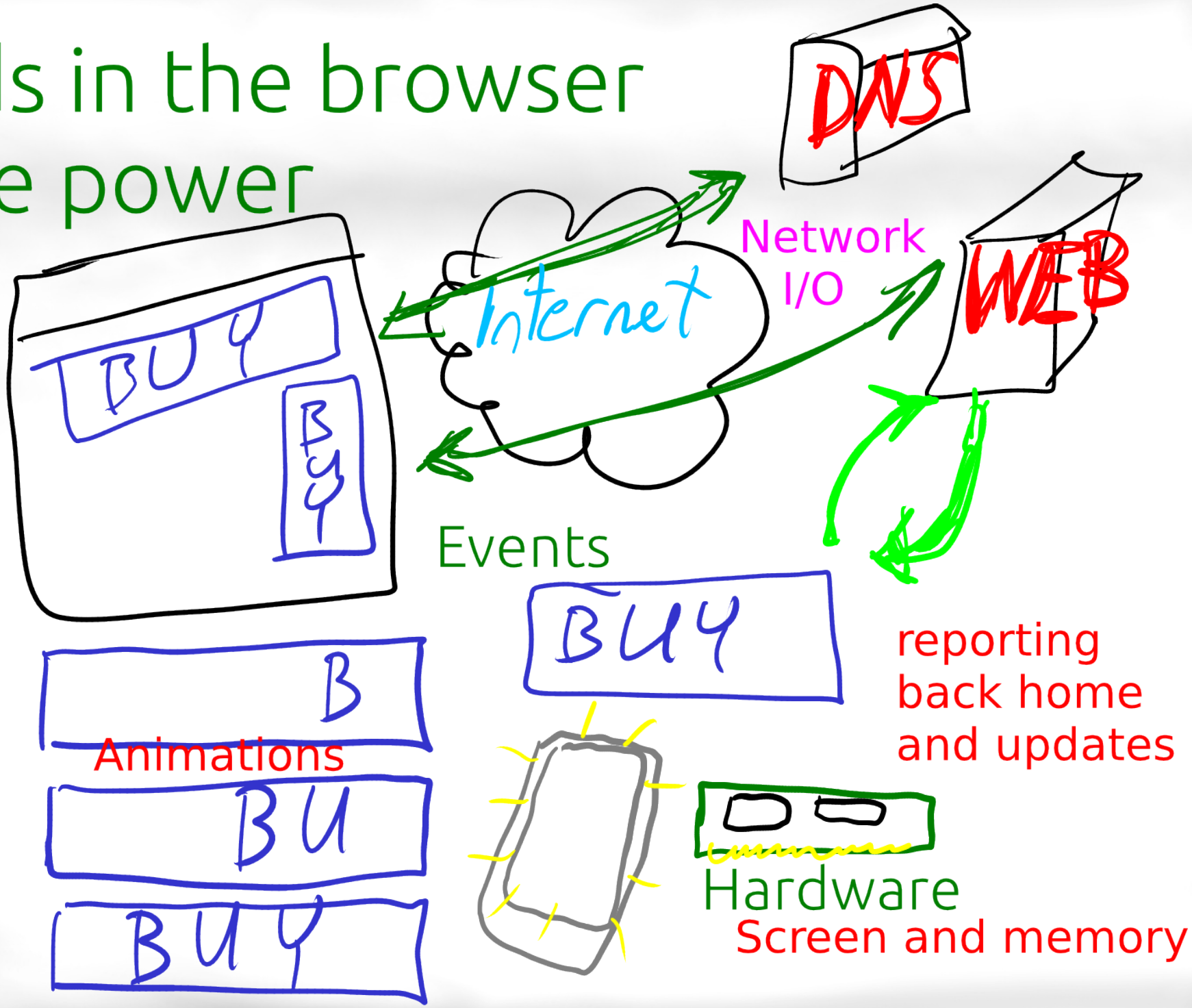
Info	Description
Power Source	Power Supply
Current Sense	ina219

Statistic	Before	After
Battery Charge	86	86
Battery Health	2	2
Battery Temperature	33°C	33°C
Airplane Mode	On	
Wireless	SERL-EMPLAB BSSID: 60:a4:4c:66:33:f7 MAC: a0:0b:ba:cf:25:61 Supplicant state: COMPLETED RSSI: -47 Link speed: 5 Net ID: 0 Metered hint: false	SERL-EMPLAB BSSID: 60:a4:4c:66:33:f7 MAC: a0:0b:ba:cf:25:61 Supplicant state: COMPLETED RSSI: -45 Link speed: 5 Net ID: 0 Metered hint: false
Bluetooth	Off	
Screen Auto Brightness	Disabled	
Screen Brightness	120/255	
Screen Timeout	30s	
Haptic Feedback	Disabled	
OS Version	4.2.2	

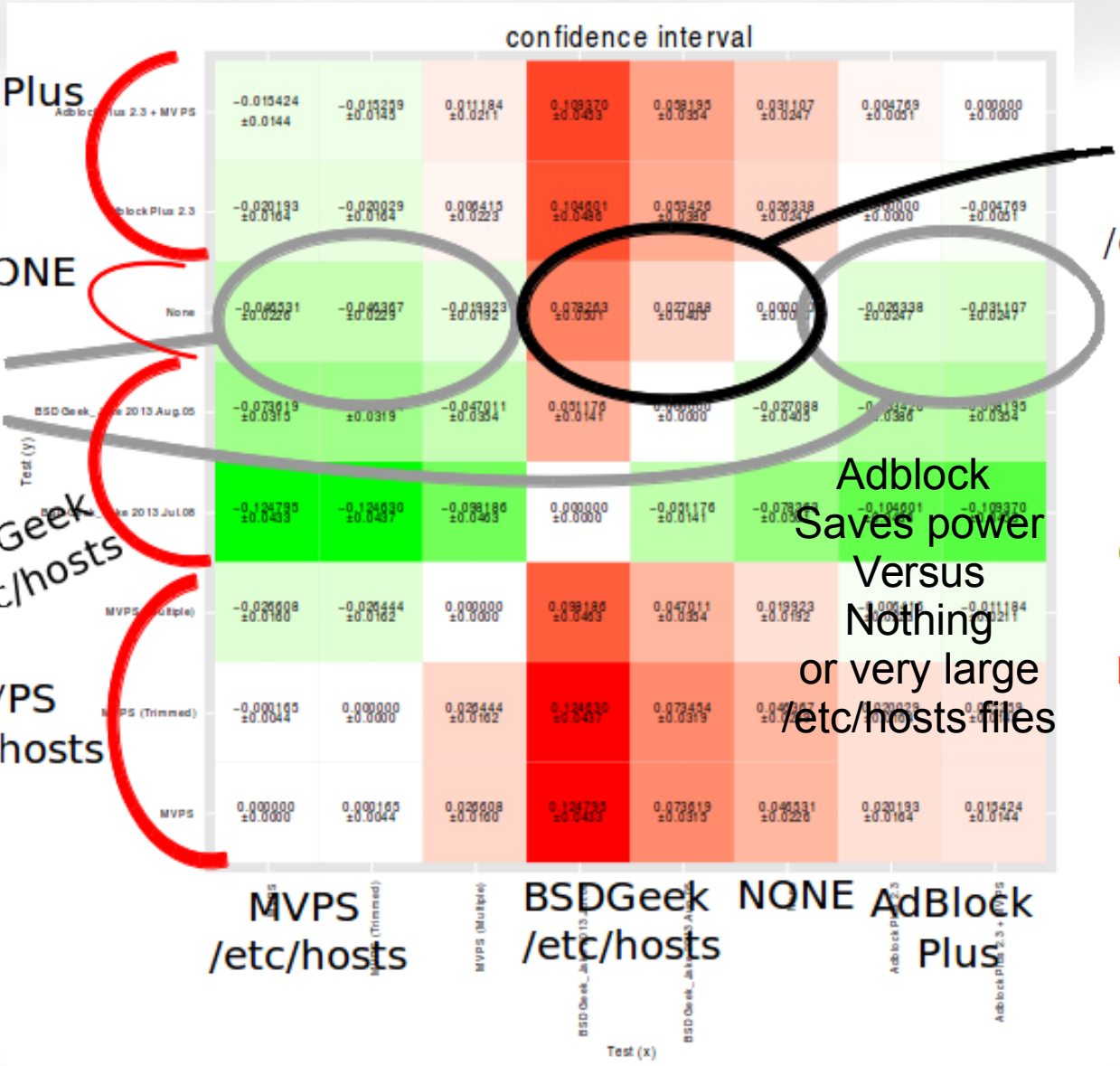
Green Miner is an enabler

- Continuous Integration and Testing for Energy Regressions
- Repeatable, logged, measureable framework.
- Enables asking of questions and repeating experiments.
- Some examples to follow

Ads in the browser use power



Does Adblocking Save Power?



Complicated
or Long
/etc/hosts files

(Perhaps a
kernel patch
is in order?)

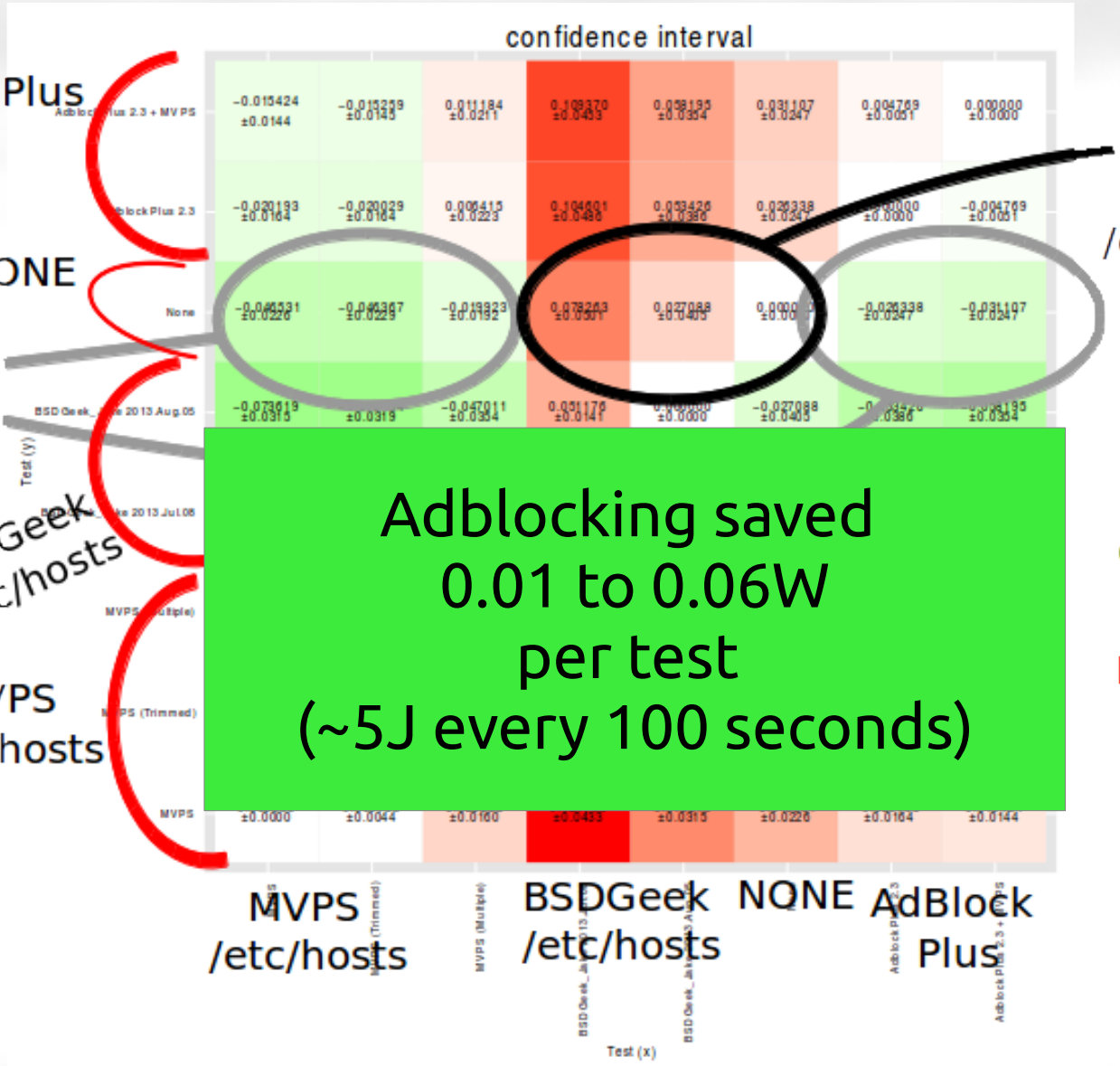
Adblock
Saves power
Versus
Nothing
or very large
/etc/hosts files

Green - Column uses
LESS than row

Red - Column uses
MORE than row

[GREENS 2014]

Does Adblocking Save Power?



Complicated or Long /etc/hosts files

(Perhaps a kernel patch is in order?)

Adblocking saved 0.01 to 0.06W per test (~5J every 100 seconds)

Green - Column uses LESS than row

Red - Column uses MORE than row

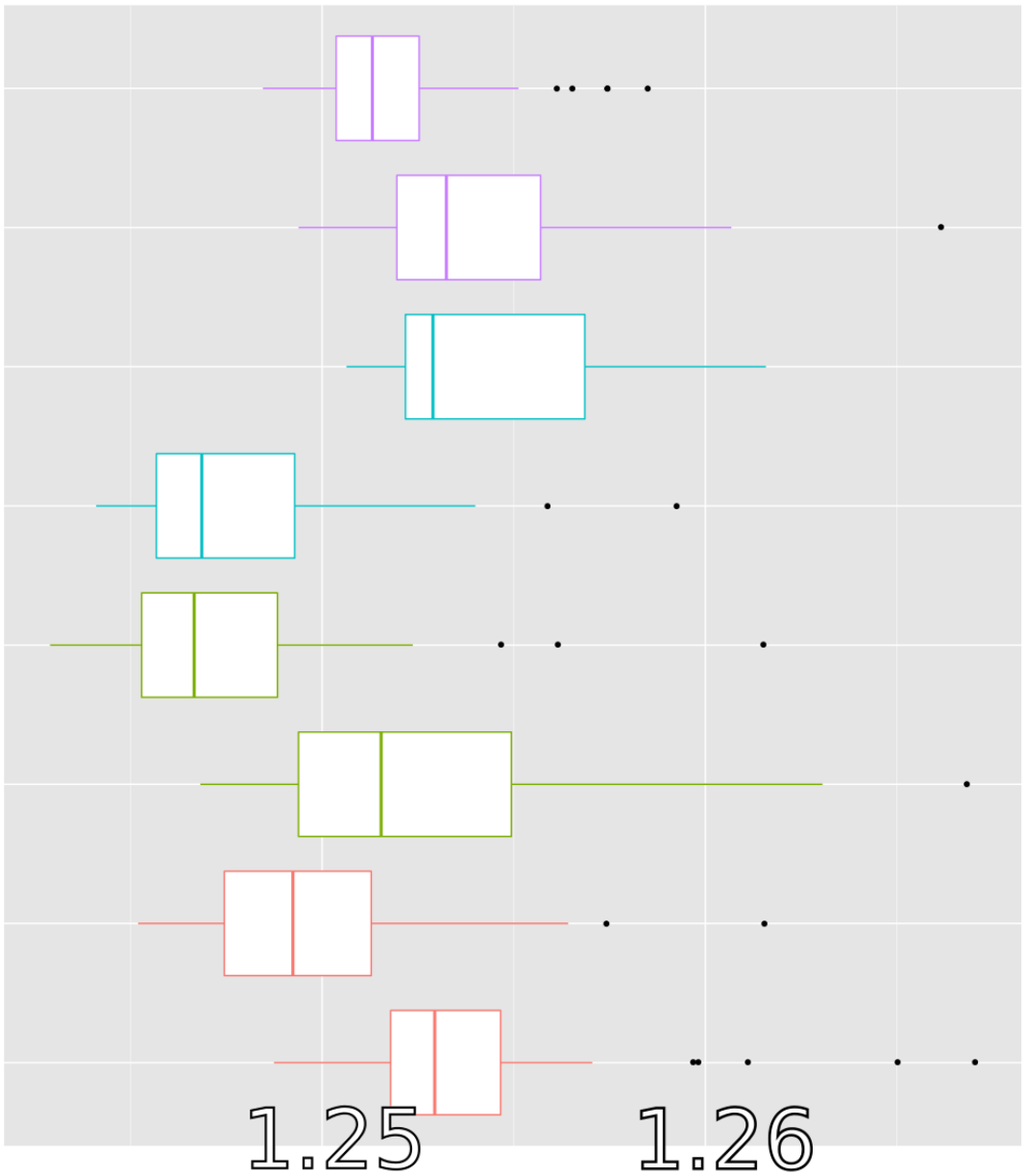
[GREENS 2014]

Which UI Theme would use More Power?

White on Black UI Theme

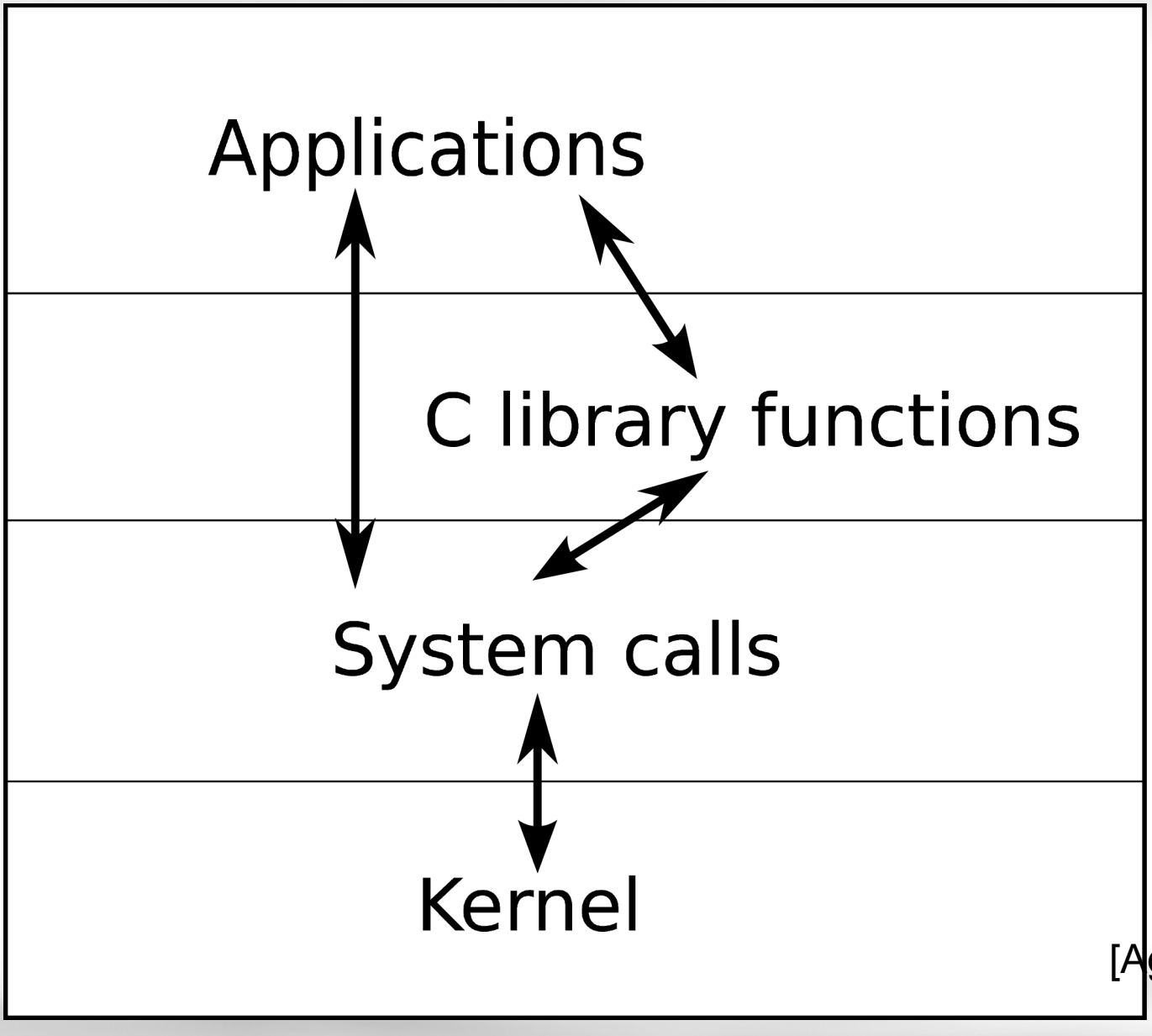
Black on White UI Theme

Black Text on White Screenshot Significant Changes



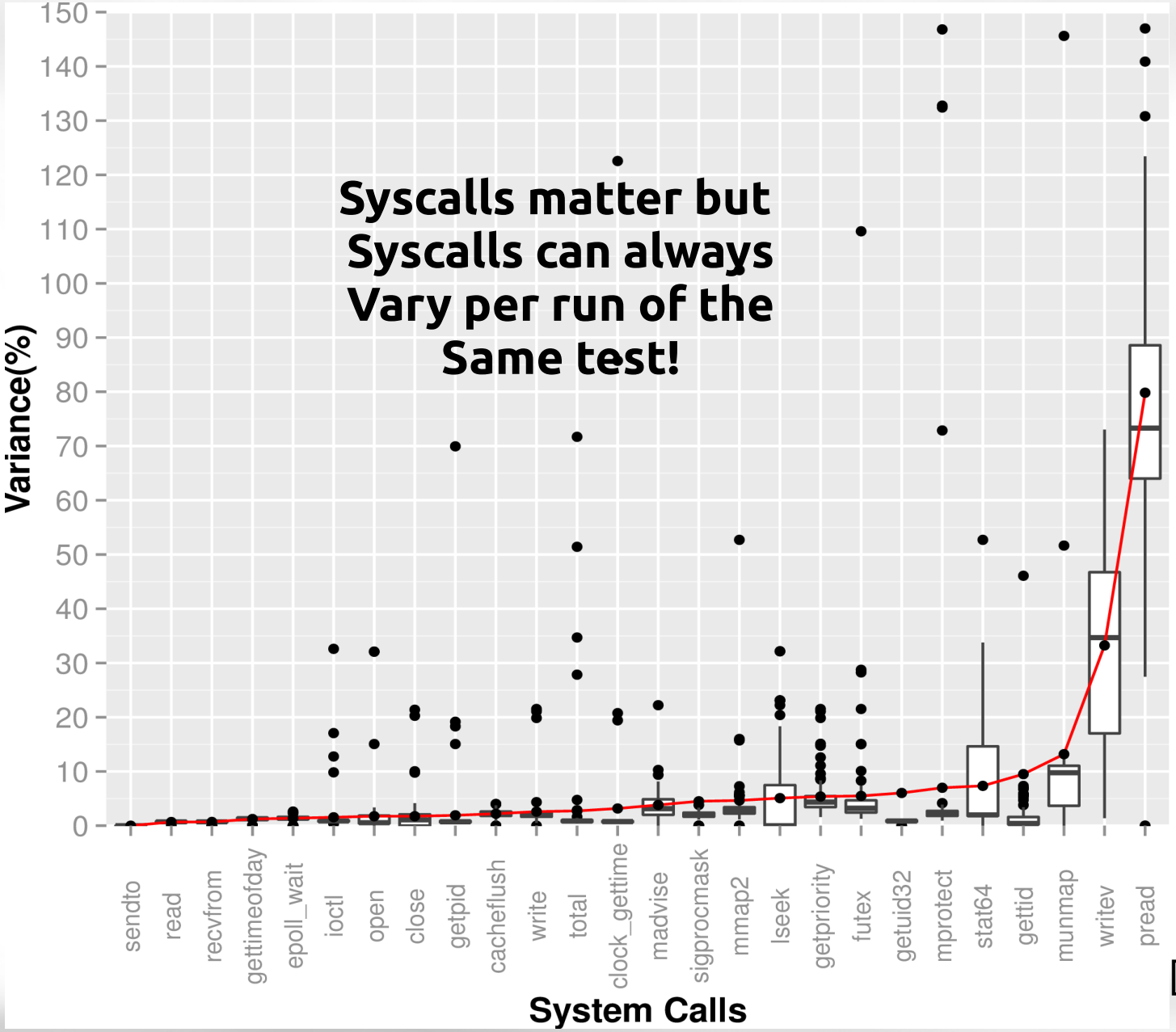
Mean Power Consumption (watts)

What Causes Software Power Use?



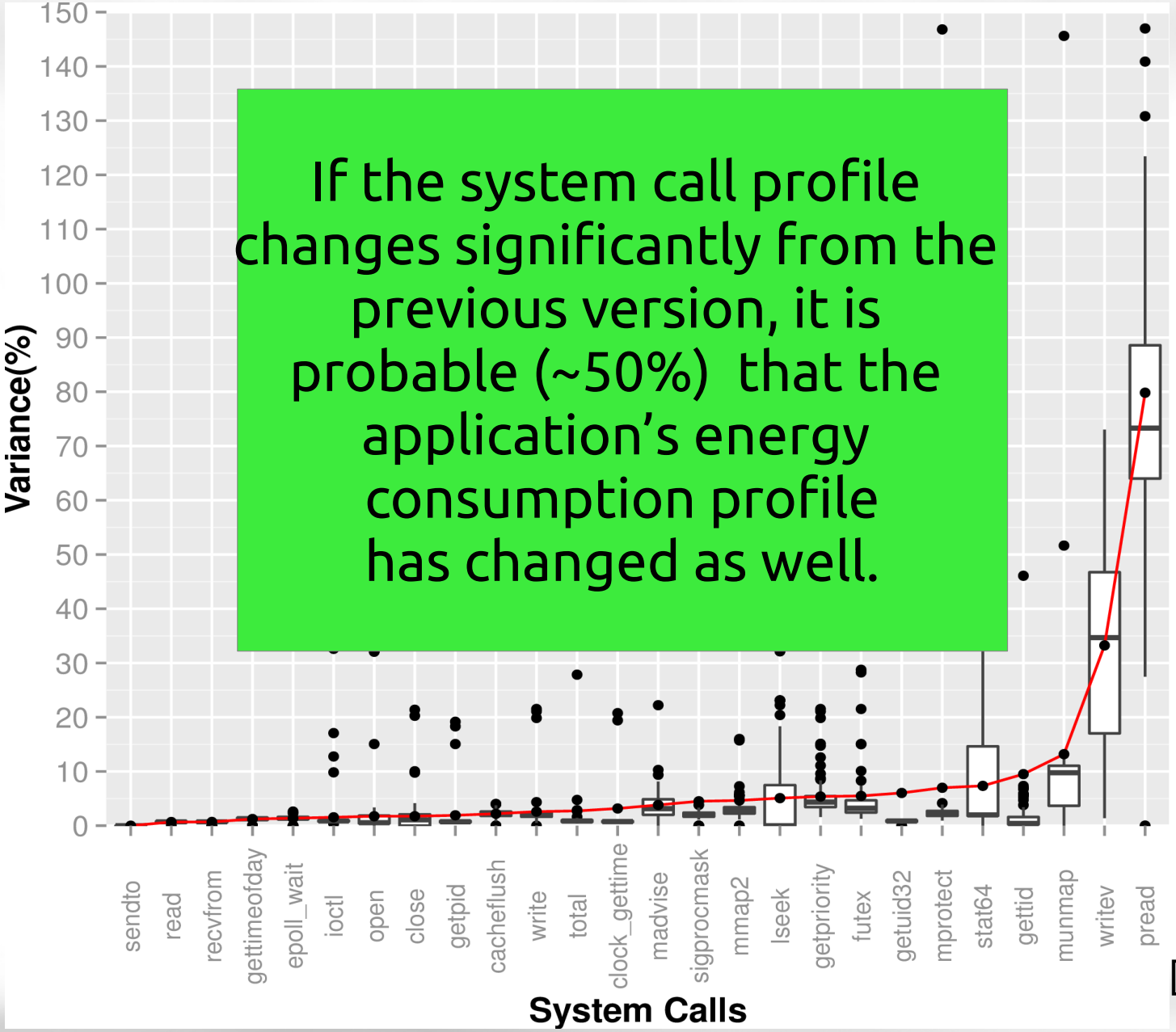
[Aggarwal et al.]

What causes Software Power Use?



[Aggarwal et al.]

What causes Software Power Use?



[Aggarwal et al.]

What causes Software Power Use?

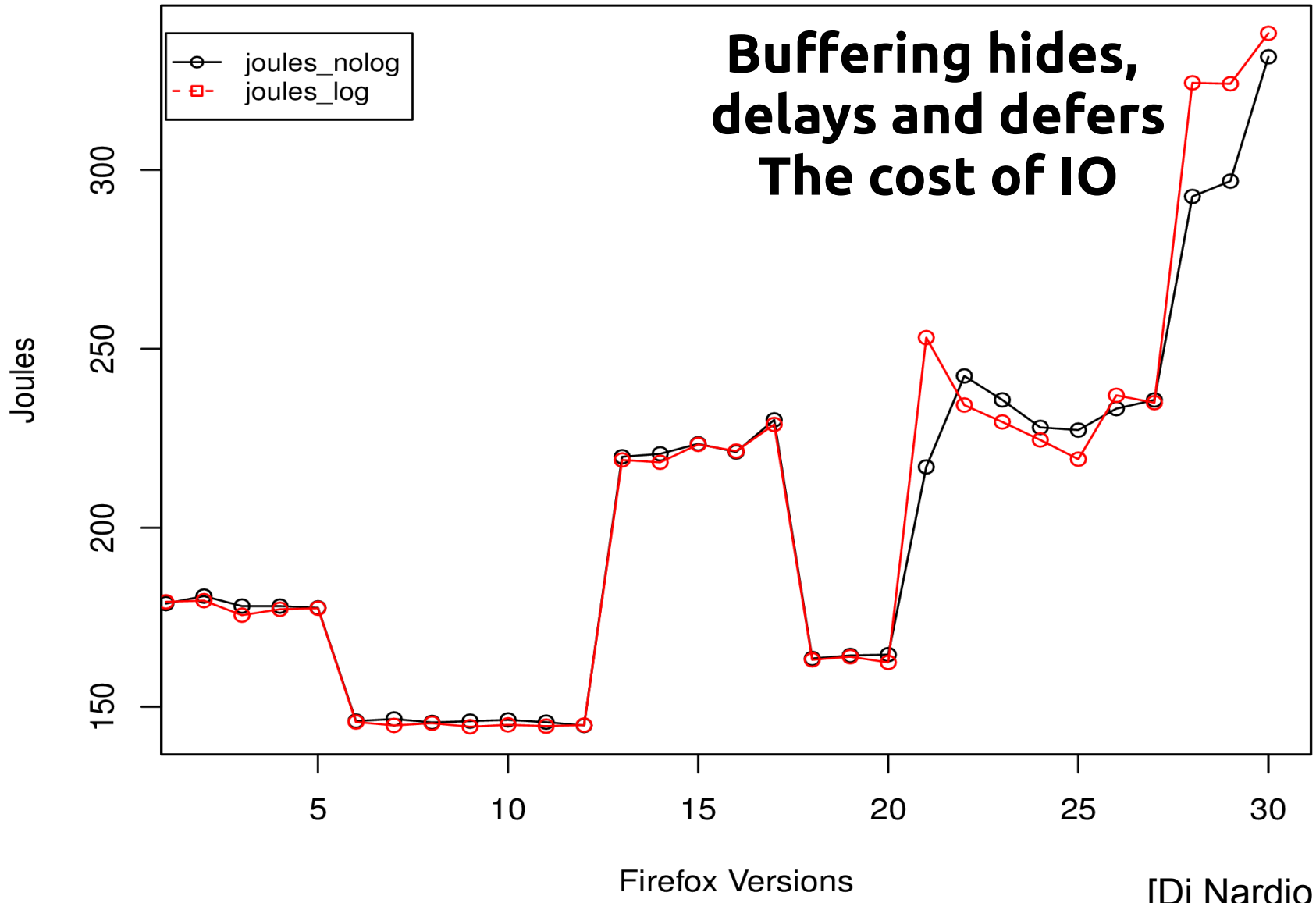
- Rule of thumb model:

  If a cumulative count of a syscall changes signficantly between versions there's a good chance of a signficiant change in power use and energy consumption!

`Calculator` application			
	Precision	Recall	Specificity
`sendto`	0	0	0.89
`stat64`	**1.00**	0.55	0.98
`cacheflush`	0.34	**0.91**	**0.98**
Sum of calls	0.35	0.72	0.96
Coin flip	0.11	0.50	0.50
`Firefox` application			
	Precision	Recall	Specificity
`fcntl64`	0.04	0.10	0.94
`ioctl`	**0.26**	0.50	**0.96**
`lstat64`	0.08	**0.60**	0.95
Sum of calls	0.18	0.60	0.97
Coin flip	0.06	0.50	0.50

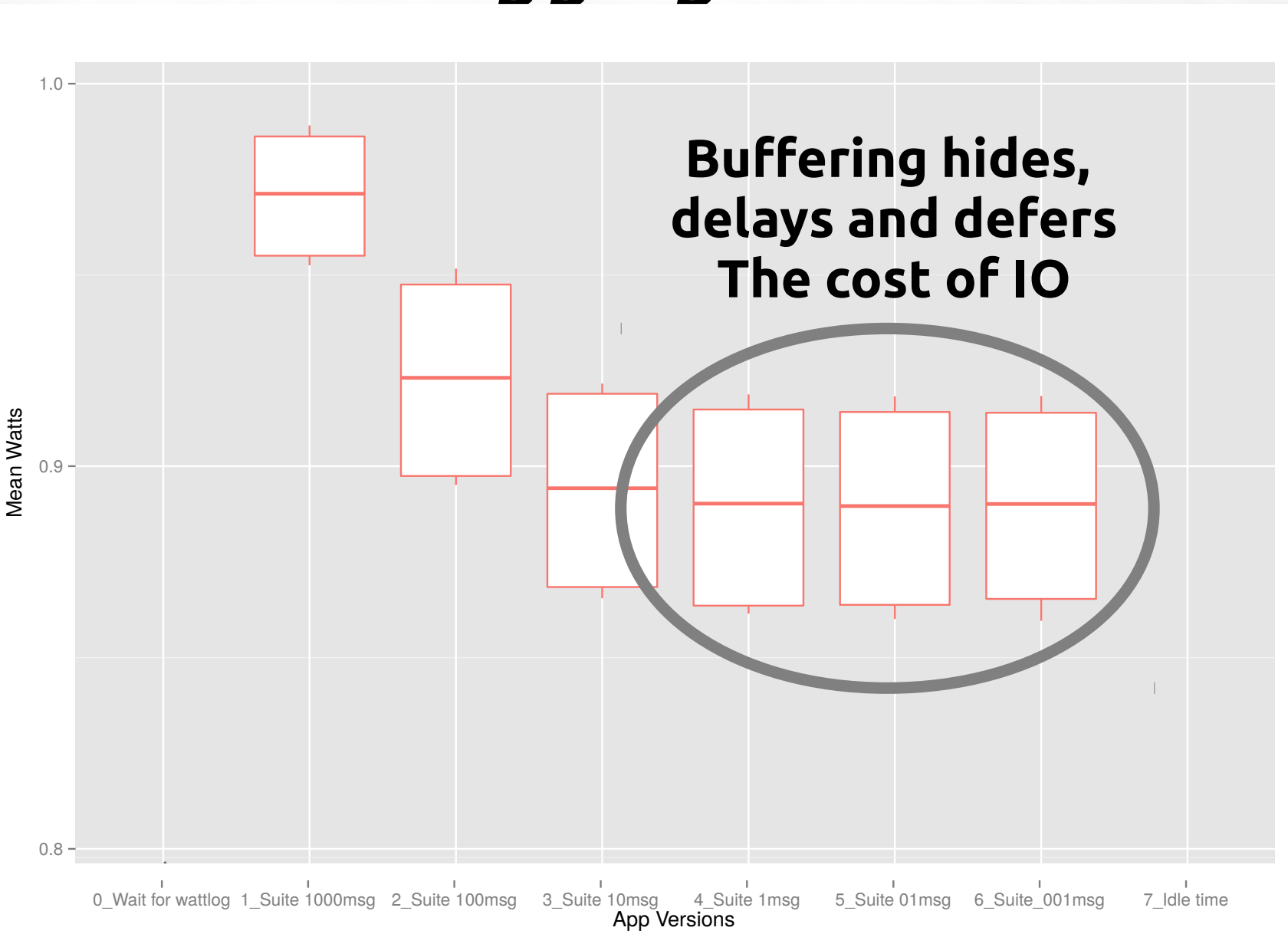
[Aggarwal et al.]

Does logging matter?



[Di Nardio et al.]

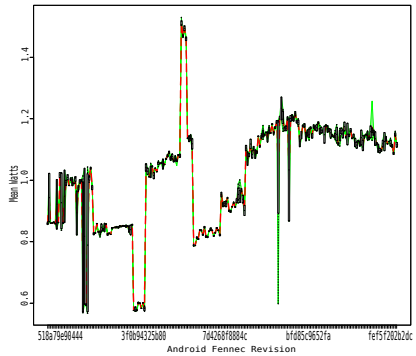
Does logging matter?



[Di Nardio et al.]

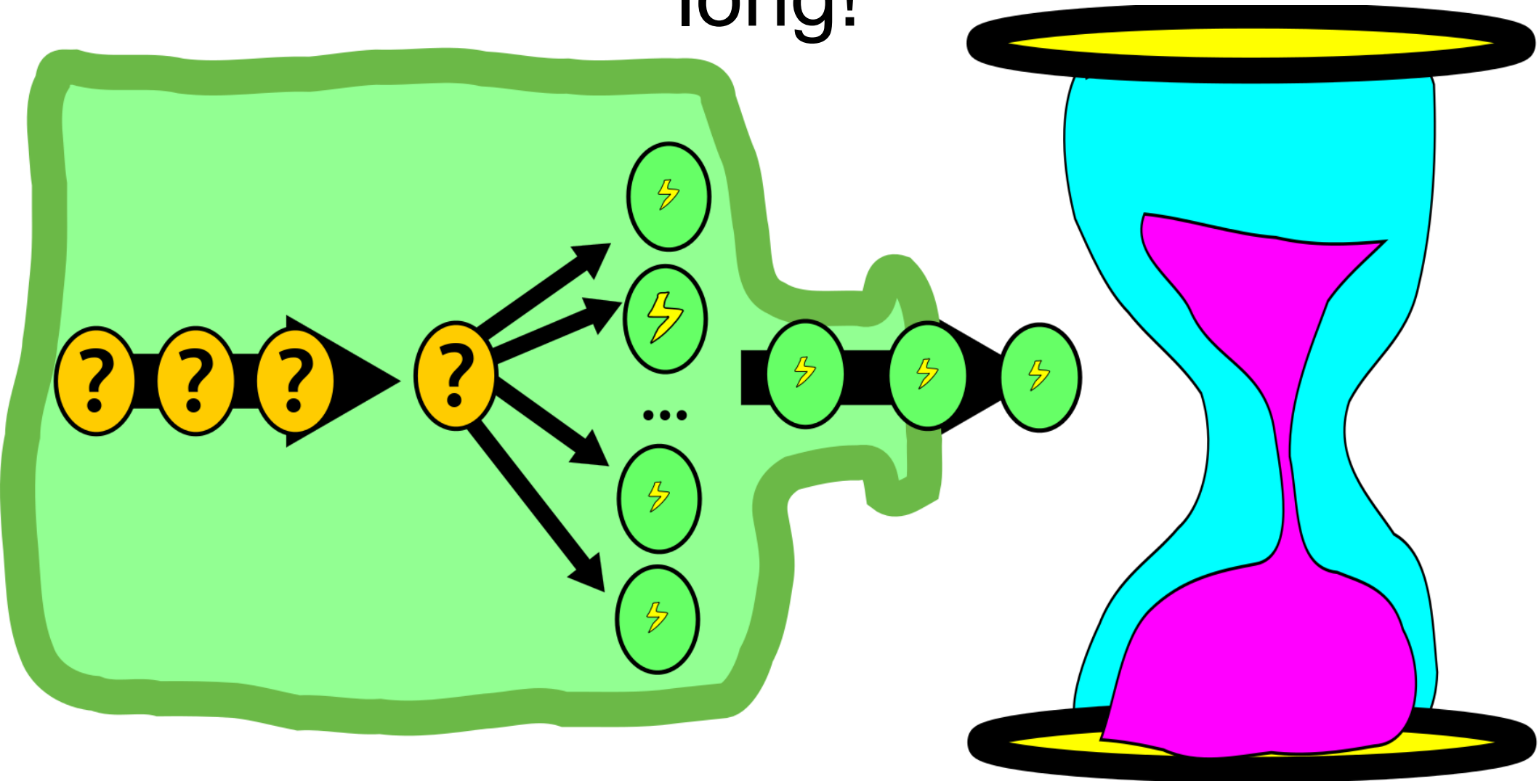
Methodological Bottleneck

Applied Exhaustively to all revisions

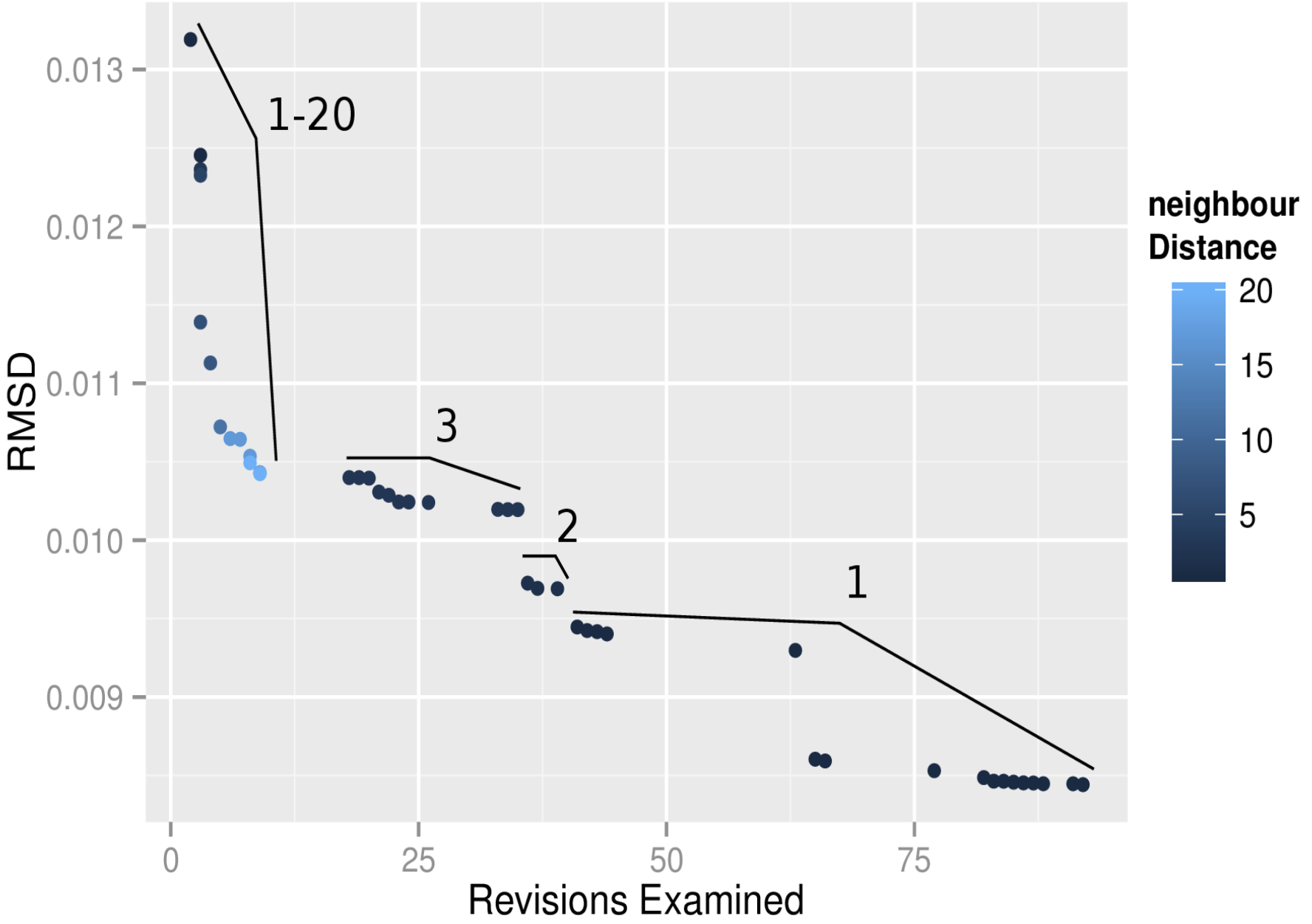


Revisions are measured multiple times for stability

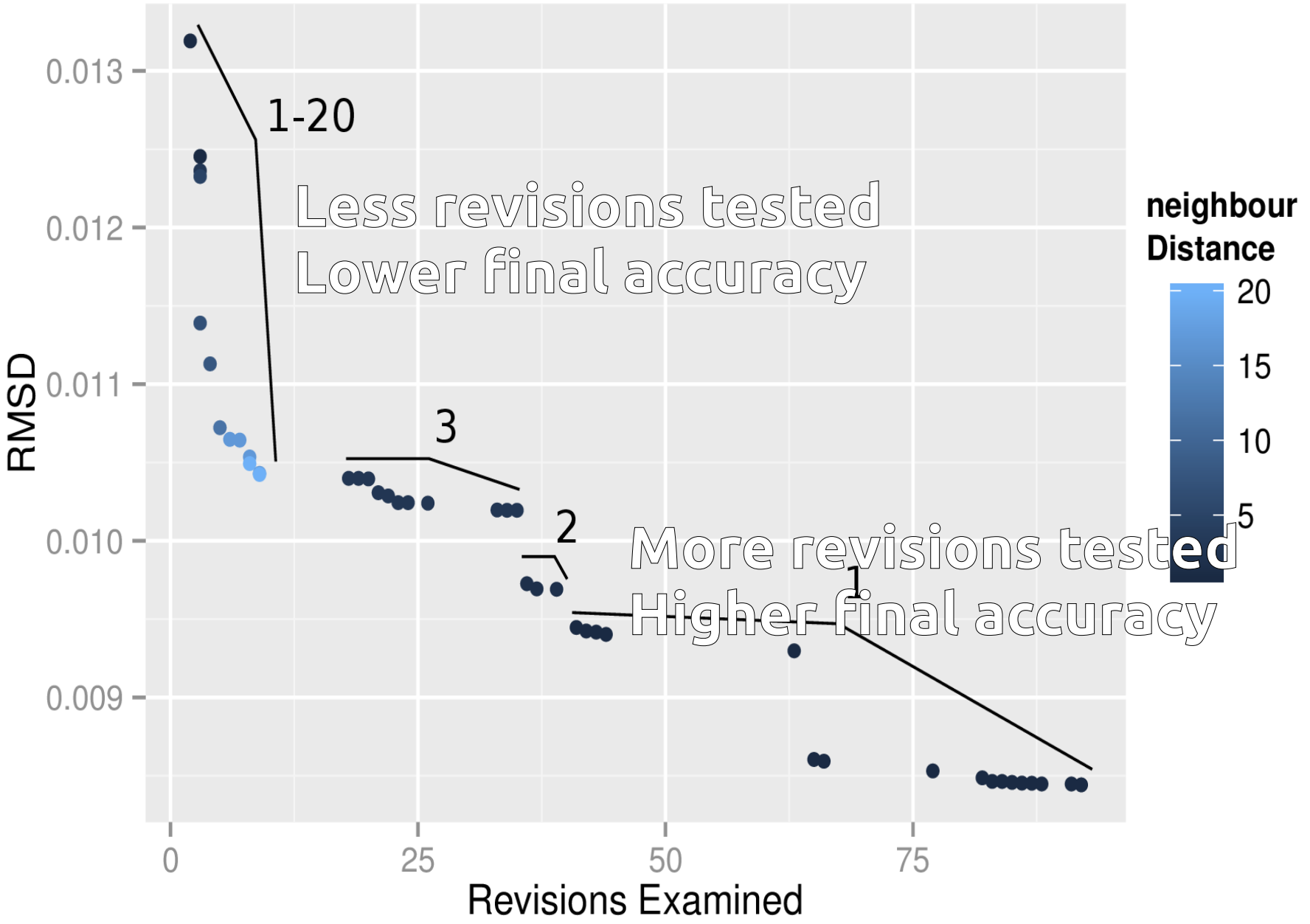
The Research Hurdle: Measuring every revision takes too long!



Pareto frontier: Most cost effective approximations per time spent



Pareto frontier: Most cost effective approximations per time spent



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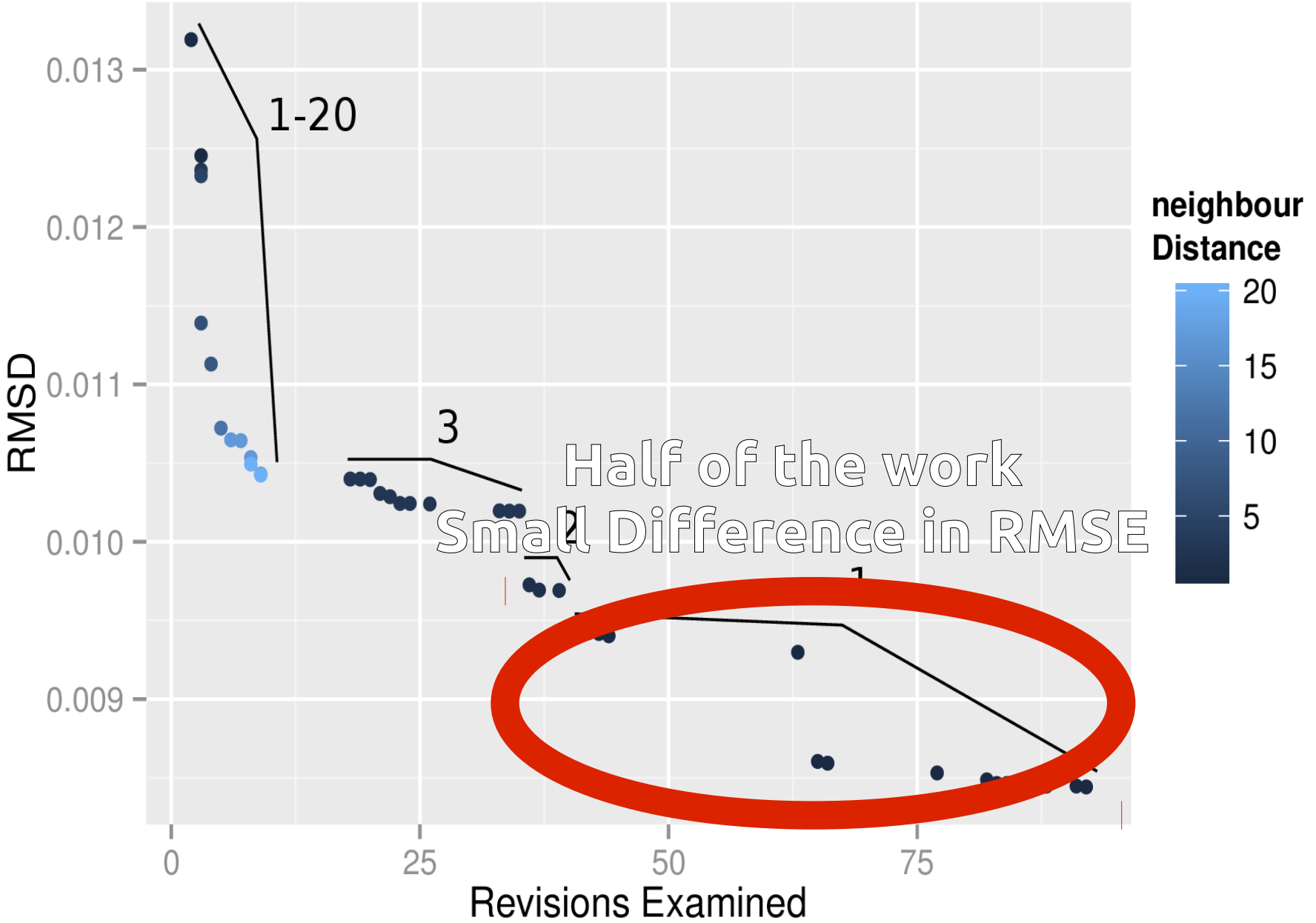

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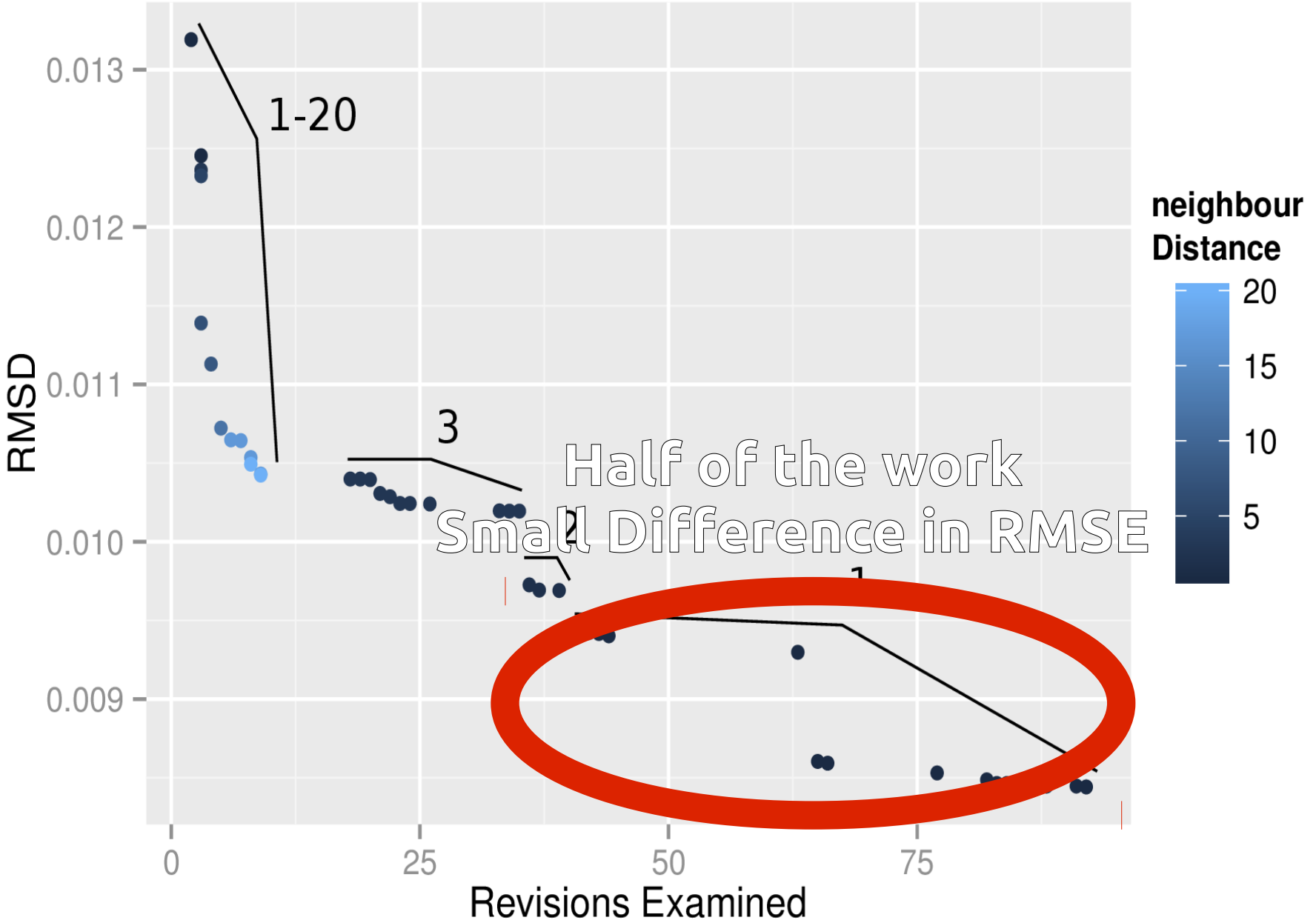

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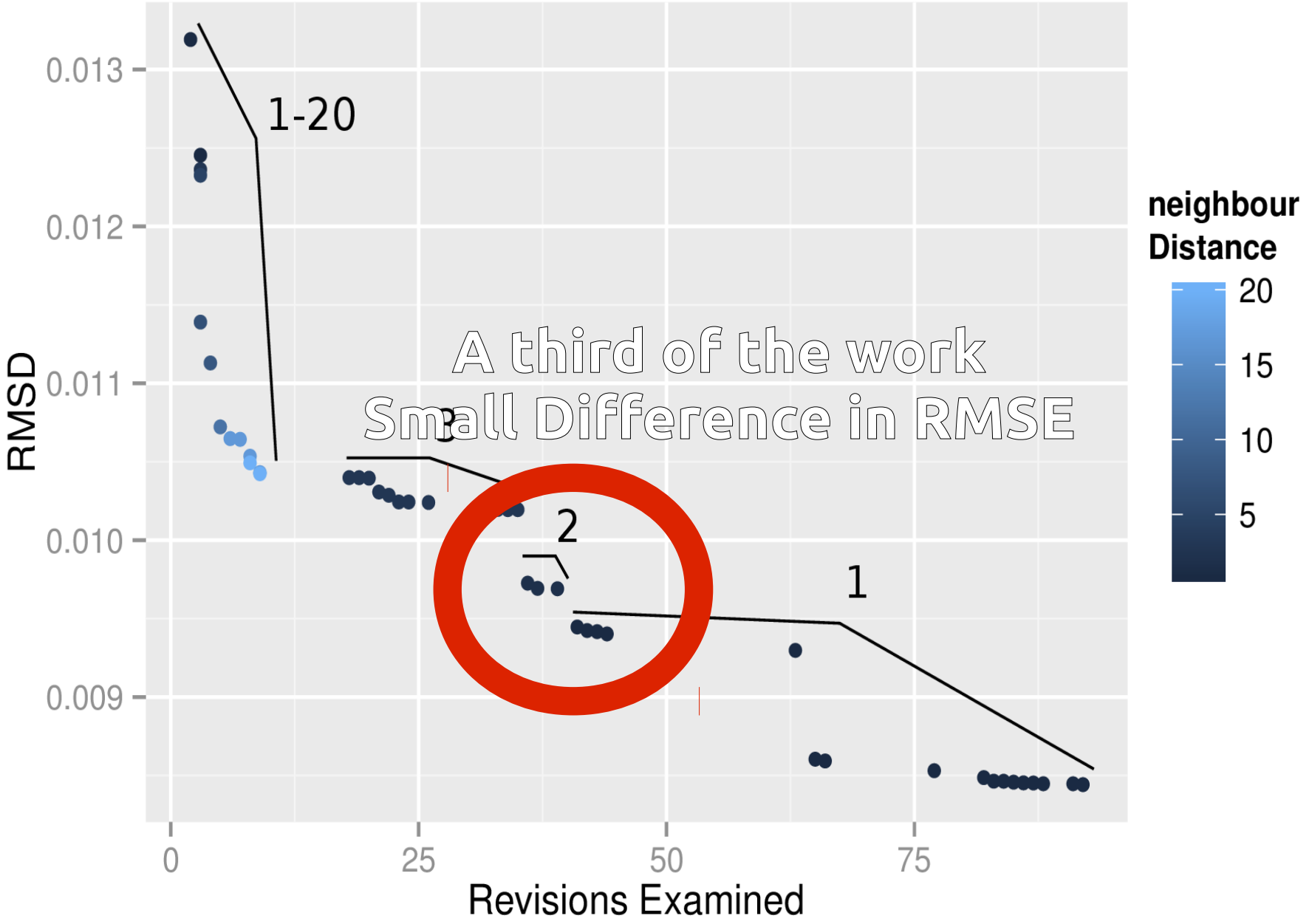

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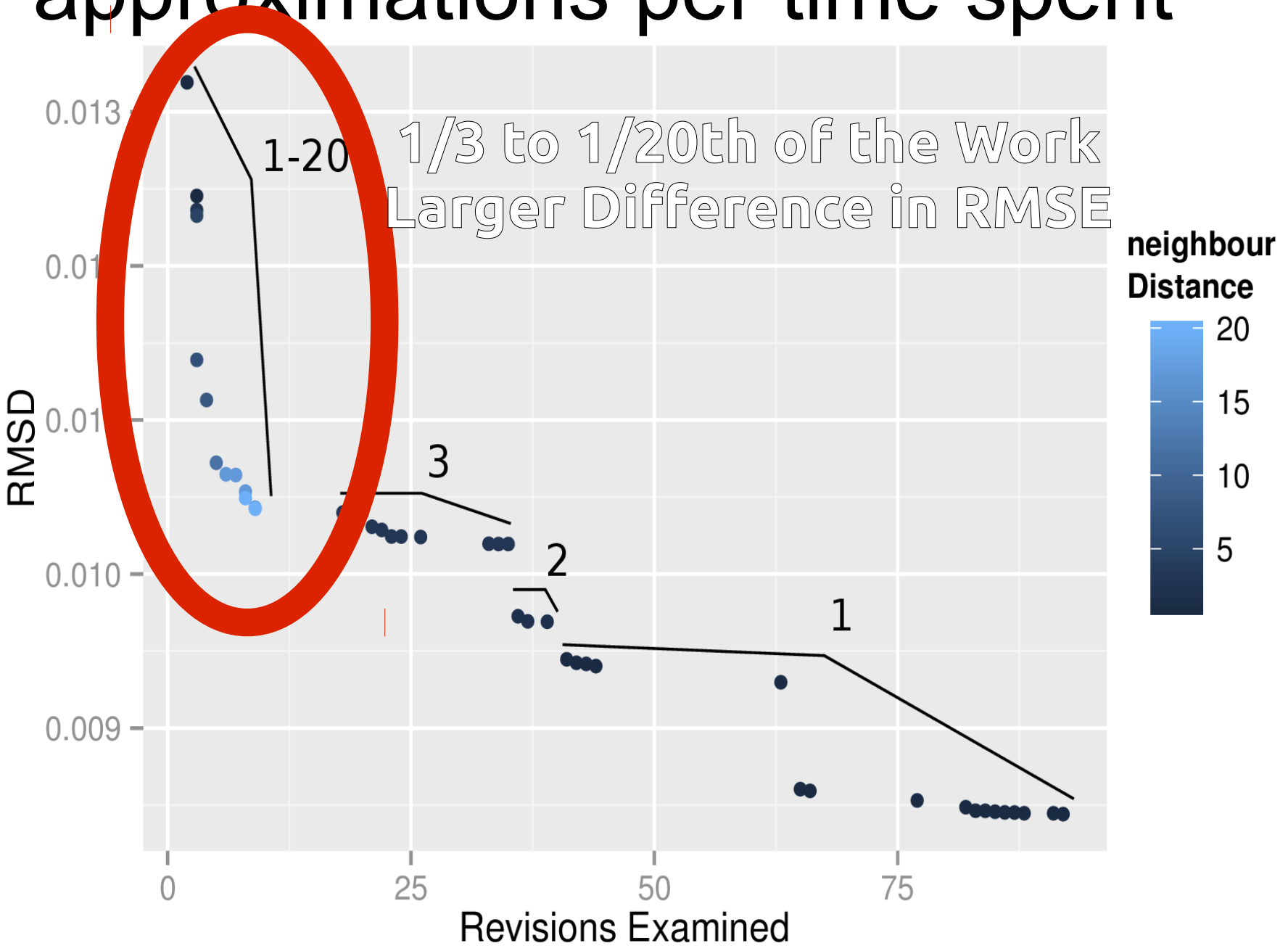

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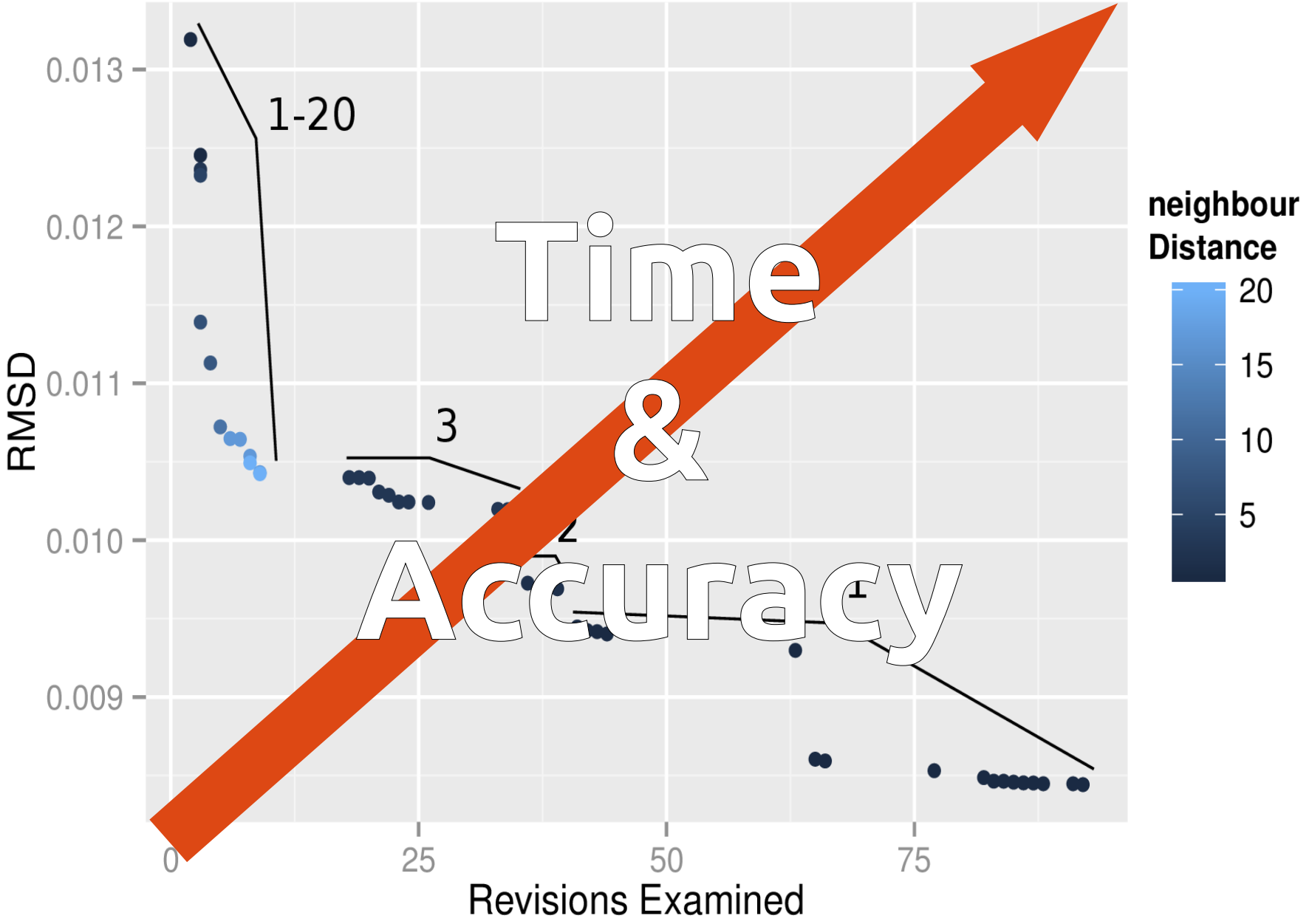


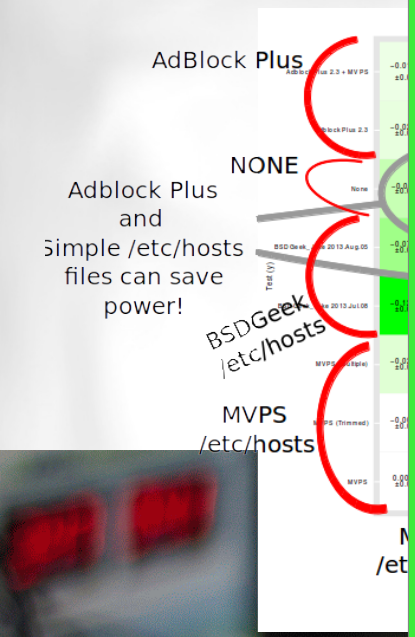
Green Mining Needs You

Got a question about power?

Looking for collaborators.

Green Miner is usable remotely.

Conclusions



1 measurement is not enough

Energy profiles change

Measurement Granularity

Software evolves, and forks,
-- it's not always now.

http://greenmining.softwareprocess.es/

Green Miner is available
For collaboration!