Data-Driven Cyber Vulnerability Maintenance

Security & Efficiency SEAL Analytics Laboratory

THE OHIO STATE UNIVERSITY

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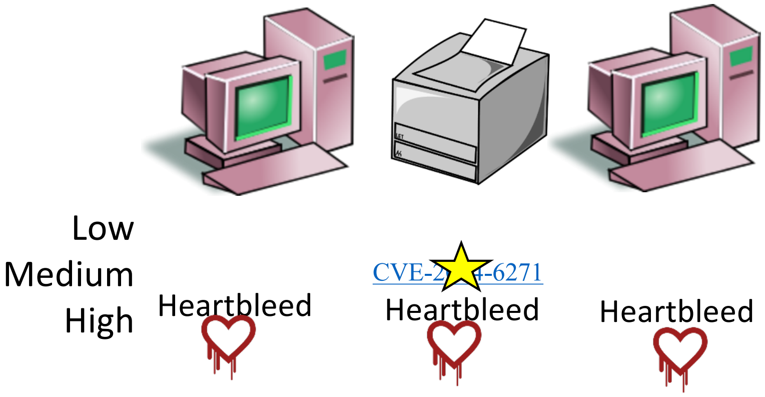
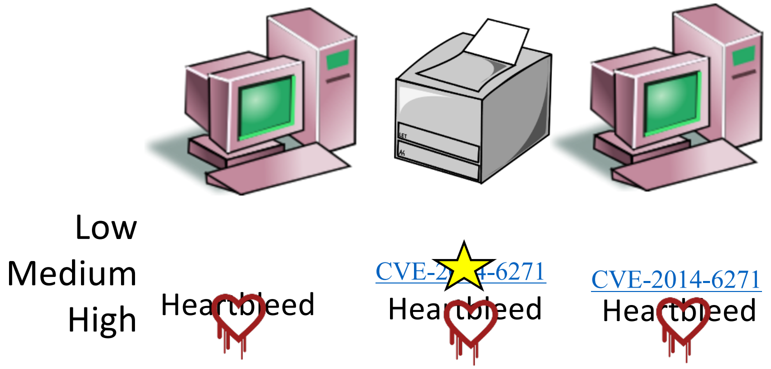
Integrated Systems Engineering



Description of Use Cases: Data Set

In our 2014 data set over 91% of warnings/”incidents” were on hosts with medium or higher vulnerabilities. It is often 90+% of incidents exploit known vulnerabilities.



Low

Medium

High

Heartbleed

CVE-2014-6271

Heartbleed

CVE-2014-6271

Heartbleed

Personnel and Tests

Fixes, Insurance, Losses

Min: Expected[Repair Cost + Intrusion Cost]

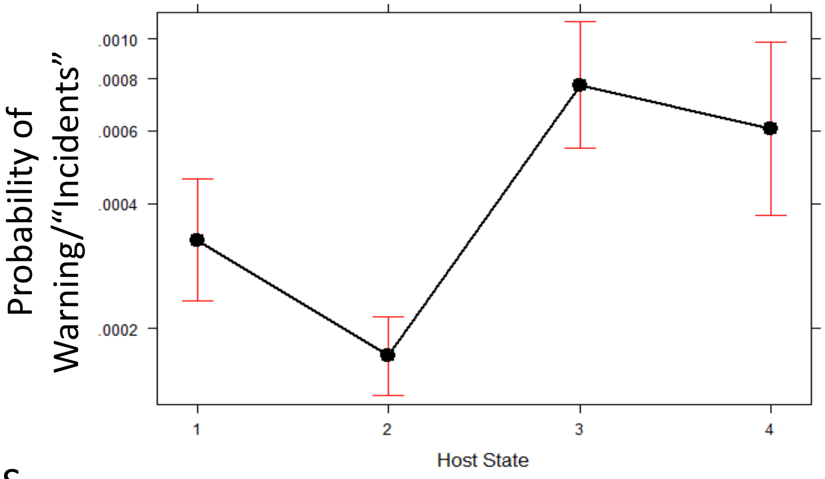
Common Vulnerability Scoring System (CVSS) Score is a number 0-10.

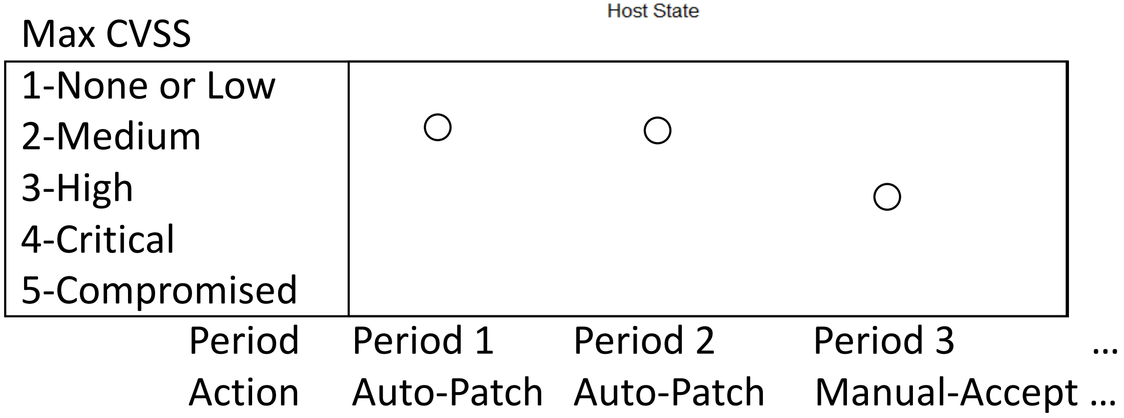
- Host differ by outside of the firewall, non-general, inside administrator privilege, restricted privalege, and critical servers
- 30,000+ host nessus scan data for 22 months and warning/“incident” data also, expected discounted sum of costs

Description of Cases: Analysis

<u>Assumptions</u>

- Host state is the level of the worst vulnerability.
- $150 on average vulnerability investigation/patching
- $2,000 for warning on non-critical server
- $10,000 for warning on critical server
- Conservative: Some incidents not included, just IDS warnings (usually data going out, black-listed IPs, IP data,…260)
- Estimated life costs are underestimates.
- If you have <10 hosts in your unit with the same OS and vulns, the local operator likely has administrator privilege.
- Ordinary Markov Decision Process and…





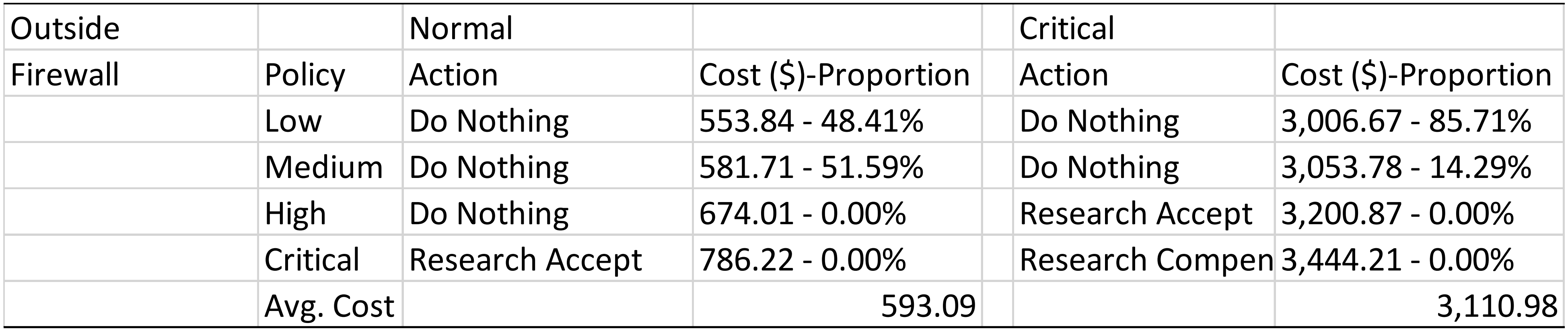
Max CVSS

1-None or Low
2-Medium
3-High
4-Critical
5-Compromised

Period — Period 1 — Period 2 — Period 3 …

Action — Auto-Patch — Auto-Patch — Manual-Accept …

Description of Use Cases: Firewalls

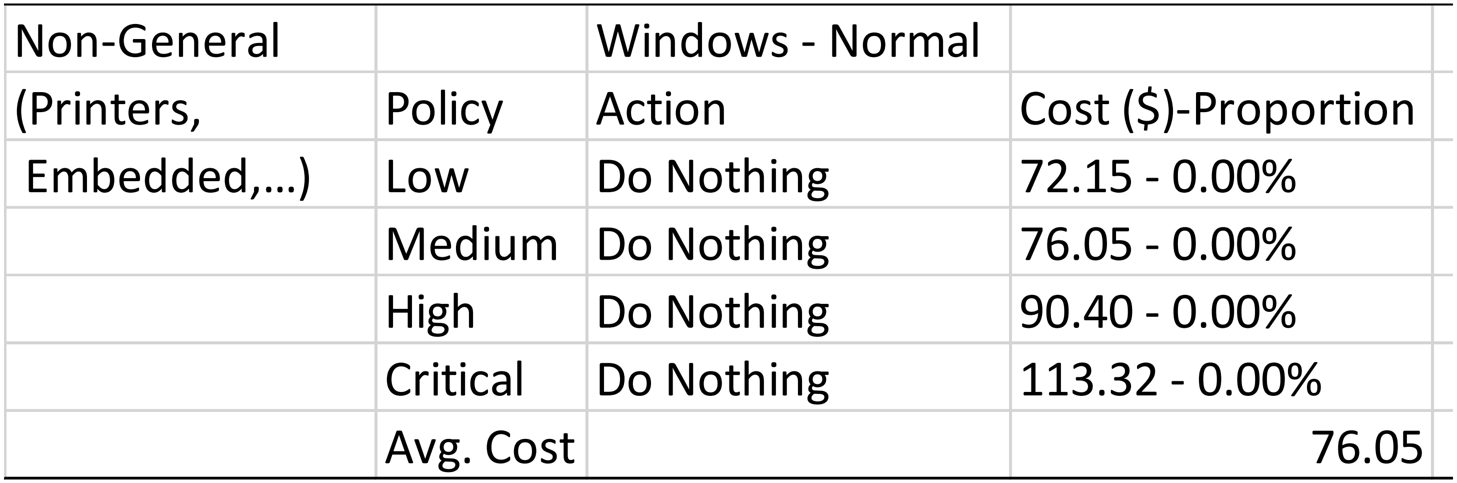


Outside		Normal			Critical	
Firewall	Policy	Action	Cost ($)-Proportion		Action	Cost ($)-Proportion
	Low	Do Nothing	553.84 - 48.41%		Do Nothing	3,006.67 - 85.71%
	Medium	Do Nothing	581.71 - 51.59%		Do Nothing	3,053.78 - 14.29%
	High	Do Nothing	674.01 - 0.00%		Research Accept	3,200.87 - 0.00%
	Critical	Research Accept	786.22 - 0.00%		Research Compen	3,444.21 - 0.00%
	Avg. Cost		593.09			3,110.98

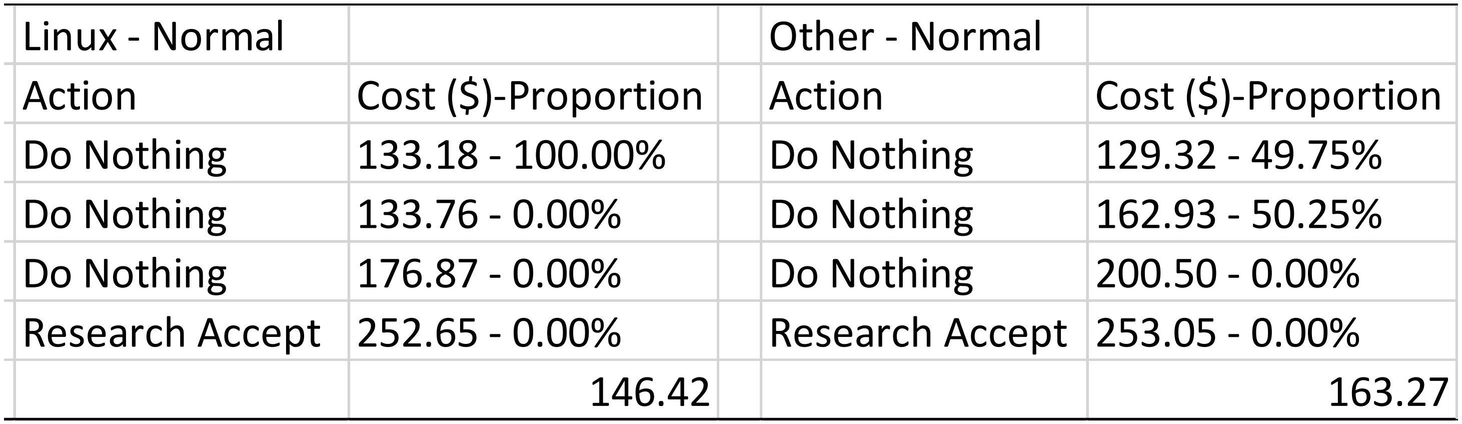
- Research accept – try to patch but do nothing if no patch is available.
- Research compensate – try to patch and remediate if no patch is available.
- Ask 1: For critical firewalls, do not risk accept critical vulnerabilities (already common)

Non-General

- Ask 1: Consider granting long term acceptance for non-general devices not associated with critical data (1 warning/“incident” over 22 months).

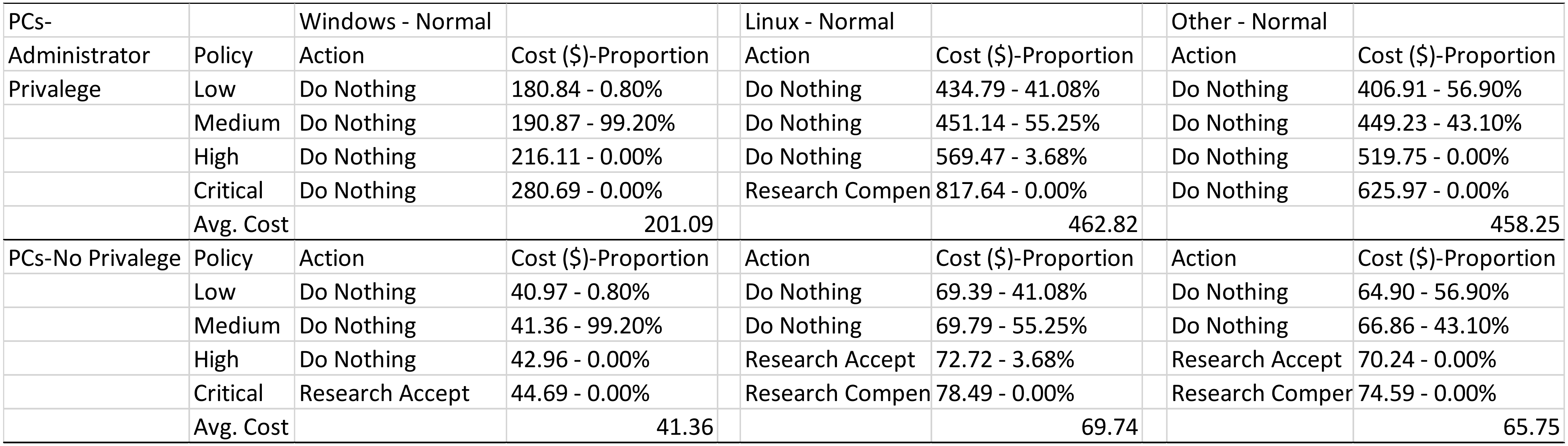


Non-General		Windows - Normal	
(Printers,	Policy	Action	Cost ($)-Proportion
Embedded,…)	Low	Do Nothing	72.15 - 0.00%
	Medium	Do Nothing	76.05 - 0.00%
	High	Do Nothing	90.40 - 0.00%
	Critical	Do Nothing	113.32 - 0.00%
	Avg. Cost		76.05



Linux - Normal			Other - Normal	
Action	Cost ($)-Proportion		Action	Cost ($)-Proportion
Do Nothing	133.18 - 100.00%		Do Nothing	129.32 - 49.75%
Do Nothing	133.76 - 0.00%		Do Nothing	162.93 - 50.25%
Do Nothing	176.87 - 0.00%		Do Nothing	200.50 - 0.00%
Research Accept	252.65 - 0.00%		Research Accept	253.05 - 0.00%
	146.42			163.27

Description of Use Cases: PCs

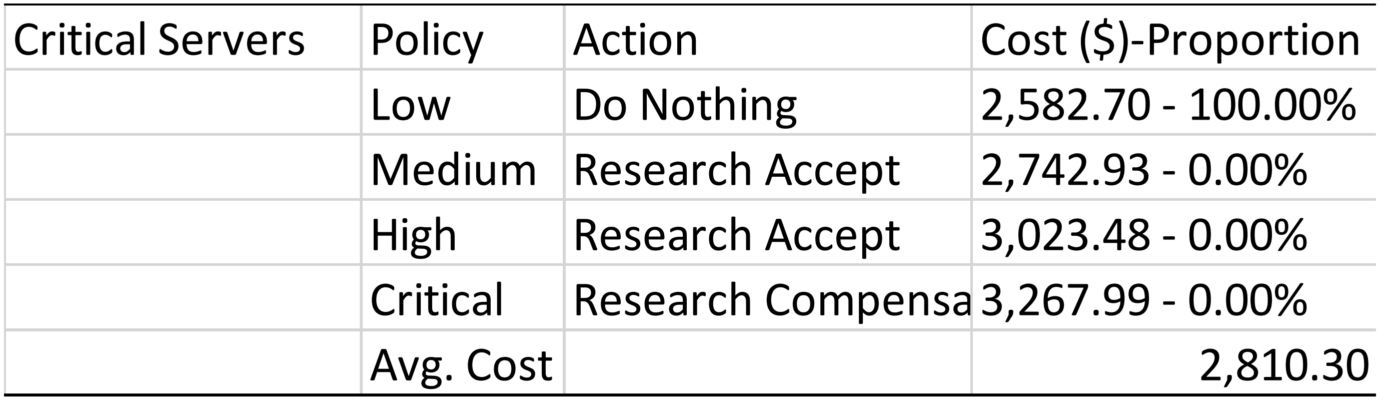


PCs-		Windows - Normal		Linux - Normal		Other - Normal	
Administrator	Policy	Action	Cost ($)-Proportion	Action	Cost ($)-Proportion	Action	Cost ($)-Proportion
Privalege	Low	Do Nothing	180.84 - 0.80%	Do Nothing	434.79 - 41.08%	Do Nothing	406.91 - 56.90%
	Medium	Do Nothing	190.87 - 99.20%	Do Nothing	451.14 - 55.25%	Do Nothing	449.23 - 43.10%
	High	Do Nothing	216.11 - 0.00%	Do Nothing	569.47 - 3.68%	Do Nothing	519.75 - 0.00%
	Critical	Do Nothing	280.69 - 0.00%	Research Compen	817.64 - 0.00%	Do Nothing	625.97 - 0.00%
	Avg. Cost		201.09		462.82		458.25
PCs-No Privalege	Policy	Action	Cost ($)-Proportion	Action	Cost ($)-Proportion	Action	Cost ($)-Proportion
	Low	Do Nothing	40.97 - 0.80%	Do Nothing	69.39 - 41.08%	Do Nothing	64.90 - 56.90%
	Medium	Do Nothing	41.36 - 99.20%	Do Nothing	69.79 - 55.25%	Do Nothing	66.86 - 43.10%
	High	Do Nothing	42.96 - 0.00%	Research Accept	72.72 - 3.68%	Research Accept	70.24 - 0.00%
	Critical	Research Accept	44.69 - 0.00%	Research Compen	78.49 - 0.00%	Research Comper	74.59 - 0.00%
	Avg. Cost		41.36		69.74		65.75

- Consider backing off administrator privilege hosts without critical data
- Ask 1: Reduced administrator privilege granting $160, $400, and $400 are est. lifetime maintenance costs for unique hosts over non-unique.
- Ask 2: Manually patch or remediate Linux critical vulns. if no patch…

Description of Cases: Critical Servers

- Critical servers → expensive incidents making big maintenance costs



Critical Servers	Policy	Action	Cost ($)-Proportion
	Low	Do Nothing	2,582.70 - 100.00%
	Medium	Research Accept	2,742.93 - 0.00%
	High	Research Accept	3,023.48 - 0.00%
	Critical	Research Compensa	3,267.99 - 0.00%
	Avg. Cost		2,810.30

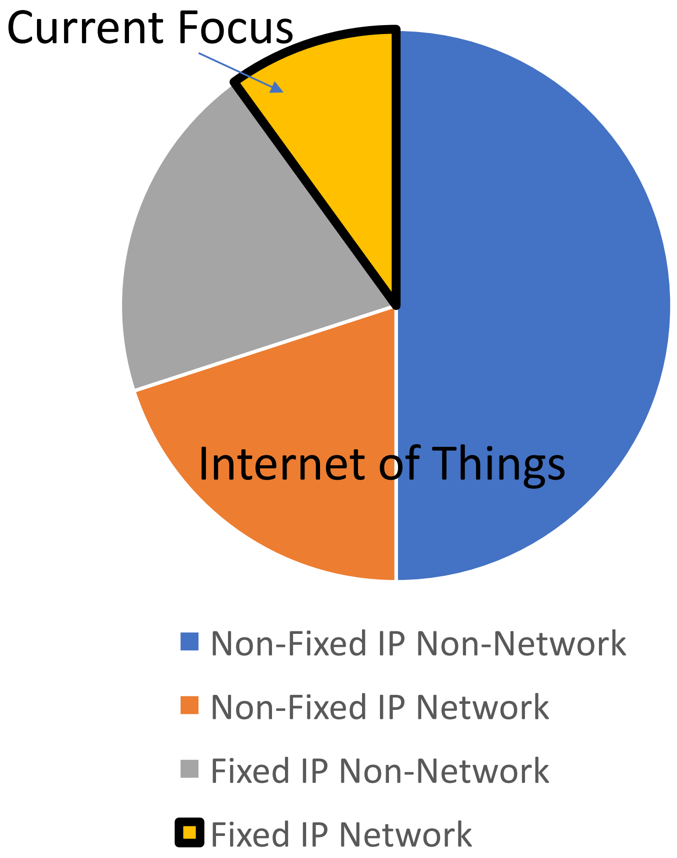
- Big Ask: Patching medium vulnerabilities is advised.
- Ask: Remediating critical vulnerabilities with no patches is advised.

Non-Fixed IP (Phones, laptops,…) and Policy

- Create a list of cell phones and laptops
- Use smart sampling to select hosts for vulnerability scanning
- Scan hosts and inspect for incidents
- Develop optimal scanning and maintenance policy

Ask: Collaboration and expertise related to non-Fixed IP address vulnerability sampling, incident clarifications, and control

- Future: Closed loop control with scans and patching actions or tickets

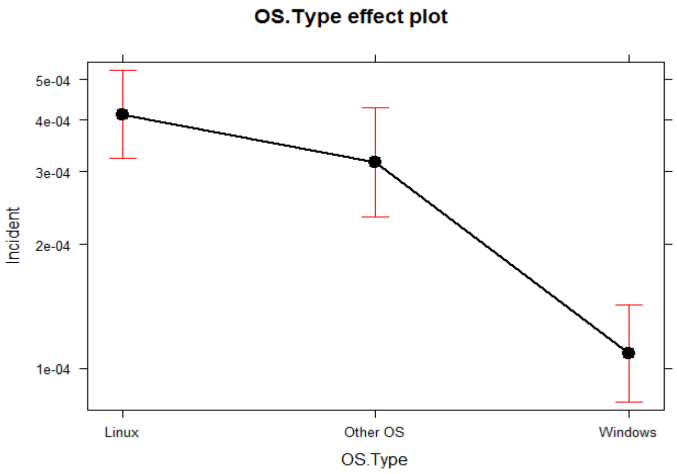


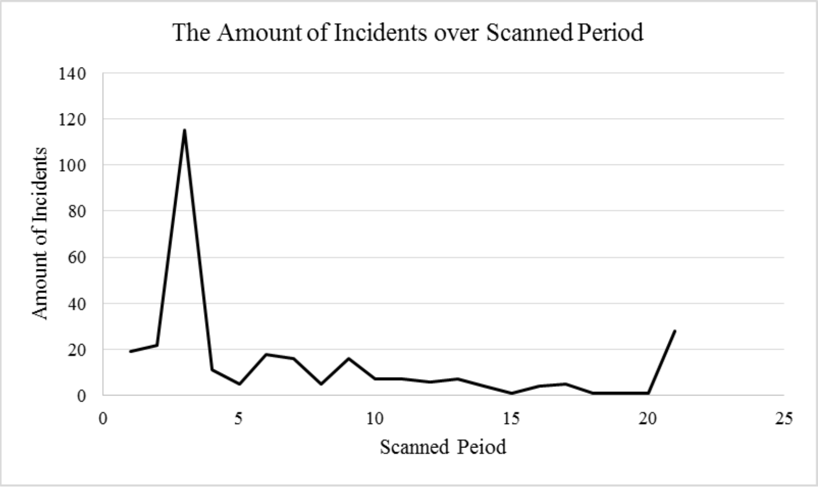
Pilots deployed to date and level of support

Description	Summary	Date Started	Date Results	Commitment
Firewalls,…,Non-General	Ask 1: Tighten crits. comps. Ask 2: Loosen non-generals.	April 2017	October 2017	≤ 65 buildings
PCs: Admin. Priv.…	Ask 1: Grant fewer privileges. Ask 2: Non-windows crits.	April 2017	October 2017	≤ 65 buildings
Critical Servers	Big Ask: Res. accept meds.	April 2017	October 2017	≤ 65 buildings
Sampling non-fixed IPs	Welcome collaboration.	Not yet	Not yet	1 department
Automatic control	Welcome collaboration.	Not yet	Not yet	1 department

- General lack of willingness to ignore high and critical vulnerabilities.
- Willingness to remediate critical vulnerabilities faster.
- Some willingness to patch selected mediums.
- If you interested in changing practices, please contact allen.515@osu.edu.

Operational technical requirements: OS, integration with current software, etc.





Vulnerability Policy

- Firewall,…,PC,…critical server policy…likely immediately relevant
- Ideally: Local vulnerability scan and incident data → Tailored policy
- Want: Aggregate data to measure success

Non-Fixed IP Sampling

- Need: List and staff willingness to bring in phones & laptops for scans

Closed Loop Control

- Want: Management software API for closed loop control

Questions?

Data Driven Markov Decision Processes (DDMDP)

$$Y_t|Y_{t-1}, a_{t-1}, \mathbf{p}_{(k)}^{a_{t-1}}, (k) \sim Multinomial[Row_{Y_{t-1}}(\mathbf{p}_{(k)}^{a_{t-1}})]$$

Additional expectation as compared with MDP

$$\max_{\mathbf{x}_1,\ldots,\mathbf{x}_{H-1}} \sum_{k=1}^{q} P(k) E_{Y_1,Y_2,\ldots,Y_H}[\sum_{t=1}^{H-1} \gamma^{t-1} r^{a_t|\mathbf{x}_t}_{Y_t|\mathbf{p}_{(k)}^{a_t}, Y_{t+1}|\mathbf{p}_{(k)}^{a_{t-1}}, \theta_{t-1}, (k)} + \gamma^{H-1} r^0_{Y_H}].$$

- Delage and Mannor (2010) OR problem is "intractable" and proposed approximate methods (hierarchical model).