Not-So-Random Numbers in Virtualized Linux and the Whirlwind RNG

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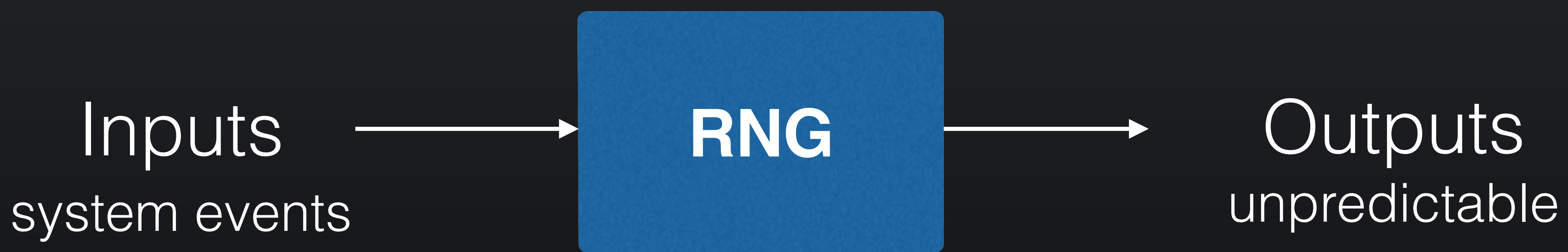
Random Number Generators



Random Number Generators

Previous Failures

Cryptanalysis of Windows RNG [DGP07]

Linux RNG [GPR08]

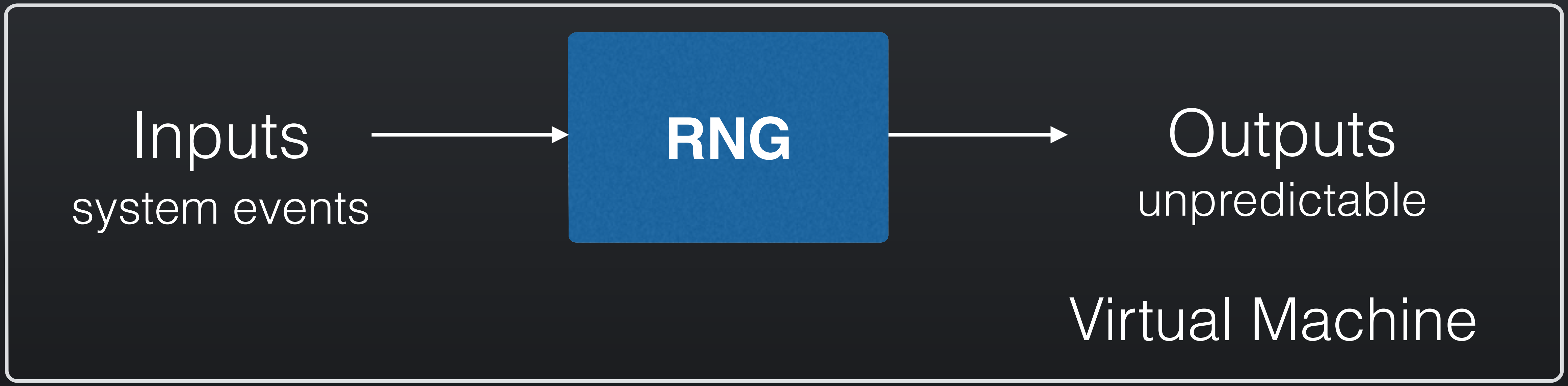
Factorable RSA Keys [HDWH12]

Linux RNG Revisited [LRSV12]

/dev/random not Robust [DPRVW13]

Taiwan National IDs [BCCCHLS13]

RNGs in Virtual Environments



1. Are there operational issues that cause problems for system RNGS? [GR05] [RY10]

2. Are input sources entropy-poor inside a virtual machine? [SBW09]

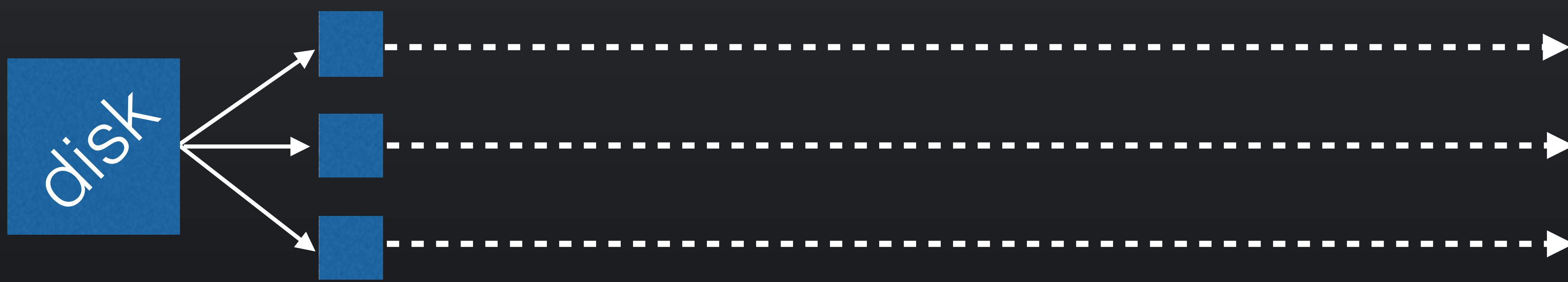
Our Contributions

- First study of system RNGs in modern virtualized settings
- Operational issues? -> YES

  Bad RSA keys from OpenSSL
- Entropy-poor inputs? -> NO
- New clean-slate RNG design — Whirlwind

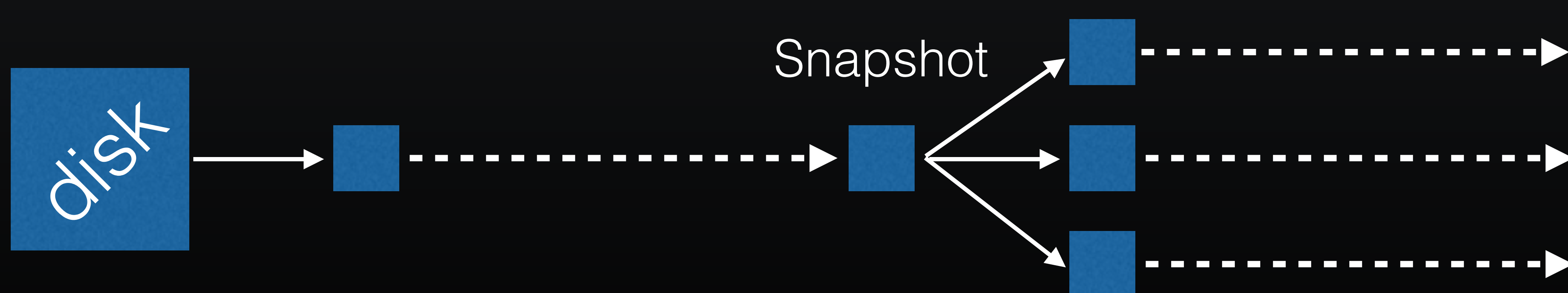
VM Use Cases

Boot-from-image



Amazon EC2 **Rackspace** **Microsoft Azure**

Snapshot-Reset

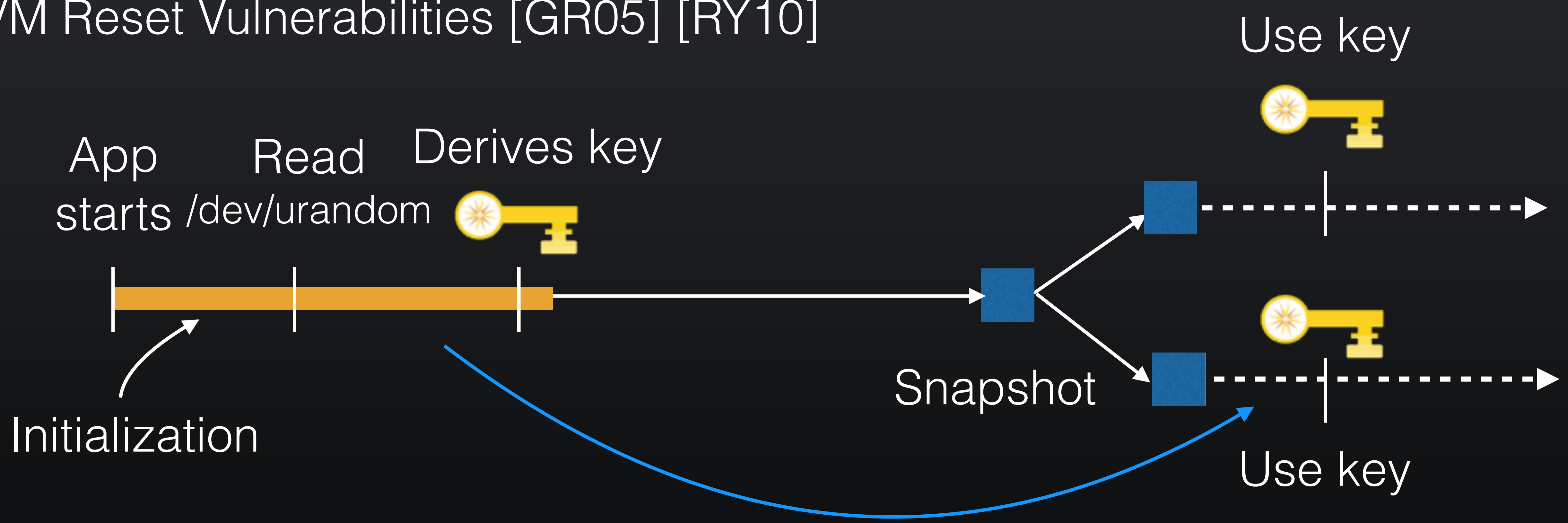


Resumption

vmware Xen Parallels

Security Problems with VM Resets

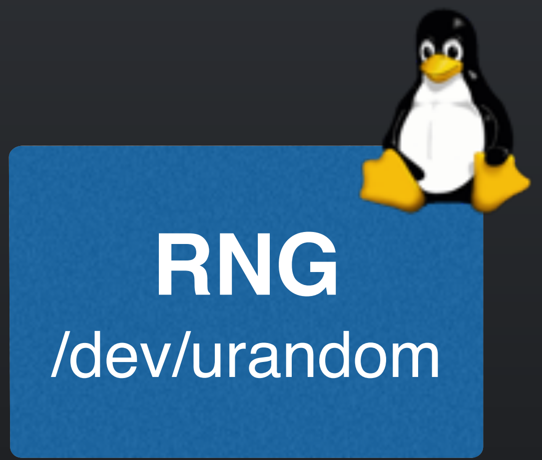
VM Reset Vulnerabilities [GR05] [RY10]



[RY10] Suggested countermeasure:
Narrow gap between deriving and using random numbers

Are system RNGs reset secure?

Linux RNG Not Reset Secure



Experiment

- Boot VM, idle for 5 minutes
- Start measurement process, capture snapshot
- Resume from snapshot,
  read 512-bits from /dev/urandom every 500 us

Repeat for 8 snapshots; 20 resumptions/snapshot

Result: 7/8 snapshots generated 1 or more identical 512-bit output

Reset Vulnerabilities on Other Platforms

FreeBSD
/dev/random produces repeat outputs
Up to 100 seconds after reset

Microsoft Windows 7
Produces repeat outputs indefinitely

`rand_s` (stdlib)
`CryptGenRandom` (Win32)
`RngCryptoServices` (.NET)

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- Entropy-poor inputs?
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Estimating Input Entropy

- Instrumented Linux RNG
- Collected all inputs, outputs on boot
- Gathered data from: native, Xen, VMware, and EC2
- Statistical hypothesis testing to determine entropy count per input

RNG
/dev/(u)random

Amazon EC2

Results: Boot Security

No inputs before first output:
constant value

Output #	Native	Xen	VMware	EC2
1	0	0	0	0
2	129	129	784	134

Entropy estimate ($\log_2$) for Linux /dev/(u)random during boot

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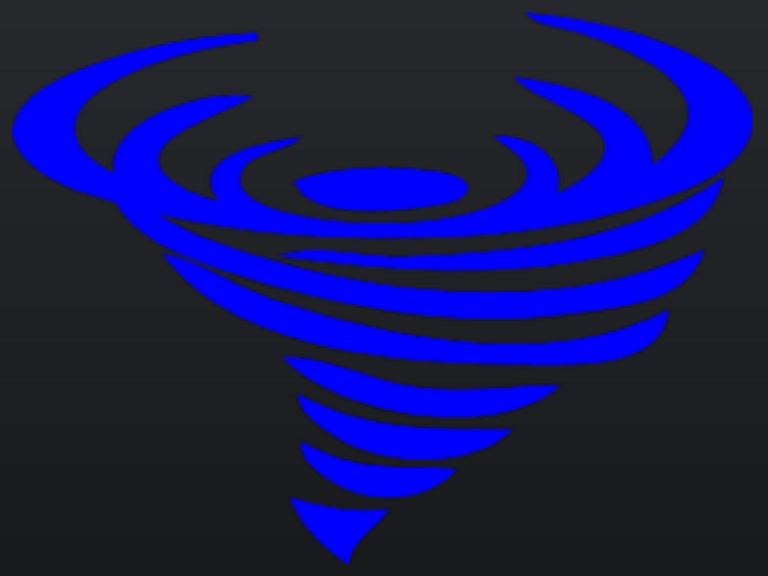
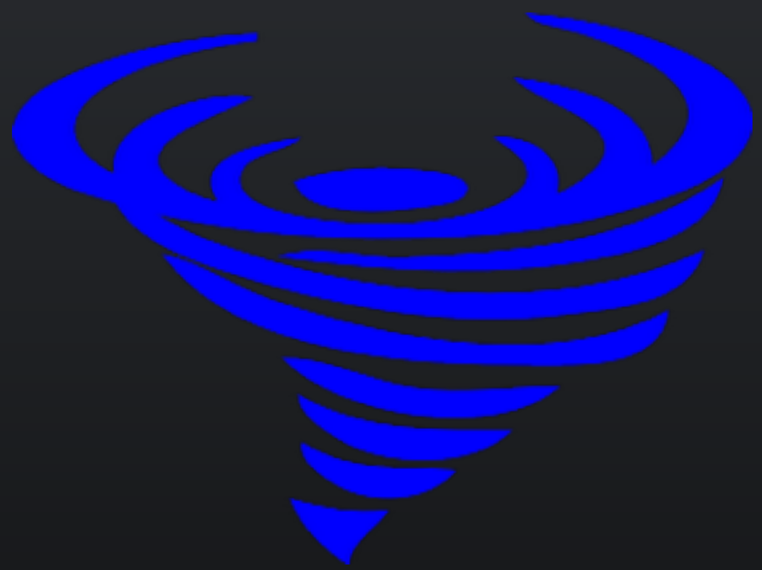
Whirlwind RNG



Goals

1. Simplicity
2. Fast Input Processing
3. Cryptographically Sound
4. Drop-in Compatibility
5. Reset Security

Whirlwind RNG



Goals

1. Simplicity
2. Fast Input Processing
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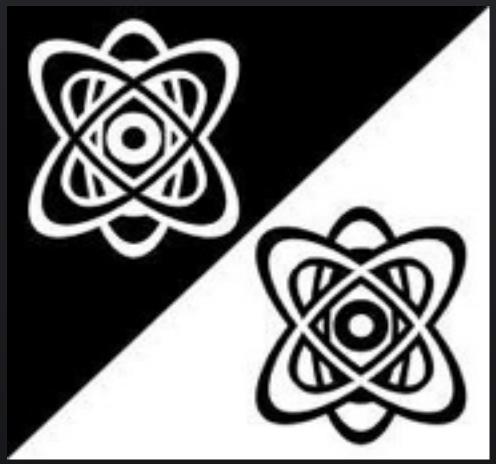
4. Drop-in Compatibility
5. **Reset Security**

Use environmental information (in addition to state data) when generating outputs.

-> Prevents reset vulnerabilities

Conclusions



- Linux, FreeBSD, and Windows are vulnerable upon snapshot resumption
- Linux /dev/(u)random has boot-time entropy hole
- Virtual settings have sufficient entropy
- Whirlwind RNG gives reset security by design