FireSim

Running a FireSim Simulation: Password Strength Checking on a RISC-V SoC with SHA-3 Accelerators and Linux

https://fires.im

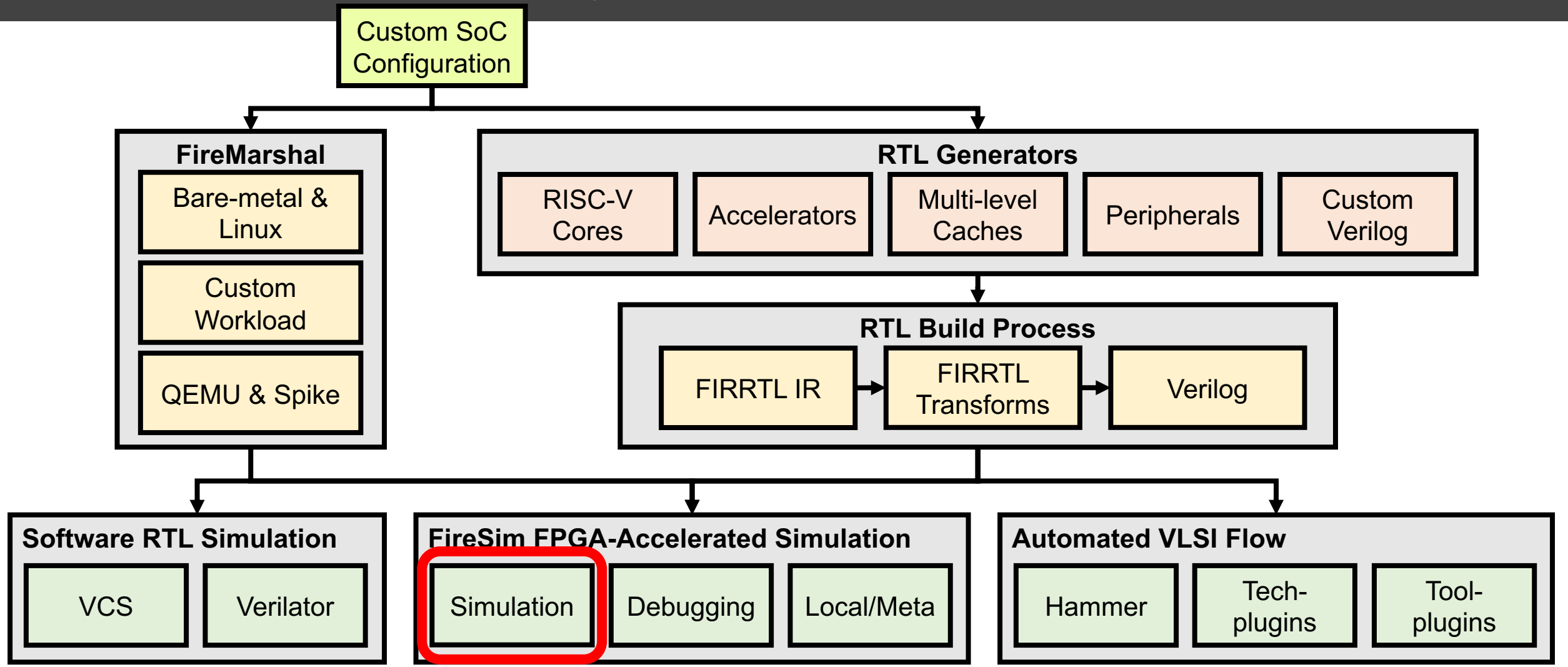
@firesimproject

ISCA Tutorial 2022

Sagar Karandikar

Berkeley Architecture Research

Tutorial Roadmap



Agenda

- Configure and launch a simulation runfarm
- Boot Linux interactively on the target hardware
- Deploy new automated workloads
- Stress the SHA-3 accelerator with a complex Linux application (John the Ripper)

Prerequisites

- Interactive shell commands intended to be run during the tutorial are highlighted in blue blocks (prefixed by "`$`")
- Some simplifying assumptions about the shell environment:
  - The `$FDIR` variable refers to the top directory of FireSim
  - `env.sh` and `sourceme-f1-manager.sh` have been sourced

```
$ cd ~/chipyard-afternoon
$ source ./env.sh

$ cd sims/firesim
$ FDIR=$PWD
$ source ./sourceme-f1-manager.sh
```

Prefetching

- We will later be setting up and launching simulations
- To hide setup latency, edit `$FDIR/deploy/config_runtime.yaml` to match the following settings:

```
run_farm:
  recipe_arg_overrides:
    run_farm_hosts_to_use:
      - f1.2xlarge: 1

target_config:
    topology: no_net_config
    no_net_num_nodes: 1
    default_hw_config: firesim_rocket_singlecore_no_nic_l2_lbp
```

Prefetching

- We will later be setting up and launching simulations
- To hide setup latency:
  - Append the following entry to `config_hwdb.yaml`:

Make sure there are no duplicate entries

```
$ cd $FDIR/deploy
$ cat built-hwdb-entries/firesim_rocket_singlecore_no_nic_l2_lbp >>
    config_hwdb.yaml
```

  - Verify that it follows this format (with a unique AGFI ID):

```
firesim_rocket_singlecore_no_nic_l2_lbp:
    agfi: agfi-0e27eb94672e2f5a9
    deploy_triplet_override: null
    custom_runtime_config: null
```

In case `firesim buildbitstream` did not finish in time, a pre-populated entry is provided for you to use

Prefetching

- We will later be setting up and launching simulations
- To hide setup latency, run the following commands:

- First verify that you aren't inside another `tmux` session.
- If so, detach from the existing `tmux` session using `Ctrl+b` then `d`.

```
$ tmux new -s sim
$ firesim launchrunfarm && firesim infrasetup
```

What did we just do?

Runtime Configuration

What to simulate and *what infrastructure is required* is controlled by `$FDIR/deploy/config_runtime.yaml`

- Target-level: Assemble a simulated system from components
  - FPGA images of SoC hardware designs
  - Network topology
  - Workload definition
- Host-level: Specify which EC2 instances to use

config_runtime.yaml

The `run_farm` section specifies the number, type, and other launch parameters of instances to be managed

```
run_farm:
  base_recipe: run-farm-recipes/aws_ec2.yaml
  recipe_arg_overrides:
    run_farm_tag: mainrunfarm
    always_expand_run_farm: true
    launch_instances_timeout_minutes: 60
    run_instance_market: ondemand
    spot_interruption_behavior: terminate
    spot_max_price: ondemand
    default_simulation_dir: /home/centos
```

config_runtime.yaml

The `run_farm` section specifies the number, type, and other launch parameters of instances to be managed

```
run_farm:
  base_recipe: run-farm-recipes/aws_ec2.yaml
  recipe_arg_overrides:
    # ...
    run_farm_hosts_to_use:
      - f1.16xlarge: 0
      - f1.4xlarge: 0
      - f1.2xlarge: 0
      - m4.16xlarge: 0
      - z1d.3xlarge: 0
      - z1d.6xlarge: 0
      - z1d.12xlarge: 0
```

config_runtime.yaml

The `target_config` section specifies the high-level configuration of the system to simulate

```
target_config:
    topology: example_8config
    no_net_num_nodes: 2
    link_latency: 6405
    switching_latency: 10
    net_bandwidth: 200
    profile_interval: -1
    default_hw_config: firesim_rocket_quadcore_nic_l2_llc4mb_ddr3
    plusarg_passthrough: ""
```

`default_hw_config` references an entry from `config_hwdb.yaml`

config_runtime.yaml

The `workload` section specifies the software to be executed on the simulated nodes

```
workload:
    workload_name: linux-uniform.json
    terminate_on_completion: no
    suffix_tag: null
```

Workload definitions live in `$FDIR/deploy/workloads/*.json`

config_runtime.yaml

Other miscellaneous sections:

- `metasimulation`
- `tracing`: TracerV trace port capture
- `autocounter`: Out-of-band performance counter collection
- `host_debug`: DRAM zeroing, synthesized assertions
- `synthprint`: Synthesized print statements

(These will be explained further in the debugging session)

Testing the new AGFI

- By now, the `buildbitstream` run that you started at the very beginning of this tutorial should have finished
- Add the hardware entry to `config_hwdb.yaml`:

First remove the old entry, if any

```
$ cd $FDIR/deploy
$ cat built-hwdb-entries/firesim_rocket_singlecore_no_nic_l2_lbp >>
    config_hwdb.yaml
```

- Verify that it follows this format (with a unique AGFI ID):

```
firesim_rocket_singlecore_no_nic_l2_lbp:
    agfi: agfi-0e27eb94672e2f5a9
    deploy_triplet_override: null
    custom_runtime_config: null
```

In case `firesim buildbitstream` did not finish in time, a pre-populated entry is provided for you to use

Single-Node Simulation

What we modified in `config_runtime.yaml` earlier:

```
run_farm:
  recipe_arg_overrides:
    run_farm_hosts_to_use:
      - f1.2xlarge: 1

target_config:
    topology: no_net_config
    no_net_num_nodes: 1
    default_hw_config: firesim_rocket_singlecore_no_nic_12_lbp
```

- Use a smaller f1.2xlarge instance (1 FPGA)
- Simulate one non-networked node without a switch model
- Load the single-core Rocket design without a NIC

Launching Simulation Instances

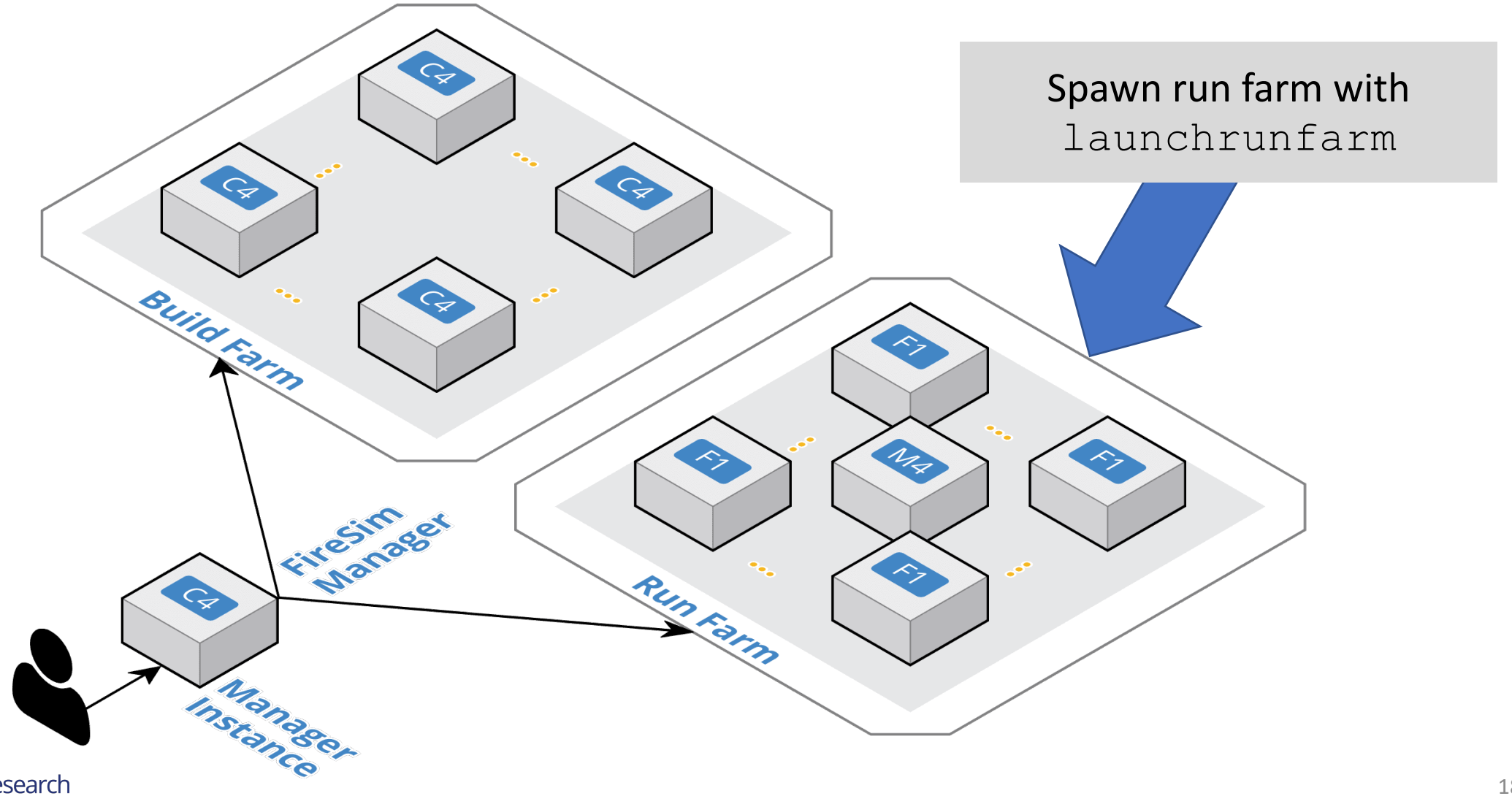
```
$ firesim launchrunfarm
```

Already running in a `tmux` session; re-attach with `tmux attach -t sim`

```
FireSim Manager. Docs: https://docs.fires.im
Running: launchrunfarm

Waiting for instance boots: 0 f1.16xlarge
Waiting for instance boots: 1 f1.2xlarge
i-0c5c6894d0ac788af booted!
Waiting for instance boots: 0 f1.4xlarge
Waiting for instance boots: 0 m4.16xlarge
Waiting for instance boots: 0 z1d.12xlarge
Waiting for instance boots: 0 z1d.3xlarge
Waiting for instance boots: 0 z1d.6xlarge
The full log of this run is:
/home/centos/chipyard/sims/firesim/deploy/logs/2022-06-17--23-52-57-launchrunfarm-R50MKTLJ42O36MZZ.log
```

Launching Simulation Instances



Deploying Simulation Infrastructure

```
$ firesim infrasetup
```

Already running!

This deploys various software prerequisites:

- Builds host-side simulation drivers for the specific build triplet
- Builds the switch model executable (if enabled)
- Collects information about simulation instances and transfers files
- Programs the FPGAs with the desired AGFIs

Deploying Simulation Infrastructure

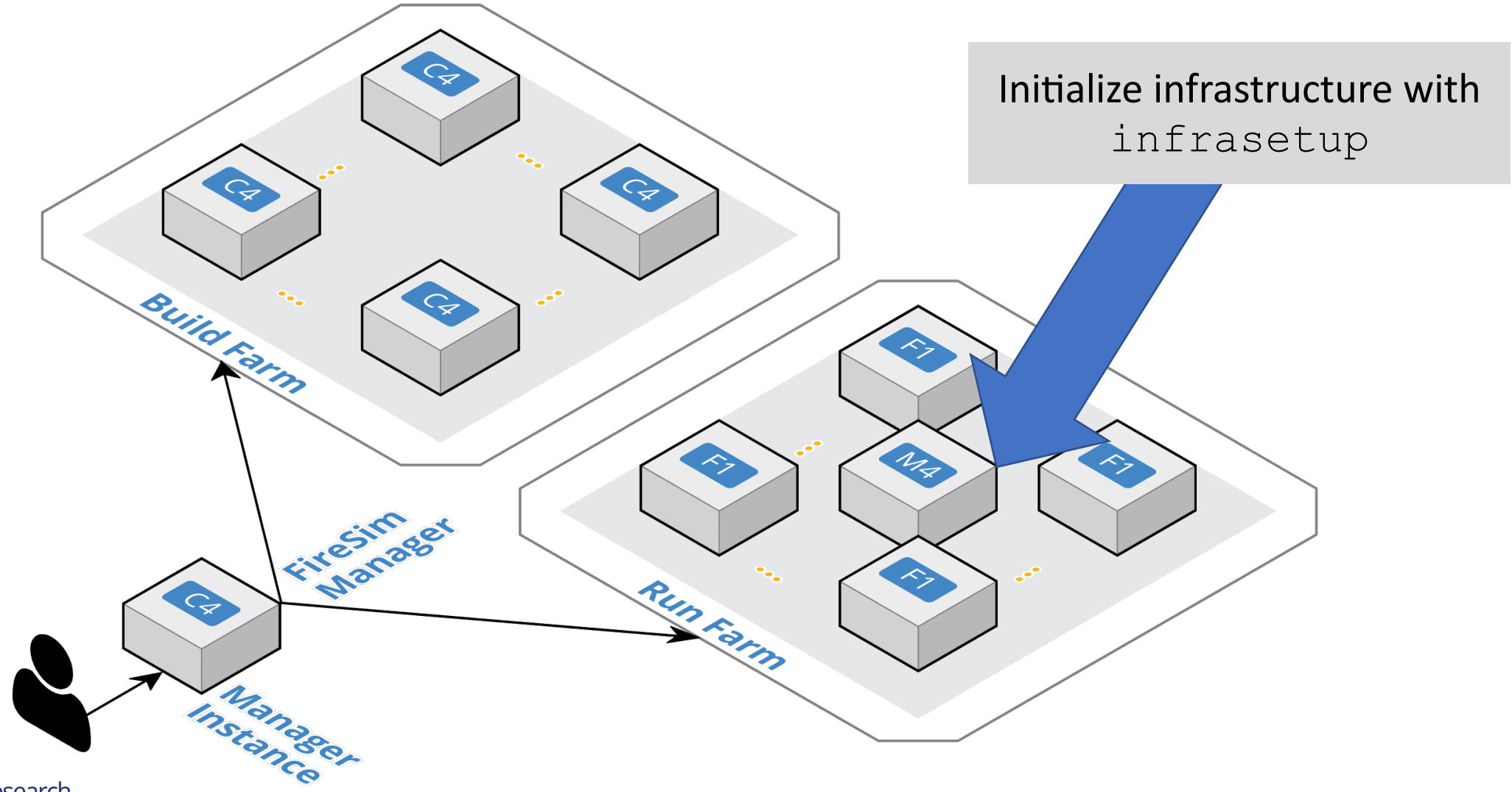
```
$ firesim infrasetup
```

Already running!

```
FireSim Manager. Docs: https://docs.fires.im
Running: infrasetup

Building FPGA software driver for FireSim-WithDefaultFireSimBridges_WithFireSimHighPerfConfigTweaks_chipyard.RocketConfig-F90MHz_BaseF1Config
[192.168.3.52] Executing task 'instance_liveness'
[192.168.3.52] Checking if host instance is up...
[192.168.3.52] Executing task 'infrasetup_node_wrapper'
[192.168.3.52] Copying FPGA simulation infrastructure for slot: 0.
[192.168.3.52] Installing AWS FPGA SDK on remote nodes. Upstream hash: 1.12.0-72-gfed0aa6
[192.168.3.52] Unloading XRT-related Kernel Modules.
[192.168.3.52] Copying AWS FPGA XDMA driver to remote node.
[192.168.3.52] Unloading XDMA Driver Kernel Module.
[192.168.3.52] Loading XDMA Driver Kernel Module.
[192.168.3.52] Setting up remote node for qcow2 disk images.
[192.168.3.52] Loading NBD Kernel Module.
[192.168.3.52] Unloading NBD Kernel Module.
[192.168.3.52] Disconnecting all NBDs.
[192.168.3.52] Clearing FPGA Slot 0.
[192.168.3.52] Checking for Cleared FPGA Slot 0.
[192.168.3.52] Flashing FPGA Slot: 0 with agfi: agfi-0e27eb94672e2f5a9.
[192.168.3.52] Checking for Flashed FPGA Slot: 0 with agfi: agfi-0e27eb94672e2f5a9.
[192.168.3.52] Unloading XDMA Driver Kernel Module.
[192.168.3.52] Loading XDMA Driver Kernel Module.
[192.168.3.52] Starting Vivado hw_server.
[192.168.3.52] Starting Vivado virtual JTAG.
The full log of this run is:
/home/centos/chipyard/sims/firesim/deploy/logs/2022-06-18--00-13-05-infrasetup-SJJBIKPWYO20THF4.log
```

Deploying Simulation Infrastructure



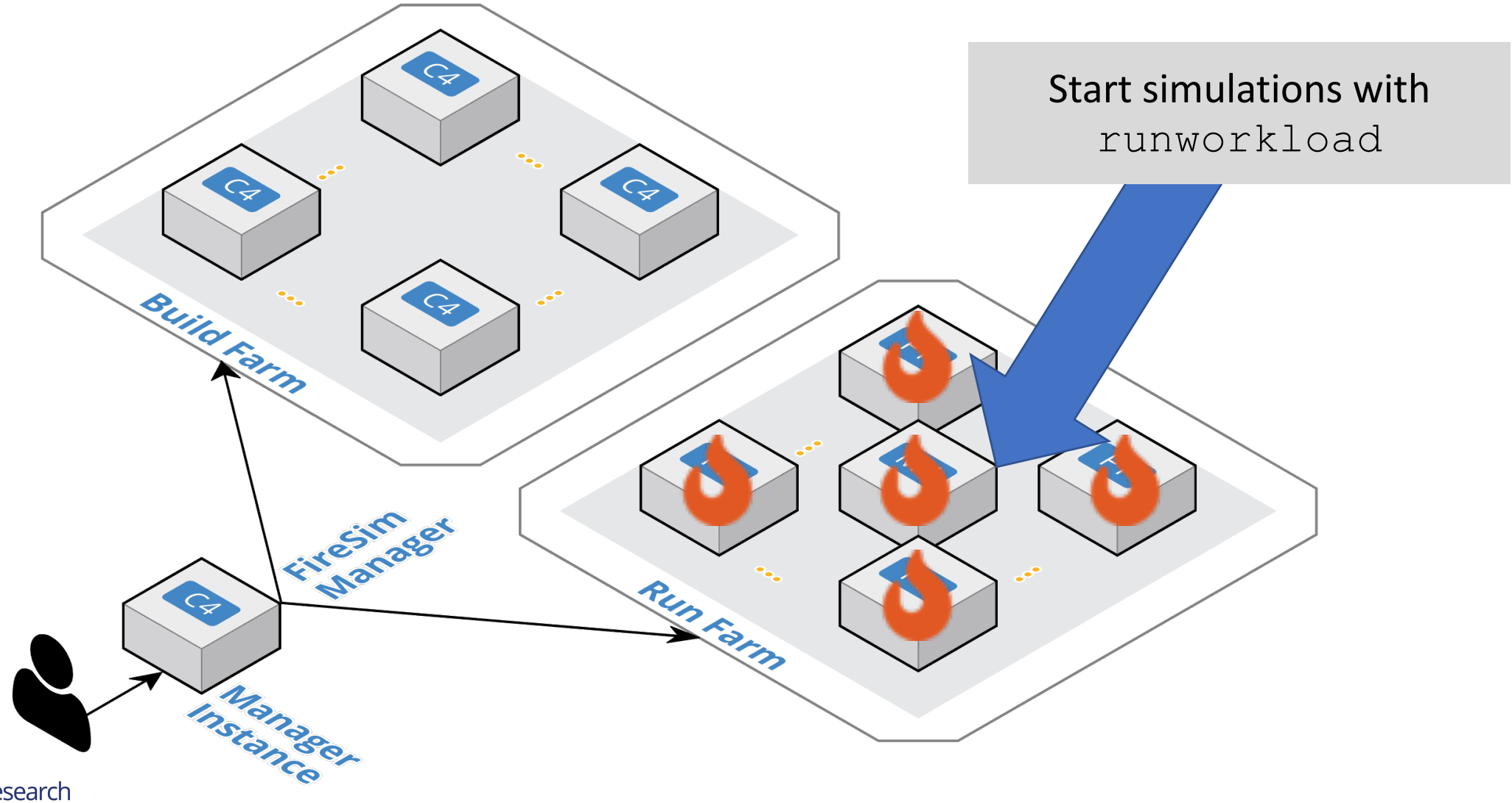
Running the Simulation

```
$ firesim runworkload
```

```
FireSim Manager. Docs: http://docs.fires.im
Running: runworkload

Creating the directory: /home/centos/chipyard/sims/firesim/deploy/results-
workload/2022-06-18--00-16-00-linux-uniform/
[192.168.3.52] Executing task 'instance_liveness'
[192.168.3.52] Checking if host instance is up...
[192.168.3.52] Executing task 'boot_switch_wrapper'
[192.168.3.52] Executing task 'boot_simulation_wrapper'
[192.168.3.52] Starting FPGA simulation for slot: 0.
[192.168.3.52] Executing task 'monitor_jobs_wrapper'
```

Running the Simulation



Monitoring the Simulation

You should see a live status report that refreshes periodically:

```
FireSim Simulation Status @ 2022-06-18 00:17:10.188191
--------------------------------------------------------------------------------
This workload's output is located in:
/home/centos/chipyard/sims/firesim/deploy/results-workload/2022-06-18--00-16-00-
linux-uniform/
This run's log is located in:
/home/centos/chipyard/sims/firesim/deploy/logs/2022-06-18--00-16-00-runworkload-
NEZCRUKBA2M44B9M.log
This status will update every 10s.
--------------------------------------------------------------------------------
Instances
--------------------------------------------------------------------------------
Hostname/IP: 192.168.3.52 | Terminated: False
--------------------------------------------------------------------------------
Simulated Switches
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Simulated Nodes/Jobs
--------------------------------------------------------------------------------
Hostname/IP: 192.168.3.52 | Job: linux-uniform0 | Sim running: True
--------------------------------------------------------------------------------
Summary
--------------------------------------------------------------------------------
1/1 instances are still running.
1/1 simulations are still running.
--------------------------------------------------------------------------------
```

Interacting with the Simulation

Look for the run instance's IP address in the status:

```
FireSim Simulation Status @ 2022-06-18 00:17:10.188191
--------------------------------------------------------------------------------
This workload's output is located in:
/home/centos/chipyard/sims/firesim/deploy/results-workload/2022-06-18--00-16-00-
linux-uniform/
This run's log is located in:
/home/centos/chipyard/sims/firesim/deploy/logs/2022-06-18--00-16-00-runworkload-
NEZCRUKBA2M44B9M.log
This status will update every 10s.
--------------------------------------------------------------------------------
Instances
--------------------------------------------------------------------------------
Hostname/IP: 192.168.3.52 | Terminated: False
--------------------------------------------------------------------------------
Simulated Switches
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Simulated Nodes/Jobs
--------------------------------------------------------------------------------
Hostname/IP: 192.168.3.52 | Job: linux-uniform0 | Sim running: True
--------------------------------------------------------------------------------
Summary
--------------------------------------------------------------------------------
1/1 instances are still running.
1/1 simulations are still running.
--------------------------------------------------------------------------------
```

Interacting with the Simulation

- On the *manager* instance, `ssh` into the run farm instance:

```
$ ssh 192.168.3.52
```

```
 ___ ___ ___   _     ___ _____  __    _   __ __ ___
| __| _ \/ __| /_\   |   \ __\ \ / /   /_\ |  \/  |_ _|
| _||  _/ (_ |/ _ \  | |) | _| \ V /   / _ \| |\/| || |
|_| |_|  \___/_/ \_\ |___/|___| \_/   /_/ \_\_|  |_|___|
AMI Version:          1.11.4
Xilinx Version:       2021.1
Readme:               /home/centos/src/README.md
AMI Release Notes:    /home/centos/src/RELEASE_NOTES.md
GUI/Cluster setup:    https://github.com/aws/aws-fpga/blob/master/developer_resources
```

- Then attach to the console of the simulated node:

```
$ screen -r fsim0
```

Logging Into the Simulated System

- Once Linux boots, the login prompt should appear over the console
- Log in as `root` with password `firesim` (password does not echo)

```
[    0.085714] EXT4-fs (iceblk): re-mounted. Opts: (null)
Starting syslogd: OK
Starting klogd: OK
Starting mdev... done.
Starting dropbear sshd: OK

Welcome to Buildroot
buildroot login: root
Password:
#
```

Logging Into the Simulated System

- Feel free to experiment with shell commands

```
# uname -a
# cat /proc/cpuinfo
# free -m
# vim
```

- When done, shut down the system

```
# poweroff -f
```

- This will also end the simulation

Finally, exit the `ssh` session with `Ctrl-d` to return to the manager instance

Custom FireSim Workloads

- *Workload*: Series of jobs (software configurations) assigned to run on individual simulations

- Two types of workloads:

  Uniform: Homogenous job run by all nodes in a simulated cluster

  Non-uniform: Each node is assigned a different job

  - Client/server configurations
  - Benchmark suites (SPEC17)

Workload Definitions

`linux-uniform`: Default workload to boot an interactive buildroot-based GNU/Linux distro on every node

```
{
    "benchmark_name" : "linux-uniform",
    "common_bootbinary" : "br-base-bin",
    "common_rootfs"     : "br-base.img",
    "common_outputs"    : ["/etc/os-release"],
    "common_simulation_outputs" : ["uartlog", "memory_stats.csv"]
}
```

`$FDIR/deploy/workloads/linux-uniform/br-base{-bin,.img}`
are symlinks to the FireMarshal-generated images

SPEC CPU2017

- 10 jobs – one per benchmark in the SPECrate Integer suite
- Build and install the workloads in `chipyard/software/spec2017` using FireMarshal
- Set up `config_runtime.yaml`
  - `f1_2xlarges: 10`
  - `topology: no_net_config`
  - `no_net_num_nodes: 10`
  - `workload_name: spec17-intrate.json`
- Select the hardware config to benchmark, then run `firesim launchrunfarm` / `infrasetup` / `runworkload`

```
{
  "common_bootbinary" : "bbl-vmlinux",
  "benchmark_name" : "spec17-intrate",
  "deliver_dir" : "spec17-intrate",
  "common_args" : ["--copies 4"],
  "common_files" : ["intrate.sh"],
  "common_outputs" : ["/output"],
  "common_simulation_outputs" : ["uartlog"],
  "workloads" : [
    {
      "name": "500.perlbench_r",
      "files": ["500.perlbench_r"],
      "command": "cd /spec17-intrate && ./intrate.sh 500.perlbench_r",
      "simulation_outputs": [],
      "outputs": []
    },
    {
      "name": "502.gcc_r",
      "files": ["502.gcc_r"],
      "command": "cd /spec17-intrate && ./intrate.sh 502.gcc_r",
      "simulation_outputs": [],
      "outputs": []
    },
    …
  ]
}
```

John the Ripper

- Open-source password checking software
- Our customized version adds support for two more hash formats:
  - **Raw-SHA3-256**: pure software implementation using generic Keccak code
  - **Raw-SHA3-256-rocc**: RoCC accelerator offload

- https://github.com/ucb-bar/JohnTheRipper/tree/riscv
  - `src/sha3_256_rocc_fmt_plug.c`
  - The `crypt_all()` function performs the actual hashing
- Minor Linux kernel patches to facilitate accelerator context switching

Changing Workloads

- Generate the FireSim workload definition for “sha3-linux-jtr-test”:

```
$ cd ~/chipyard-afternoon/generators/sha3/software
$ marshal install marshal-configs/sha3-linux-jtr-test.yaml
```

- Update `$FDIR/deploy/config_runtime.yaml` accordingly:

```
default_hw_config: firesim_rocket_singlecore_sha3_no_nic_l2_llc4mb_ddr3
workload_name: sha3-linux-jtr-test.json
```

- Then start another simulation:

```
$ firesim infrasetup && firesim runworkload
```

Basic Benchmarking

- The workload first runs John the Ripper's low-level self-tests and benchmarks to measure raw hash performance
  - Passwords constitute a less optimal input for the accelerator
  - Many unrelated messages much shorter than the block size (1088 bits)
- "Crypts per second" (C/s) metric
  - *Real*: elapsed real time
  - *Virtual*: total CPU time

```
Benchmarking: Raw-SHA3-256 [SHA3 256 32/64]... DONE
Raw:    164928 c/s real, 164928 c/s virtual

Benchmarking: Raw-SHA3-256-rocc [SHA3 256 32/64]... DONE
Raw:    10171K c/s real, 10222K c/s virtual
```

Password Solving

- In the second half of the workload, the SHA-3 accelerator is used to attack sample hashes from the default wordlist
- `john` is given input files of one hash per line, unsalted for simplicity:

```
hash_0:be87f99a67e48ec4ec9f05b565f6ca531e24b9c71a62cfd3a58f54ebc60115ea
hash_1:f706280cdf972ed4af636d540e7d2ea2ff3e9f91e63bc389b2aa0fa288c486a9
hash_2:2cd81e6887b1618af765e2bc127f68b563e6a1b4abd397331b759f878eb8515e
hash_3:9cdc6b9ff3d0d0a90cb8670fb972debc08947697c6b63903458abbaaa0fe93c9
```

- The companion “sha3-linux-jtr-crack” workload includes a more challenging scenario that tests the incremental (brute-force) mode

Capturing Results

- Once the workload terminates automatically, the results are copied to the manager instance:

```
FireSim Simulation Exited Successfully. See results in:
/home/centos/chipyard/sims/firesim/deploy/results-workload/2022-06-17--00-38-00-sha3-linux-jtr-test/
```

- The exact directory path will contain a different timestamp
- Console output recorded in `sha3-linux-jtr-test0/uartlog`
- HW configuration in `sha3-linux-jtr-test0/HW_CFG_SUMMARY`