FireSim

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

https://fires.im

@firesimproject

MICRO Tutorial 2021

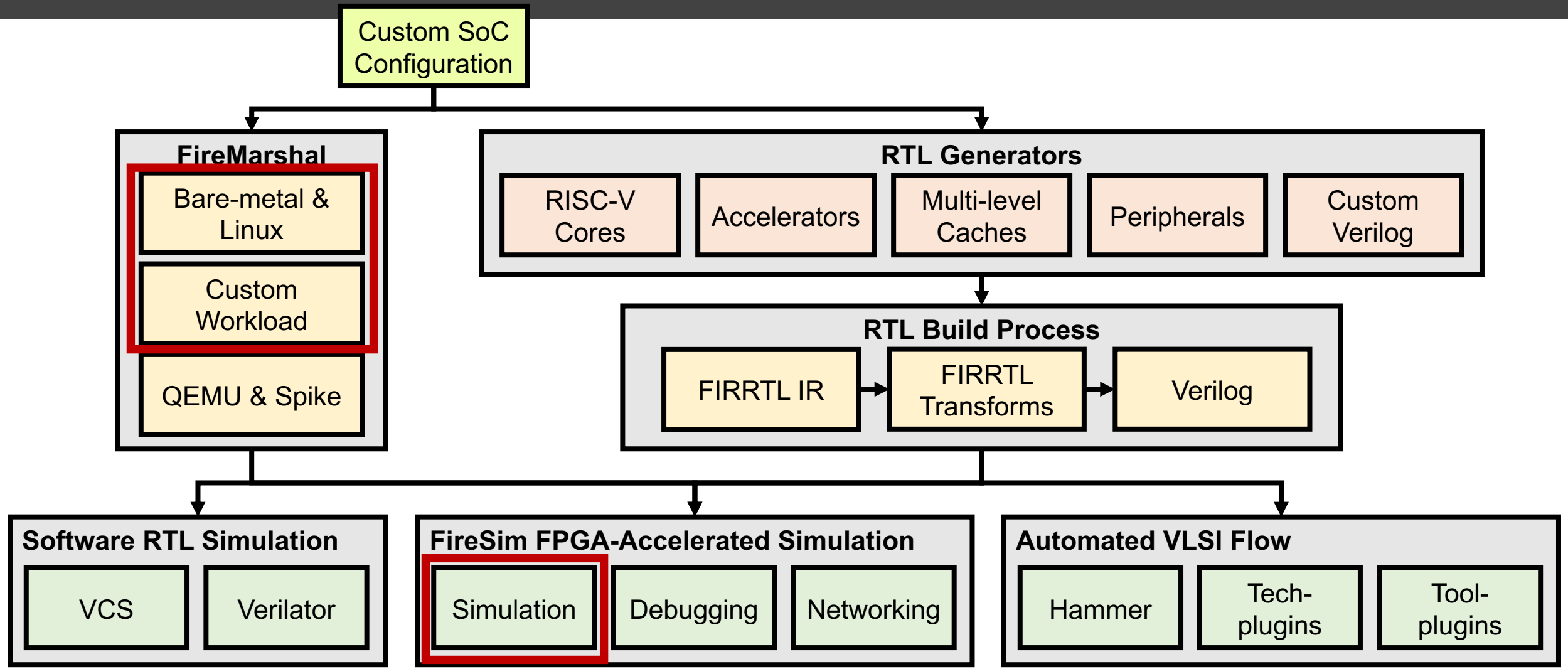
Albert Ou

Berkeley Architecture Research

Agenda

- Configure and launch a simulation runfarm
- Boot Linux interactively on the target hardware
- Run custom automated workloads
- Demonstrate a complex Linux application (John the Ripper) that exercises an example SHA-3 accelerator

Tutorial Roadmap



Prerequisites

- Interactive shell commands are highlighted in blue blocks (prefixed with a "`$`" prompt)
- Initialize the shell environment:
  - `FDIR` variable refers to the top FireSim directory within Chipyard

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

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

Runtime Configuration

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

- 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

Refer to FireSim documentation for explanation of all parameters:
https://docs.fires.im/en/latest/Advanced-Usage/Manager/Manager-Configuration-Files.html

config_runtime.ini

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

```
[runfarm]
runfarmtag=mainrunfarm

f1_16xlarges=1
m4_16xlarges=0
f1_4xlarges=0
f1_2xlarges=0

runinstancemarket=ondemand
spotinterruptionbehavior=terminate
spotmaxprice=ondemand
```

config_runtime.ini

The `[targetconfig]` section specifies the high-level configuration of the system to simulate

```
[targetconfig]
topology=example_8config
no_net_num_nodes=2
linklatency=6405
switchinglatency=10
netbandwidth=200
profileinterval=-1

defaulthwconfig=firesim-rocket-quadcore-nic-l2-llc4mb-ddr3
```

`defaulthwconfig` references an entry from `config_hwdb.ini`

config_runtime.ini

Configuration sections for various instrumentation facilities

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

config_runtime.ini

The `[workload]` section specifies the software to be executed on the simulated system

```
[workload]
workloadname=linux-uniform.json
terminateoncompletion=no
suffixtag=
```

- Workload definitions located in `$FDIR/deploy/workloads/*.json`
- Some sample workloads are provided, including those to reproduce experiments from ISCA 2018 paper

Custom FireSim Workloads

- *Workload*: Specification for a series of jobs (software configurations) assigned to run on individual simulated nodes
- 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 (**SPEC CPU2017**)
- Can be manually written or generated by FireMarshal

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

Building linux-uniform

`linux-uniform` corresponds to `br-base` FireMarshal workload

```
$ cd ~/chipyard/software/firemarshal
$ marshal -v build boards/firechip/base-workloads/br-base.json
```

Single-Node Simulation

Edit `config_runtime.ini` to match the following settings:

```
[runfarm]
f1_16xlarges=0
f1_2xlarges=1

[targetconfig]
topology=no_net_config
no_net_num_nodes=1

defaulthwconfig=firesim-rocket-quadcore-no-nic-l2-llc4mb-ddr3
```

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

Launching Simulation Instances

```
$ firesim launchrunfarm
```

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

Waiting for instance boots: 0 f1.16xlarges
Waiting for instance boots: 0 f1.4xlarges
Waiting for instance boots: 0 m4.16xlarges
Waiting for instance boots: 1 f1.2xlarges
i-053d65f4b514170be booted!
The full log of this run is:
/home/centos/chipyard/sims/firesim/deploy/logs/2021-06-18--00-32-29-launchrunfarm-
VAEU6Y2339M00YH1.log
```

Deploying Simulation Infrastructure

```
$ firesim infrasetup
```

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
- Builds and loads the XDMA kernel driver
- Loads the NBD kernel driver for mounting qcow2 disk images
- Programs the FPGAs with the desired AGFIs

Deploying Simulation Infrastructure

```
$ firesim infrasetup
```

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

Building FPGA software driver for FireSim-DDR3FRFCFSLLC4MB_WithDefaultFireSimBridges_WithFireSimTestChipConfigTweaks_chipyard.QuadRocketConfig-
WithAutoILA_F90MHz_BaseF1Config
[192.168.3.73] Executing task 'instance_liveness'
[192.168.3.73] Checking if host instance is up...
[192.168.3.73] Executing task 'infrasetup_node_wrapper'
[192.168.3.73] Copying FPGA simulation infrastructure for slot: 0.
[192.168.3.73] Installing AWS FPGA SDK on remote nodes. Upstream hash: 6c707ab4a26c2766b916dad9d40727266fa0e4ef
[192.168.3.73] Unloading XDMA/EDMA/XOCL Driver Kernel Module.
[192.168.3.73] Copying AWS FPGA XDMA driver to remote node.
[192.168.3.73] Unloading XDMA/EDMA/XOCL Driver Kernel Module.
[192.168.3.73] Loading XDMA Driver Kernel Module.
[192.168.3.73] Setting up remote node for qcow2 disk images.
[192.168.3.73] Unloading NBD Kernel Module.
[192.168.3.73] Disconnecting all NBDs.
[192.168.3.73] Loading NBD Kernel Module.
[192.168.3.73] Clearing FPGA Slot 0.
[192.168.3.73] Checking for Cleared FPGA Slot 0.
[192.168.3.73] Flashing FPGA Slot: 0 with agfi: agfi-0a6cbb217f7cc16d6.
[192.168.3.73] Checking for Flashed FPGA Slot: 0 with agfi: agfi-0a6cbb217f7cc16d6.
[192.168.3.73] Unloading XDMA/EDMA/XOCL Driver Kernel Module.
[192.168.3.73] Loading XDMA Driver Kernel Module.
[192.168.3.73] Starting Vivado hw_server.
[192.168.3.73] Starting Vivado virtual JTAG.
The full log of this run is:
/home/centos/chipyard/sims/firesim/deploy/logs/2021-06-18--00-44-47-infrasetup-3DIBA22C96MNT5GN.log
```

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/2021-06-18--01-02-45-linux-uniform/
[192.168.3.73] Executing task 'instance_liveness'
[192.168.3.73] Checking if host instance is up...
[192.168.3.73] Executing task 'boot_switch_wrapper'
[192.168.3.73] Executing task 'boot_simulation_wrapper'
[192.168.3.73] Starting FPGA simulation for slot: 0.
[192.168.3.73] Executing task 'monitor_jobs_wrapper'
```

Monitoring the Simulation

You should see a live status report that refreshes periodically:

```
FireSim Simulation Status @ 2021-06-18 01:03:54.145398
--------------------------------------------------------------------------------
This workload's output is located in:
/home/centos/chipyard/sims/firesim/deploy/results-workload/2021-06-18--01-02-45-
linux-uniform/
This run's log is located in:
/home/centos/chipyard/sims/firesim/deploy/logs/2021-06-18--01-02-45-runworkload-
8Y0DIA0UA7RIEBTL.log
This status will update every 10s.
--------------------------------------------------------------------------------
Instances
--------------------------------------------------------------------------------
Instance IP:   192.168.3.73 | Terminated: False
--------------------------------------------------------------------------------
Simulated Switches
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Simulated Nodes/Jobs
--------------------------------------------------------------------------------
Instance IP:   192.168.3.73 | 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 @ 2021-06-18 01:03:54.145398
--------------------------------------------------------------------------------
This workload's output is located in:
/home/centos/chipyard/sims/firesim/deploy/results-workload/2021-06-18--01-02-45-
linux-uniform/
This run's log is located in:
/home/centos/chipyard/sims/firesim/deploy/logs/2021-06-18--01-02-45-runworkload-
8Y0DIA0UA7RIEBTL.log
This status will update every 10s.
--------------------------------------------------------------------------------
Instances
--------------------------------------------------------------------------------
Instance IP:   192.168.3.73 | Terminated: False
--------------------------------------------------------------------------------
Simulated Switches
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
Simulated Nodes/Jobs
--------------------------------------------------------------------------------
Instance IP:   192.168.3.73 | 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 simulation instance:

```
$ ssh 192.168.3.73
```

```
 ___ ___ ___   _     ___ _____  __    _   __ __ ___
| __| _ \/ __| /_\   |   \ __\ \ / /   /_\ |  \/  |_ _|
| _||  _/ (_ |/ _ \  | |) | _| \ V /   / _ \| |\/| || |
|_| |_|  \___/_/ \_\ |___/|___| \_/   /_/ \_\_|  |_|___|
AMI Version:          1.6.1
Xilinx Version:       2018.3
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
Developer Support:    https://github.com/aws/aws-fpga/blob/master/README.md#developer-support
Centos Common code: /srv/git/centos-git-common
Xilinx XRT source:    https://github.com/Xilinx/XRT
```

- 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, cleanly shut down the system

```
# poweroff
```

- This will then end the simulation automatically

John the Ripper

- Open-source password cracking 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
  - `JohnTheRipper/src/sha3_256_rocc_fmt_plug.c`
  - The `crypt_all()` function performs the actual hashing
- Minor Linux kernel patches to facilitate accelerator context switching

Defining a New Hardware Configuration

John the Ripper requires a custom target configuration that instantiates the SHA-3 accelerator

- Add to `config_build_recipes.ini`:

```
[firesim-rocket-singlecore-sha3-no-nic-l2-llc4mb-ddr3]
DESIGN=FireSim
TARGET_CONFIG=DDR3FRFCFSLLC4MB_WithDefaultFireSimBridges_WithFireSimConfigT
weaks_chipyard.Sha3RocketConfig
PLATFORM_CONFIG=WithAutoILA_F110MHz_BaseF1Config
instancetype=z1d.2xlarge
deploytriplet=None
```

Same SHA3-accelerated SoC design generated during the morning Chipyard session

Building a New Hardware Configuration

- Set in `config_build.ini`:

```
[builds]
firesim-rocket-singlecore-sha3-no-nic-l2-llc4mb-ddr3
# Comment out all other entries
```

- Build custom AGFI:

```
$ firesim buildagfi
```

- Update `config_hwdb.ini`:

```
$ cd $FDIR/deploy
$ cat built-hwdb-entries/firesim-*-sha3-* >> config_hwdb.ini
```

Configuring a New Workload

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

```
$ cd ~/chipyard/generators/sha3/software
$ marshal -v build marshal-configs/sha3-linux-jtr-test.json
$ marshal install marshal-configs/sha3-linux-jtr-test.json
```

- Update `config_runtime.ini` accordingly:

```
defaulthwconfig=firesim-singlecore-sha3-no-nic-l2-llc4mb-ddr3
workloadname=sha3-linux-jtr-test.json
```

```
$ 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:    66423 c/s real, 66756 c/s virtual

Benchmarking: Raw-SHA3-256-rocc [SHA3 256 32/64]... DONE
Raw:    3037K c/s real, 3037K c/s virtual
```

Password Cracking

- 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/2021-06-18--01-09-42-
sha3-linux-jtr-test/
```

- The exact directory path will contain a different timestamp
- Console output recorded in `sha3-linux-jtr-test0/uartlog`
  - As well as other output files named in the workload definition

Password Cracking

- “sha3-linux-jtr-crack” includes two different tests
  1. A short test based on passwords present in the default wordlist
  2. A long test that resorts to incremental (brute-force) mode

- Repeat the same procedure as “sha3-linux-jtr-test”
  - Use the same AGFI: `firesim-singlecore-sha3-no-nic-l2-llc4mb-ddr3`
  - Generate the workload definition with `marshal`
  - Edit `config_runtime.ini` to reference this workload

- Start the simulation and attach the UART console to watch progress

Killing a Simulation

- Brute-forcing the last hash takes a few minutes of simulated time
- Too long to complete at this tutorial
- To stop a simulation in the middle:

```
$ firesim kill
```

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

[192.168.3.73] Executing task 'kill_switch_wrapper'
[192.168.3.73] Executing task 'kill_simulation_wrapper'
[192.168.3.73] Killing FPGA simulation for slot: 0.
[192.168.3.73] Disconnecting all NBDs.
[192.168.3.73] Executing task 'screens'
Confirming exit...
```

Terminating Simulation Instances

```
$ firesim terminaterunfarm
```

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

IMPORTANT!: This will terminate the following instances:
f1.16xlarges
[]
f1.4xlarges
[]
m4.16xlarges
[]
f1.2xlarges
['i-053d65f4b514170be']
Type yes, then press enter, to continue. Otherwise, the operation will be cancelled.

yes

Instances terminated. Please confirm in your AWS Management Console.
```

Type yes at the prompt to confirm

Workflow Summary

1. Build an AGFI (“Building Hardware Designs in FireSim” session)
2. Build target software (“Building Software Workloads with FireMarshal” session)
3. Customize `config_runtime.ini`
4. `firesim launchrunfarm`
5. `firesim infrasetup`
6. `firesim runworkload`
7. `firesim terminaterunfarm`