



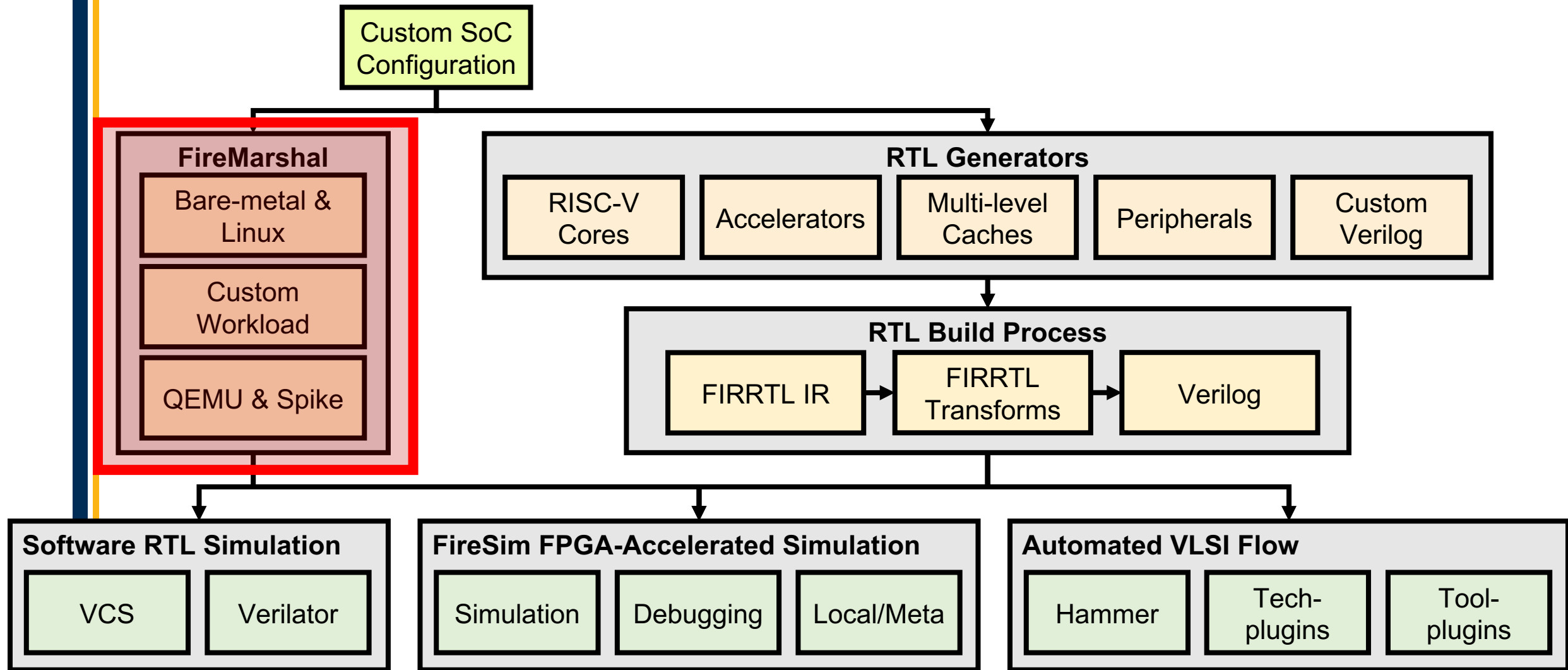
FireMarshal

Software Workload Management

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Tutorial Roadmap



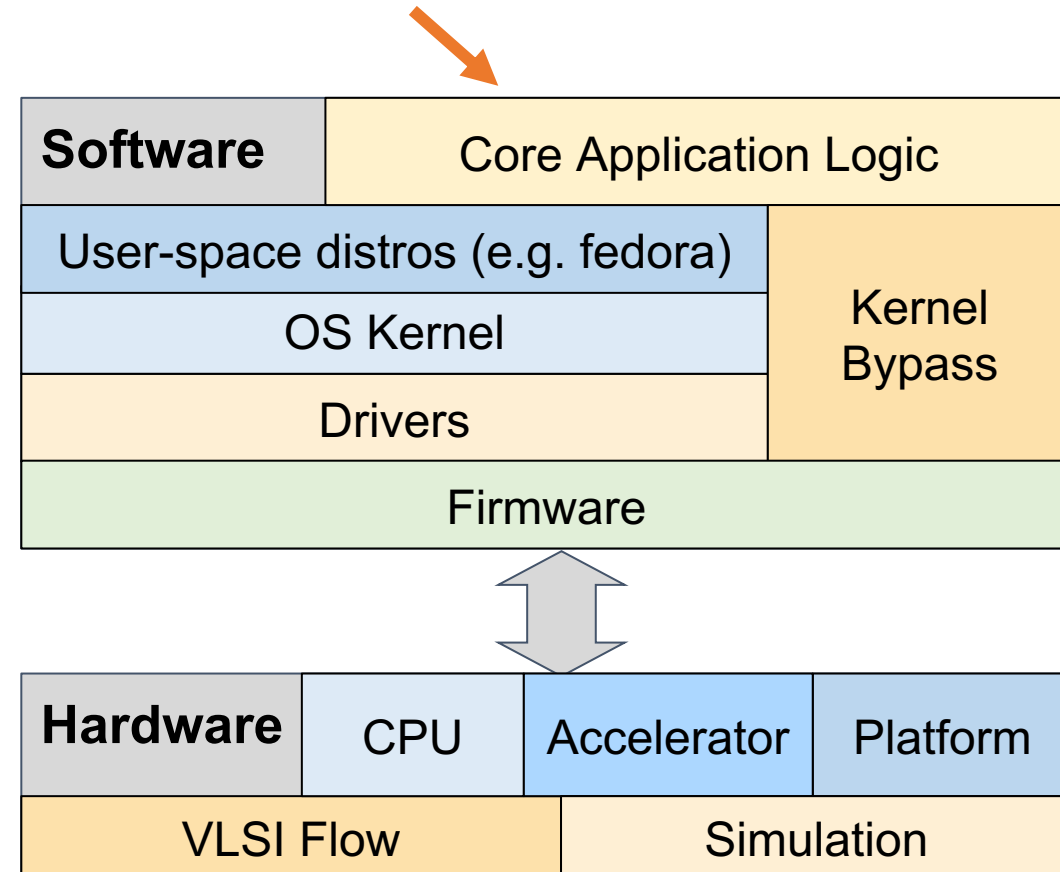


Software Workload Management

Workload Management Tasks:

- Building Binaries and Filesystems
- Experiment Management
 - Inputs and outputs
 - Repeatable execution
 - Multiple levels of simulation
- Reproducibility and Reusability
 - Share workloads with the community

Provided by FireMarshal



Provided by Chipyard



Hardware/Software Co-Design Flow

Requirements

Write Spec

Super_Cool_accel.md

Functional Model

Spike_{sca}

Write HW/SW

sca.rtl

sca.img/bin

Evaluate

FireSim



Tool Challenges

Write Spec

Super_Cool_accel.md

Functional Model

Spike_{sca}

Write HW/SW

sca.rtl

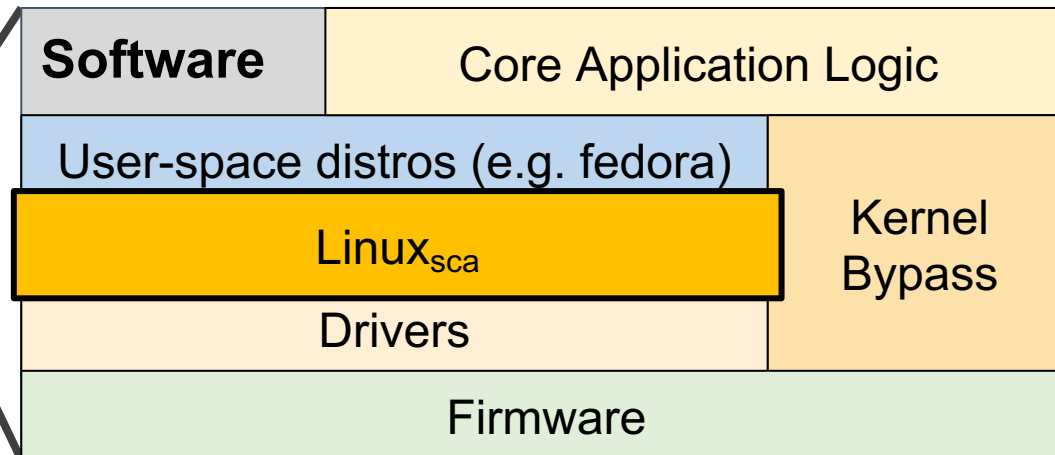
sca.img/bin

Evaluate

FireSim

Requirements

1. **Flexible Design:** Can change anything, without changing everything





Tool Challenges

Write Spec

Super_Cool_accel.md

Functional Model

Spike_sca

RTL.git

Write HW/SW

sca.rtl

sca.img/bin

???

Evaluate

FireSim

linux.git
mitsuba.git
openSBI.git
benchmark.git

buildOS.sh
linkSBI.sh
convertImg.sh

Requirements

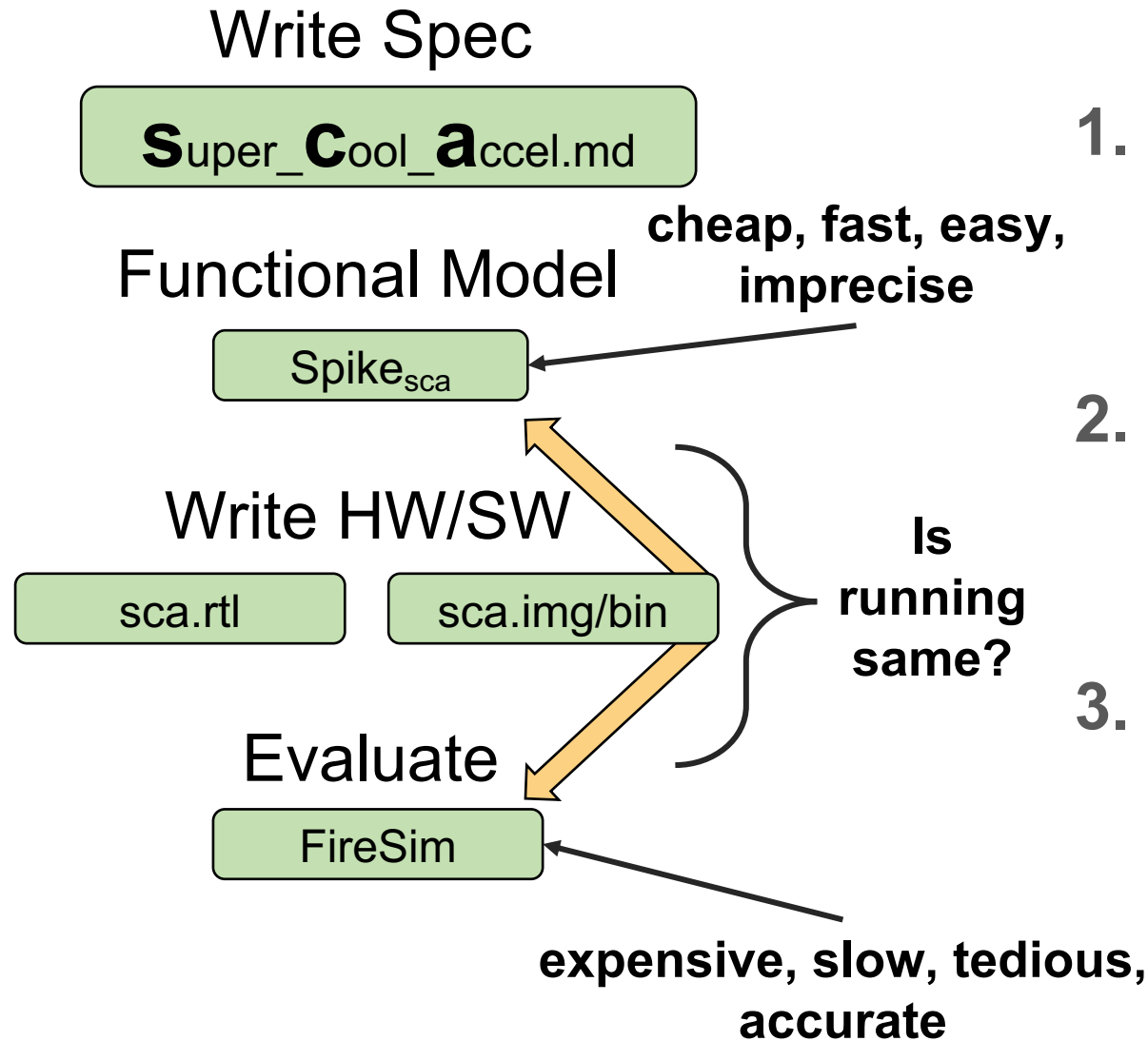
1. **Flexible Design:** Can change anything, without changing everything
2. **Maximal Reuse:** Can rebuild from unambiguous description and without inside knowledge



Alice: How big was your image?
Bob: lol, idk. Like 256kB? maybe?
Alice: I'll just try something



Tool Challenges



Requirements

1. **Flexible Design:** Can change anything, without changing everything
2. **Maximal Reuse:** Can rebuild from unambiguous description and without inside knowledge
3. **Flexible Simulation:** Minimize SW differences across simulation levels



Where FireMarshal comes in...

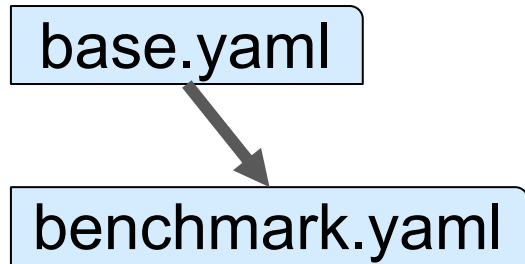


FireMarshal Workflow



FireMarshal Workflow

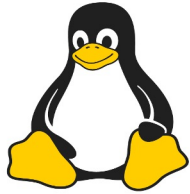
Specify a “workload”





What's in a "workload"?

Sources



OpenSBI

Inputs/Outputs

Overlays

```
/etc
/init.d
/S20foo
```

File Lists

```
["/res.csv",
"/cfg.json"]
```

Serial Console

```
# vda mounted
# run /init
experiment start
time: 50s
# poweroff
```

User Scripts

```
host_setup.sh
```

```
target_setup.sh
```

```
on_boot.sh
```

```
after_run.sh
```

Miscellaneous

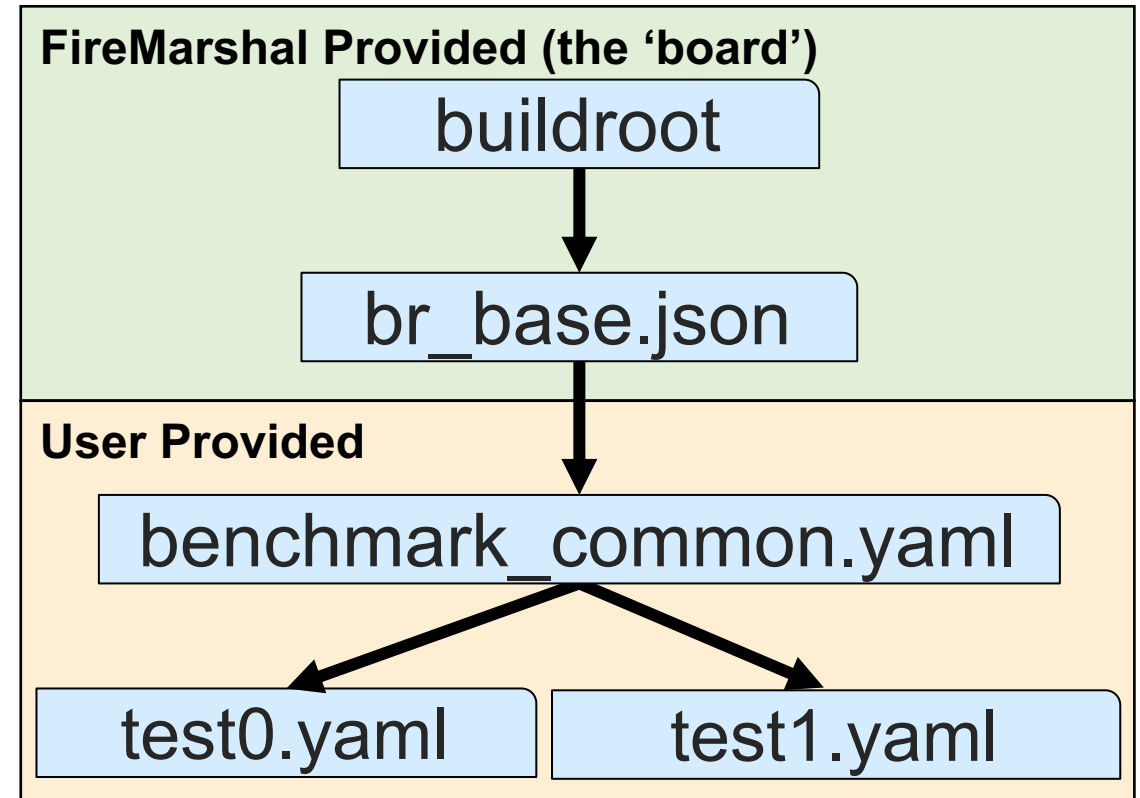
Option	Description
base	Start from a pre-existing workload - inherit all options unless explicitly overridden
overlay/files	Files to include in the image (e.g. utilities, benchmarks, config files, etc...)
host-init	Script to run before building (e.g. cross-compile)
guest-init	Script to run once on guest (e.g. install packages)
run/command	Script to run every time the image boots (e.g. default experiment)
outputs	Files to copy out of the image after an experiment
post-run-hook	Script to run on the output of the experiment (parse or format results)
linux	Linux customization options including Linux source directory, kernel configuration options to modify, as well as any needed kernel module sources
firmware	Firmware-related options including choice of firmware, and build options.
spike	custom Spike binary to use
spike/qemu-args	Additional arguments to pass to functional simulators
jobs	Additional, related images to build (e.g. each node of a networked workload)





Enabling Reuse

- **Inheritance:** Workloads are relative to a “base”
 - Inheritance rules vary by option
- **The “Board”:** Sane defaults for a hardware platform
- **User Hierarchies:** arbitrary inheritance tree

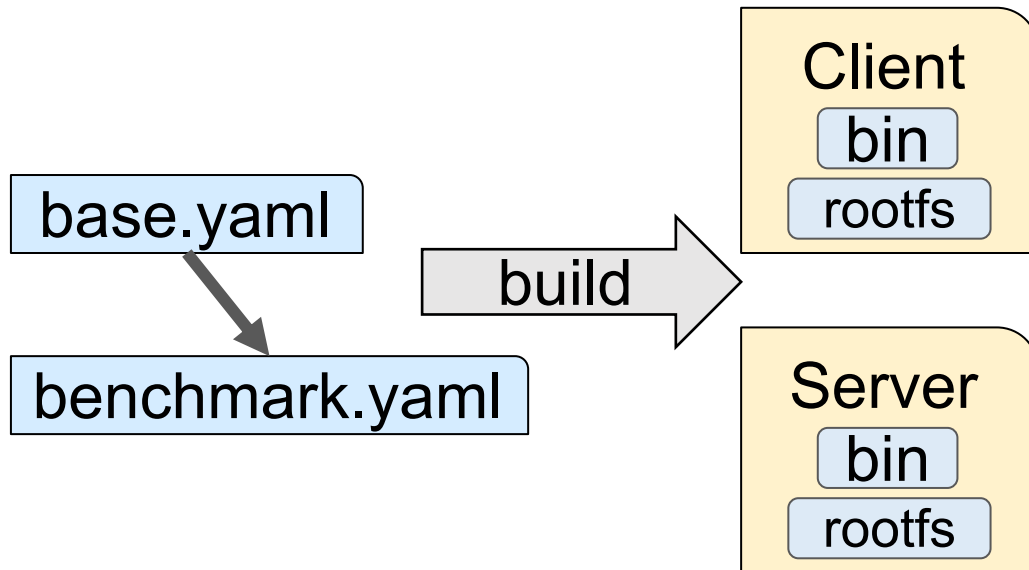




FireMarshal Workflow

Specify

Build





Build Steps

- Construct software artifacts
 - Make-like dependency tracking
- Steps
 1. Run workload setup script (host-init)
 2. Recursively construct parent images
 3. Compile Linux kernel and link firmware
 4. Copy parent image and modify as needed

```
$ marshal build example.json
. build.sh
Applying host-init: build.sh
-- BuildBusybox
. br-base/host-init.sh
Applying host-init: br-base/host-init.sh
-- br.04dc.img
. calc_br-base_dep
-- br-base.img
-- parent-bin
. calc_parent_dep
-- parent.img
. example-bin
. calc_example-test_dep
. example.img
Applying file list: ...
Applying run command: /root/test.sh
Log available at: logs/example-build.log
```



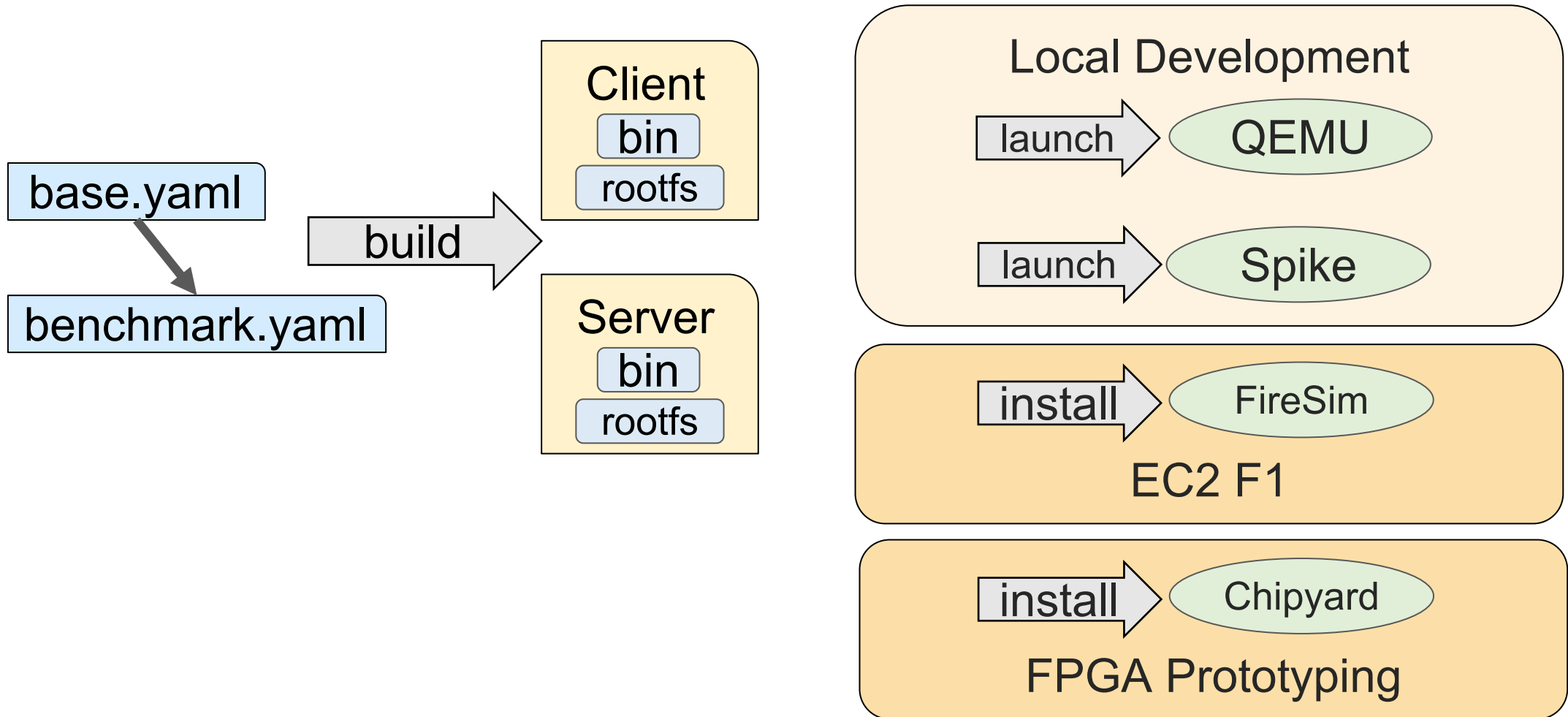
FireMarshal Workflow

Specify

Build

Install

Launch





Launch Workload in SW Sims

- Run workload in built-in functional simulation
 - QEMU
 - Spike
 - *Your tool here*
- Steps
 1. Boot Linux
 2. Automatically run benchmark
 3. Return serial and file outputs

```
$ marshal launch example.json
```

```
Linux version 5.7.0-rc3
```

```
earlycon: sbi0 at I/O port 0x0
```

```
printk: bootconsole [sbi0] enabled
```

```
...
```

```
launching workload run/command
```

```
Start basic test 1.
```

```
output[0]:203 ==? results[0]:203
```

```
output[1]:52 ==? results[1]:52
```

```
output[2]:27 ==? results[2]:27
```

```
Success!
```

```
execution took 8 cycles
```

```
reboot: Power down
```

```
Workload outputs available at:
```

```
output/example-launch/
```

```
Log available at: logs/example-launch.log
```




Install To Other Tools

- Hook to export workload to external tools
 - FireSim and Chipyard FPGA prototyping supported
 - Extensible to other simulation infrastructures
- Does *not* rebuild workload: The same workload runs on all platforms
 - Simplify debugging
 - Ensure consistency

```
$ marshal install example.json
```

```
Workload installed to FireSim at  
firesim/example.json
```

```
Log available at:  
logs/example-install.log
```

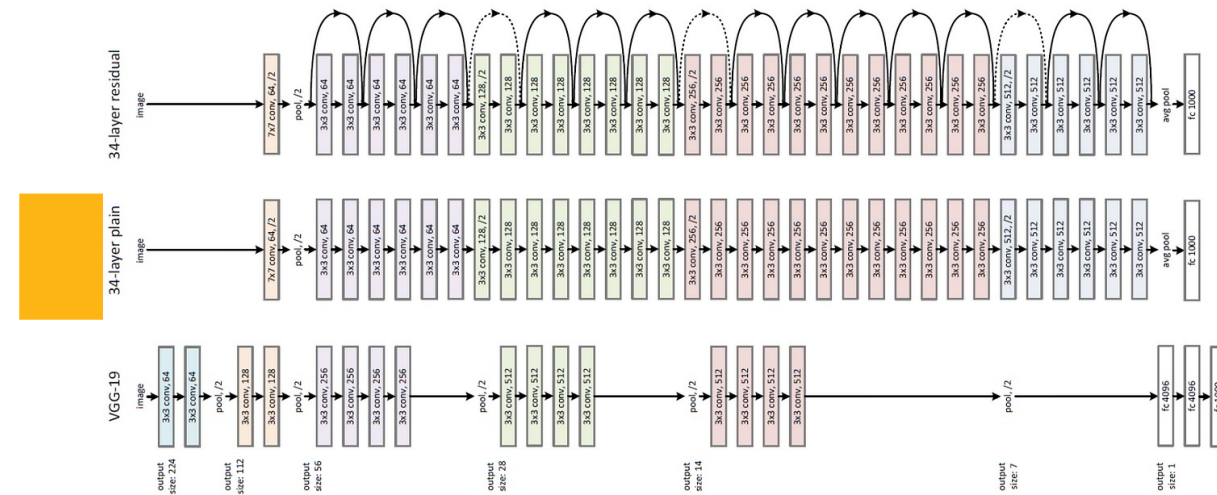
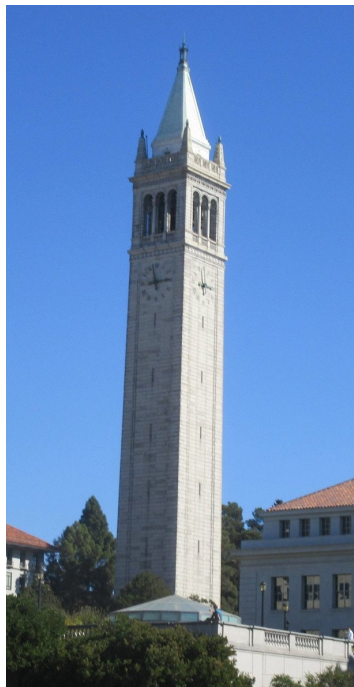


Hands On: Gemmini Workloads



Running ResNet50 on a Gemmini SoC

- ResNet50 – deep learning model used for computer vision
- Gemmini – Berkeley’s machine learning accelerator
- Predicting four unique images



Berkeley Tower!



Workload Inheritance

FireMarshal-Provided

bare-base

br-base

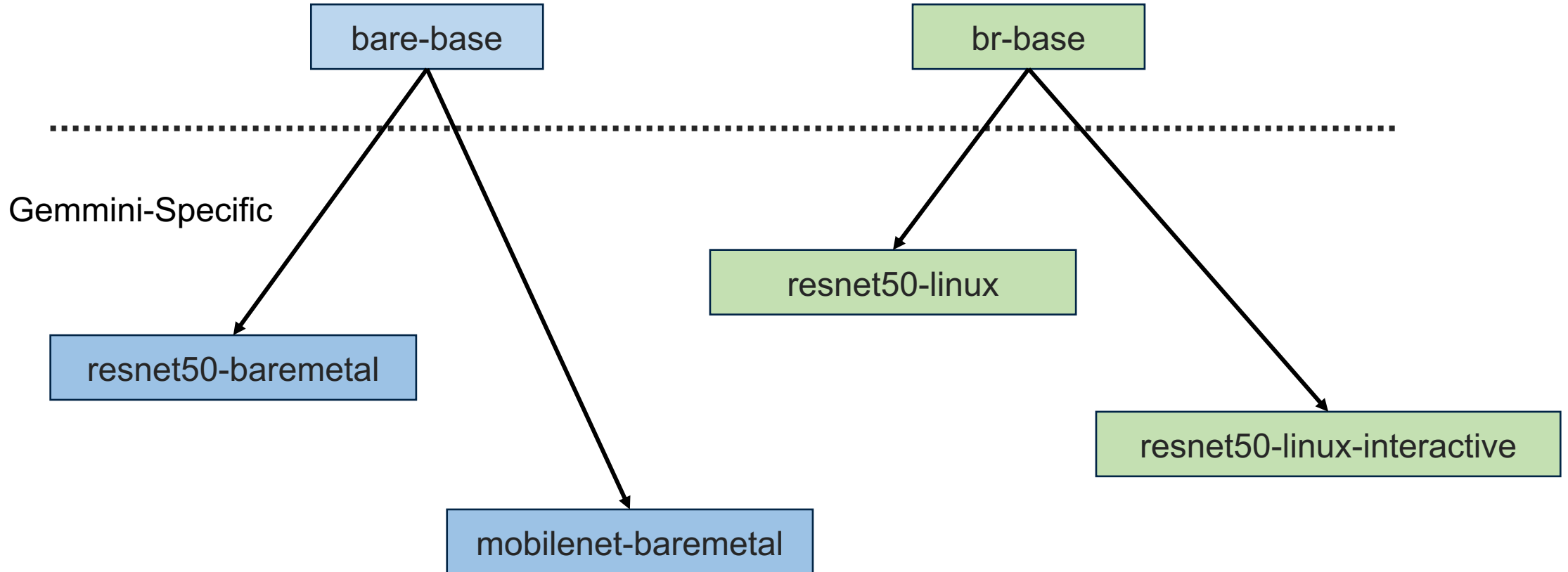
Gemmini-Specific

- FireMarshal provides several “base” workloads to act as starting points for user workloads.
- Today, we will use:
 - “br-base”: Interactive Buildroot-based Linux workload.
 - “bare-base”: A trivial workload used for bare-metal experiments



Workload Inheritance

FireMarshal-Provided





Interactive

Navigate to the Gemmini FireMarshal directory

```
$ cd $ACYDIR/software/tutorial
$ ls

$ cd marshal-configs
$ ls
```

```
chipyard-afternoon/
  software/
    tutorial/
      build.sh
      marshal-configs/
        *.yaml
```



Interactive

```
$ marshal -v build resnet50-linux.yaml
```

- This should take ~3m!
 - Building ResNet-50 for Gemmini
 - Building Linux kernel + disk image
- Next run the Linux simulation with the Gemmini functional model

```
$ marshal launch -s resnet50-linux.yaml
```

- While that is running...

```
chipyard-afternoon/  
software/  
  tutorial/  
    build.sh  
    marshal-configs/  
      *.yaml
```



resnet50-linux.yaml

Script to run on host first
(build.sh cross-compiles
the unit test)

```
{  
  "name" : "resnet50-linux",  
  "base" : "br-base.json",  
  "workdir" : "..",  
  "host-init" : "build.sh",  
  "overlay" : "overlay",  
  "command" : "/root/resnet50-linux"  
  "spike-args" : "--extension=gemmini"  
}
```

Hard-coded binary to use
after Linux boots
(produced by build.sh)

Custom Spike arguments (use
Gemmini functional model)



Running ResNet50 on Linux

- We'll get back to this once complete...

```
chipyard-afternoon/  
  software/  
    tutorial/  
      build.sh  
      marshal-configs/  
        *.yaml
```



More Complex Use-Cases



Multi-Node Workloads (“jobs”)

job-example.yaml

```
{
  "name" : "job-example",
  "base" : "br-base.json",
  "jobs" : [
    { "name" : "node0",
      "command" : "ping -c 1 172.16.0.3",
    },
    { "name" : "node1",
      "command" : "ping -c 1 172.16.0.2",
    }
  ]
}
```

- Each job runs on a single node in multi-node simulations.
- Described the same as any workload
 - implicitly ‘base’d on the enclosing workload
- Runs in parallel in SW simulation
 - FireSim already supported a network



Native Initialization (“guest-init”)

guest-init-example.yaml

```
{  
  “name” : “guest-init-example”,  
  “base” : “fedora-base.json”,  
  “guest-init” : “init.sh”  
}
```

init.sh

```
#!/bin/bash  
yum install -y blas python3 ...  
  
cd cafe2_src/  
make
```

- “guest-init” script is run once on the guest in build
 - Run in QEMU
 - Internet access available
- Useful for
 - Installing packages
 - Natively compiling benchmarks



Results Hooks (“post-run-hook”)

results-example.yaml

```
{  
  "name" : "results-example",  
  "base" : "mytest.yaml",  
  "outputs" : ["/root/res.csv"],  
  "post-run-hook" : "results.py"  
}
```

“post-run-hook” executed on the host after every run

- Good for post-processing of more complex experiments

results.py

```
#!/usr/bin/env python  
from pathlib import Path  
import csv  
  
resultPath = Path(sys.argv[1]) /  
  'results-example' / 'res.csv'  
  
processResult(resultPath)
```

Path to the results directory passed to the script

Do anything you want with the results. For example, copy to a known location, or sanity check



Running ResNet50 on Linux

- By now you should see output like...

```
[ 7.238320] icenet: loading out-of-tree module taints kernel.  
...  
launching firemarshal workload run/command  
Starting test...  
Gemmini extension configured with:  
  dim = 16  
...  
matmul 54 cycles: 2754  
Prediction: 75 (score: 45)  
Prediction: 900 (score: 43)  
Prediction: 641 (score: 40)  
Prediction: 897 (score: 57)  
  
Total cycles: 5142712 (100%)  
Matmul cycles: 681563 (13%)  
Im2col cycles: 0 (0%)  
Conv cycles: 1954627 (38%)  
Pooling cycles: 0 (0%)  
Depthwise convolution cycles: 0 (0%)  
Res add cycles: 2463893 (47%)  
Other cycles: 42629 (0%)  
PASS
```

Predicted 4 images like



“PASS” in the UART output is a success! (ignore the bug in FireMarshal on terminating the workload)

```
chipyard-afternoon/  
software/  
  tutorial/  
    build.sh  
    marshal-configs/  
      *.yaml
```



Exporting to FireSim



Interactive

Install the baremetal ResNet50 workload to FireSim

```
$ marshal install resnet50-baremetal.yaml
```

View the installed FireSim-specific collateral

```
$ cd $FDIR/deploy/workloads  
$ cat resnet50-baremetal.json
```

```
chipyard-afternoon/  
software/  
  tutorial/  
    build.sh  
    marshal-configs/  
      *.yaml
```

Prefetching for future sections



Many many more features!

<https://firemarshal.readthedocs.io/en/stable/>