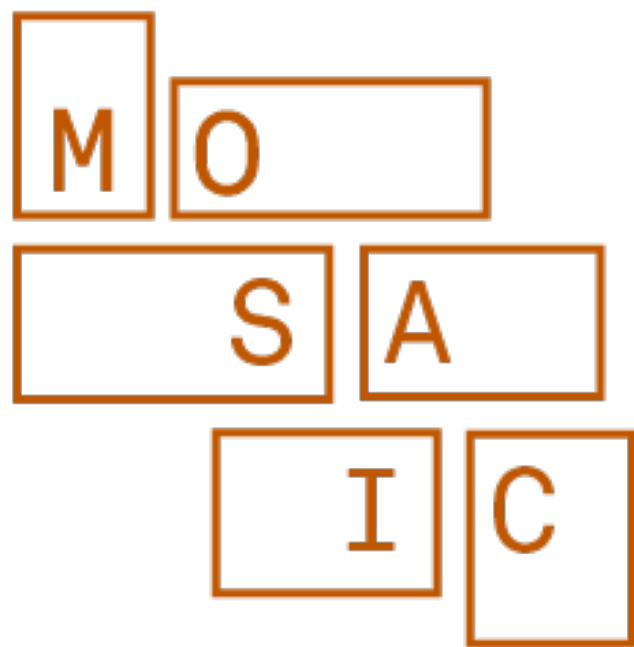




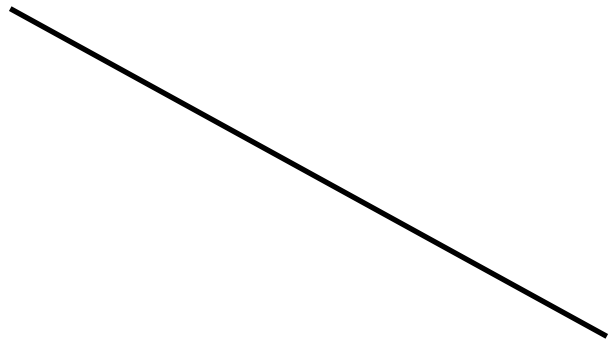
Mosaic: Cross-platform User-interaction Record and Replay for the Fragmented Android Ecosystem

Matthew Halpern, Yuhao Zhu, Ramesh Peri*, Vijay Janapa Reddi
Department of Electrical and Computer Engineering, UT Austin
*Intel Corporation

ISPASS - March 31st, 2015

Building **Better** Computer Systems

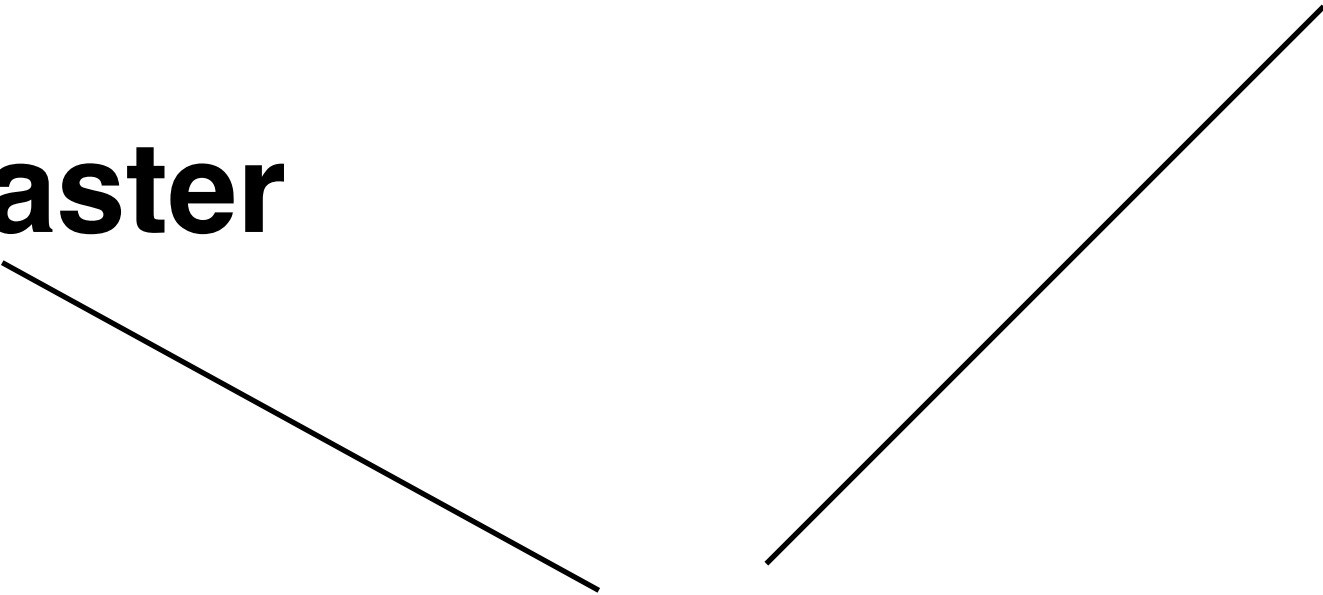
Run **faster**



Building **Better** Computer Systems

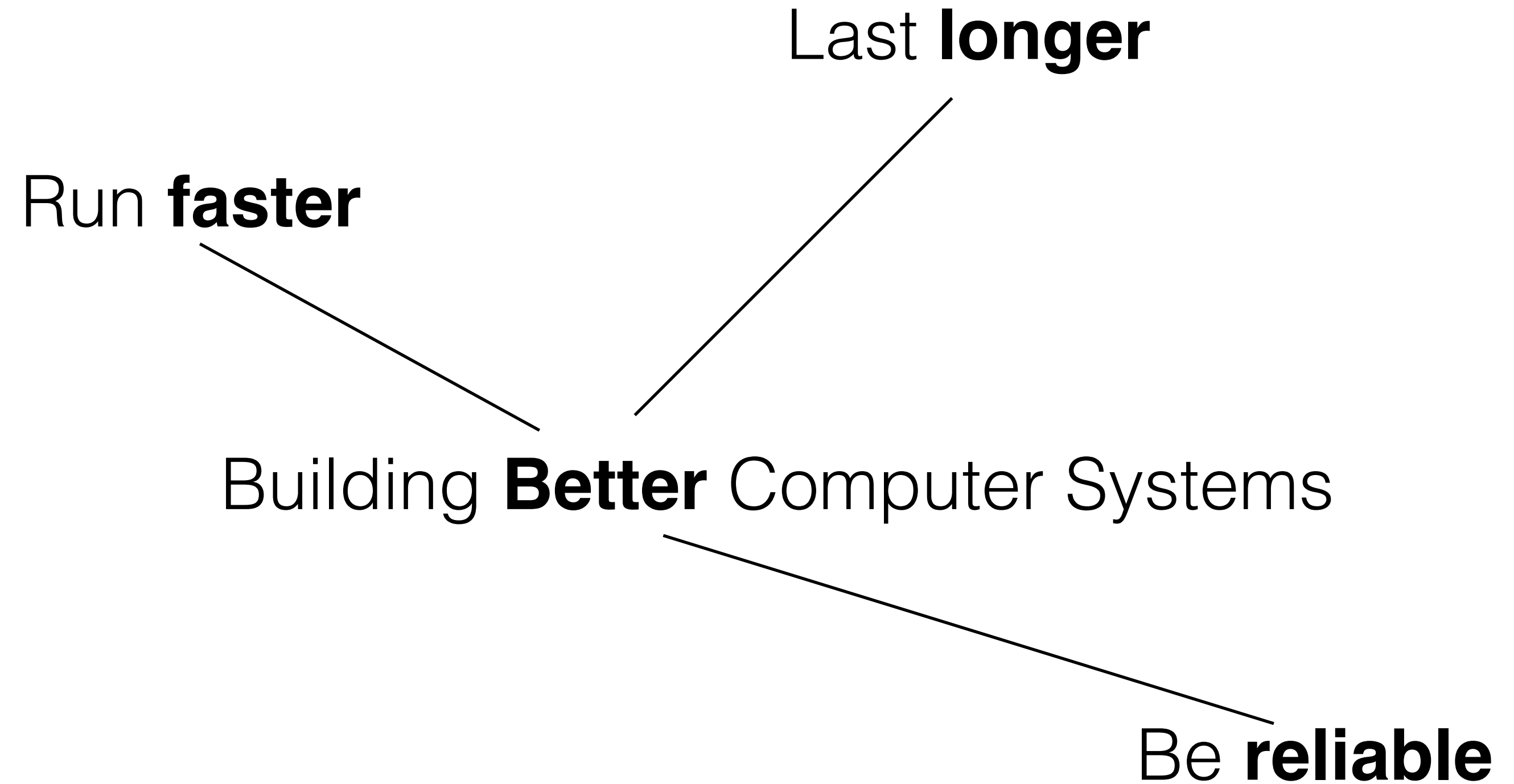
Last **longer**

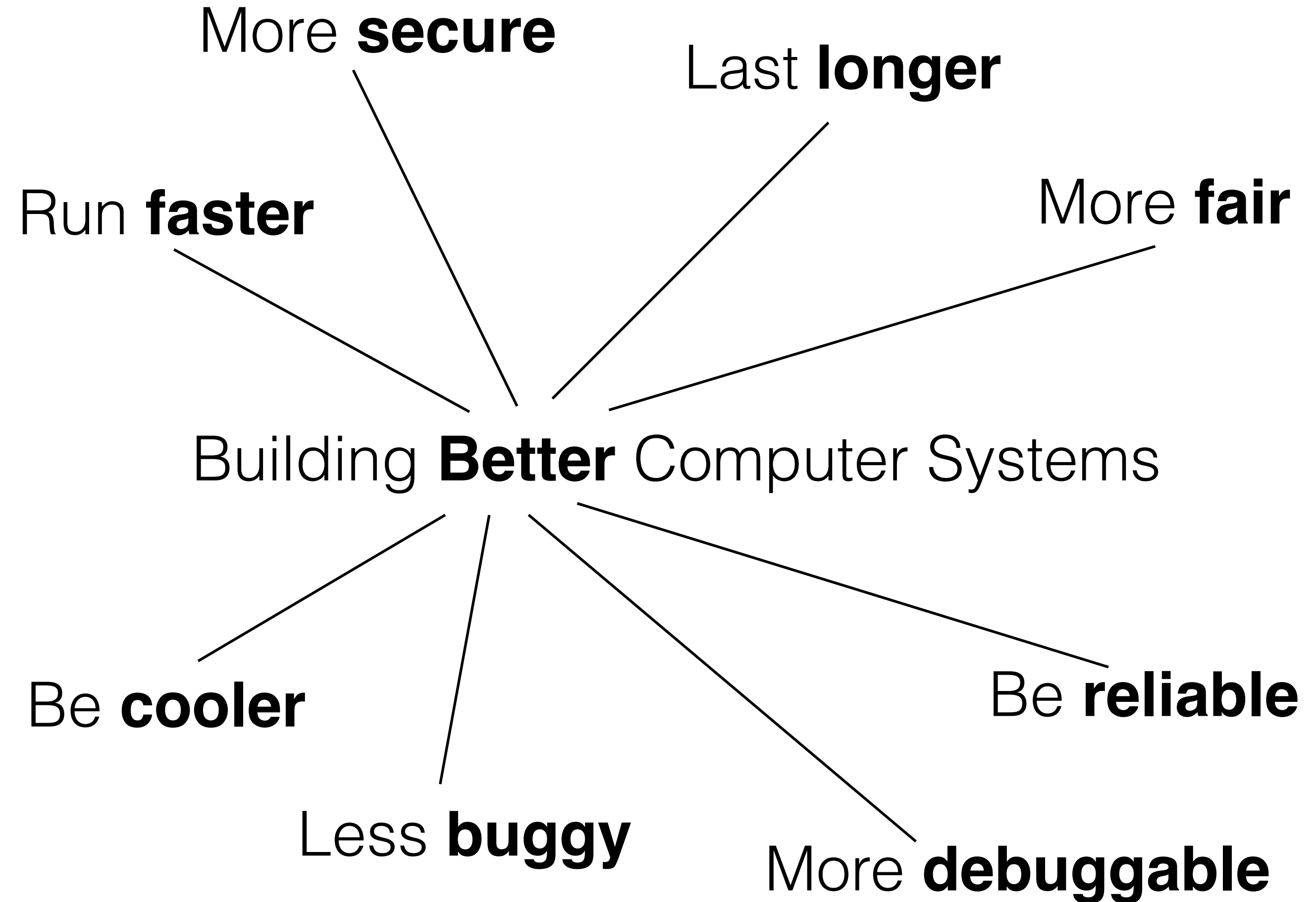
Run **faster**



```
graph TD; A[Run faster] --> C[Building Better Computer Systems]; B[Last longer] --> C;
```

Building **Better** Computer Systems





Building “**Better**” Computer Systems

How Do We Know We Are
Building “**Better**” Computer Systems?

How Do We Know We Are
Building “**Better**” Computer Systems?

We compare them.

Quantitative Performance Comparisons

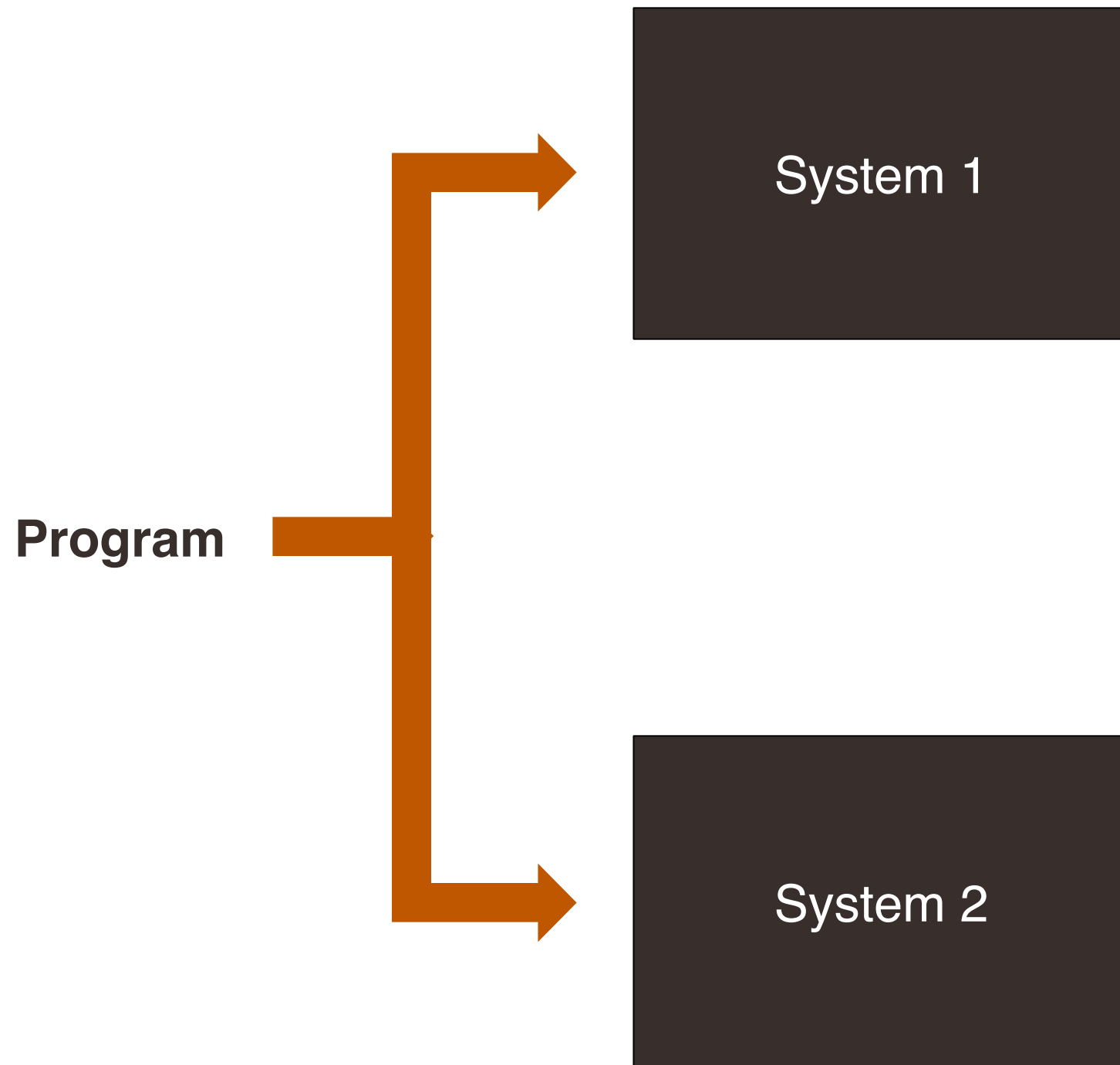
Quantitative Performance Comparisons



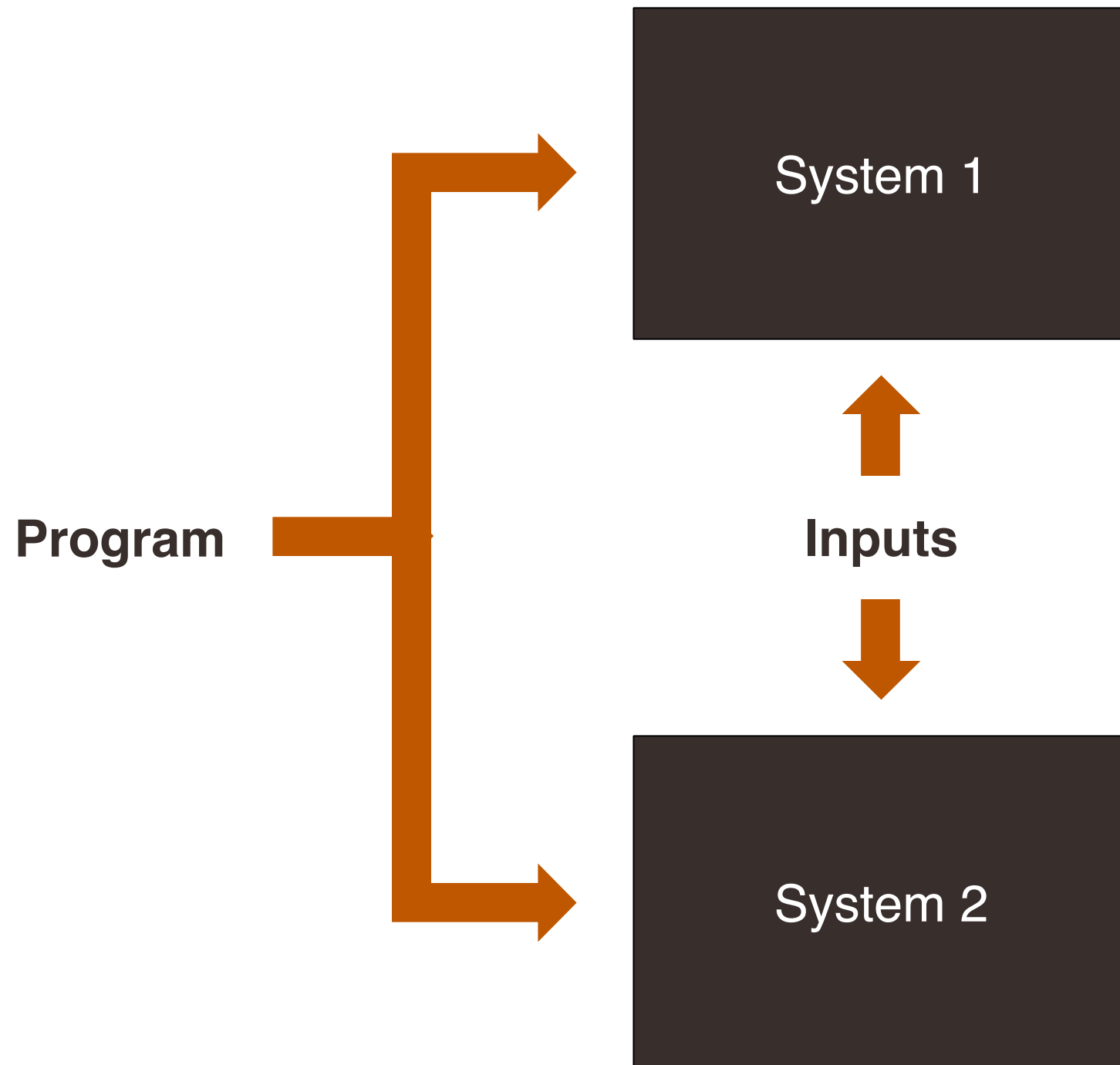
System 1

System 2

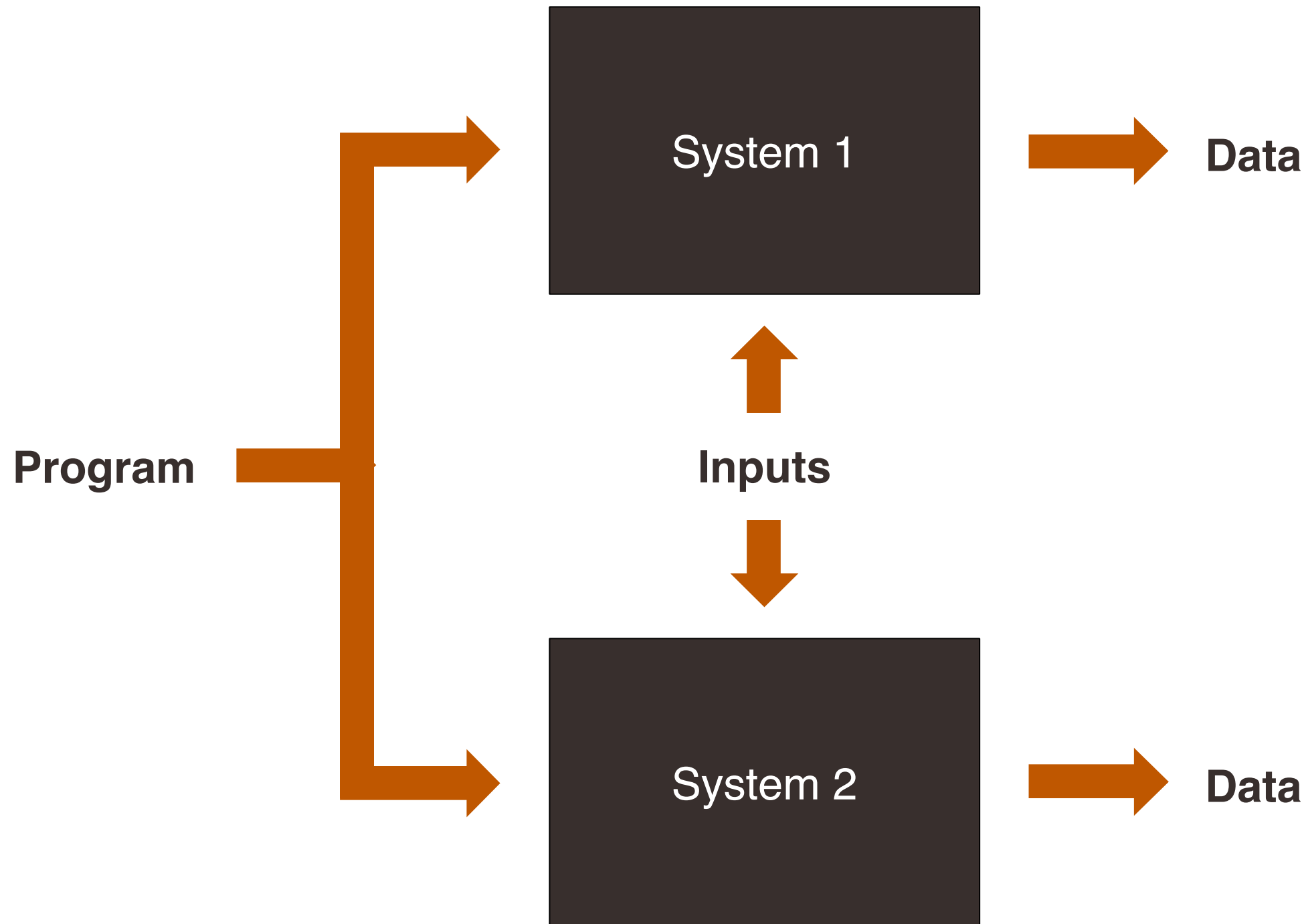
Quantitative Performance Comparisons



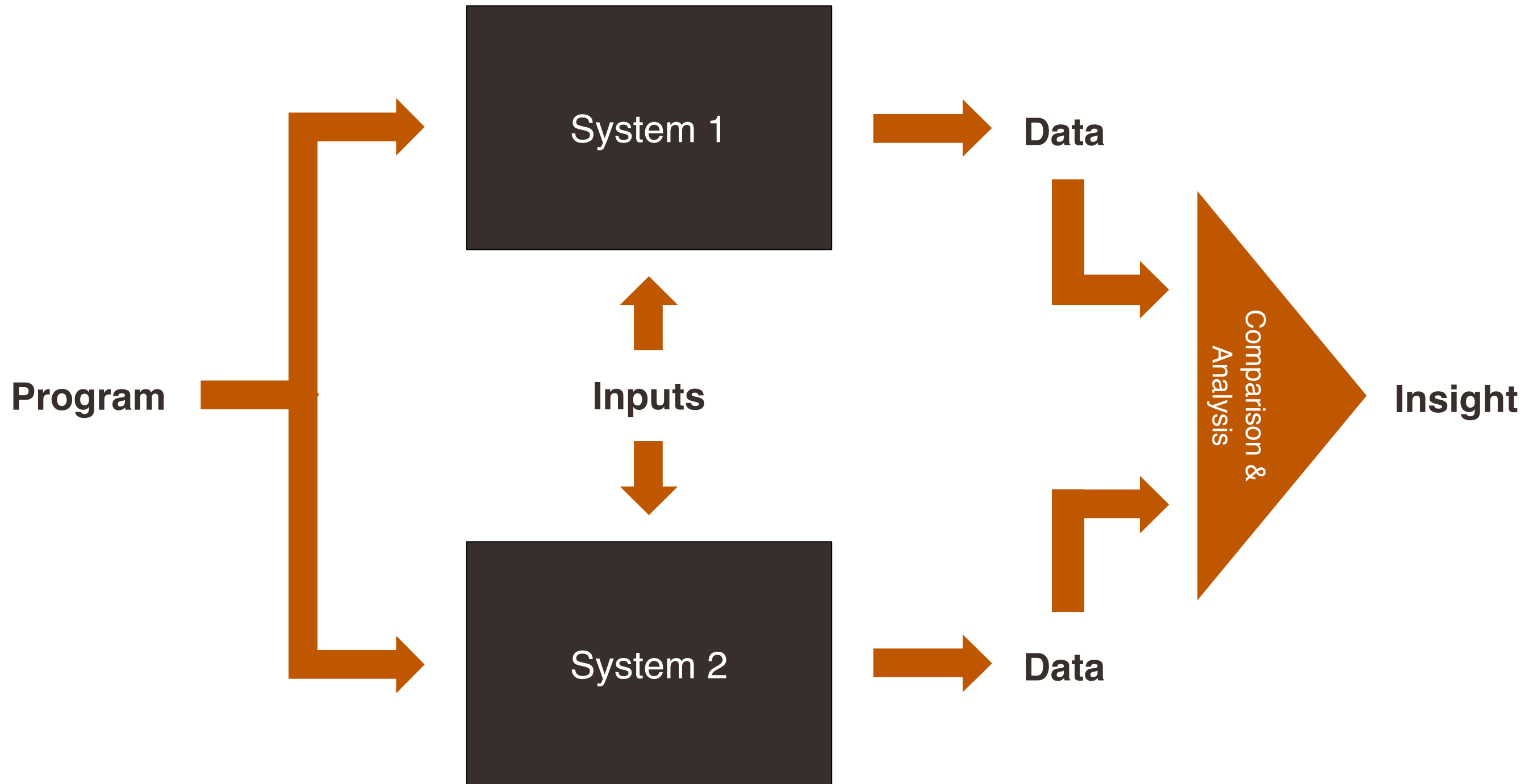
Quantitative Performance Comparisons



Quantitative Performance Comparisons



Quantitative Performance Comparisons



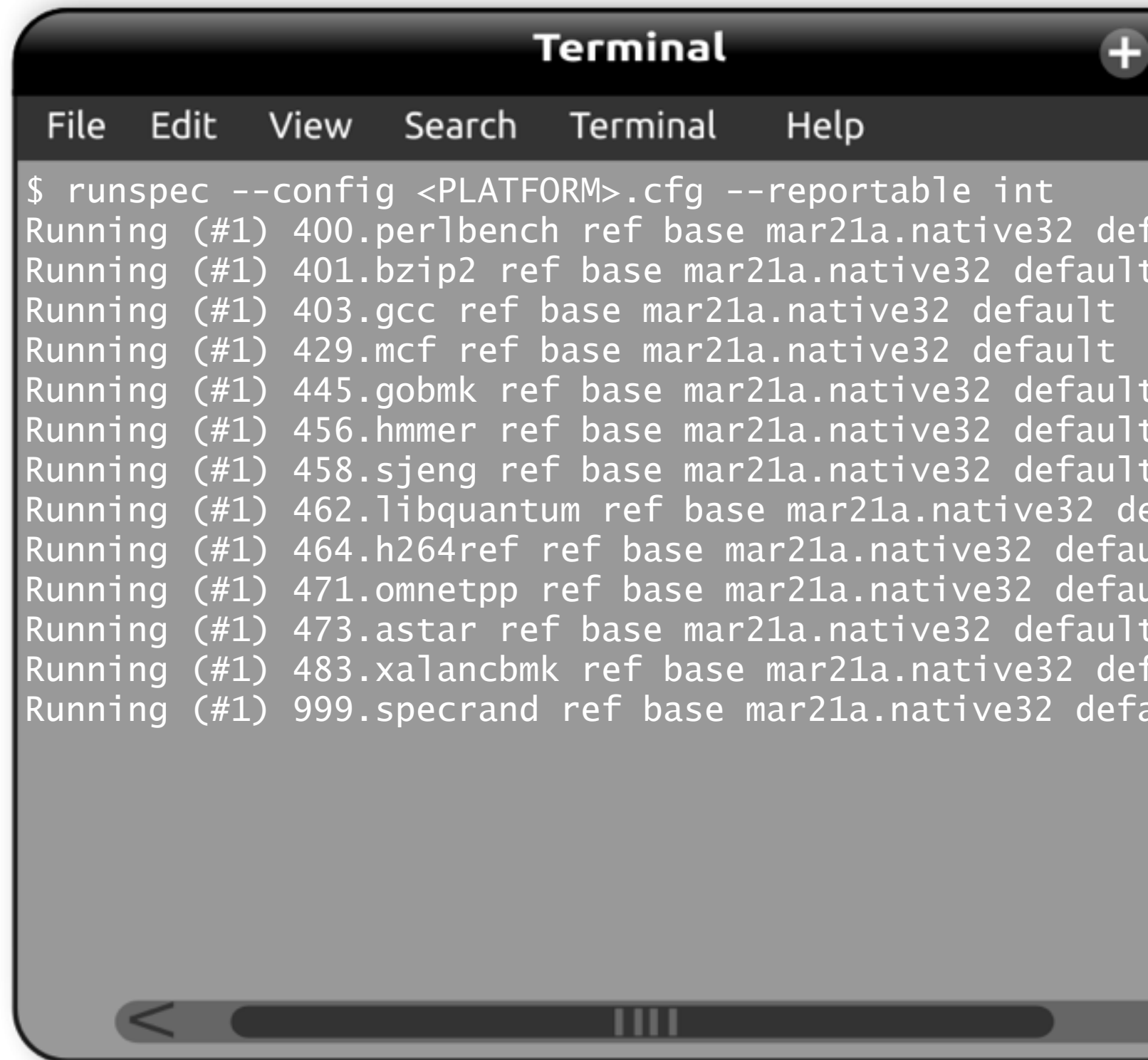
SPEC CPU 2006

A terminal window titled "Terminal" with standard macOS window controls (plus, minus, close buttons). The menu bar includes "File", "Edit", "View", "Search", "Terminal", and "Help". The terminal content shows the execution of the 'runspec' command with various benchmarks. The output lists 13 benchmarks, each preceded by "Running (#1)" and followed by a reference base and "default".

```
$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
```


SPEC CPU 2006

- **Representative**
- **Repeatable**
- **Cross-Platform**

A terminal window titled "Terminal" with a standard macOS-style title bar (including a close button). The window has a menu bar with "File", "Edit", "View", "Search", "Terminal", and "Help". The terminal content shows the command "\$ runspec --config <PLATFORM>.cfg --reportable int" followed by a list of benchmarks being run, each preceded by "Running (#1)". The benchmarks listed are: 400.perlbench, 401.bzip2, 403.gcc, 429.mcf, 445.gobmk, 456.hmmer, 458.sjeng, 462.libquantum, 464.h264ref, 471.omnetpp, 473.astar, 483.xalancbmk, and 999.specrand. Each entry is followed by "ref base mar21a.native32 defa". At the bottom of the terminal window, there is a scroll bar with a left arrow and a progress indicator.

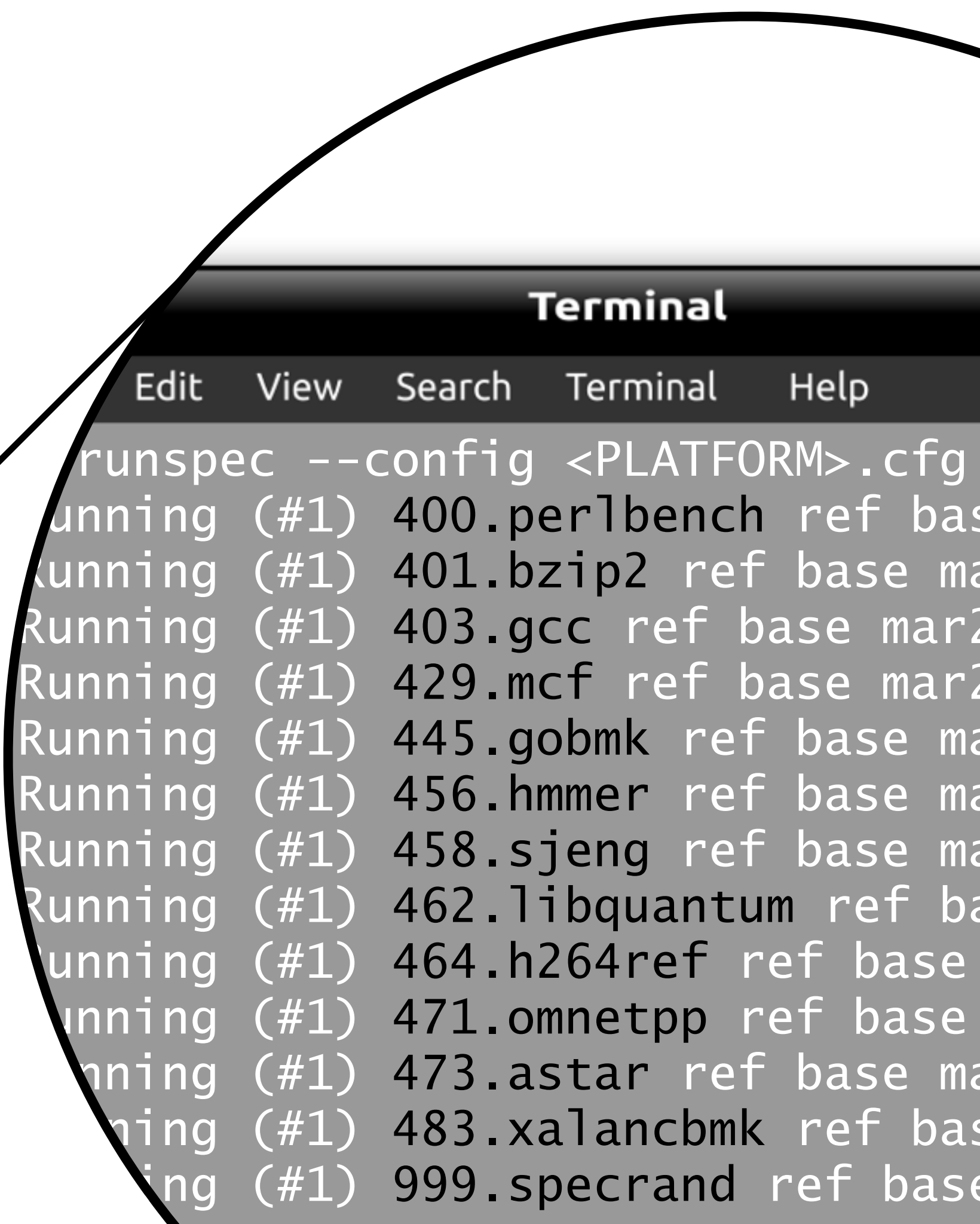
SPEC CPU 2006

- **Representative**
- **Repeatable**
- **Cross-Platform**



SPEC CPU 2006

- ✓ **Representative**
- **Repeatable**
- **Cross-Platform**



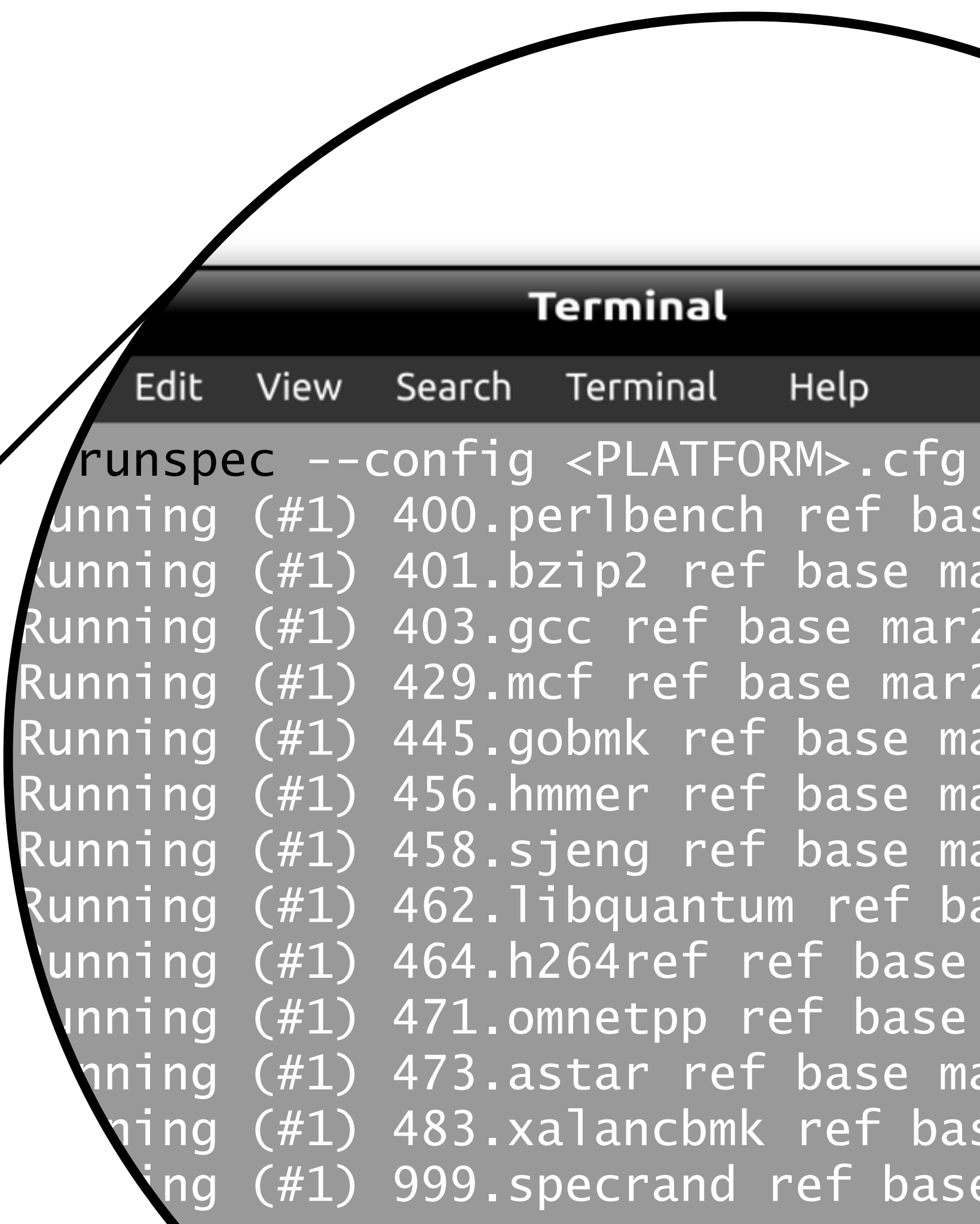
Terminal

Edit View Search Terminal Help

```
runspec --config <PLATFORM>.cfg
Running (#1) 400.perlbench ref base
Running (#1) 401.bzip2 ref base ma
Running (#1) 403.gcc ref base mar2
Running (#1) 429.mcf ref base mar2
Running (#1) 445.gobmk ref base ma
Running (#1) 456.hmmer ref base ma
Running (#1) 458.sjeng ref base ma
Running (#1) 462.libquantum ref ba
Running (#1) 464.h264ref ref base
Running (#1) 471.omnetpp ref base
Running (#1) 473.astar ref base ma
Running (#1) 483.xalancbmk ref bas
Running (#1) 999.specrand ref base
```

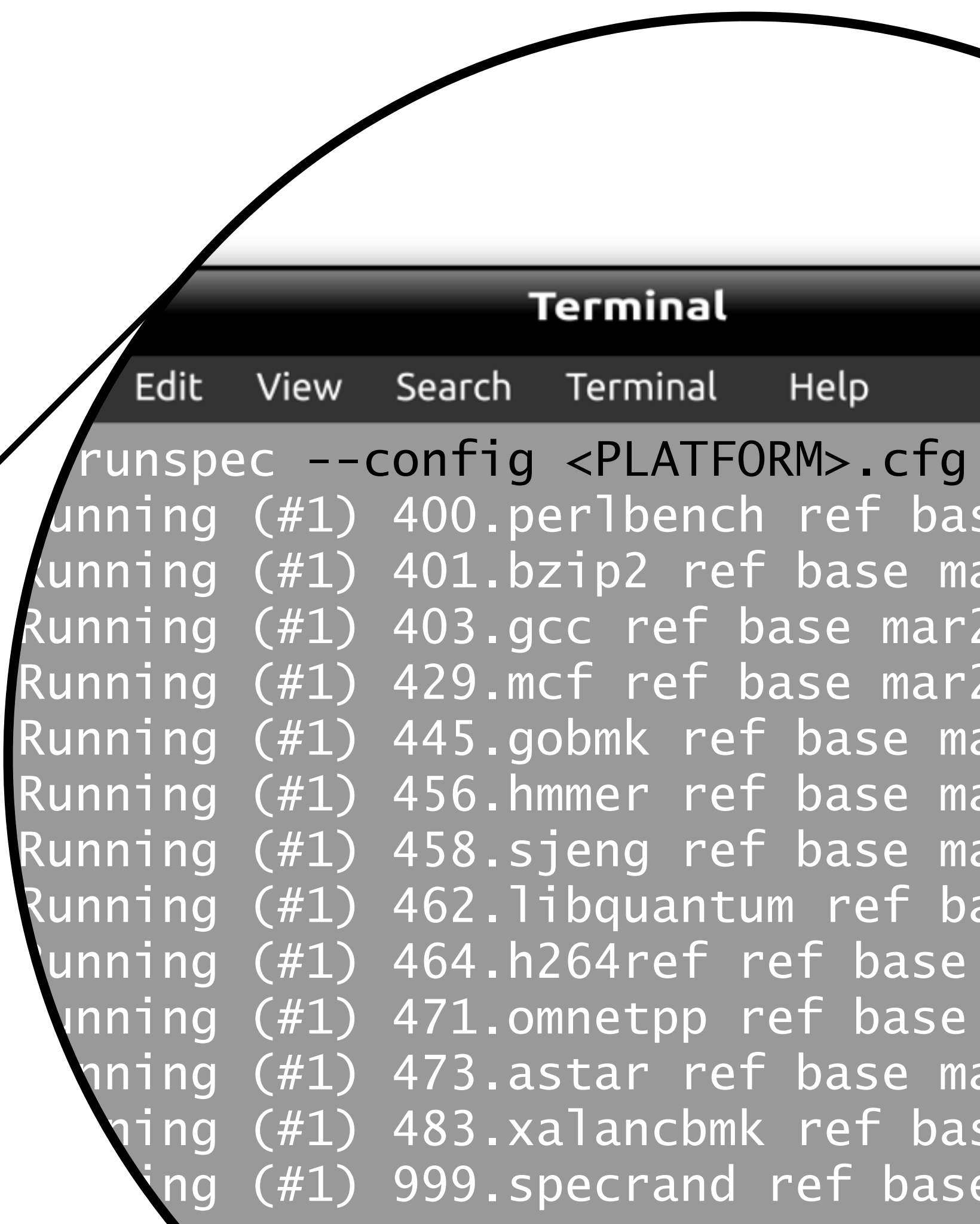
SPEC CPU 2006

- ✓ Representative
- ✓ Repeatable
- Cross-Platform



SPEC CPU 2006

- ✓ Representative
- ✓ Repeatable
- ✓ **Cross-Platform**



SPEC CPU 2006



A terminal window titled "Terminal" with standard macOS window controls (plus, minus, close buttons). The menu bar includes "File", "Edit", "View", "Search", "Terminal", and "Help". The terminal content shows the execution of the `runspec` command with the following output:

```
$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
```


SPEC CPU 2006



A terminal window titled "Terminal" with standard macOS window controls (plus, minus, close buttons). The menu bar includes "File", "Edit", "View", "Search", "Terminal", and "Help". The terminal content shows the execution of the `runspec` command with the following output:

```
$ runspec --config <PLATFORM>.cfg --reportable int
Running (#1) 400.perlbench ref base mar21a.native32 default
Running (#1) 401.bzip2 ref base mar21a.native32 default
Running (#1) 403.gcc ref base mar21a.native32 default
Running (#1) 429.mcf ref base mar21a.native32 default
Running (#1) 445.gobmk ref base mar21a.native32 default
Running (#1) 456.hmmer ref base mar21a.native32 default
Running (#1) 458.sjeng ref base mar21a.native32 default
Running (#1) 462.libquantum ref base mar21a.native32 default
Running (#1) 464.h264ref ref base mar21a.native32 default
Running (#1) 471.omnetpp ref base mar21a.native32 default
Running (#1) 473.astar ref base mar21a.native32 default
Running (#1) 483.xalancbmk ref base mar21a.native32 default
Running (#1) 999.specrand ref base mar21a.native32 default
```

Mobile Applications Require Interactivity

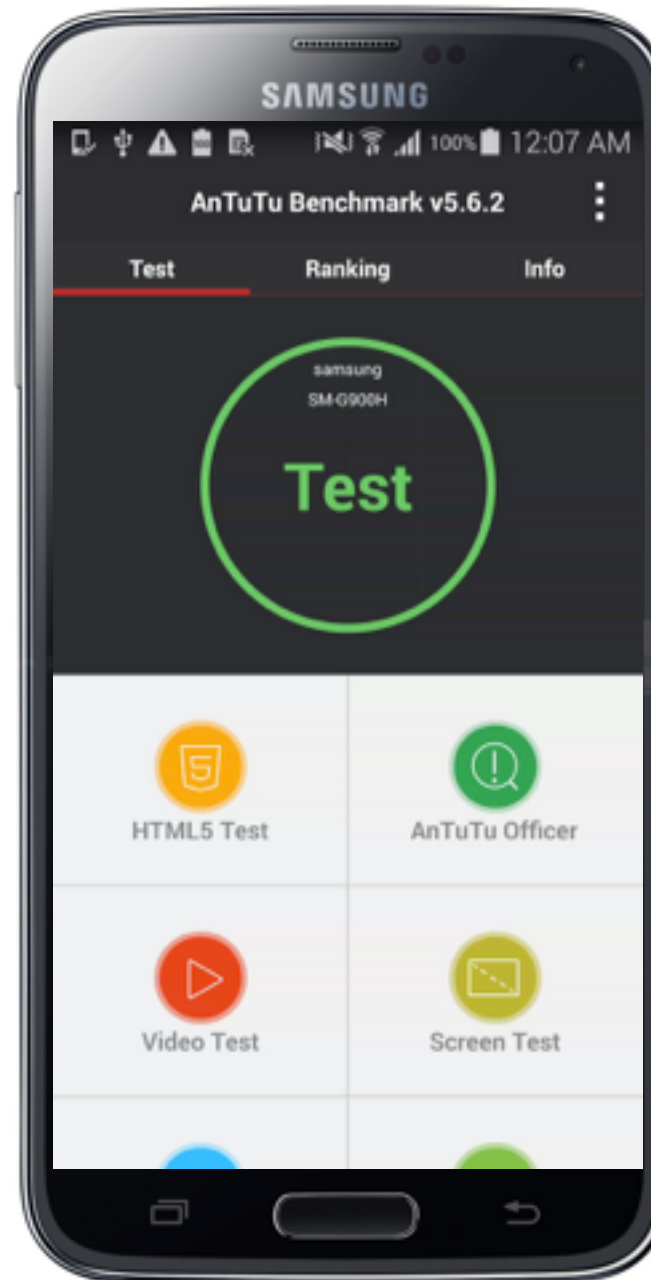


Mobile Applications Require Interactivity



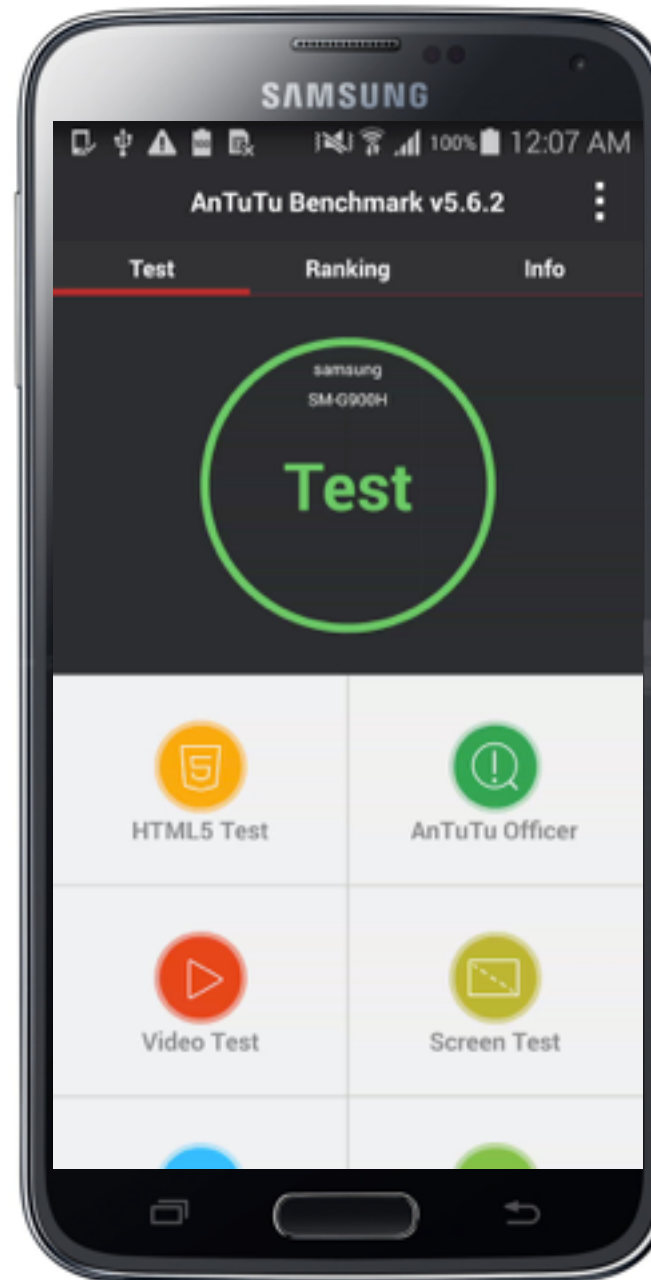
Mobile Applications

- **Representative**
- Repeatable
- Cross-Platform



Mobile Applications

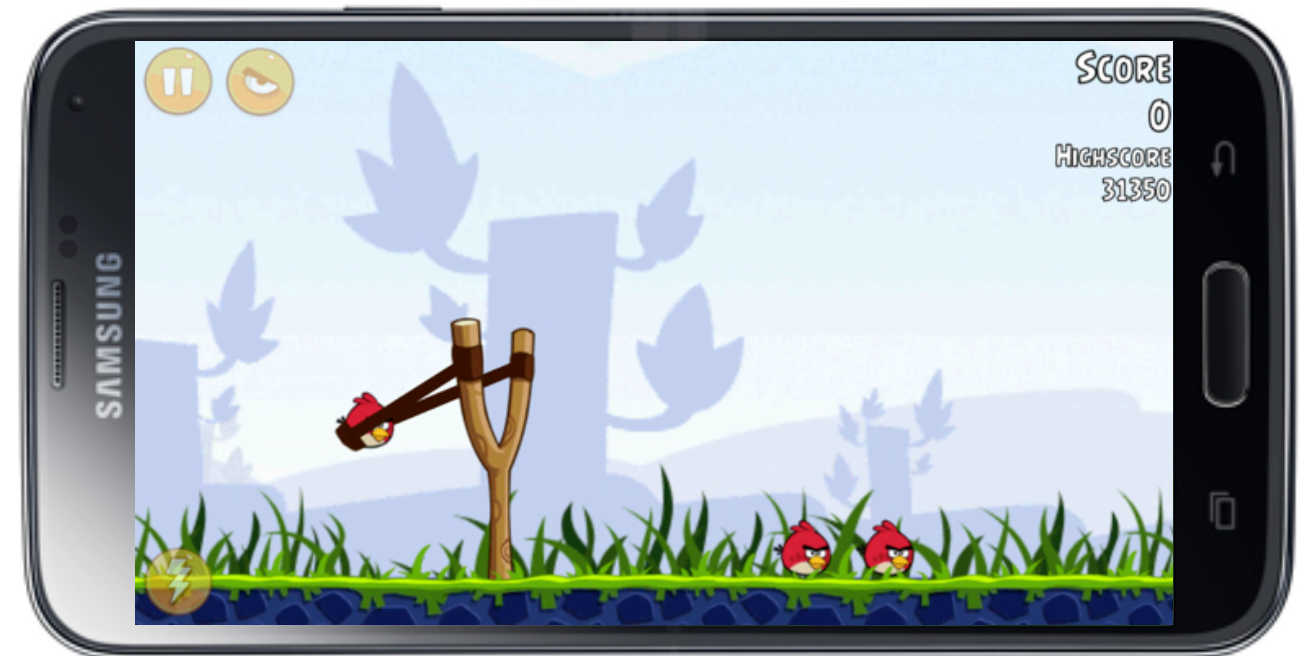
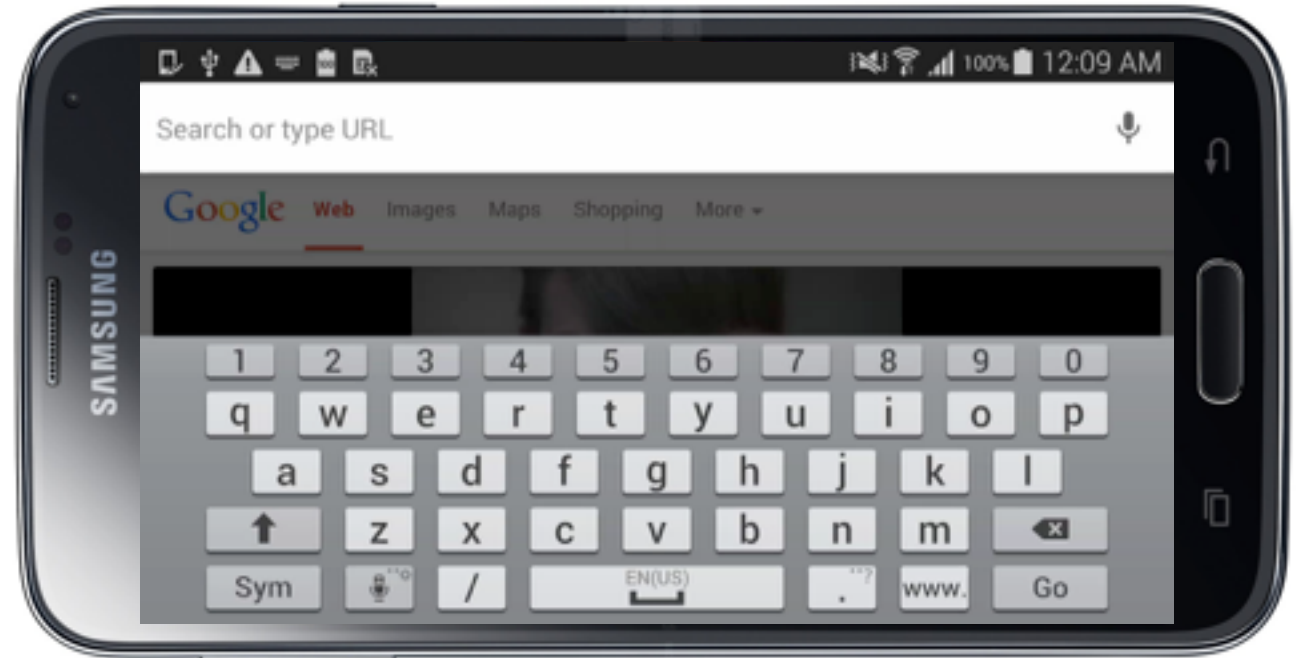
- **Representative**
- Repeatable
- Cross-Platform



Mobile Applications

X Representative

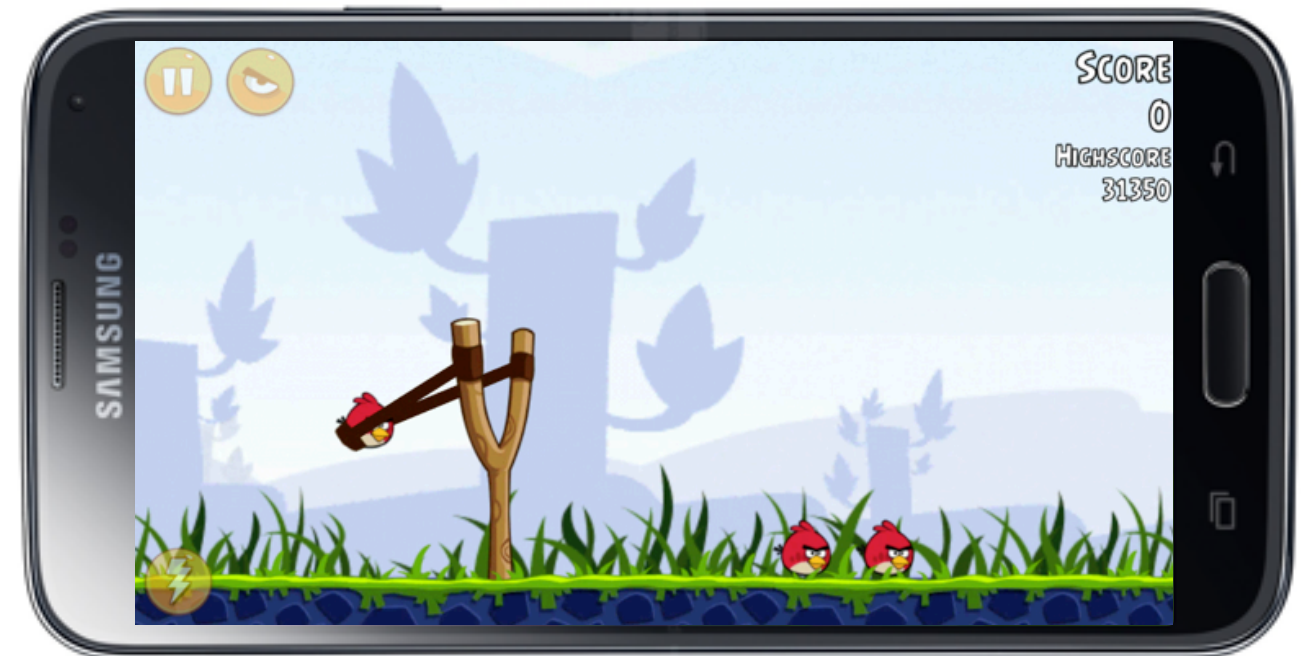
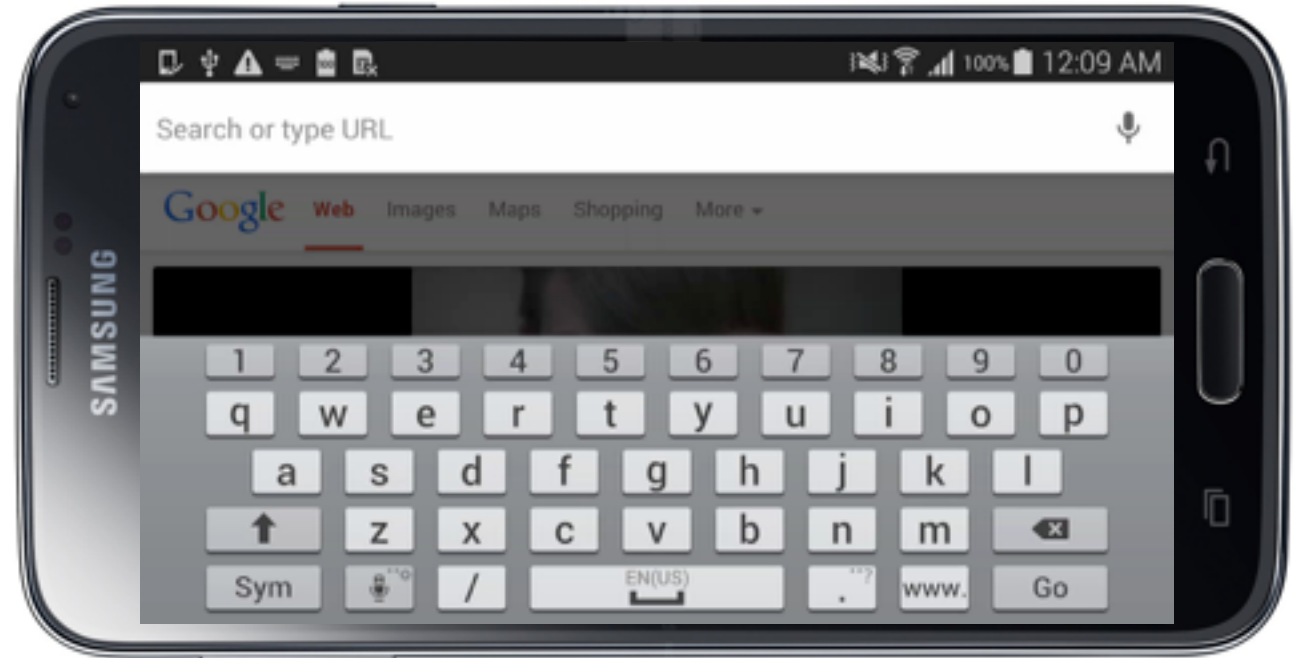
- Repeatability
- Cross-Platform



Mobile Applications

X Representative

- Repeatability
- Cross-Platform

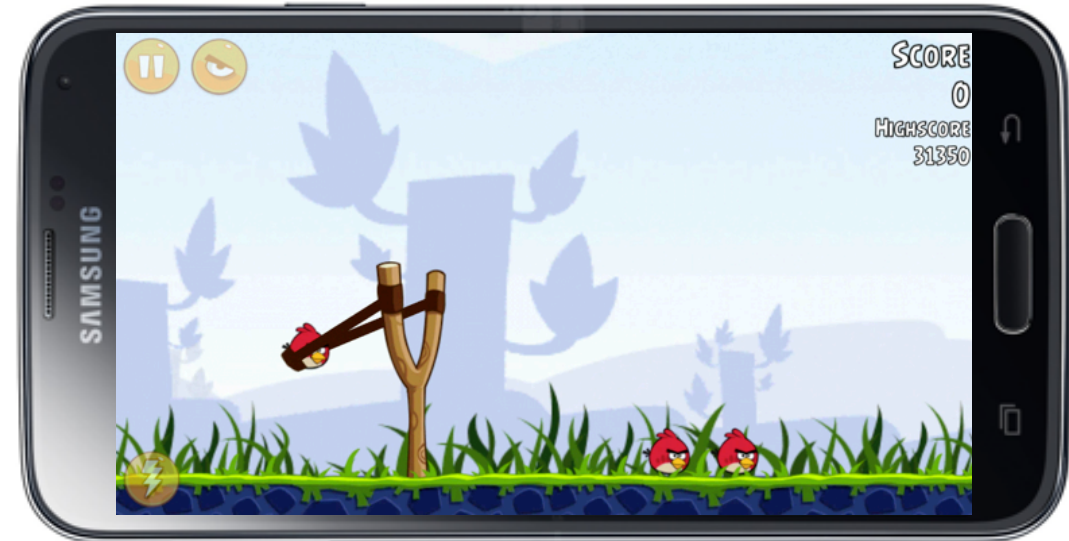


Mobile Applications

X Representative

X Repeatability

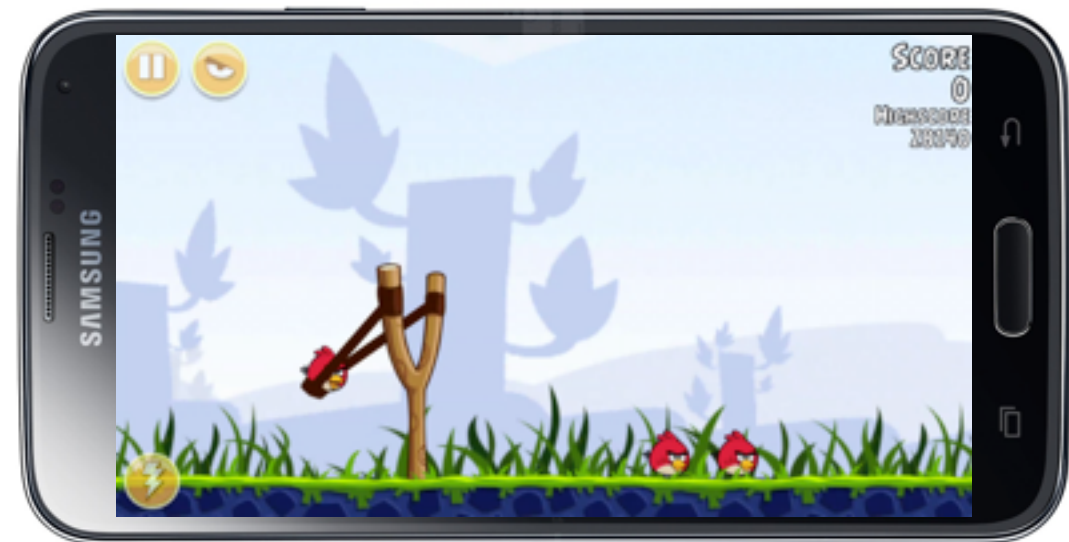
- Cross-Platform



Yuhao



Ramesh



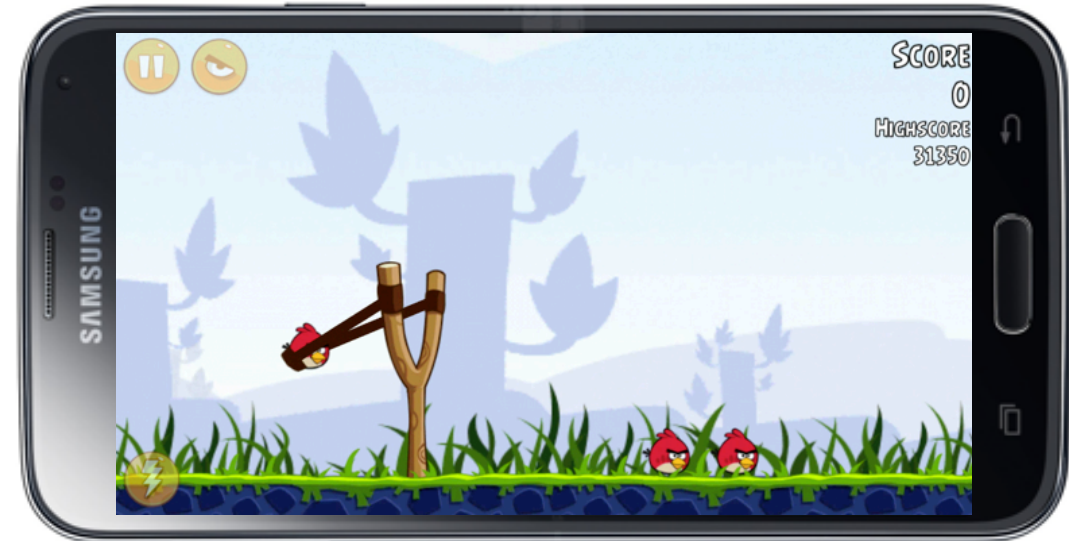
Vijay

Mobile Applications

X Representative

X Repeatability

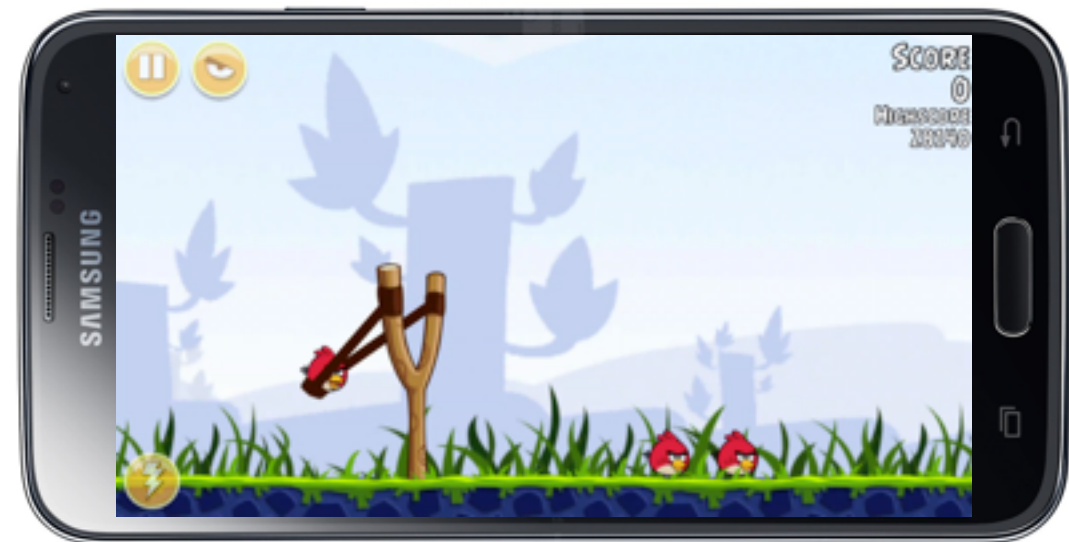
- Cross-Platform



Yuhao



Ramesh



Vijay

Mobile Applications

X Representative

X Repeatable

X **Cross-Platform**

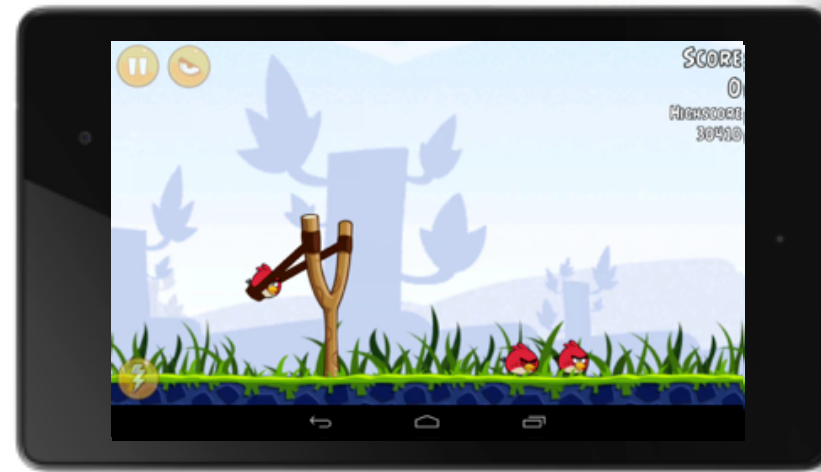


Mobile Applications

X Representative

X Repeatable

X **Cross-Platform**



The Cross-Platform Requirement

Samsung Galaxy S5



Asus Nexus 7



The Cross-Platform Requirement



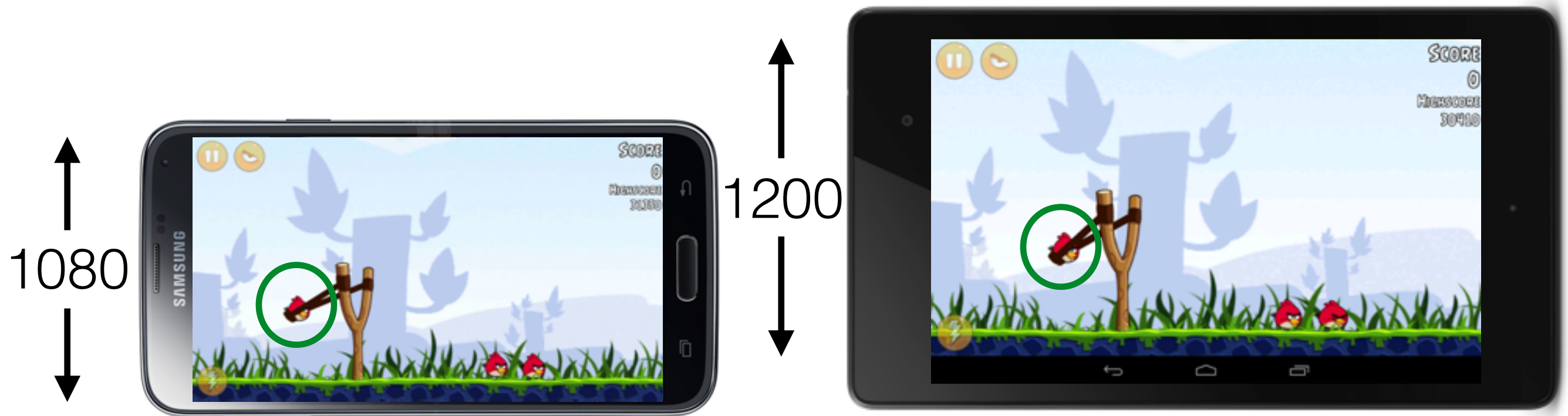
The Cross-Platform Requirement



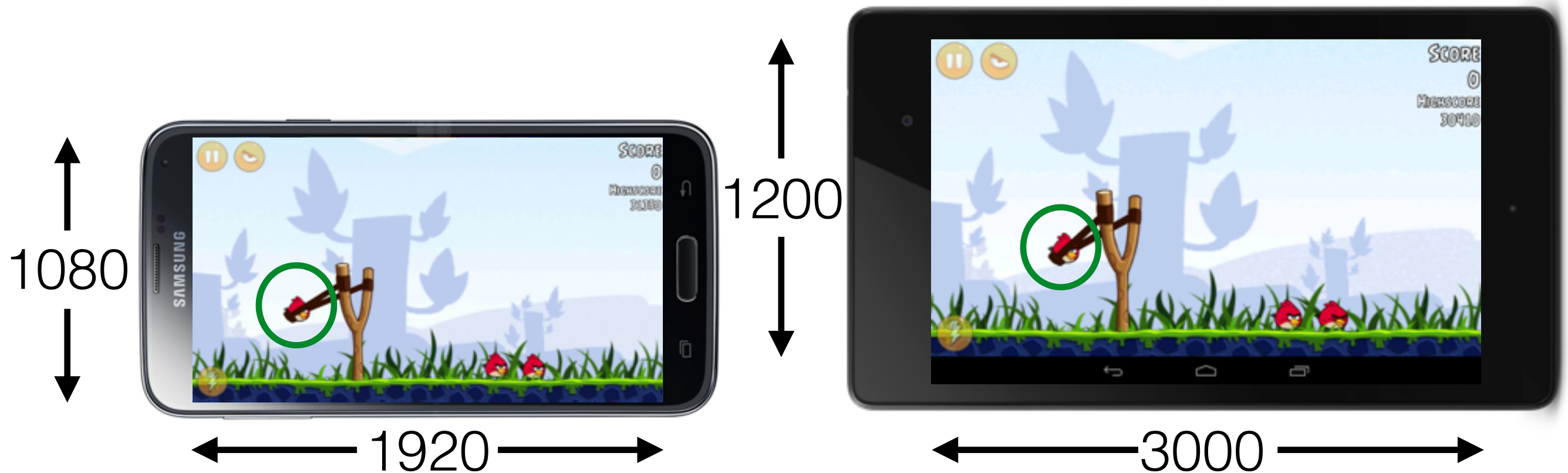
The Cross-Platform Requirement



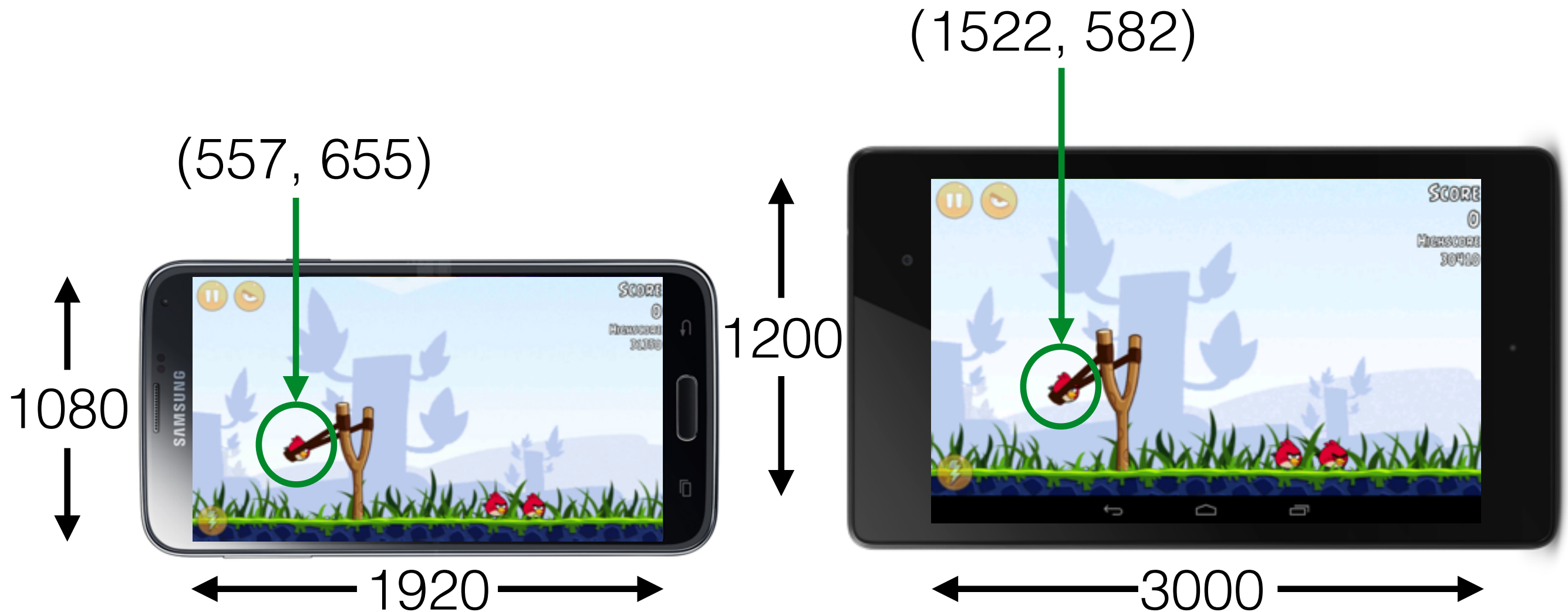
The Cross-Platform Requirement



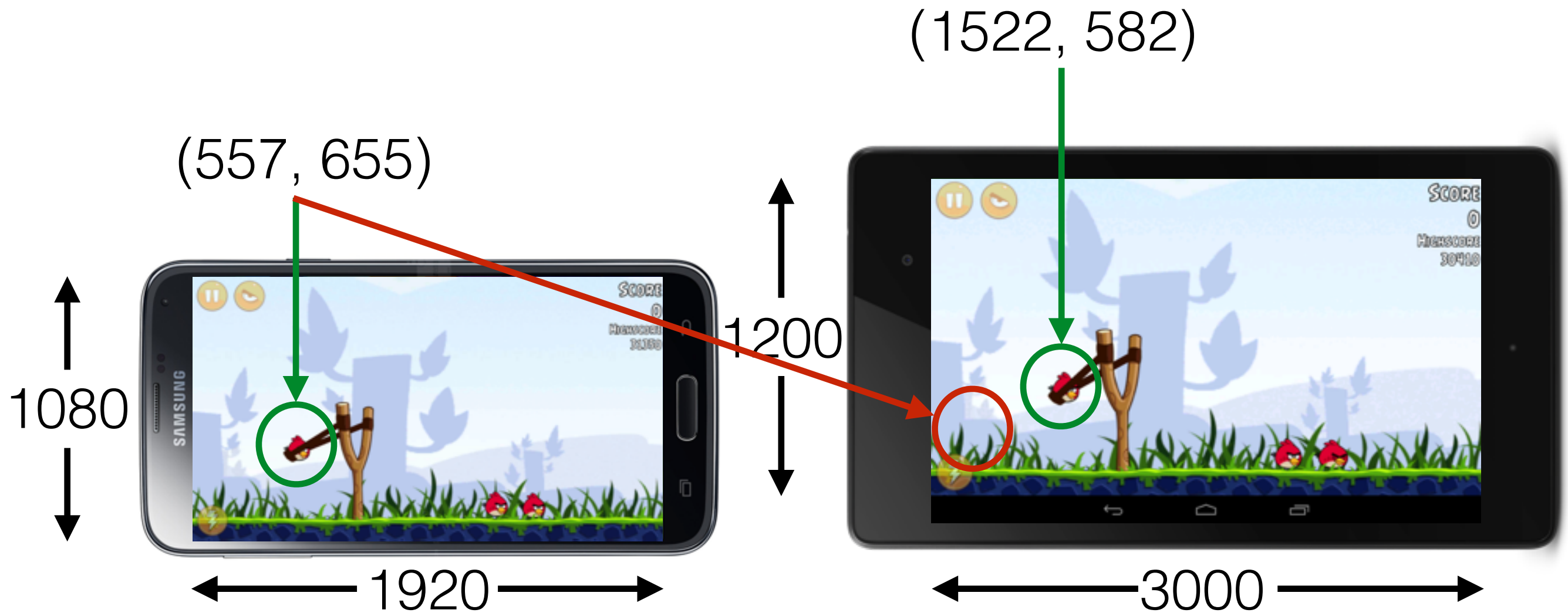
The Cross-Platform Requirement



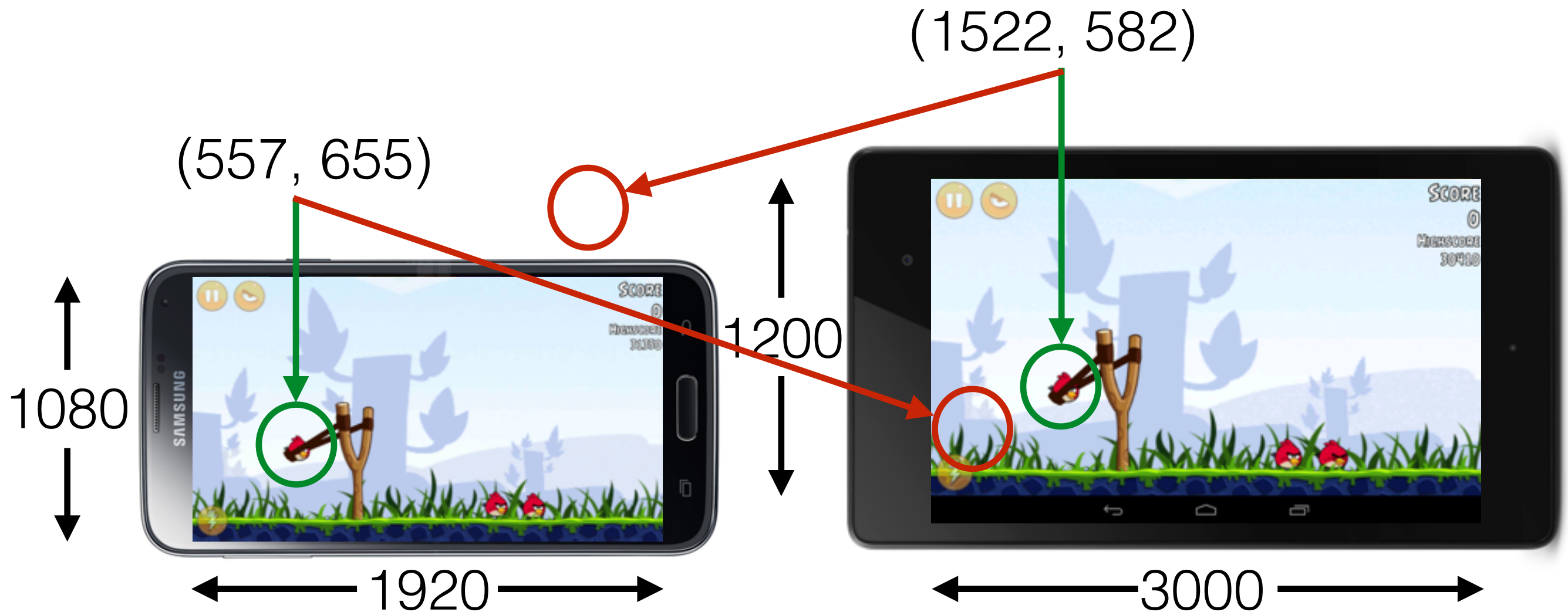
The Cross-Platform Requirement



The Cross-Platform Requirement



The Cross-Platform Requirement



The Cross-Platform Requirement

Samsung Galaxy S5



Asus Nexus 7



The Cross-Platform Requirement

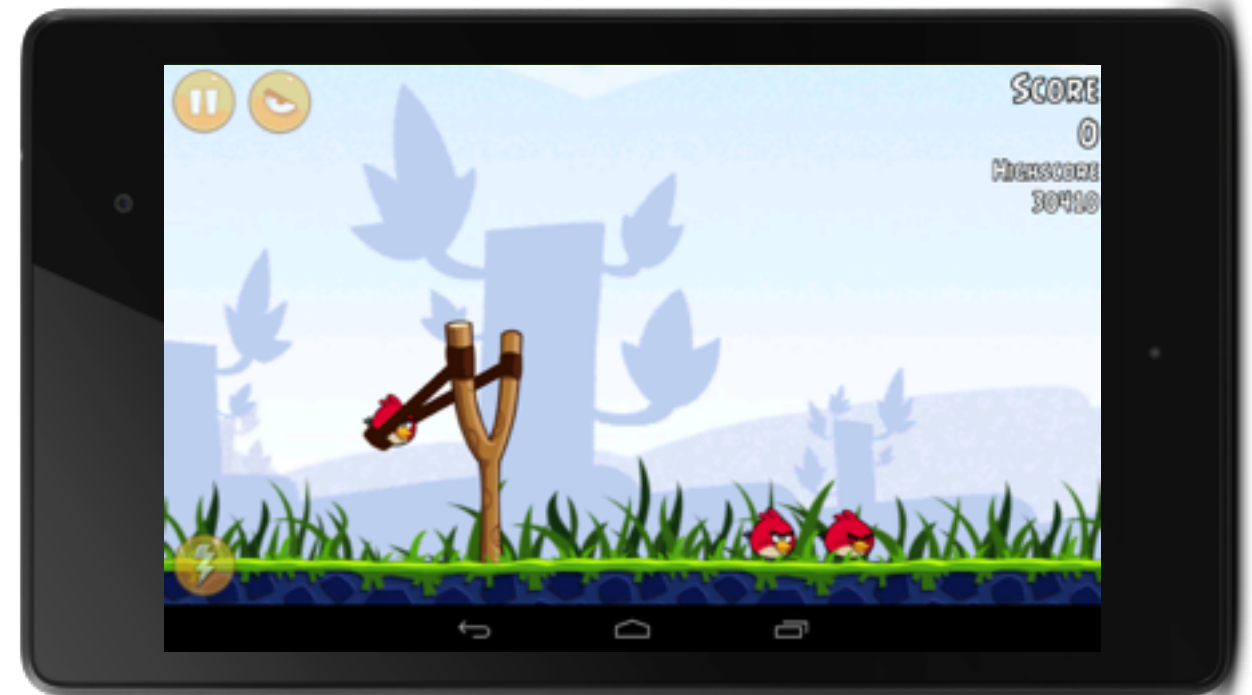
Samsung Galaxy S5



1080 x 1920

Touchscreen

Asus Nexus 7



3000 x 1200

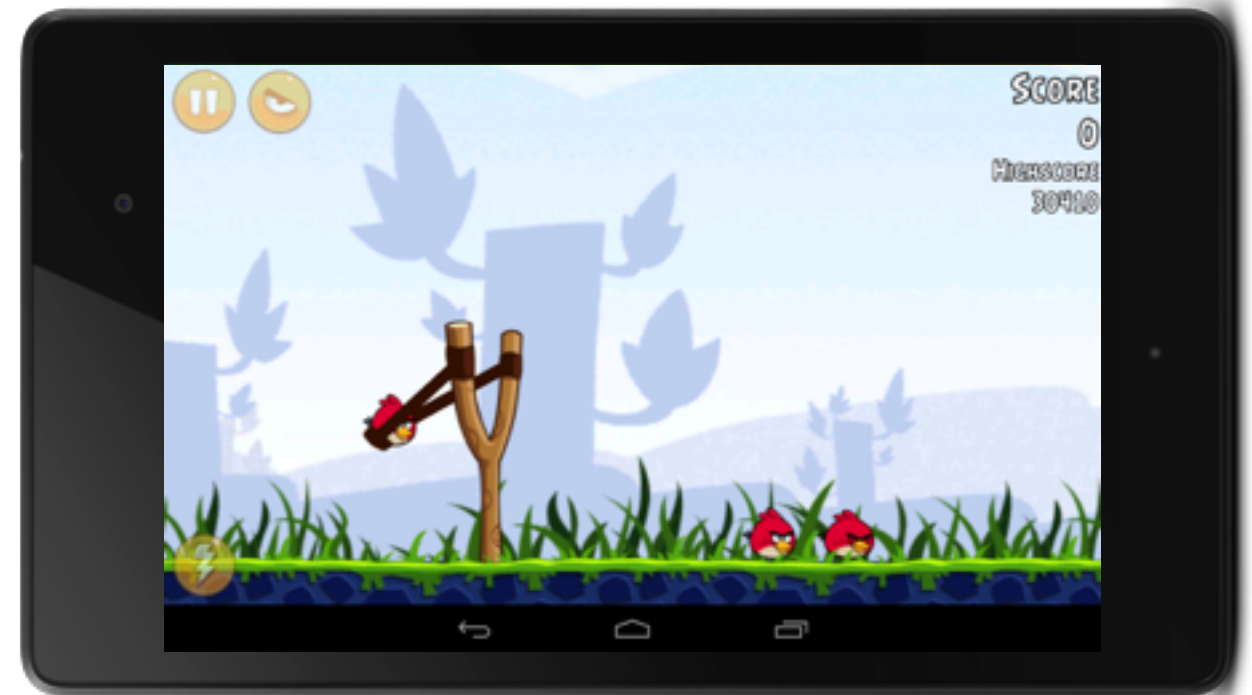
The Cross-Platform Requirement

Samsung Galaxy S5



1080 x 1920
Smartphone

Asus Nexus 7



3000 x 1200
Tablet

Touchscreen
Form Factor

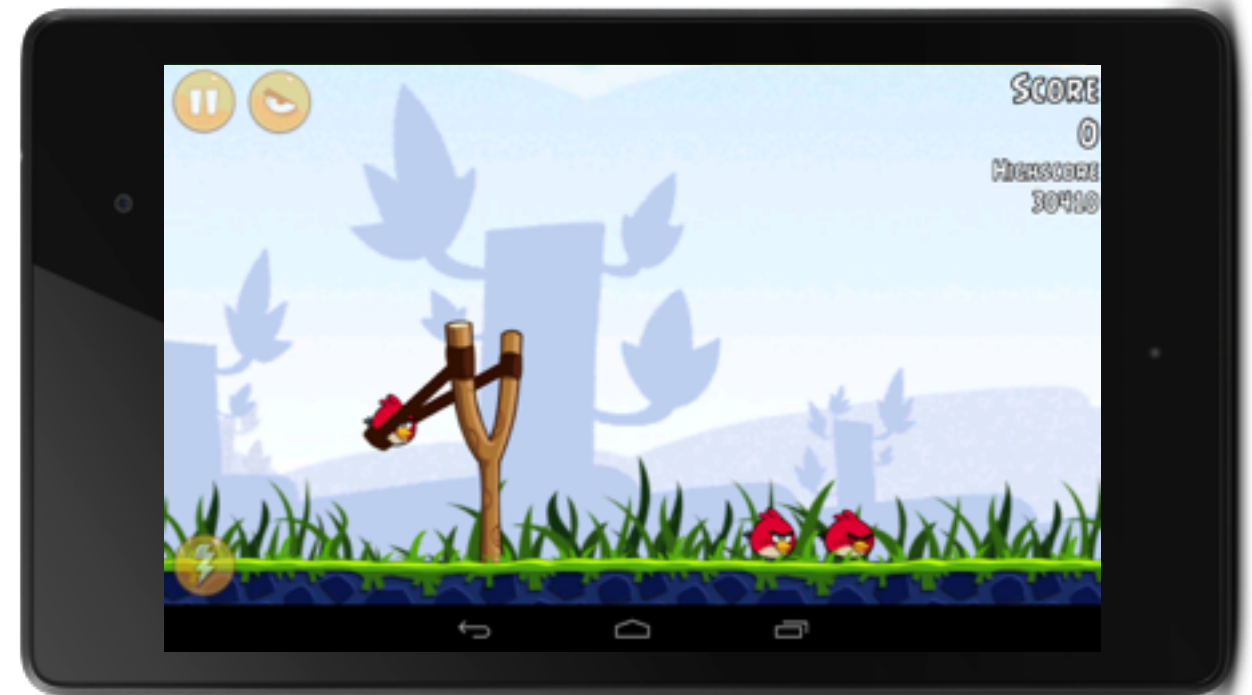
The Cross-Platform Requirement

Samsung Galaxy S5



1080 x 1920
Smartphone
Android 4.4.2

Asus Nexus 7



3000 x 1200
Tablet
Android 4.1

Touchscreen
Form Factor
OS Version

The Cross-Platform Requirement

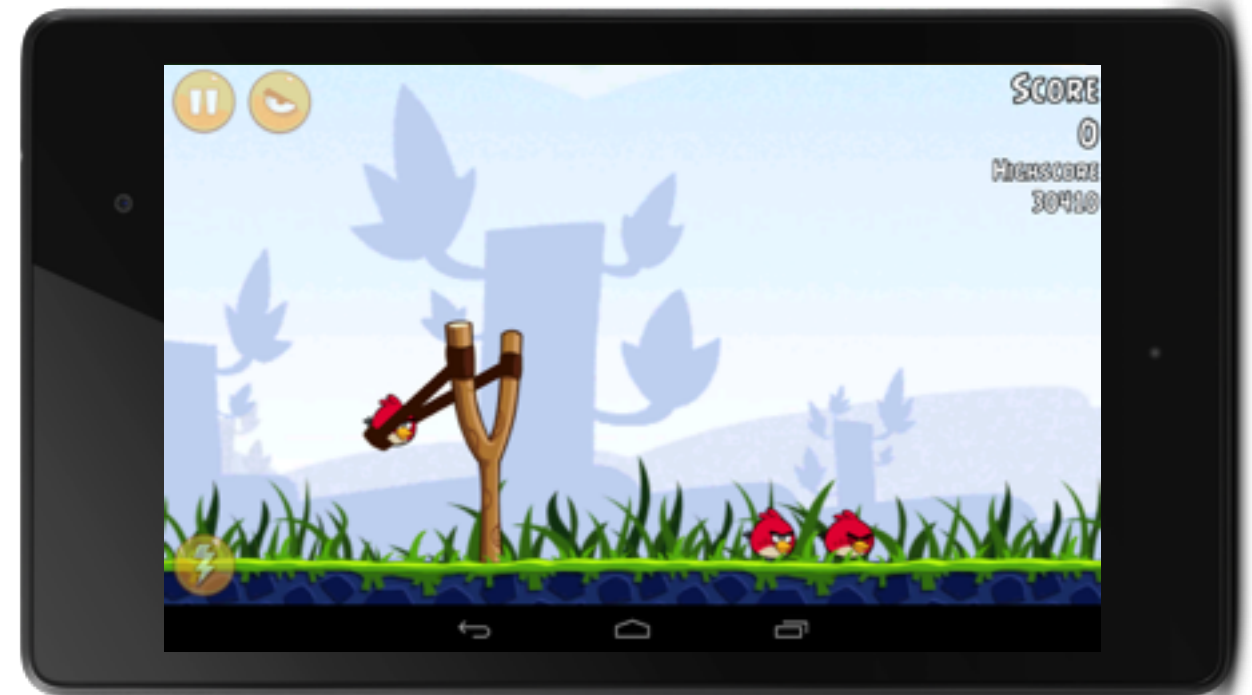
Samsung Galaxy S5



1080 x 1920
Smartphone
Android 4.4.2

...

Asus Nexus 7

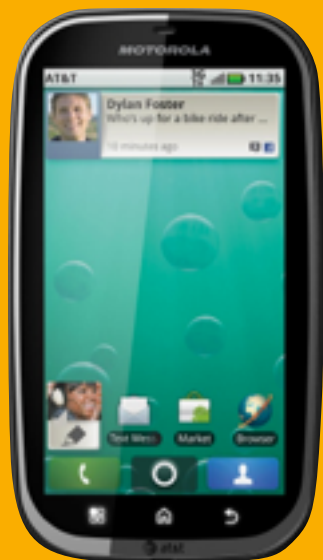


Touchscreen
Form Factor
OS Version

...

3000 x 1200
Tablet
Android 4.1

...



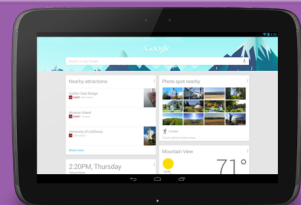
Galaxy S III (GT-I9300)

Galaxy S II (GT-I9100)

Galaxy Y (GT-S5360)

Galaxy S4 (GT-I9505)

Nexus 4



Galaxy Nexus

Galaxy Note II (GT-N7100)



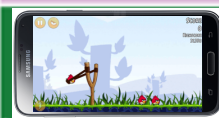
Nexus 7



HTC One

GT-I9500

DROID RAZR



HTC One X

GT-P3110

LG-L38C

HTC One S

ST26i

Desire HD



GT-I9082LC517

EVO

ST23i

AD683

LG-P7

IS06

5860E

H866C

A2...

LGL86CM980

ST26a

MB886

E860

LT28h..

MI 1S

W732

LT18a

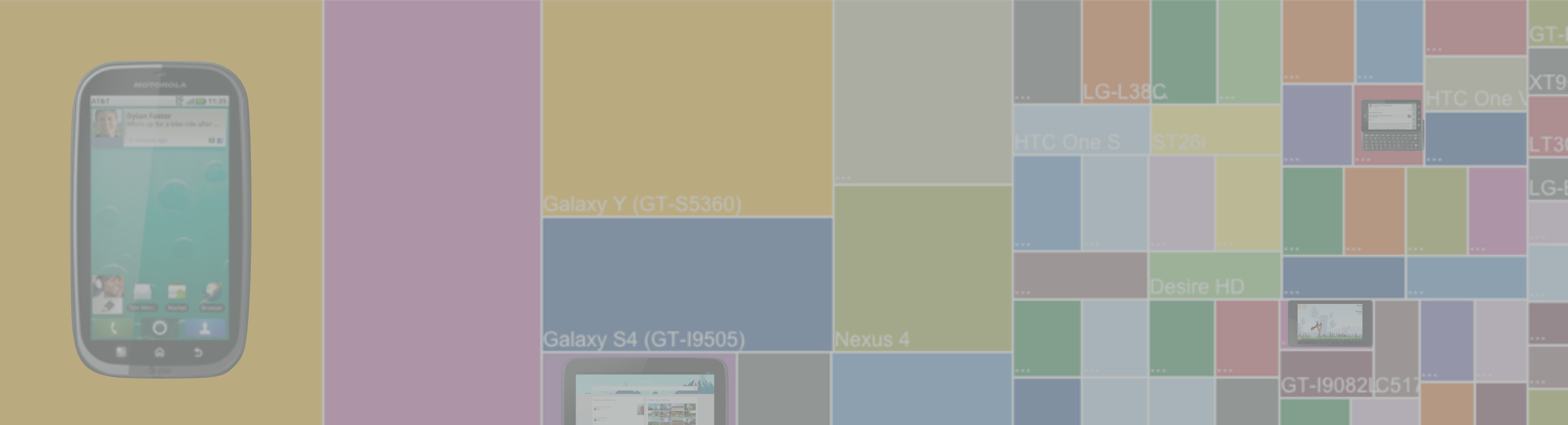
A1

A8

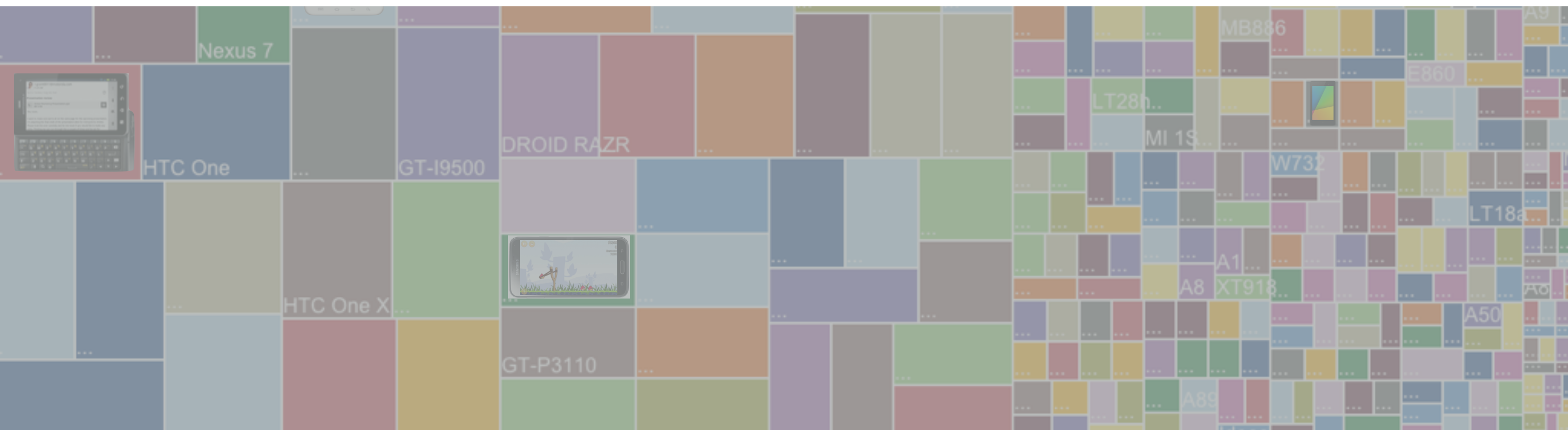
XT918

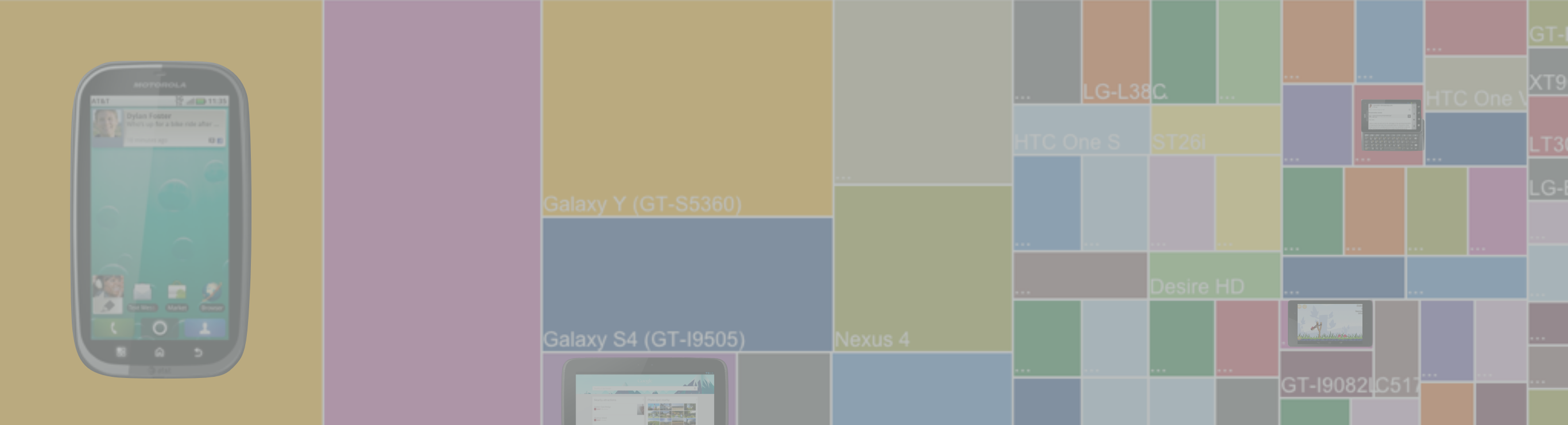
A50

A89



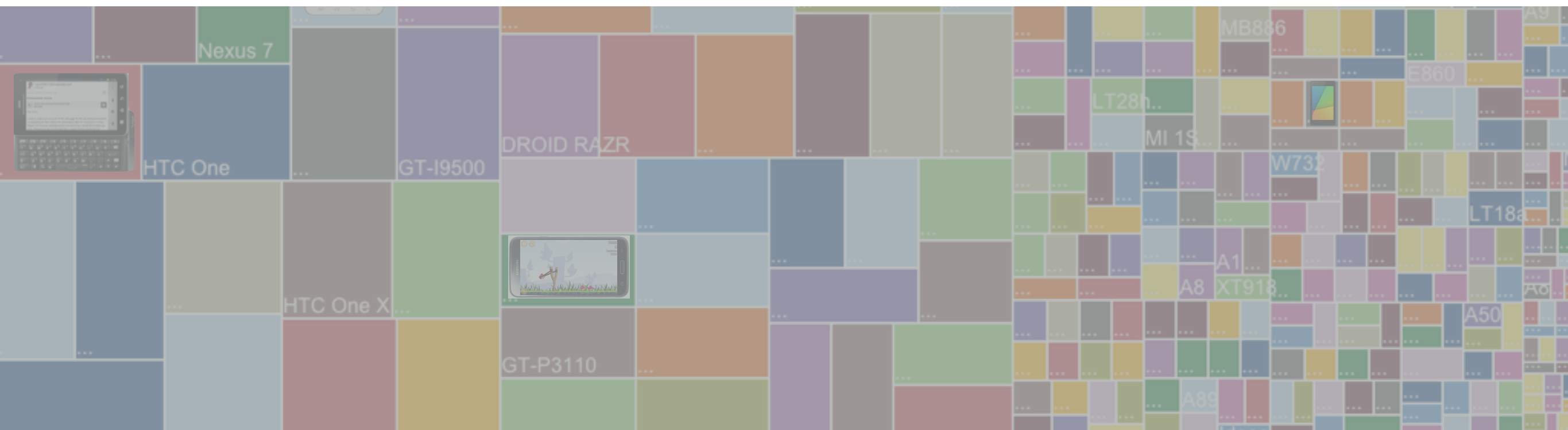
“The Fragmentation Problem”





“The Fragmentation Problem”

Form Factors x Displays x Processors x OS's x UI's x Drivers



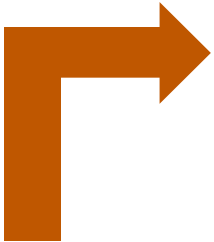
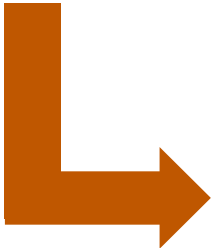
Program



Inputs



Data



Data



Insight

**Interactive
Mobile
Applications**



Inputs



Data

Data

**Comparison &
Analysis**

Insight

**Interactive
Mobile
Applications**



User Interactivity



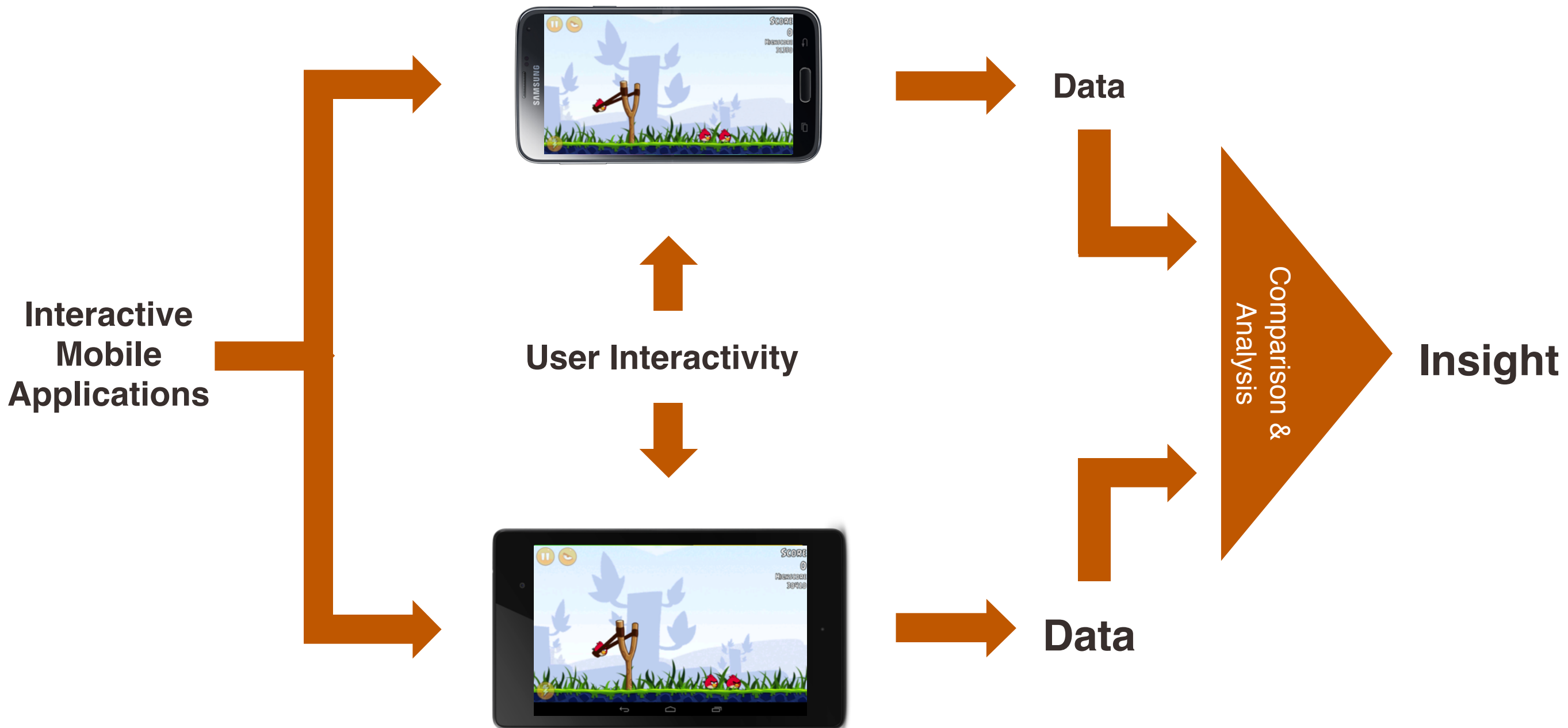
Data

Data

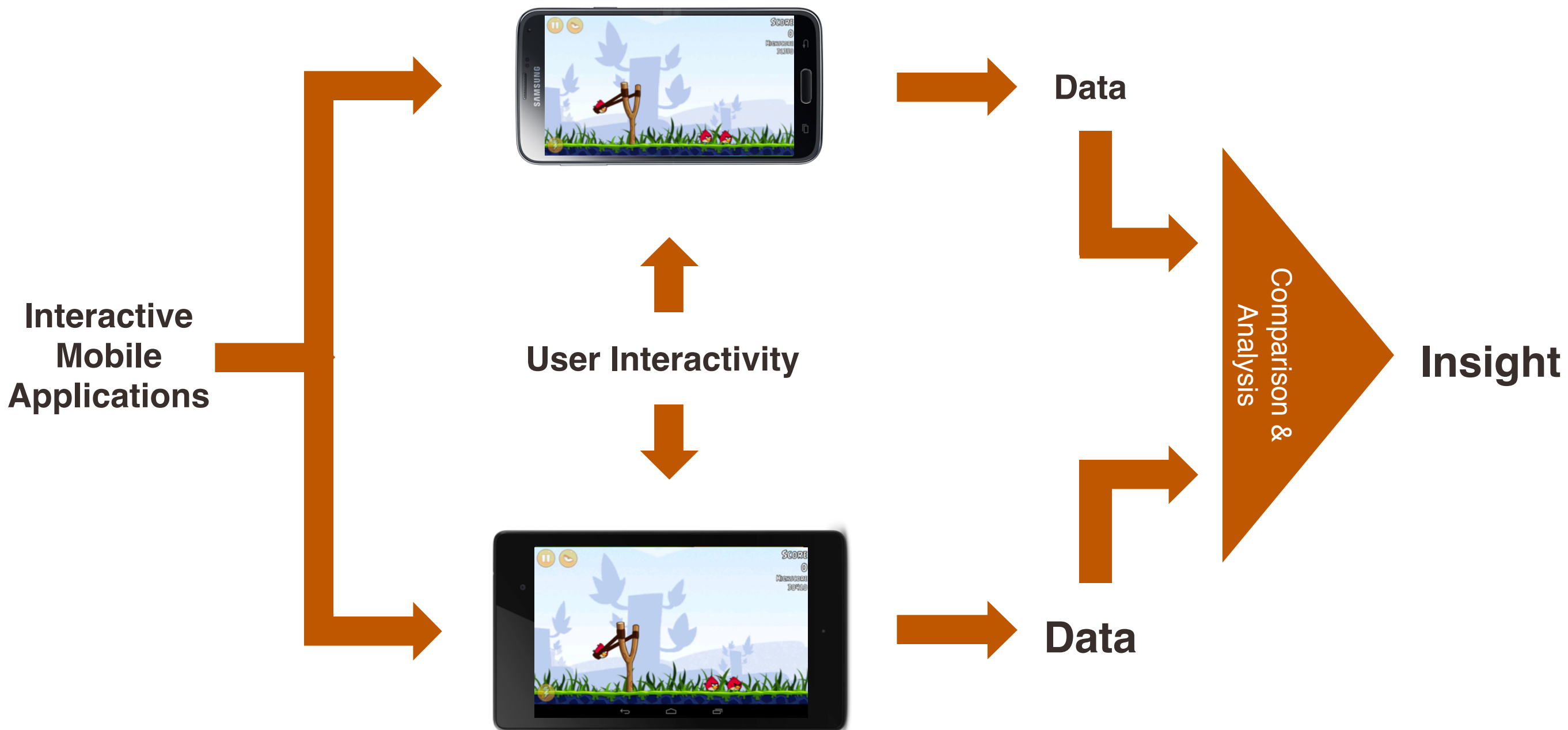
**Comparison &
Analysis**

Insight

Portable user interactivity that is **device agnostic**.



Portable user interactivity that is **device agnostic**.



Representative user interactivity is **device specific**.

Portable user interactivity that is **device agnostic**.



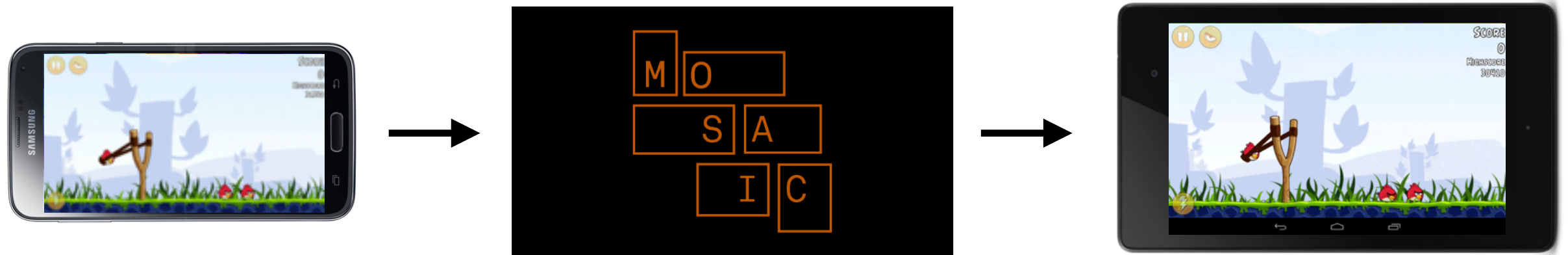
Representative user interactivity is **device specific**.

Portable user interactivity that is **device agnostic**.



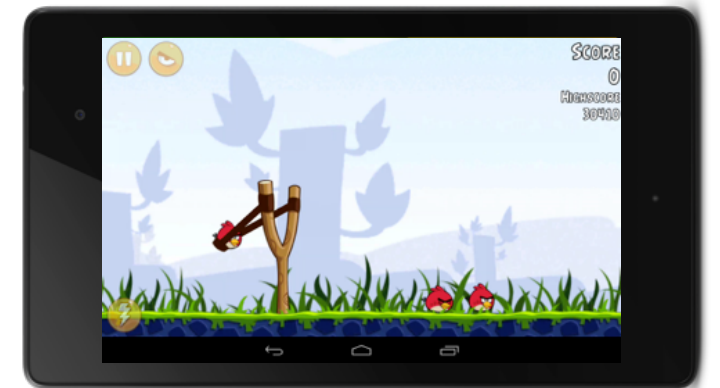
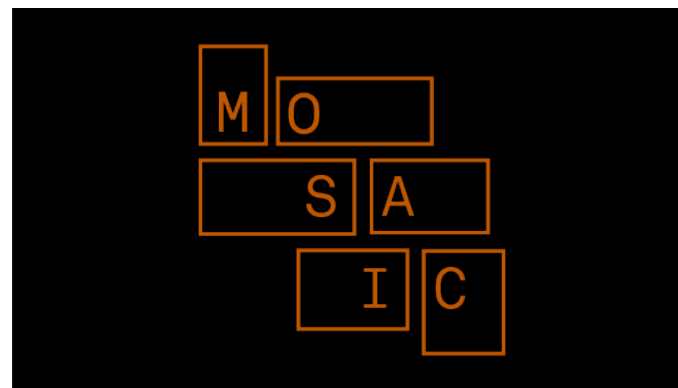
Representative user interactivity is **device specific**.

Mosaic Makes Interactivity Portable



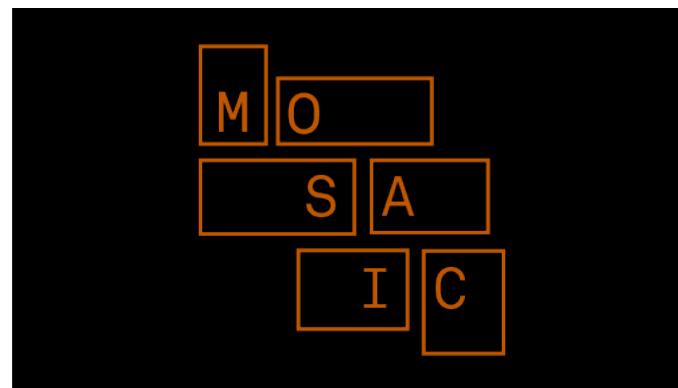
Mosaic Makes Interactivity Portable

Record

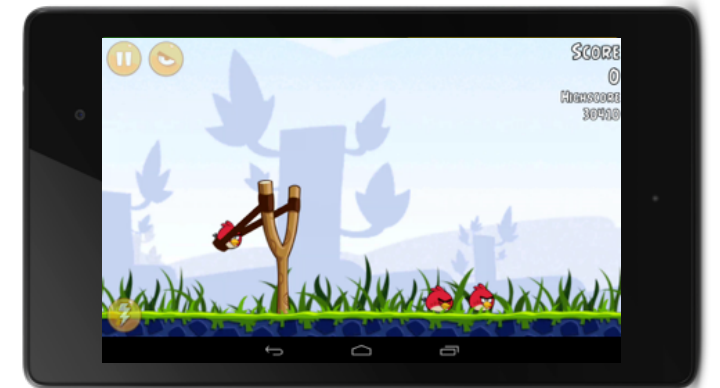


Mosaic Makes Interactivity Portable

Record



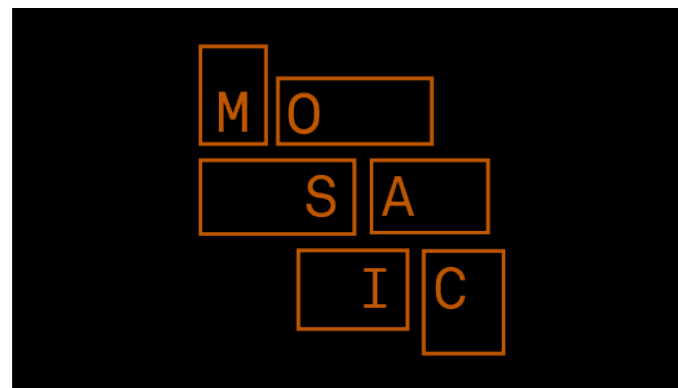
Replay



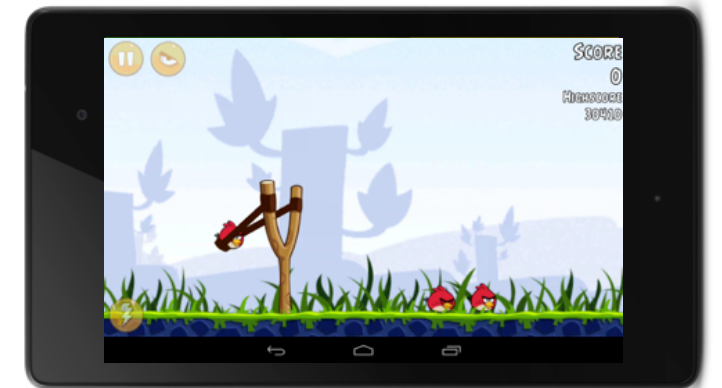
Mosaic Makes Interactivity Portable

✓ Off-the-shelf Mobile Devices

Record



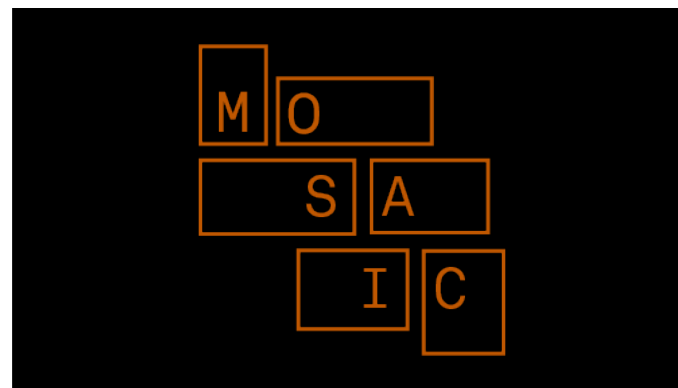
Replay



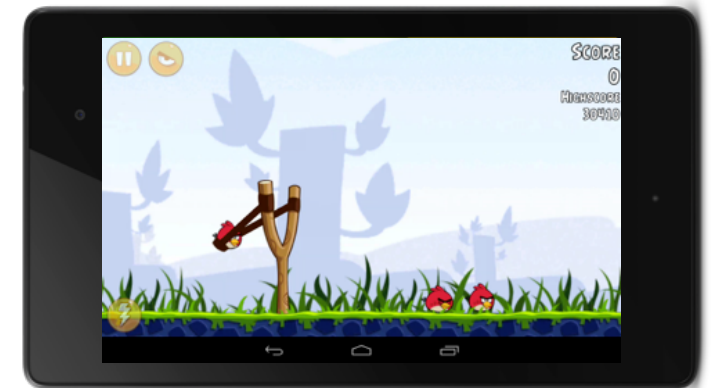
Mosaic Makes Interactivity Portable

- ✓ Off-the-shelf Mobile Devices
- ✓ Mainstream Mobile Applications

Record



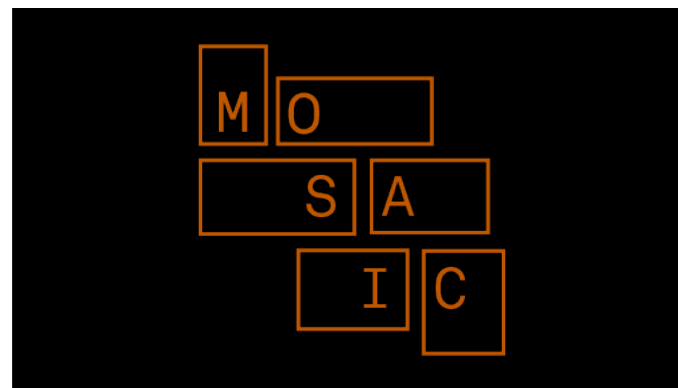
Replay



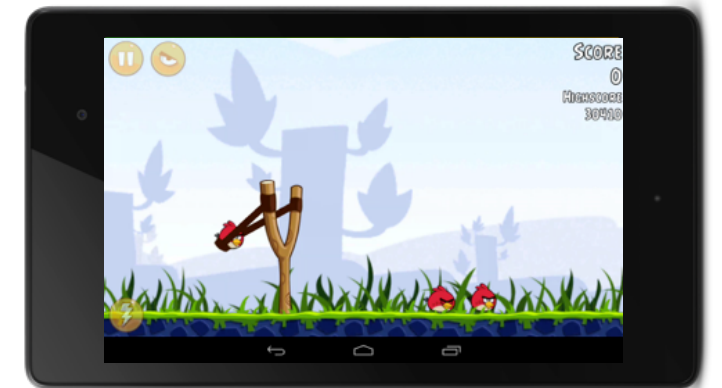
Mosaic Makes Interactivity Portable

- ✓ Off-the-shelf Mobile Devices
- ✓ Mainstream Mobile Applications
- ✓ Low Overhead

Record

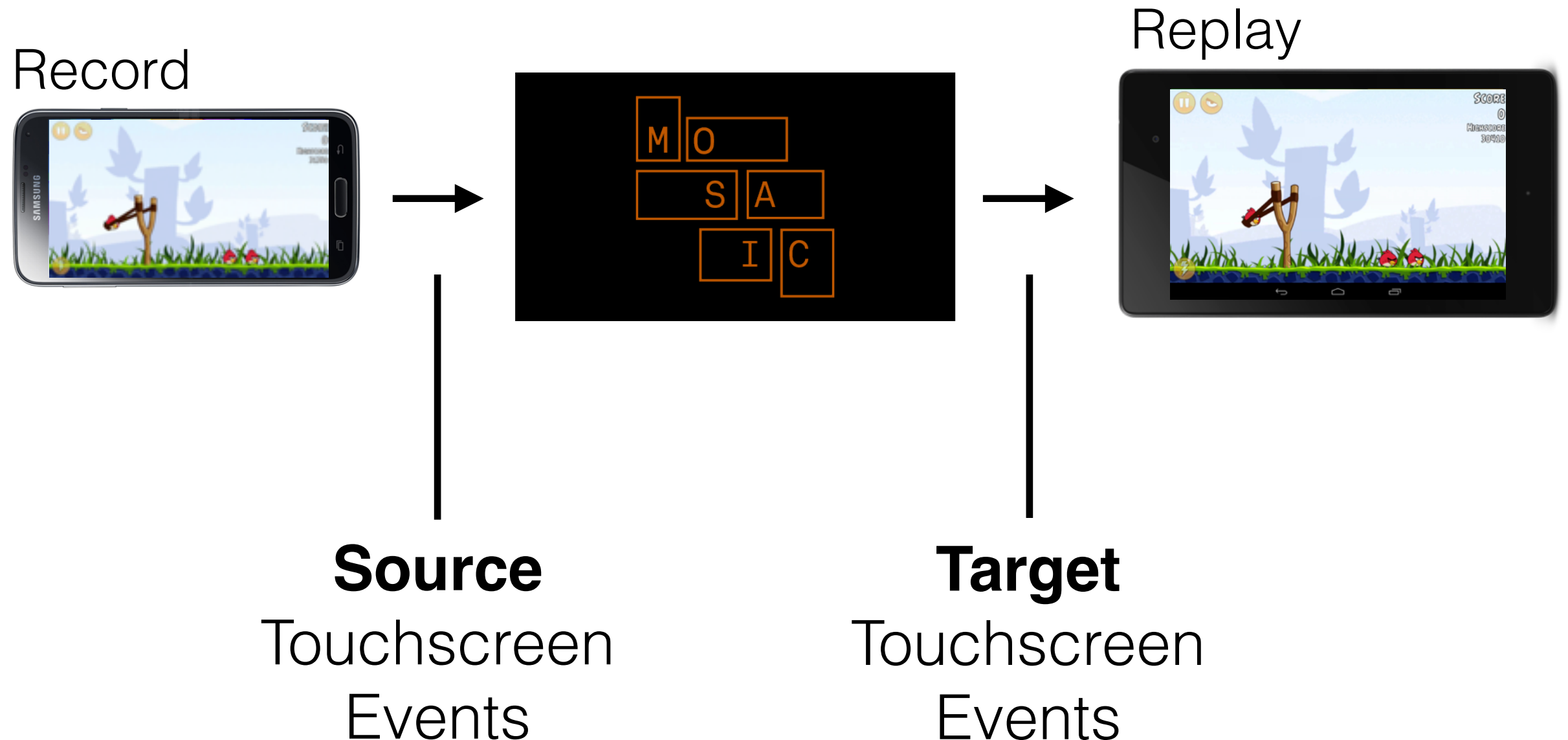


Replay



Mosaic Makes Interactivity Portable

- ✓ Off-the-shelf Mobile Devices
- ✓ Mainstream Mobile Applications
- ✓ Low Overhead



Touchscreen Events



Touchscreen Events



Touchscreen Events



Contact point 1 found

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended

Touchscreen Events



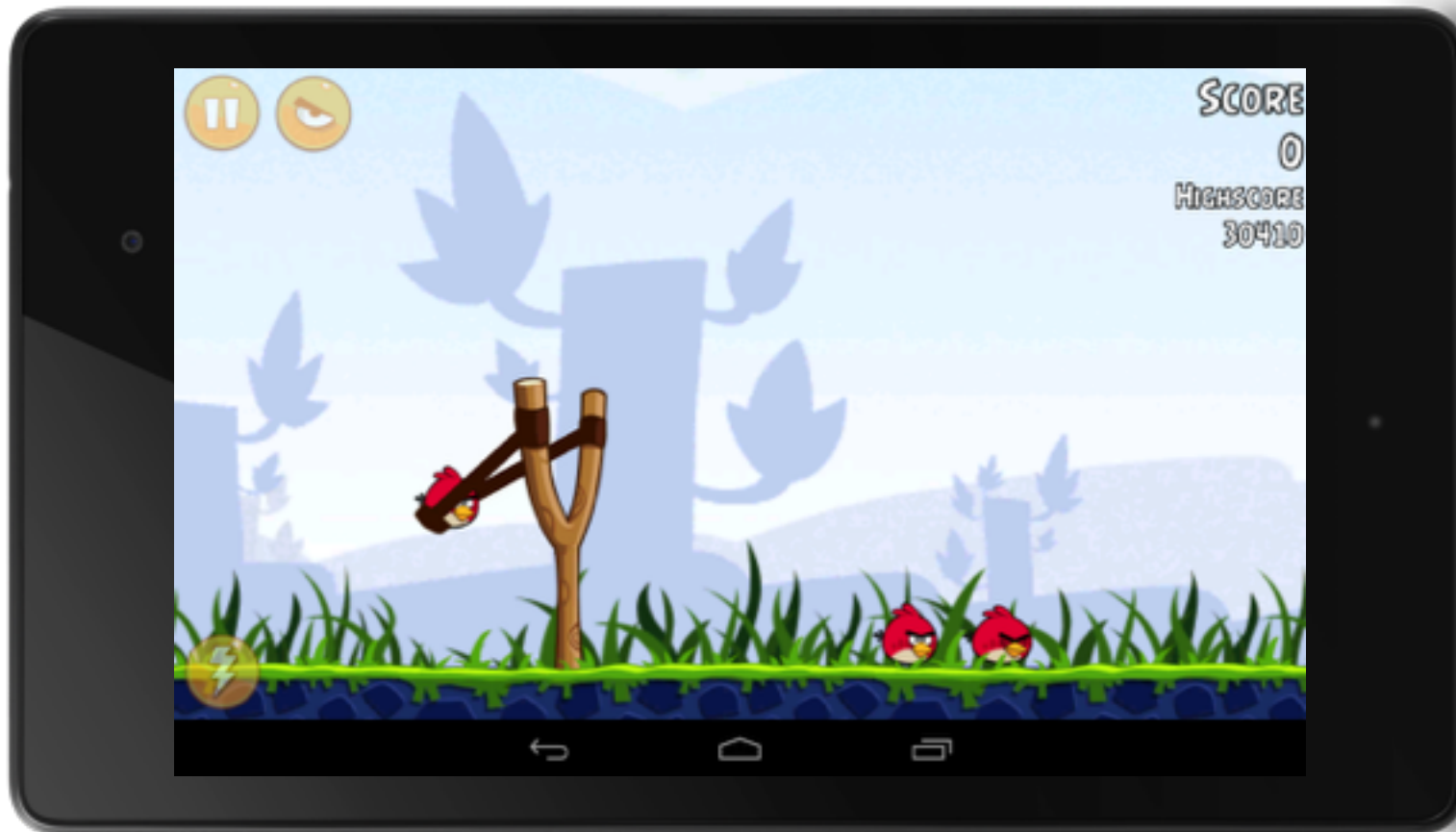
Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended

Touchscreen Events



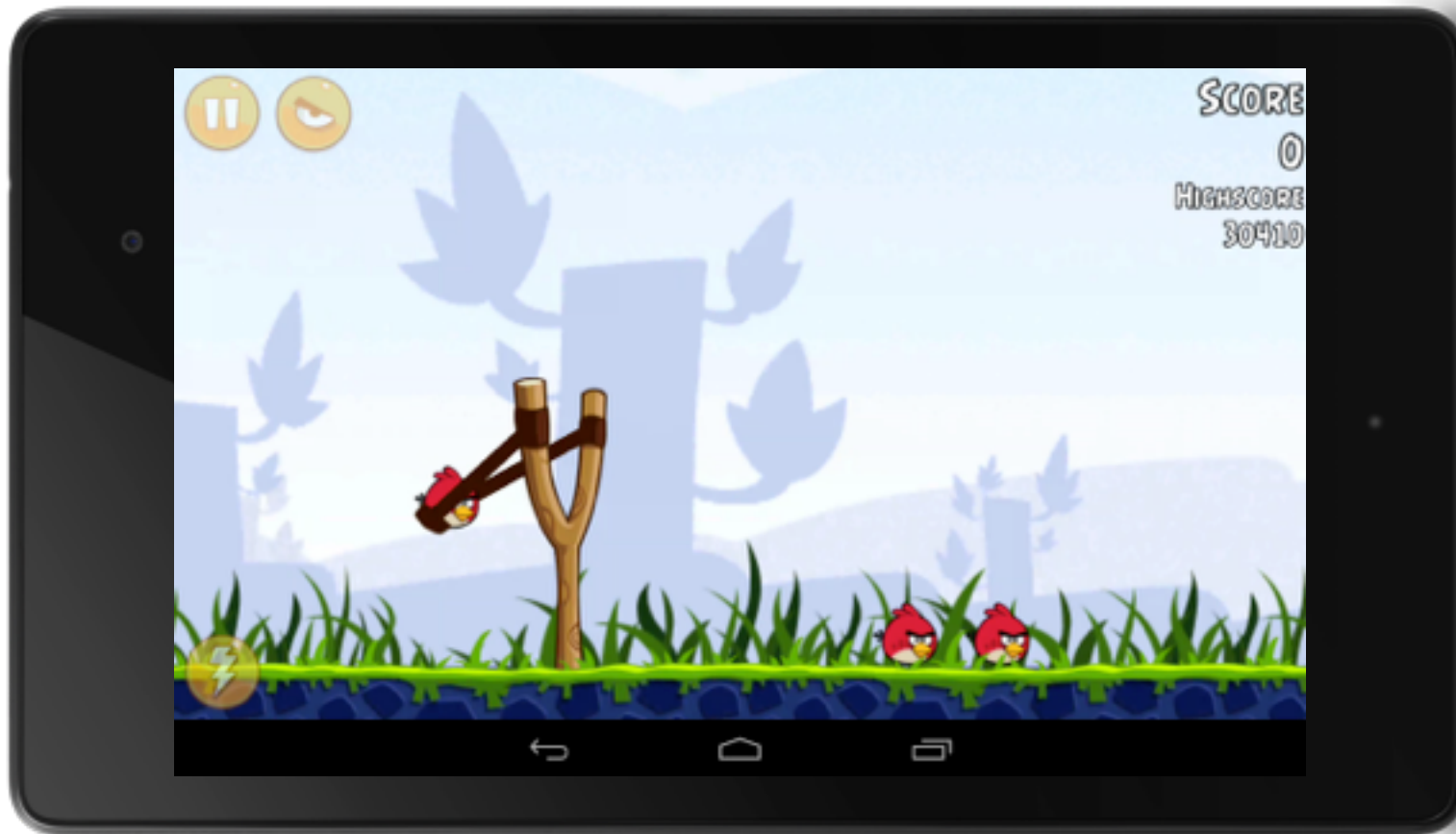
Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 is gone

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 is gone
Interaction has ended

Touchscreen Events



Contact point 1 found
X-position is at X0
Y-position is at Y0
Pressure is N
Interaction has ended
X-position is at X1
Y-position is at Y1
Interaction has ended
Contact point 1 is gone
Interaction has ended

Touchscreen Events

<u>Event Code</u>	<u>Event Value</u>	<u>Event Description</u>
ABS_MT_TRACKING_ID	1	Contact point 1 found
ABS_MT_POSITION_X	X0	X-position is at X0
ABS_MT_POSITION_Y	Y0	Y-position is at Y0
ABS_MT_PRESSURE	N	Pressure is N
SYN_REPORT	NULL	Interaction has ended
ABS_MT_POSITION_X	X1	X-position is at X1
ABS_MT_POSITION_Y	Y1	Y-position is at Y1
SYN_REPORT	NULL	Interaction has ended
ABS_MT_TRACKING_ID	-1	Contact point 1 is gone
SYN_REPORT	NULL	Interaction has ended

Touchscreen Events

<u>Event Code</u>	<u>Event Value</u>	<u>Event Description</u>
ABS_MT_TRACKING_ID	1	Contact point 1 found
ABS_MT_POSITION_X	X0	X-position is at X0
ABS_MT_POSITION_Y	Y0	Y-position is at Y0
ABS_MT_PRESSURE	N	Pressure is N
SYN_REPORT	NULL	Interaction has ended
ABS_MT_POSITION_X	X1	X-position is at X1
ABS_MT_POSITION_Y	Y1	Y-position is at Y1
SYN_REPORT	NULL	Interaction has ended
ABS_MT_TRACKING_ID	-1	Contact point 1 is gone
SYN_REPORT	NULL	Interaction has ended

Touchscreen Event Differences



Touchscreen Event Differences



Touchscreen Event Differences



ABS_MT_TRACKING_ID

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT



ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

Touchscreen Event Differences



ABS_MT_TRACKING_ID

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

SYN_REPORT



ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

SYN_REPORT

Touchscreen Event Differences



ABS_MT_TRACKING_ID

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

SYN_REPORT

ABS_MT_TRACKING_ID

SYN_REPORT



ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

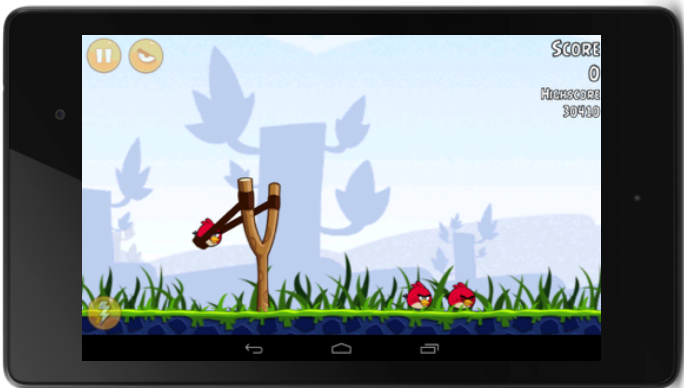
SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

SYN_REPORT

Touchscreen Event Differences



ABS_MT_TRACKING_ID

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_POSITION_Y

ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

ABS_MT_PRESSURE

SYN_REPORT

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_POSITION_Y

SYN_REPORT

SYN_REPORT

ABS_MT_TRACKING_ID

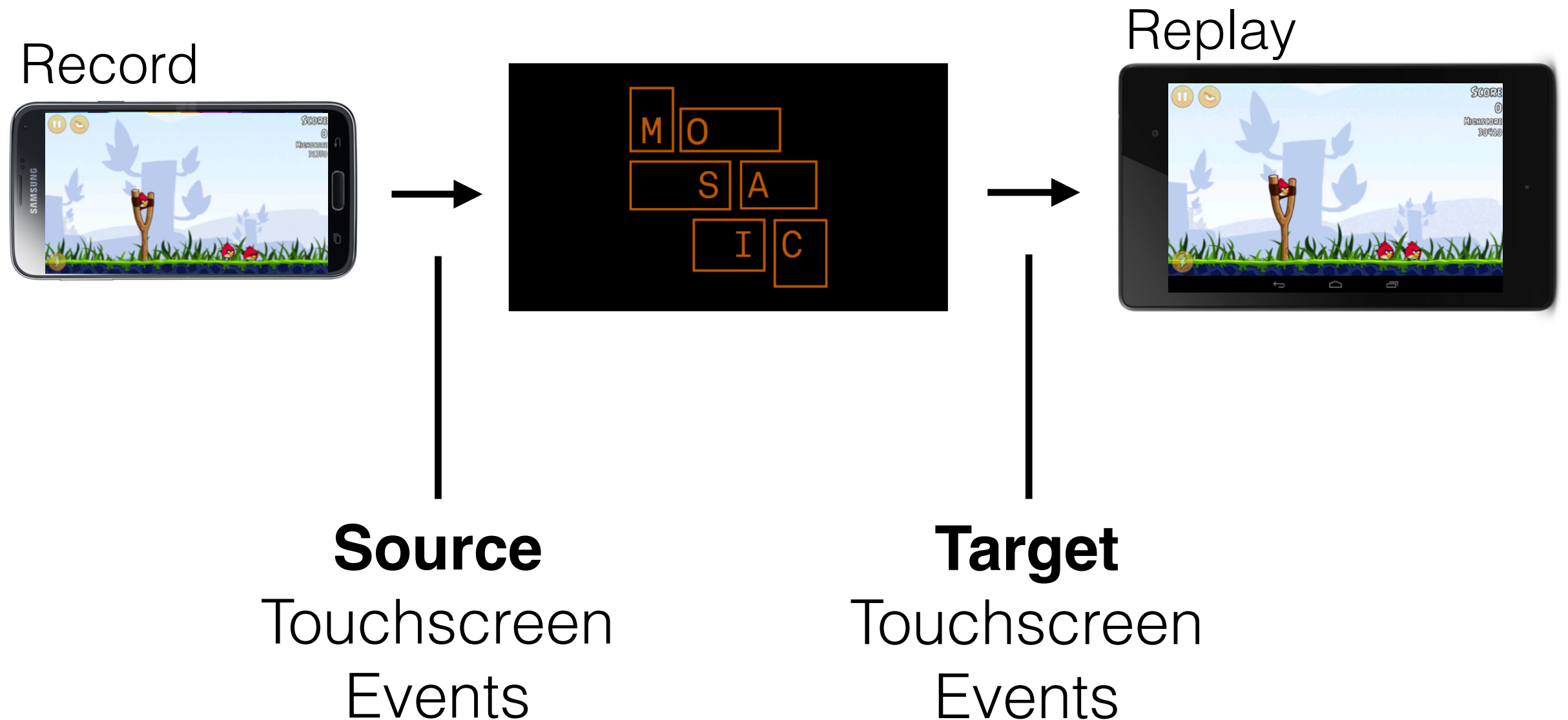
ABS_MT_TRACKING_ID

BTN_TOUCH

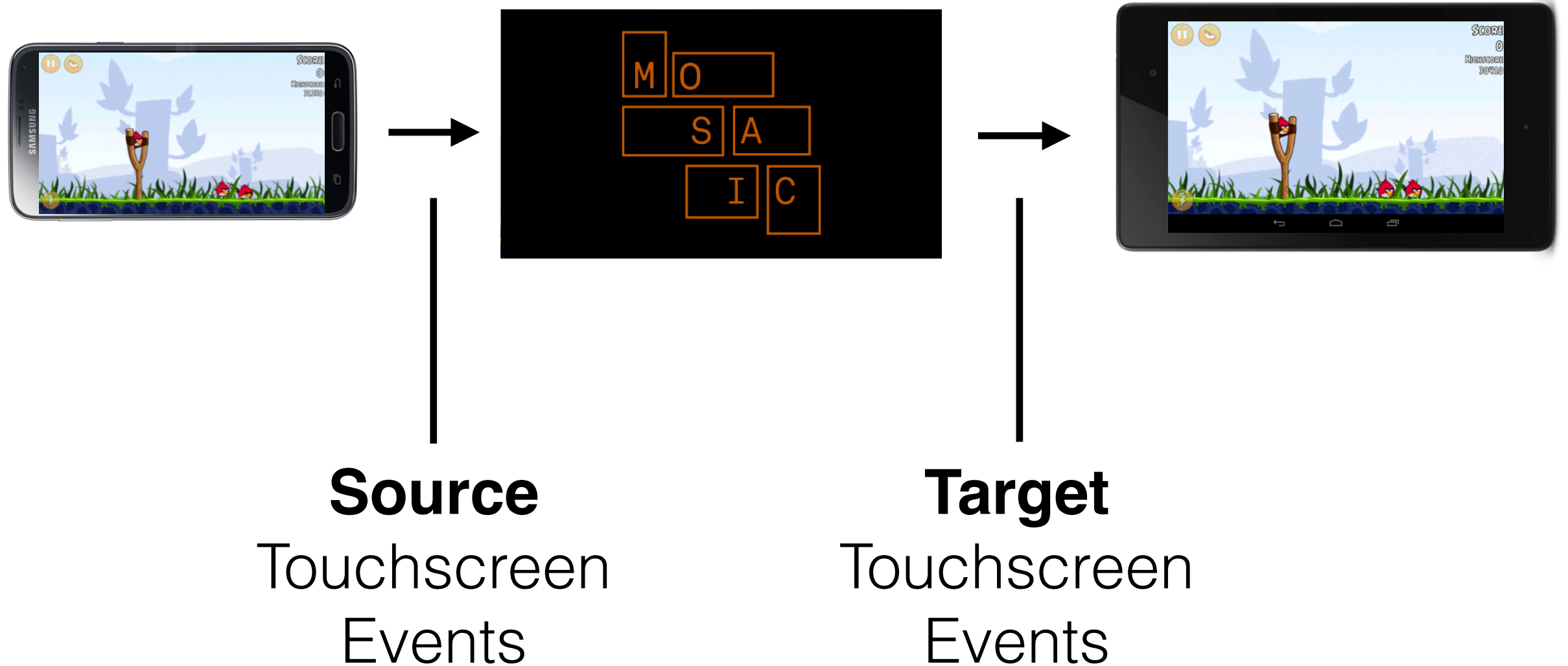
SYN_REPORT

SYN_REPORT

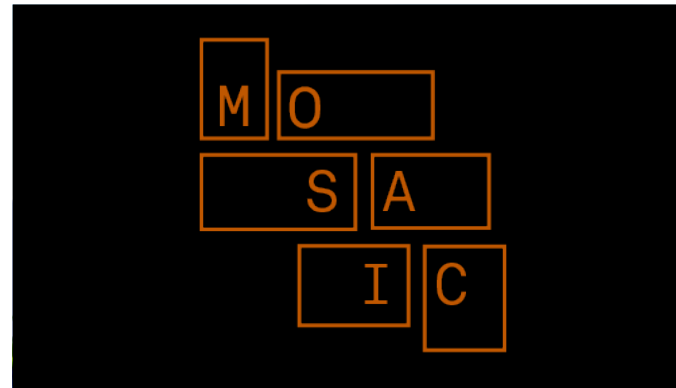
How Mosaic Makes Interactivity Portable



Touchscreen Driver



Touchscreen Driver



ABS_MT_TRACKING_ID

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

Touchscreen Driver

Virtualized Interactivity



ABS_MT_TRACKING_ID

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

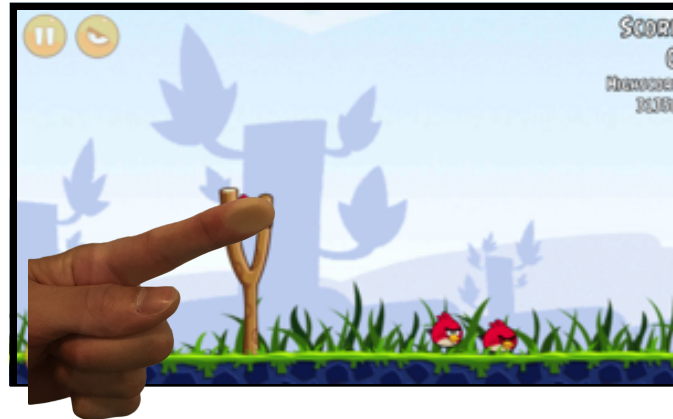
ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

Touchscreen Driver

Virtualized Interactivity



ABS_MT_TRACKING_ID

ABS_MT_POSITION_X
ABS_MT_POSITION_Y

ABS_MT_PRESSURE
SYN_REPORT

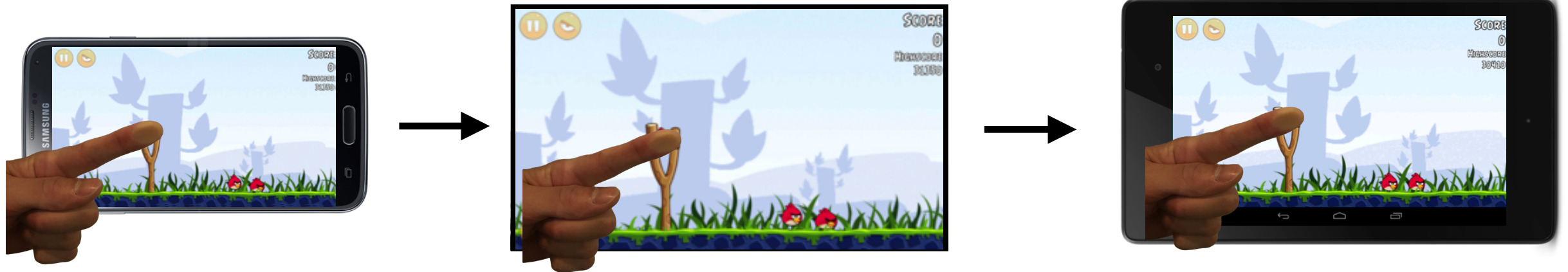
Press XYX YXY

ABS_MT_TRACKING_ID
BTN_TOUCH
ABS_MT_POSITION_X
ABS_MT_POSITION_Y
ABS_MT_TOUCH_MAJOR
ABS_MT_TOUCH_MINOR

SYN_REPORT

Touchscreen Driver

Virtualized Interactivity



ABS_MT_TRACKING_ID

Press XYX YXY

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

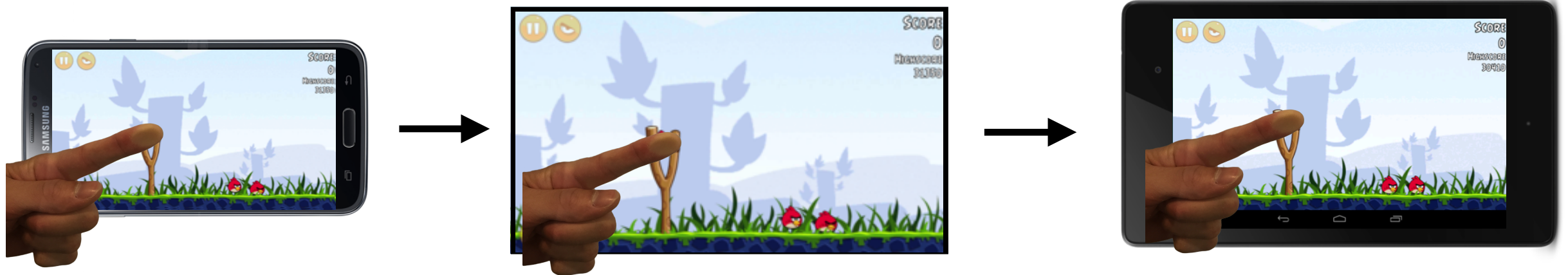
ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

Touchscreen Driver

Virtualized Interactivity



ABS_MT_TRACKING_ID

Press XYX YXY

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

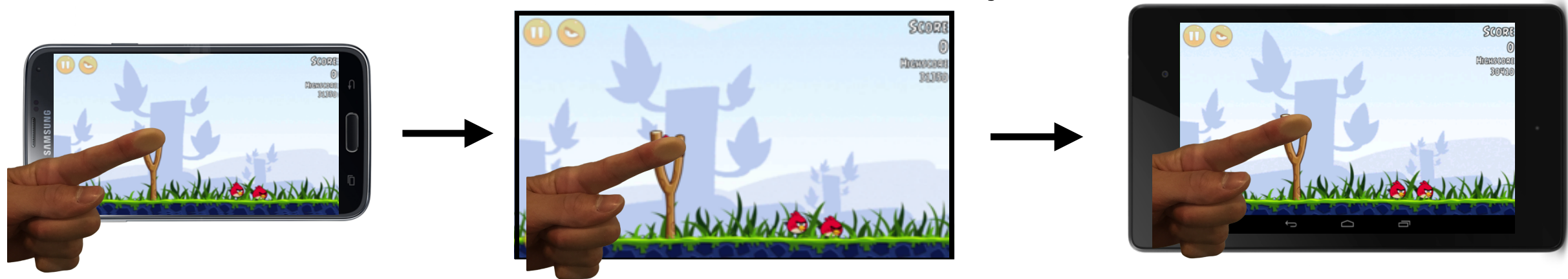
ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

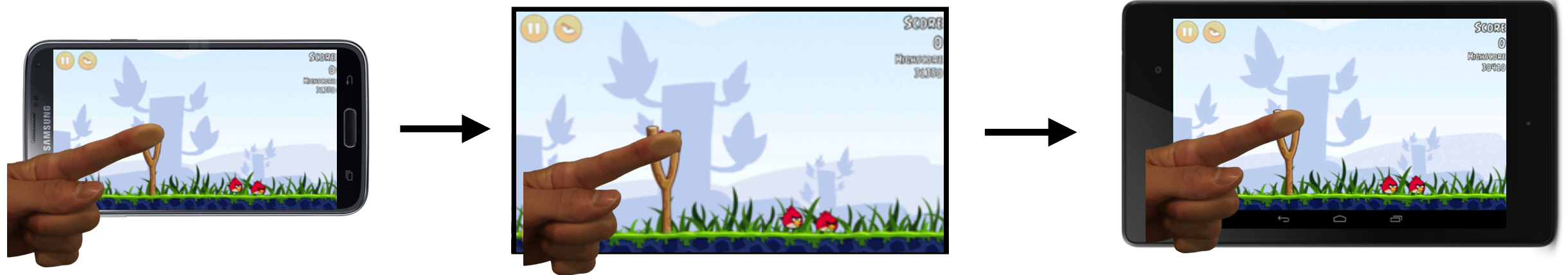
Touchscreen Driver

Virtualized Interactivity



Touchscreen Driver

Virtualized Interactivity



ABS_MT_TRACKING_ID

Press XYX YXY

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

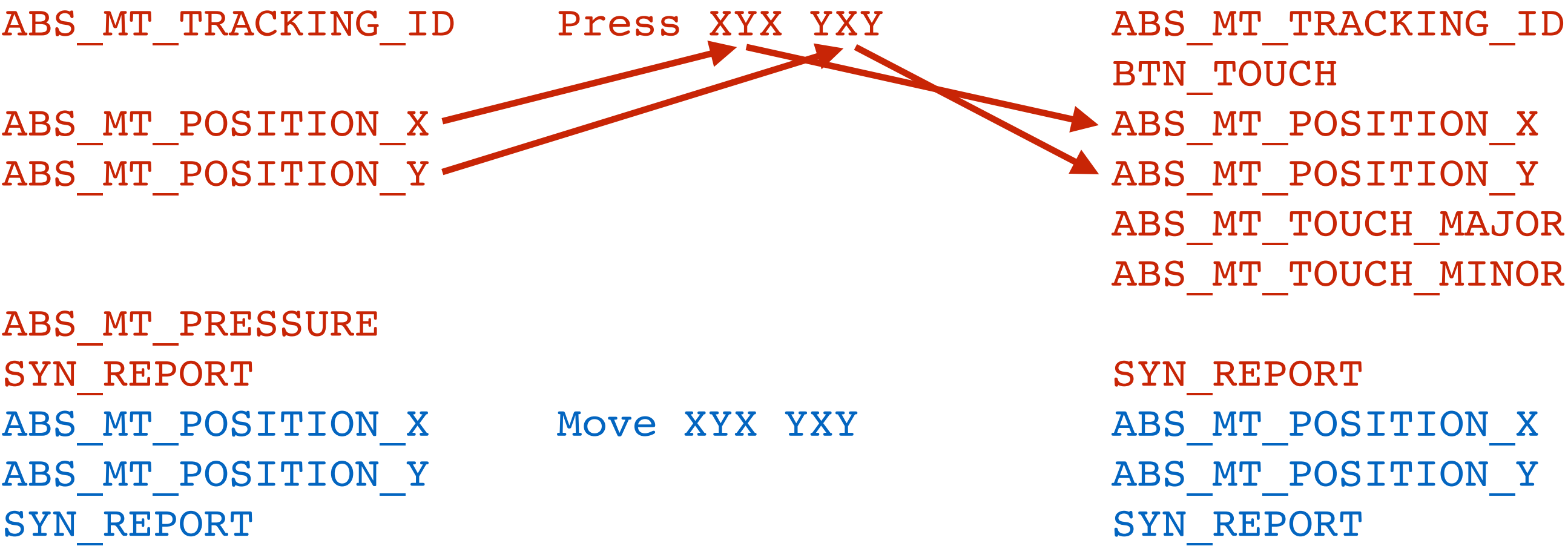
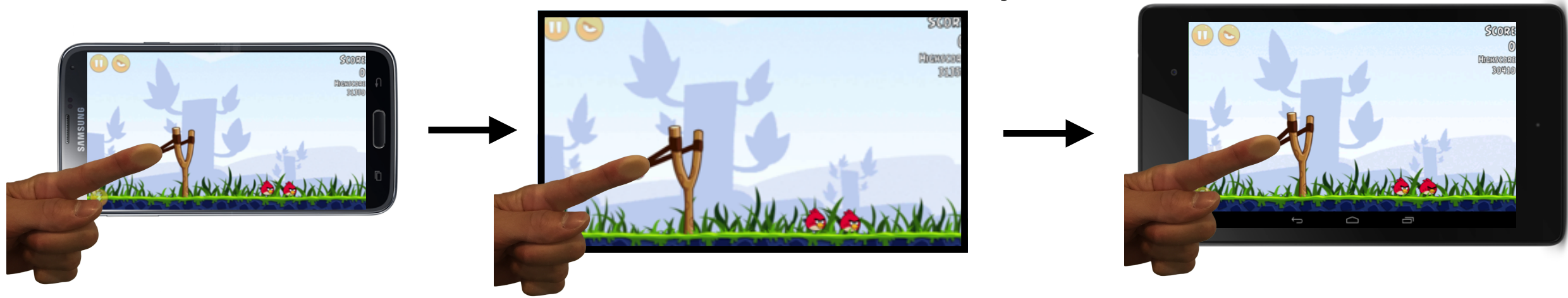
ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

Touchscreen Driver

Virtualized Interactivity



Touchscreen Driver

Virtualized Interactivity



ABS_MT_TRACKING_ID

Press XYX YXY

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_PRESSURE

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

SYN_REPORT

ABS_MT_TRACKING_ID

Move XYX YXY

Release

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

ABS_MT_TOUCH_MAJOR

ABS_MT_TOUCH_MINOR

SYN_REPORT

ABS_MT_POSITION_X

ABS_MT_POSITION_Y

SYN_REPORT

ABS_MT_TRACKING_ID

BTN_TOUCH

SYN_REPORT

Virtualizing Interactions



Virtualizing Interactions

- **Timing**
- **Type**
- **Location**



Virtualizing Interactions

- Timing
- Type
- Location

`time finger <N> <interaction> [[x] [y]]`



Virtualizing Interactions

✓ **Timing**

• **Type**

• **Location**

time **finger** <N> <interaction> [[x] [y]]



Virtualizing Interactions

✓ Timing

• Type

• Location

`time` `finger` `<N>` `<interaction>` `[[x] [y]]`



Virtualizing Interactions

✓ Timing

• Type

• Location

`time finger <N> <interaction> [[x] [y]]`

Press



Virtualizing Interactions

✓ Timing

• Type

• Location

`time finger <N> <interaction> [[x] [y]]`

Press

Move



Virtualizing Interactions

✓ Timing

• Type

• Location

`time finger <N> <interaction> [[x] [y]]`

Press

Move

Release



Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]



Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]

Press



Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]

Press

Move



Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]

Press

Move

Release



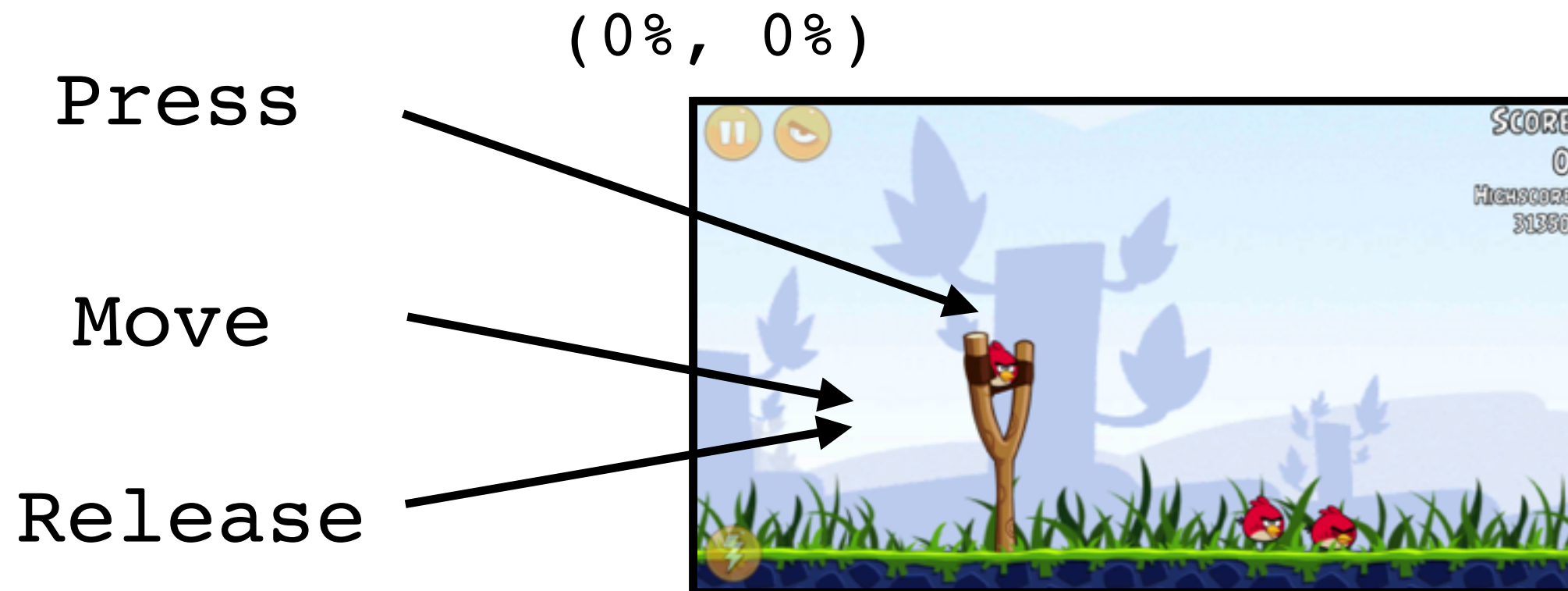
Virtualizing Interactions

✓ Timing

• Type

• Location

time finger <N> <interaction> [[x] [y]]



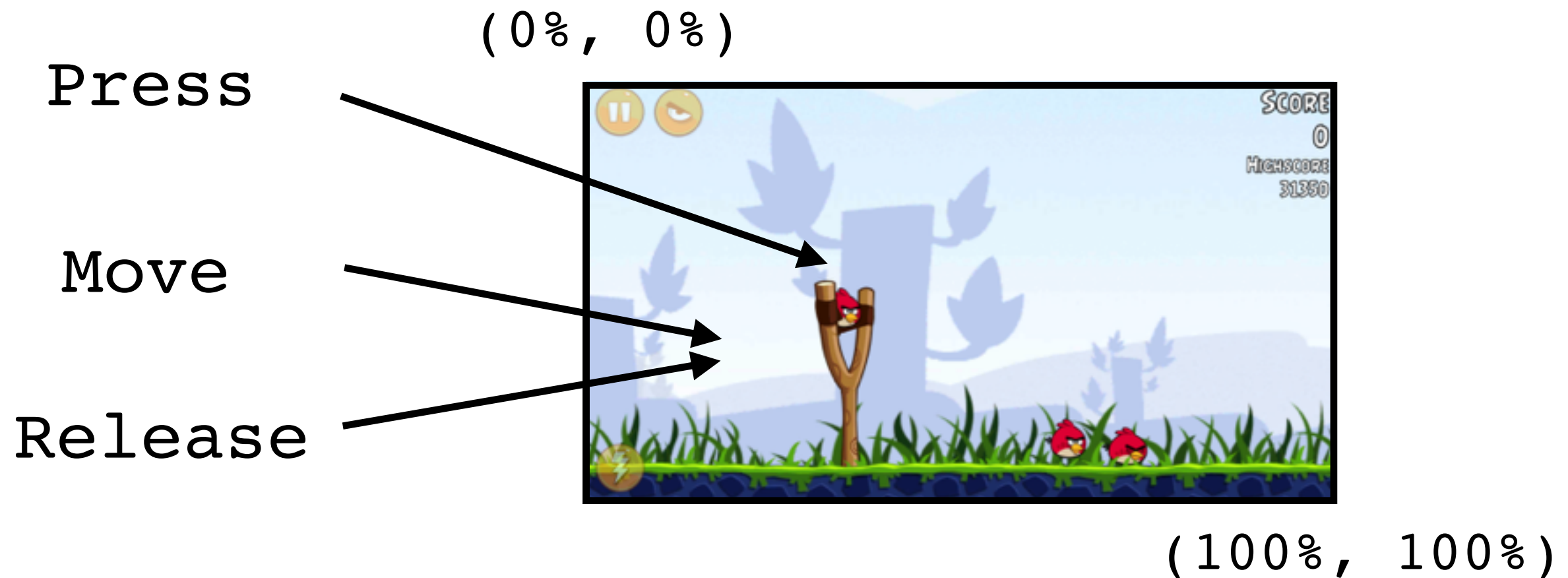
Virtualizing Interactions

✓ Timing

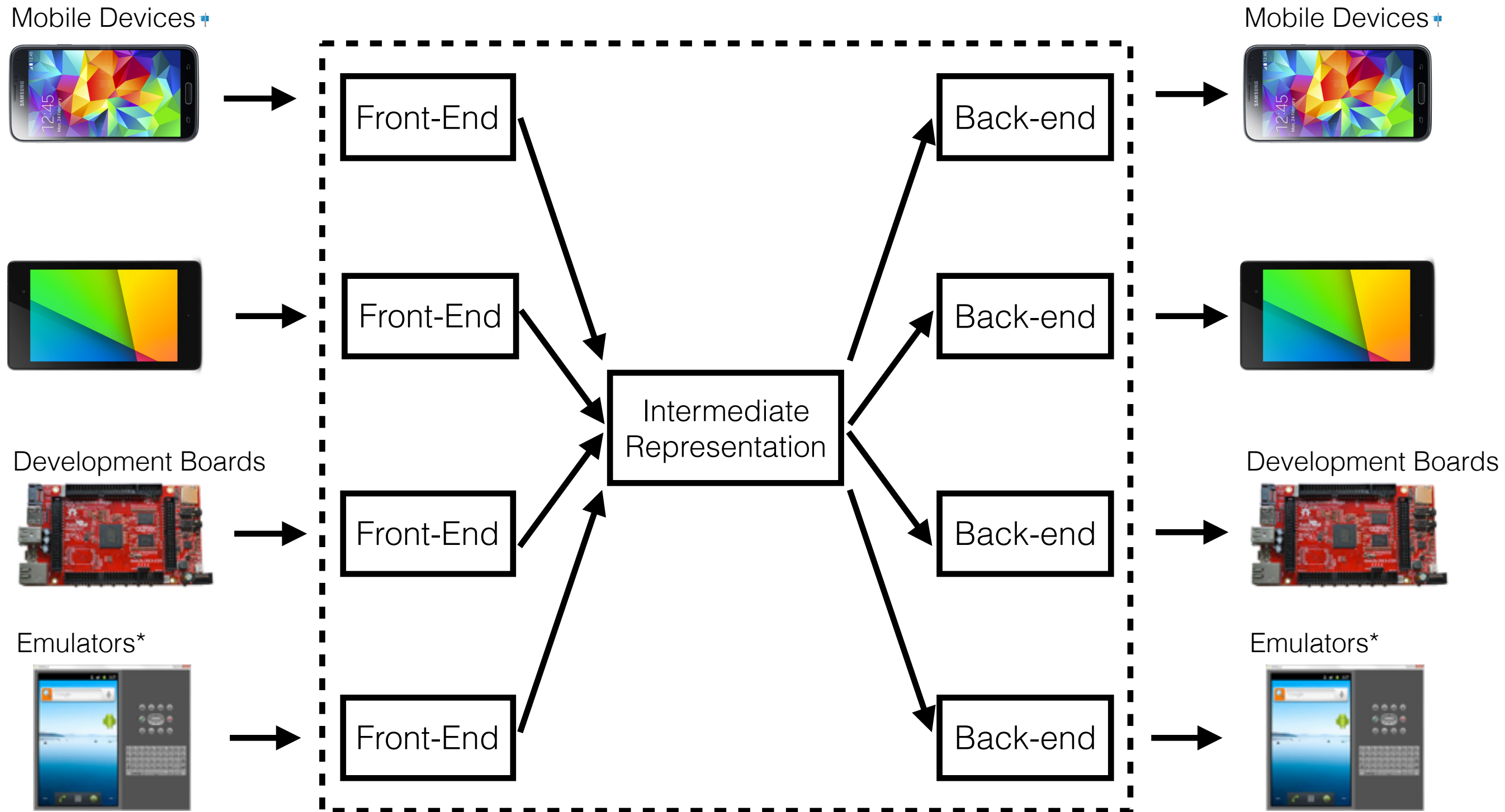
• Type

• Location

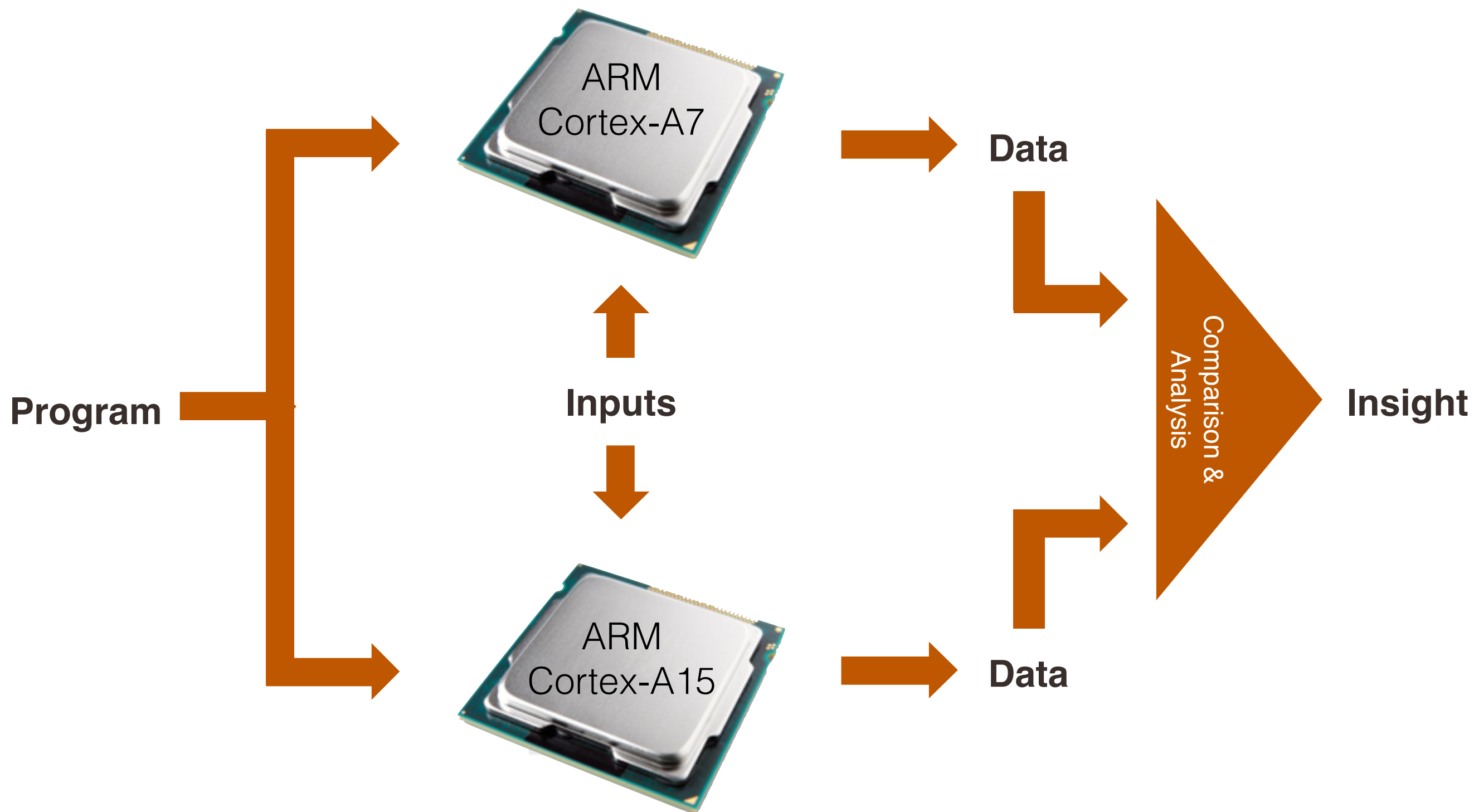
time finger <N> <interaction> [[x] [y]]

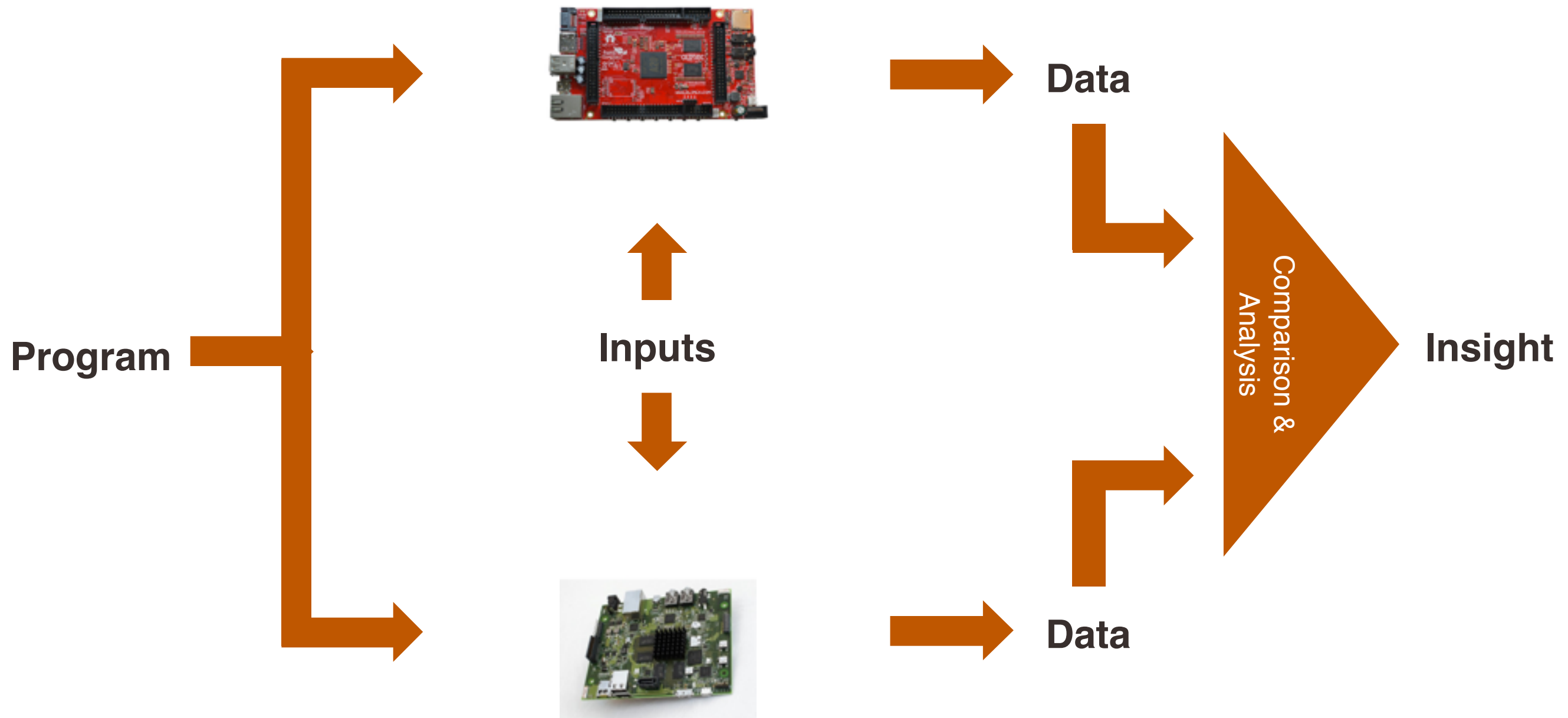


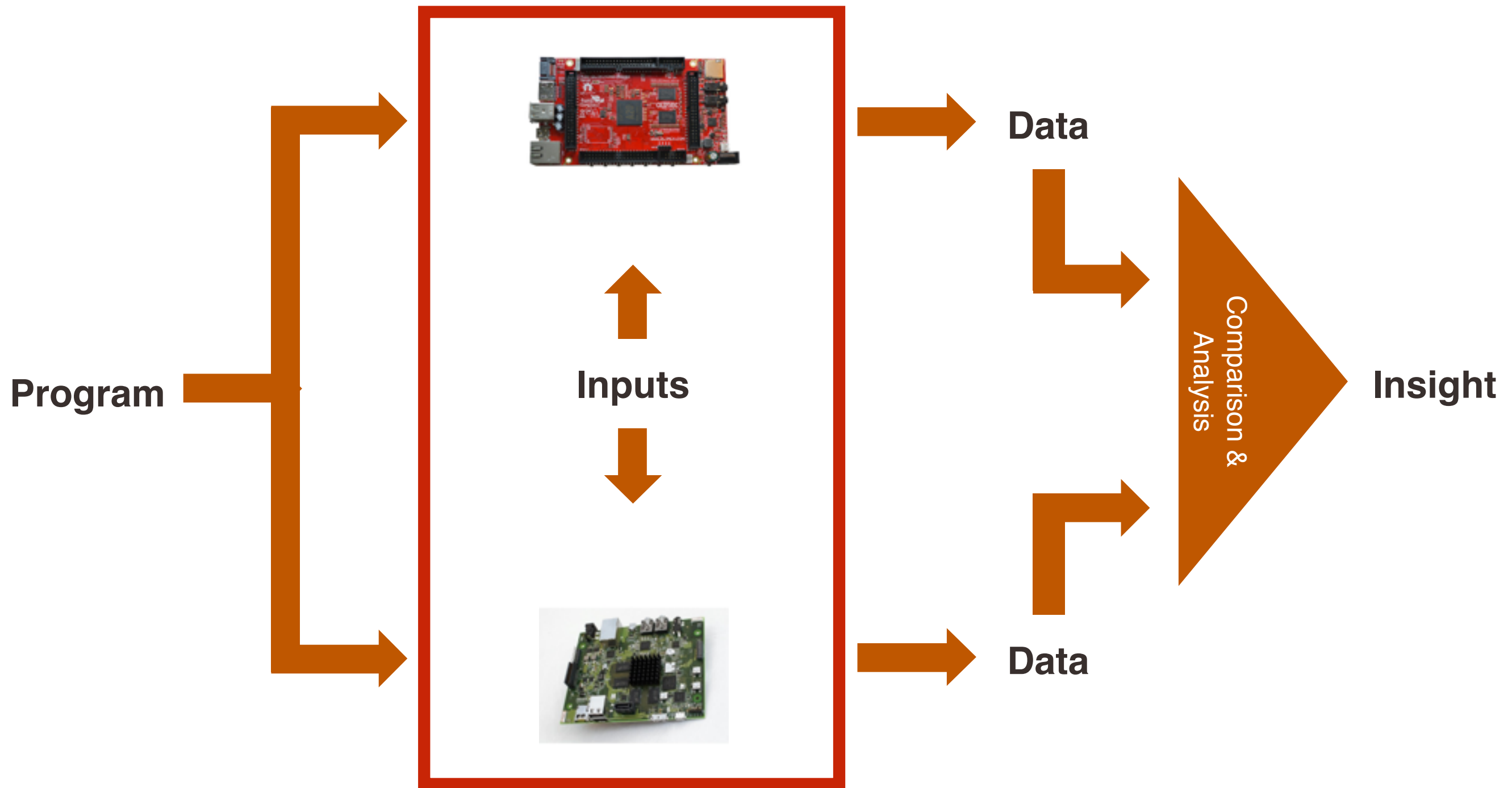
How Mosaic Solves The Portability Paradox

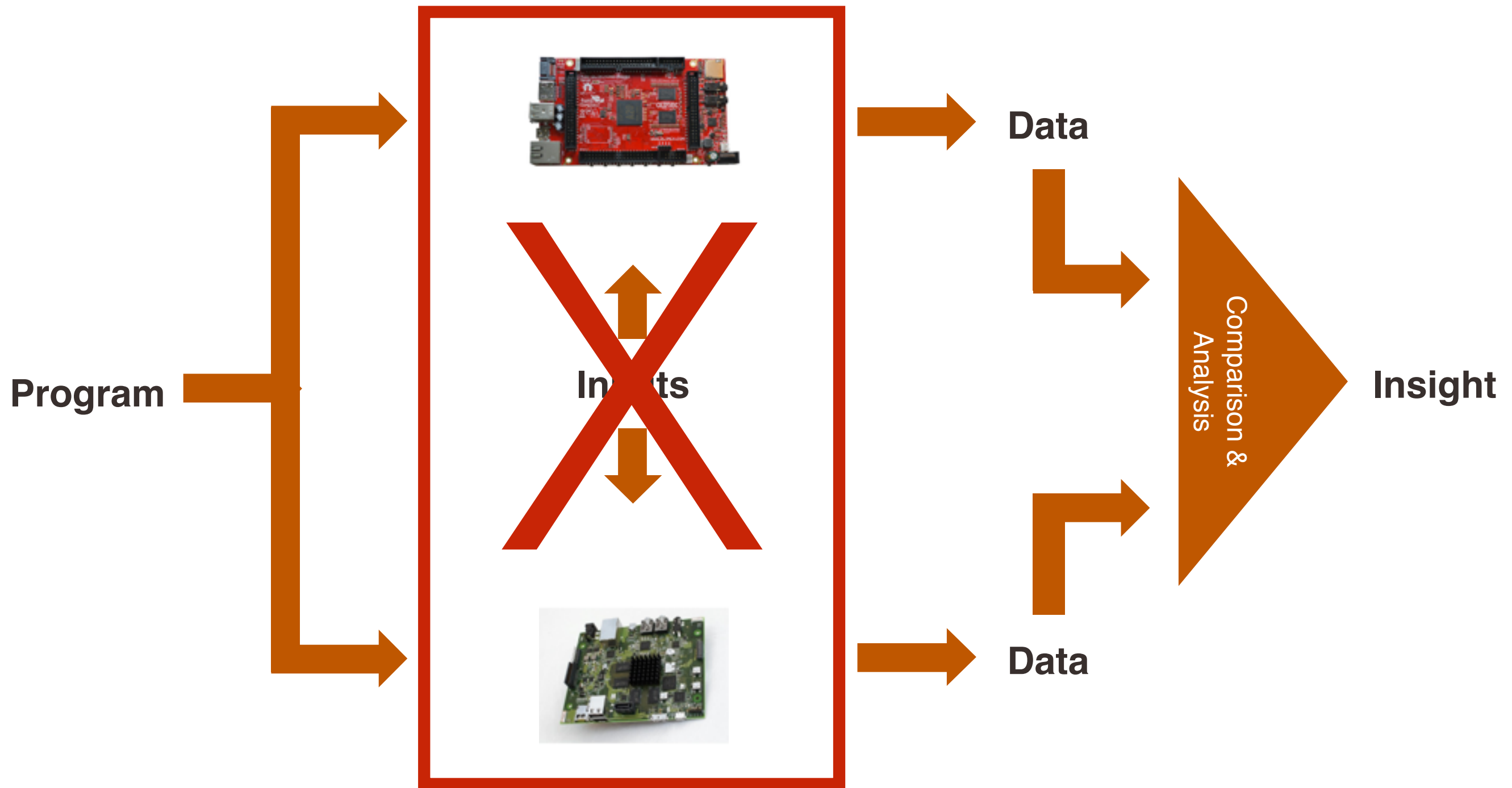


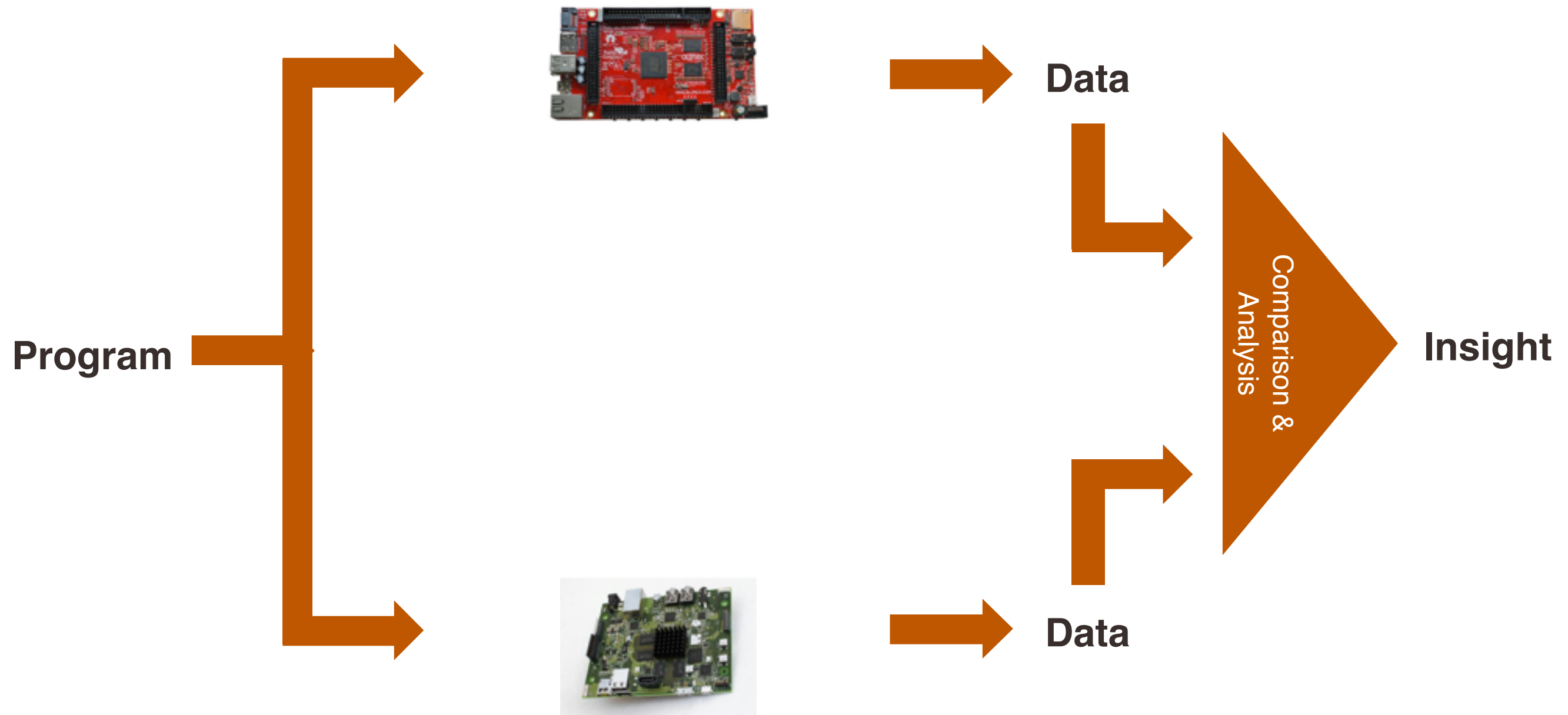
* Modifications to emulator needed - see paper for details

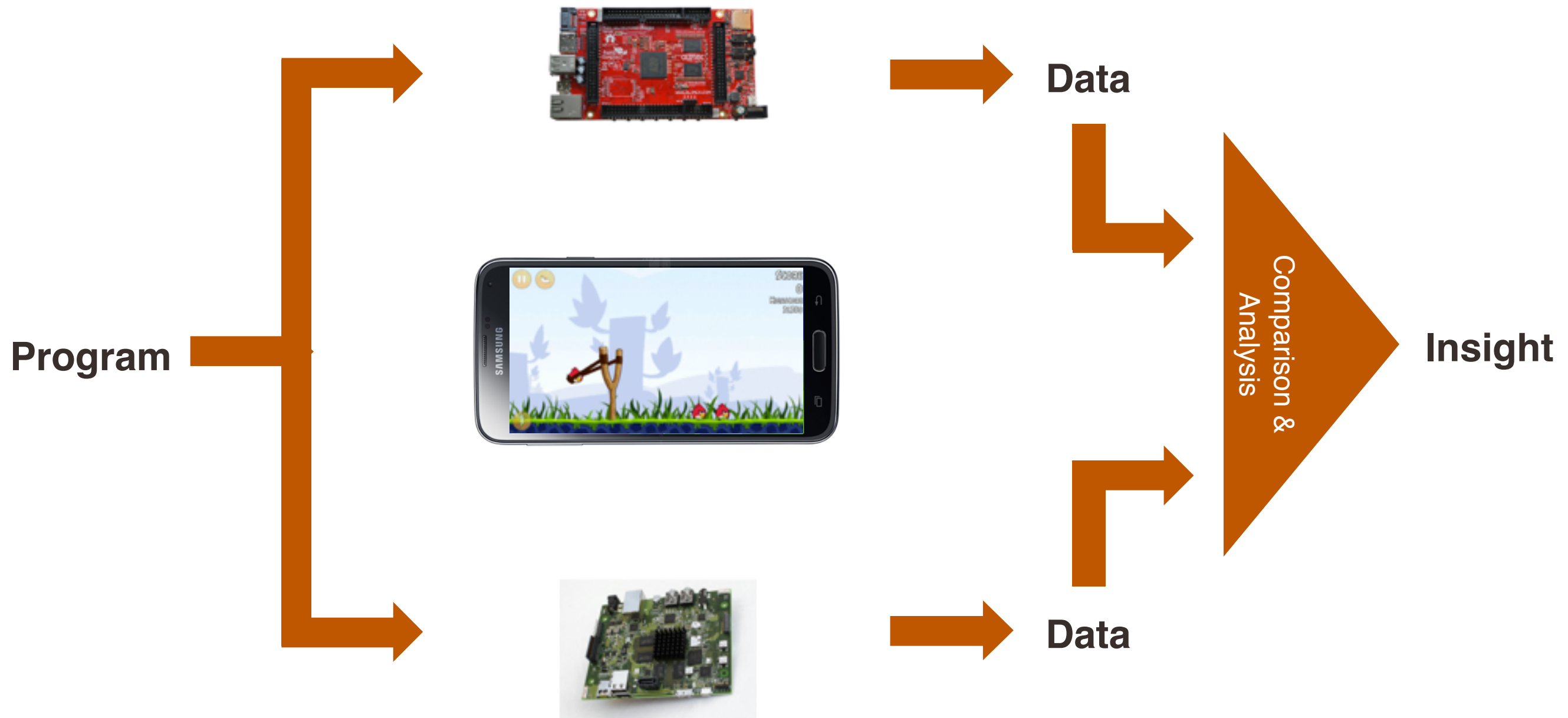


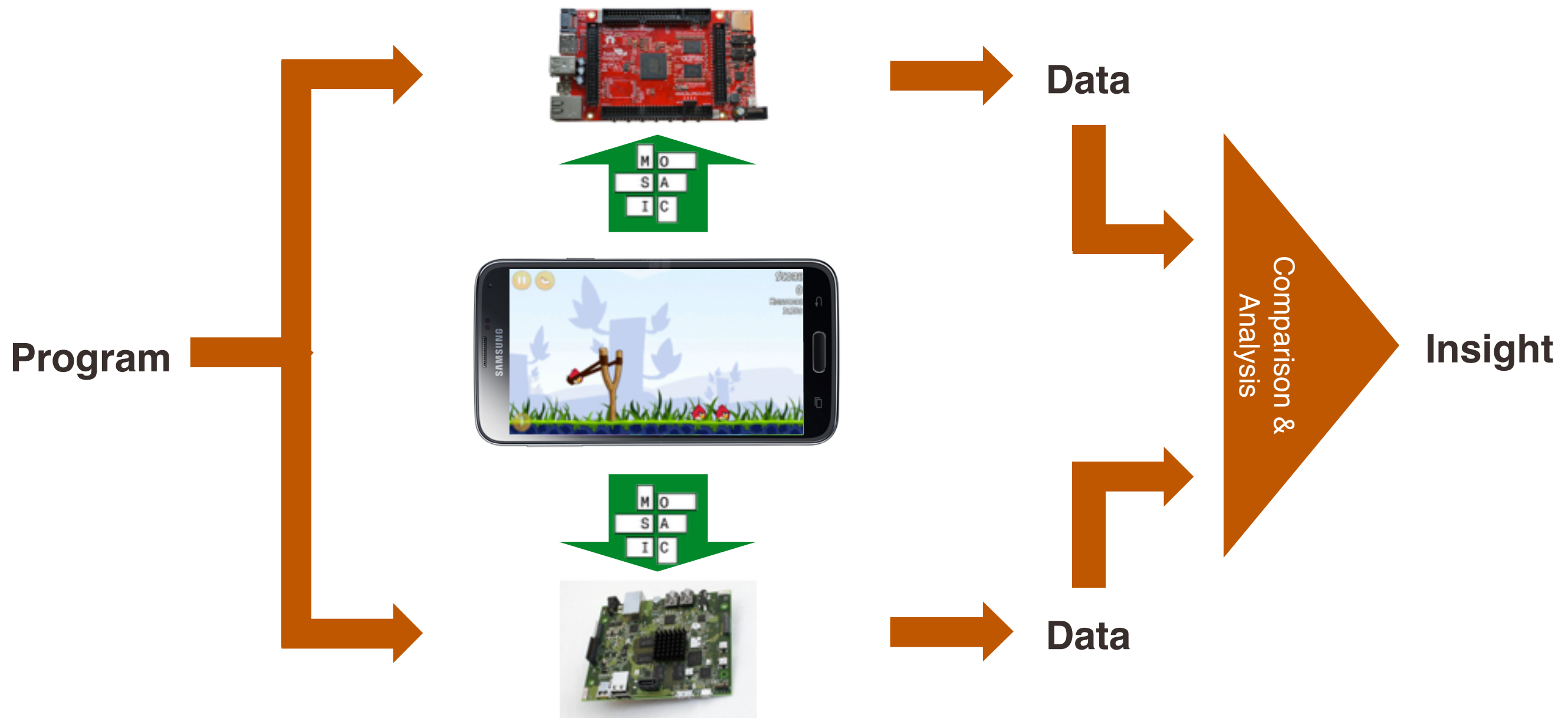


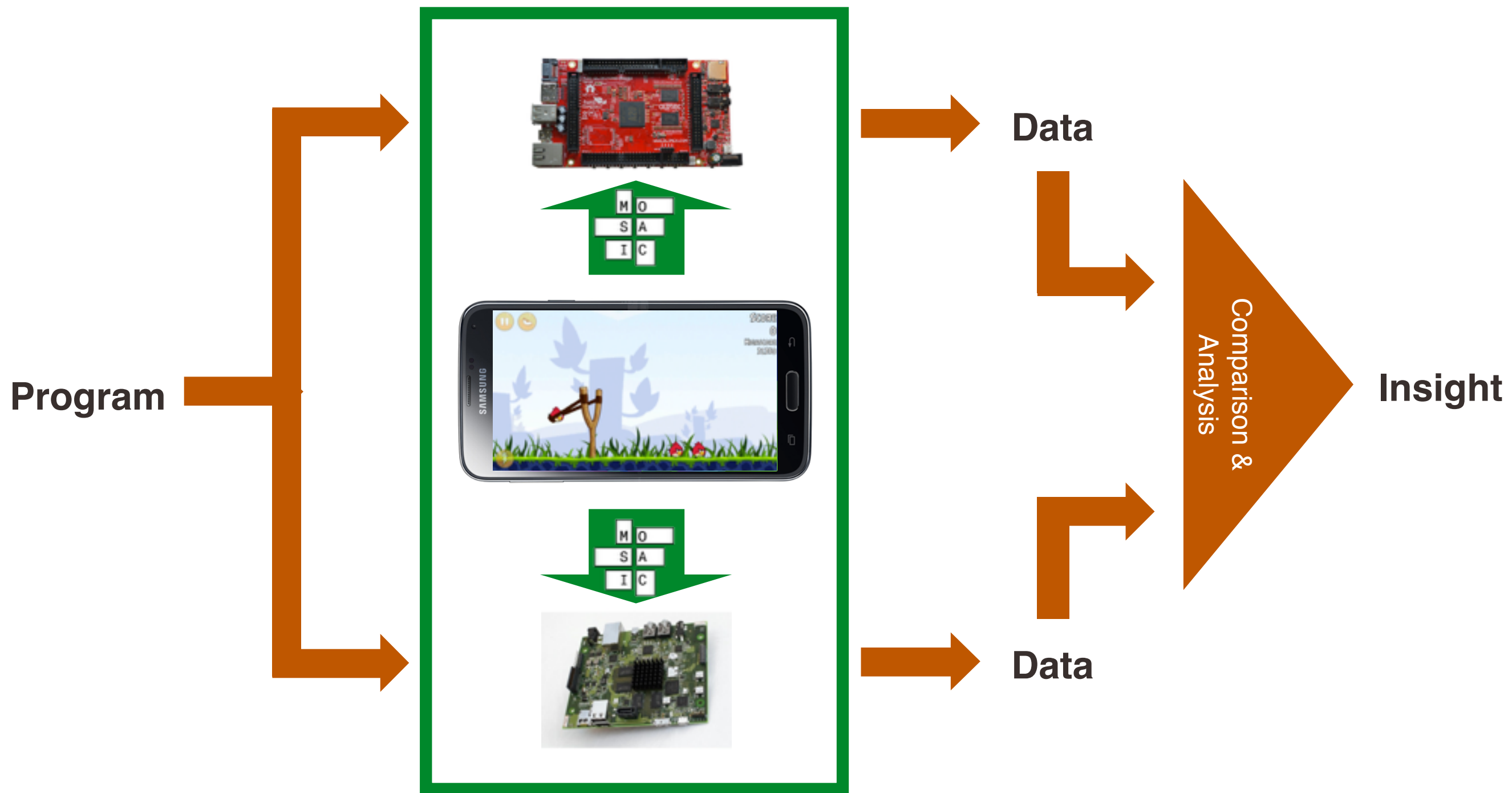






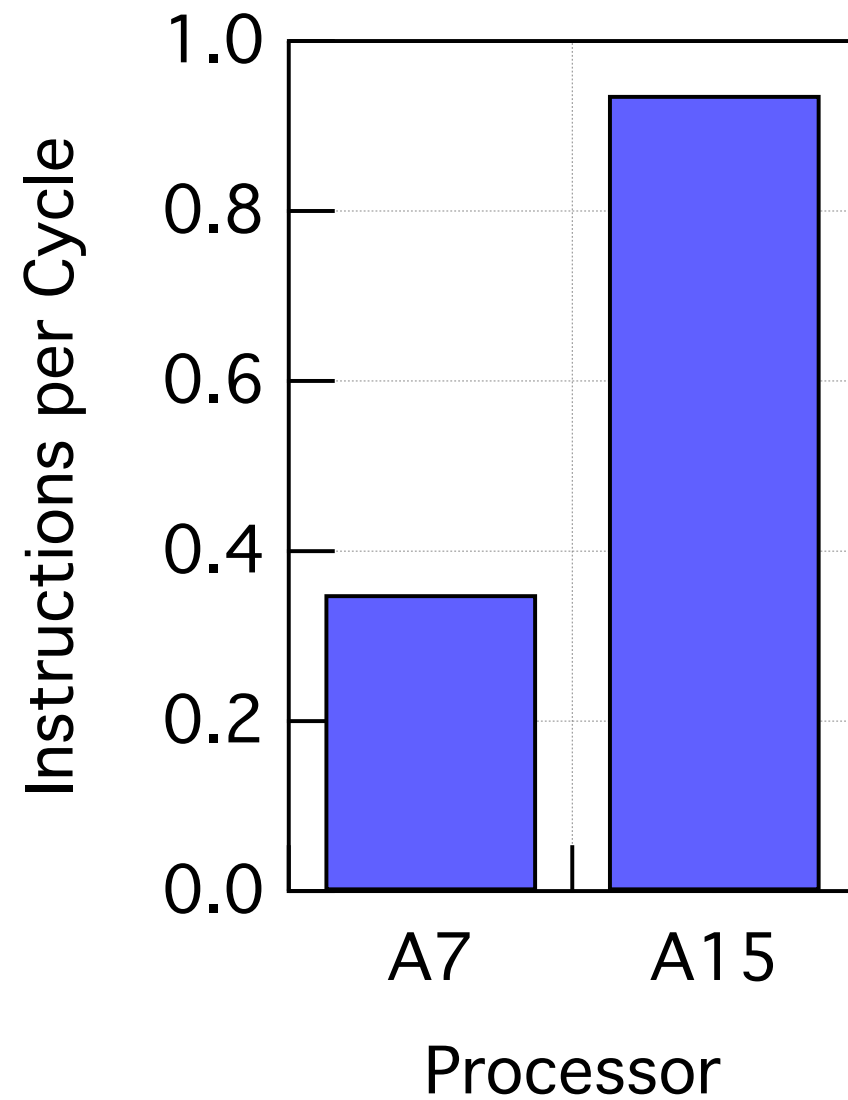




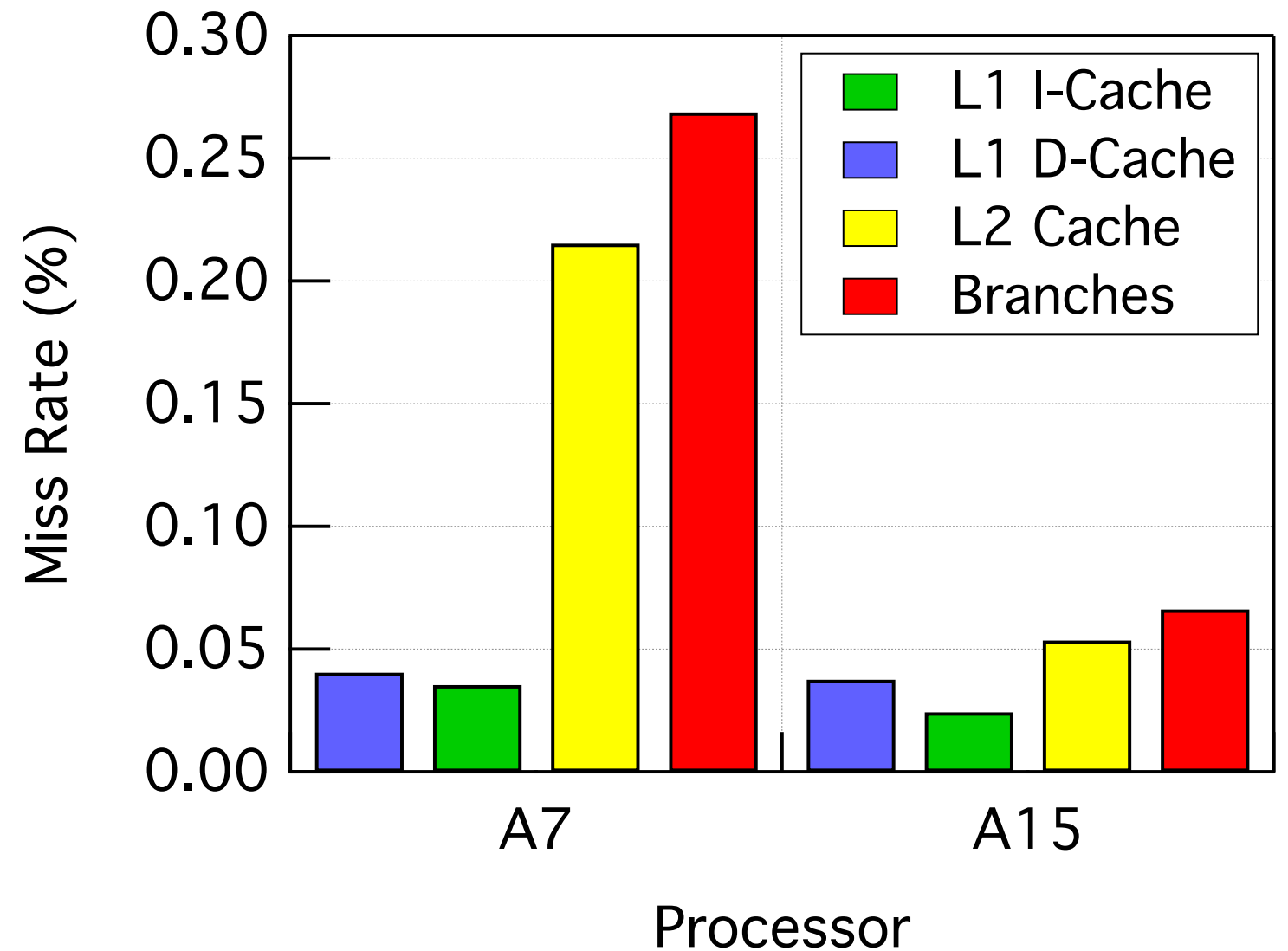
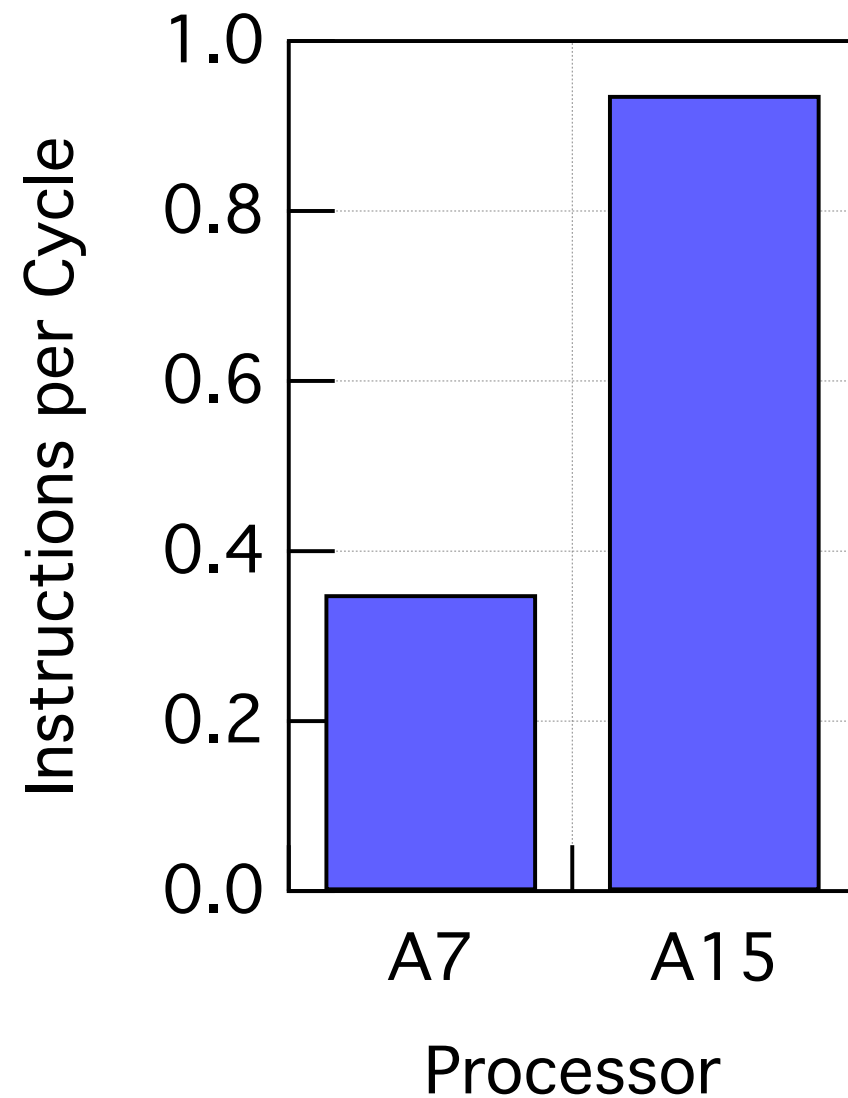


Identifying Microarchitectural Bottlenecks

Identifying Microarchitectural Bottlenecks



Identifying Microarchitectural Bottlenecks



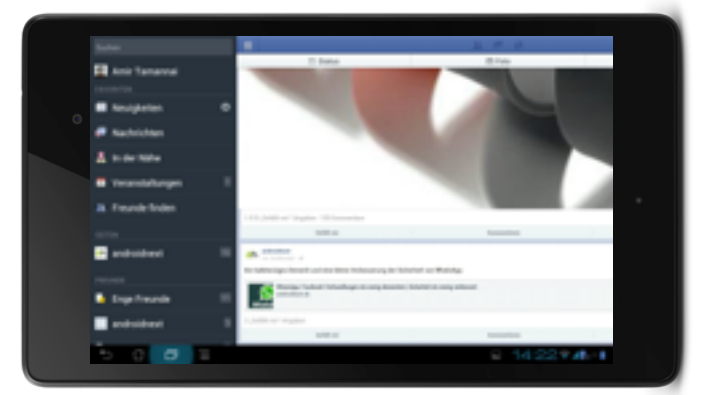
Mosaic Assumptions and Requirements

Mosaic Assumptions and Requirements

- **Linear UI Scaling**

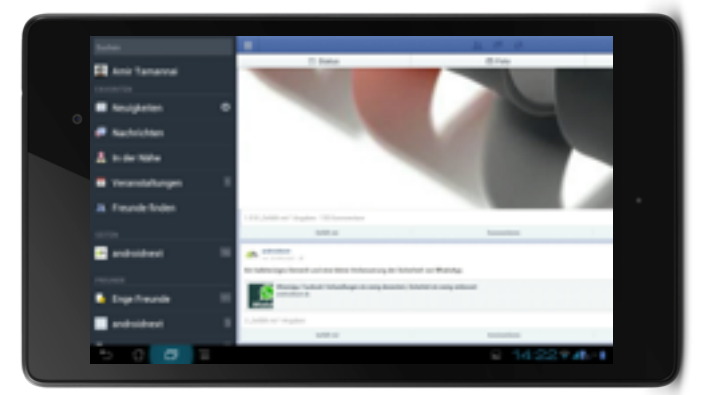
Mosaic Assumptions and Requirements

- **Linear UI Scaling**



Mosaic Assumptions and Requirements

- **Linear UI Scaling**



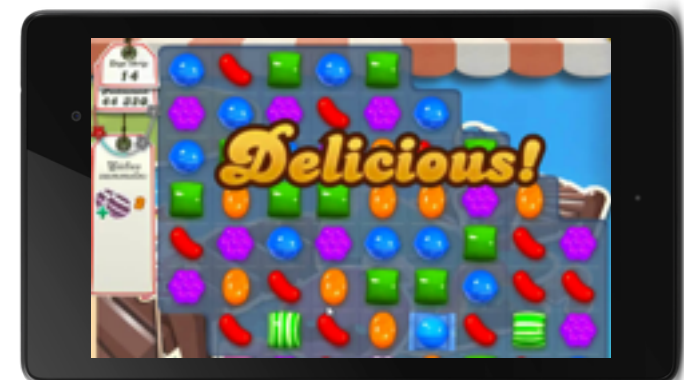
- **Repeatable Application Behavior**

Mosaic Assumptions and Requirements

- **Linear UI Scaling**

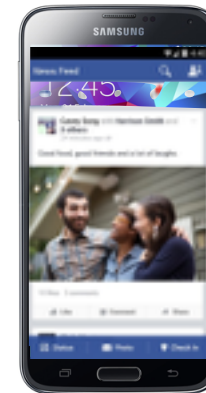


- **Repeatable Application Behavior**

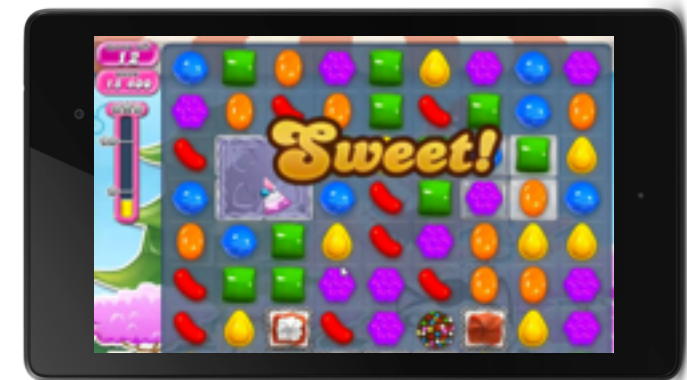


Mosaic Assumptions and Requirements

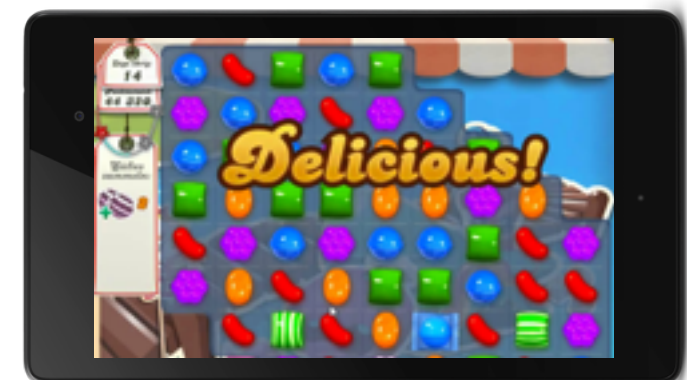
- **Linear UI Scaling**



- **Repeatable Application Behavior**



- **“Imperceptible” Performance**



Mosaic Assumptions and Requirements

Many Applications Meet These Requirements

Adobe Reader*	Angry Birds*	Big Fish Casino	Bingo Fever - World Trip	Bingo - Secret Cities
Bubble Bee	Bubble Blaze	Bubble Witch Saga 2	Chase	Chrome*
Clash of Lords 2	Clean Master	Coin Dozer	Destiny	DH 2014
Diamond Digger Saga	Dolphin Browser	Five Nights at Freddy's	Flashlight*	Flipagram
Google Play Newsstand	Hill Climb Racing*	iHeartRadio	Instagram	Jump Ninja
Legend of Master Online	Messenger	Minion Rush	MonsterWarlord	News & Weather
Firefox	Photo Grid	Piano Tiles	Slotomania	Slots Fever
Slots - House Of Fun	Solitaire	Spider-Man	Steel Avengers	Temple Run 2*
Tycoon Mania	Video Poker	Walmart	WatchESPN	YouTube*

Evaluated across several different Android-based platforms



Mobile Devices

Dev Boards

Emulators*

with less than 1% performance and 6 kB memory overheads

Conclusion

Conclusion

- ▶ **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research



Conclusion

- ▶ **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research
- ▶ We developed a **novel user-interaction virtualization technique** to overcome device fragmentation



Conclusion

- ▶ **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research
- ▶ We developed a **novel user-interaction virtualization technique** to overcome device fragmentation



Conclusion

- ▶ **Mobile device fragmentation** is not only a developer issue, but also complicates mobile systems research
- ▶ We developed a **novel user-interaction virtualization technique** to overcome device fragmentation
- ▶ **Mosaic enables cross-platform performance comparisons** that incorporate representative and repeatable user interactivity



You can **checkout** Mosaic soon

 Watch ▼

0

@ `https://github.com/matthalp/mosaic`