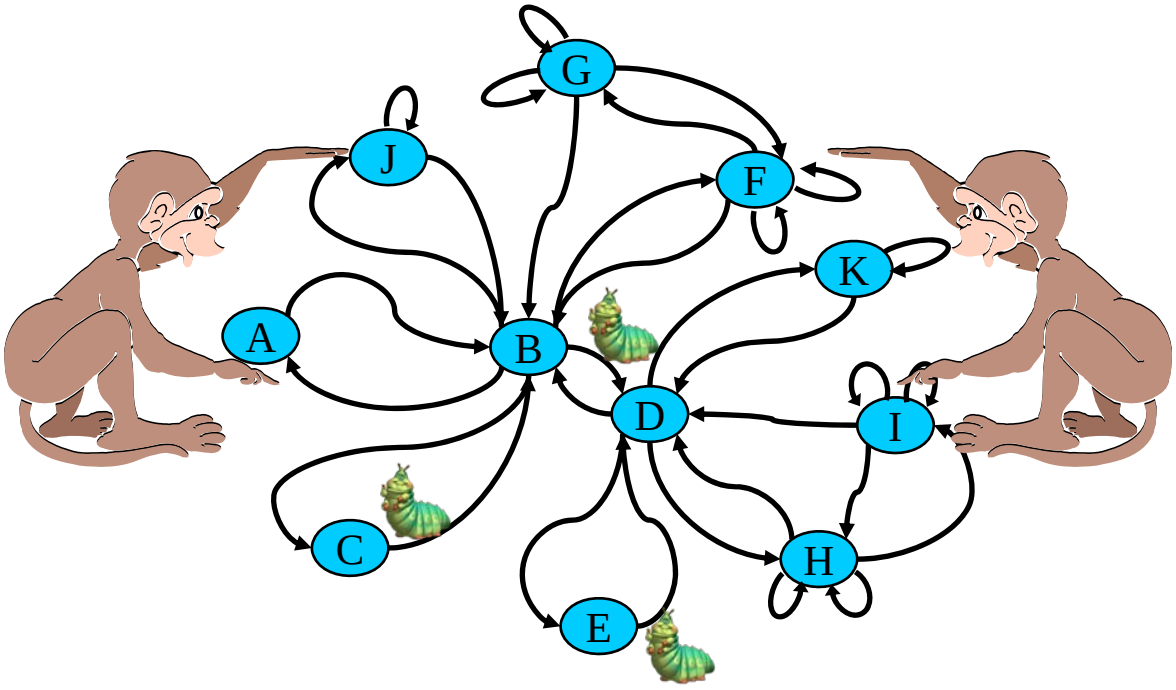
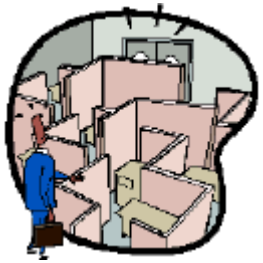
# Model-Based Testing: Introduction

(Adapted from Harry Robinson's slides)



# What are the Problems of Software Testing?

- Time is limited (time-to-market)



- Applications are complex

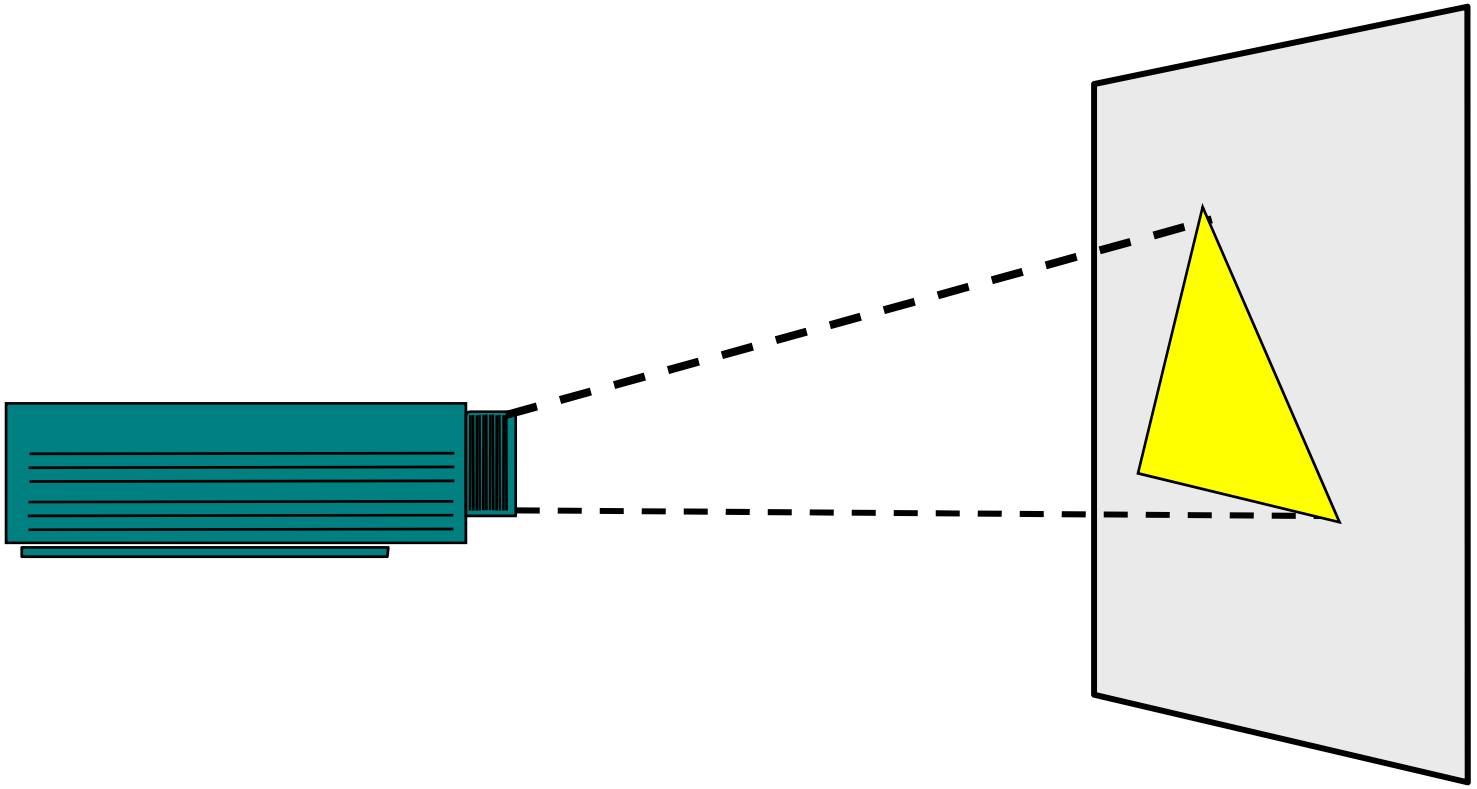
- Requirements are fluid

# Scripted Test Automation

```
WSetWndPosSiz(CurrentWindow, 7, 3, 292, 348)
WMenuSelect("&Settings\&Analog")
Sleep(2.193)
WMenuSelect("&Settings\&Digital")
Sleep(2.343)
Play "{DblClick 130, 188, Left}"
WResWnd(CurrentWindow)
Sleep(2.13)
Play "{Click 28, 36, Left}"
Play "{Click 142, 38, Left}"
Play "{DblClick 287, 16, Left}"
```

- Unchanging
- Chiseled in stone
- Usually undecipherable

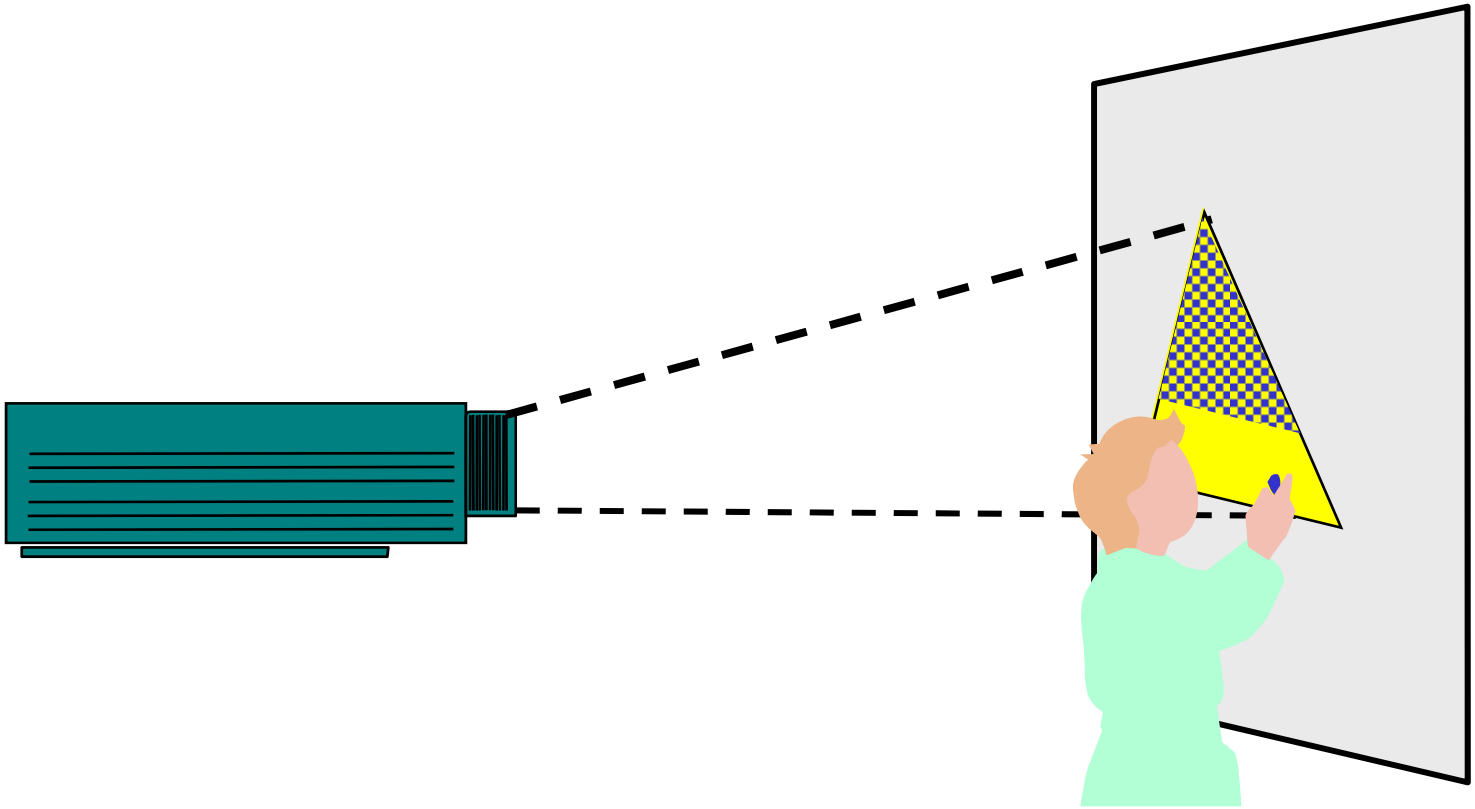
# Traditional Software Development



Imagine this projector is the software under test,

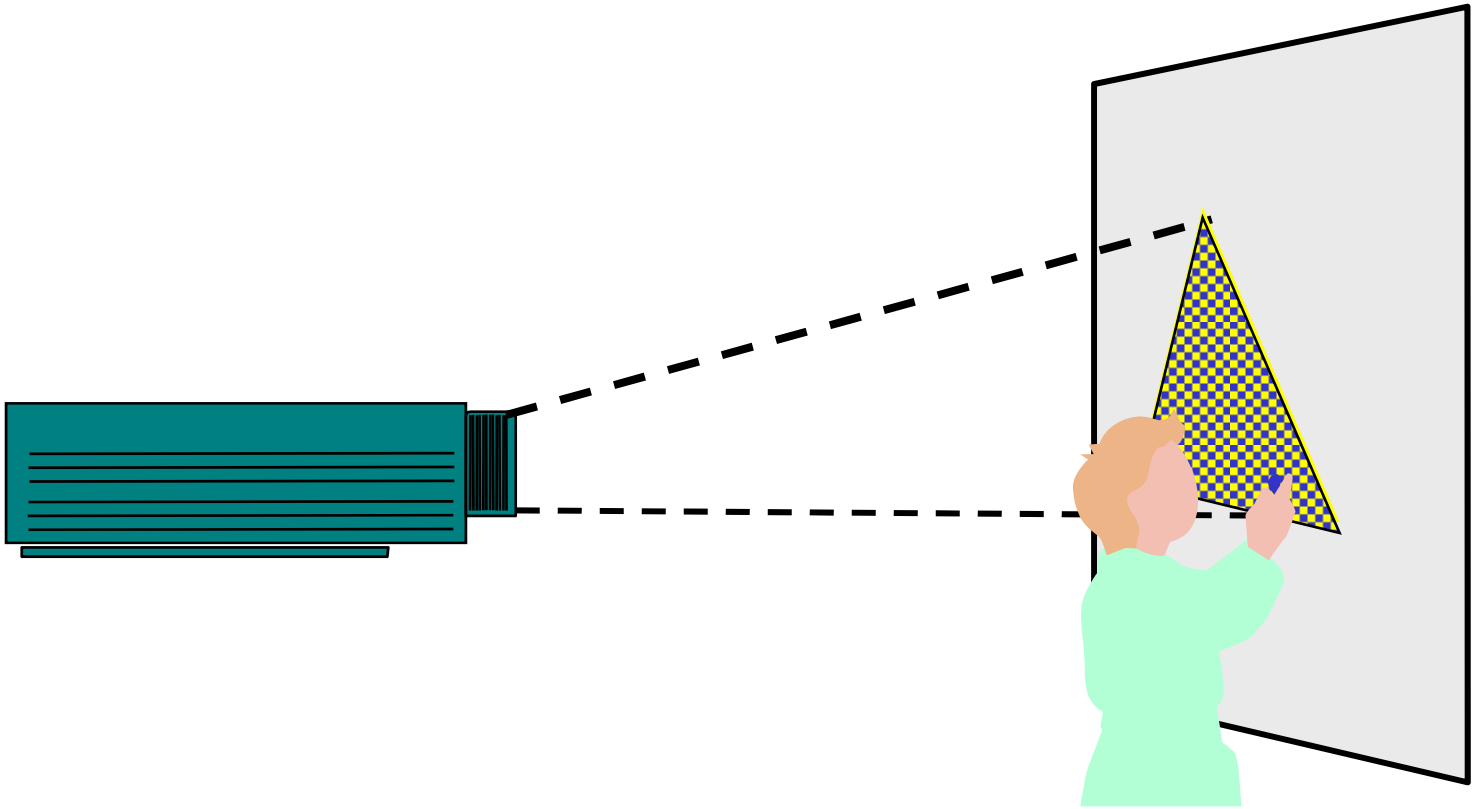
and the triangle is the behavior exposed to you

# Traditional Automated Testing



Typically, testers automate by creating **static** scripts.

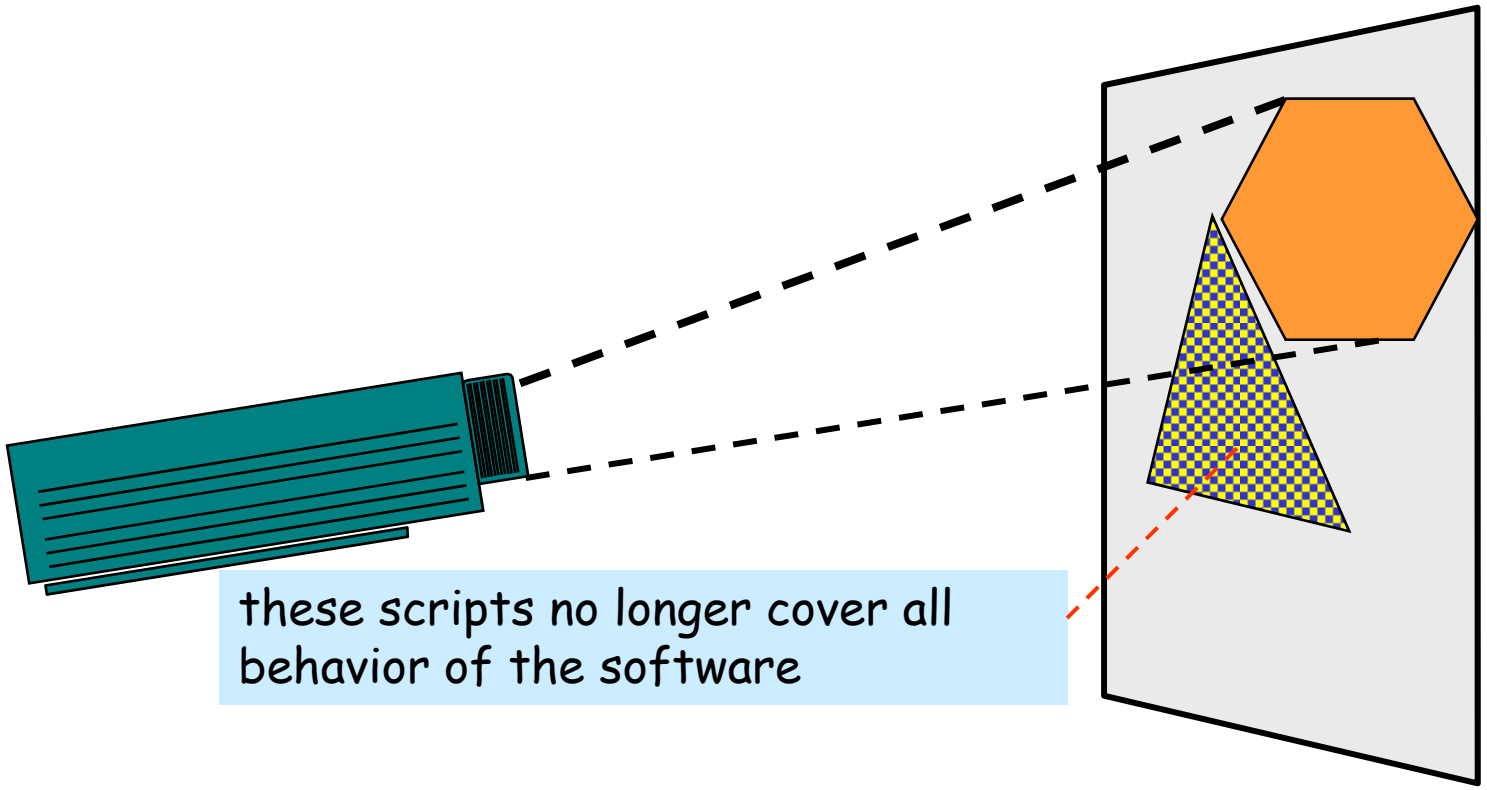
# Traditional Automated Testing



Given enough time, these scripts will cover the behavior.

may be up to thousands of years ...

# Traditional Automated Testing

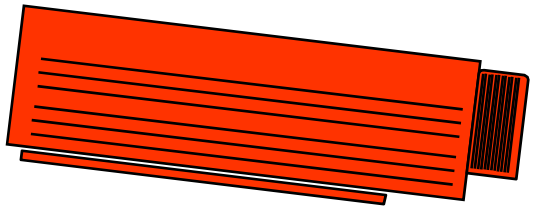


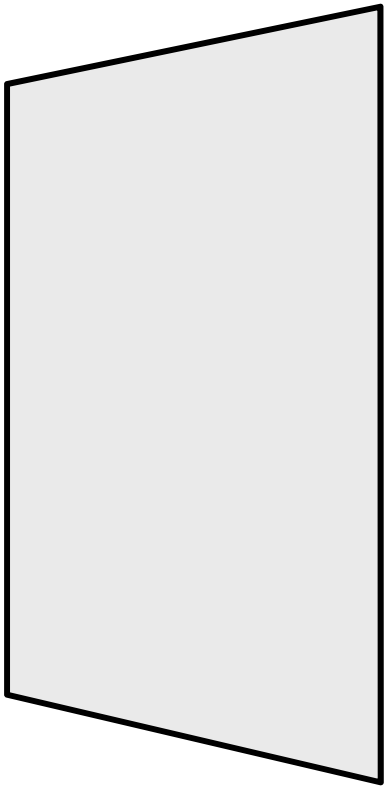

But what happens when the software's behavior changes?

(due to, e.g., requirement change or software maintenance)

… a remedy…

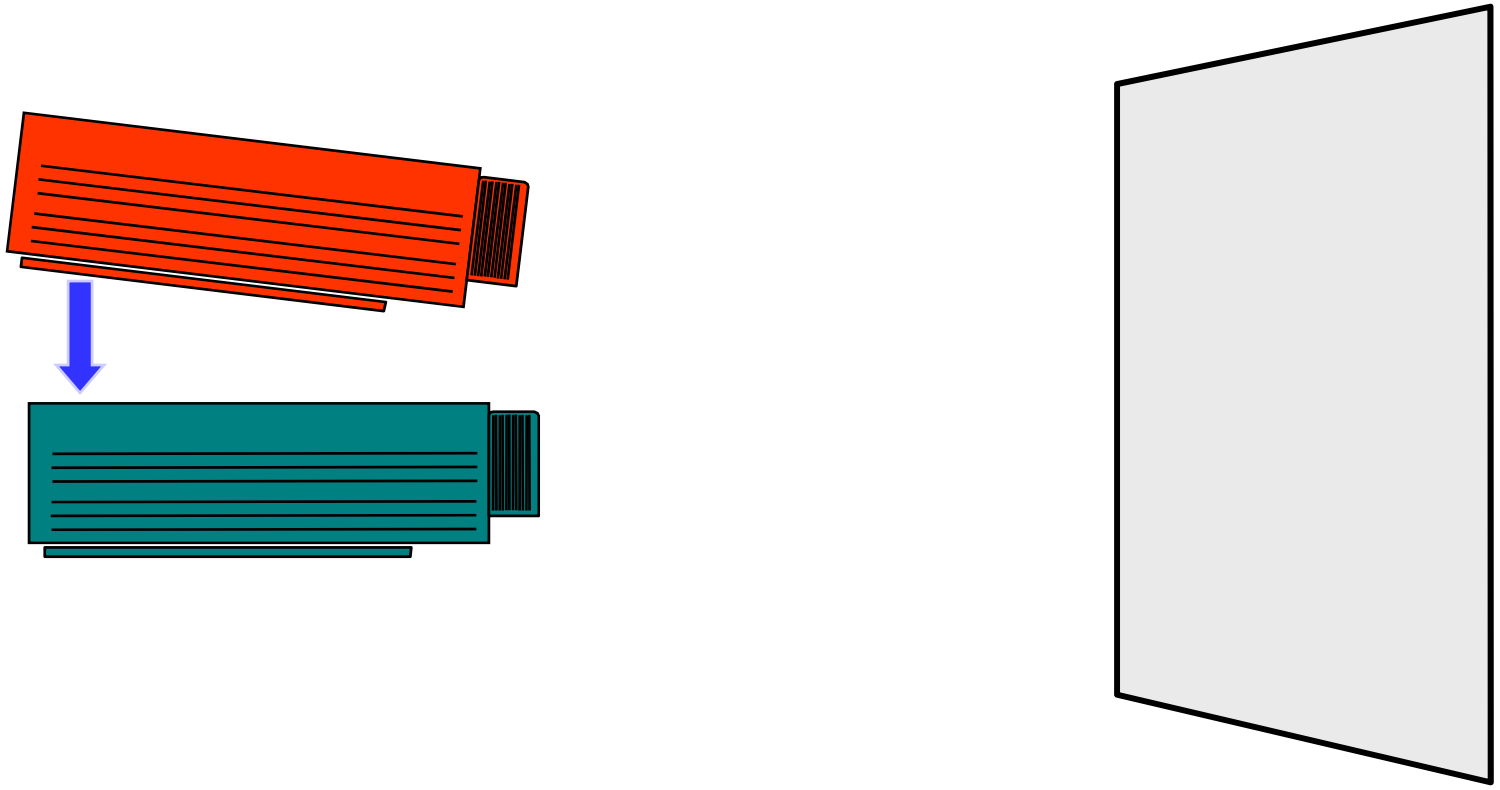
# Model-Based Development





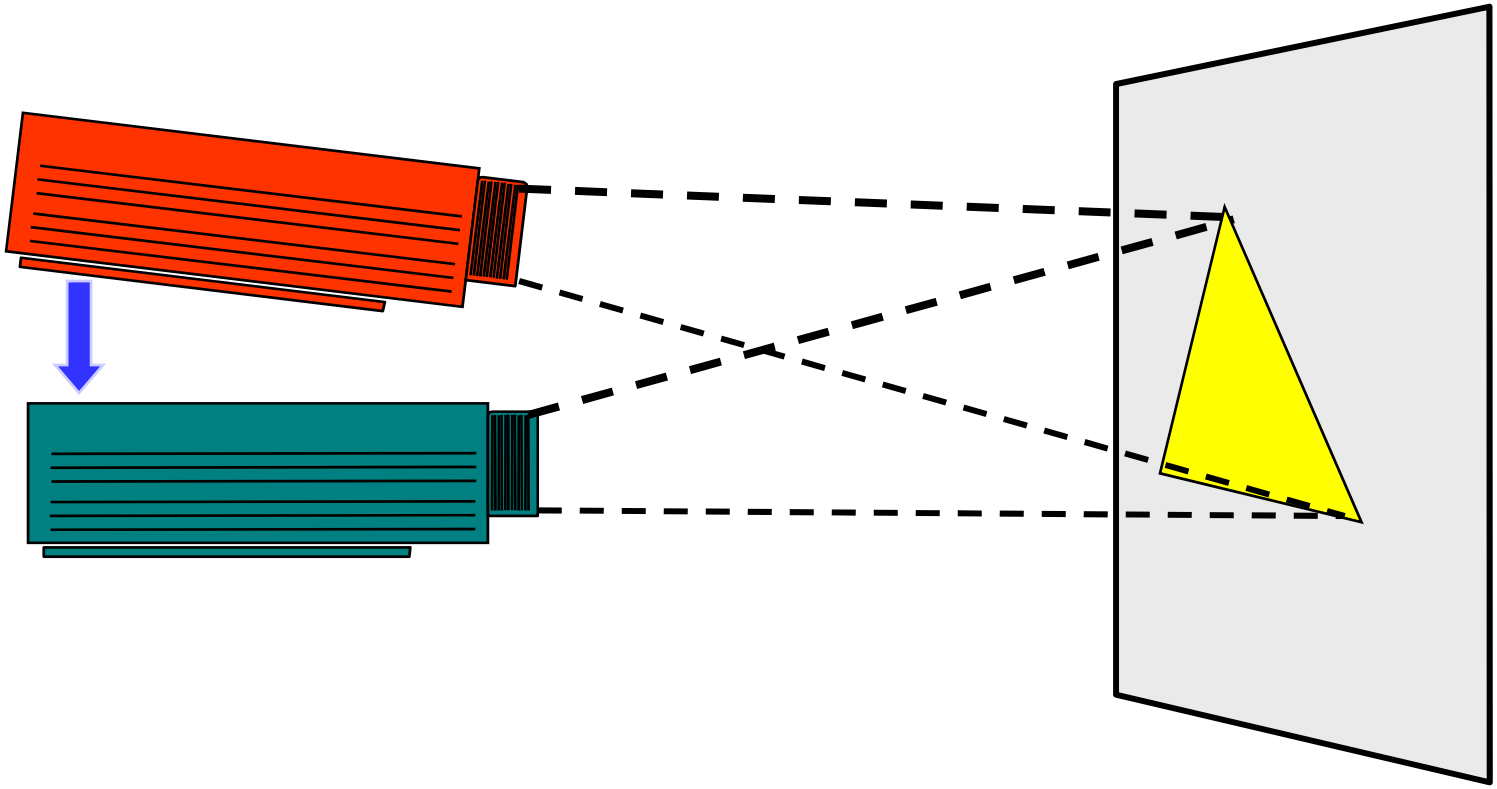
Now, imagine initially you build a model (the upper projecter)

# Model-Based Development



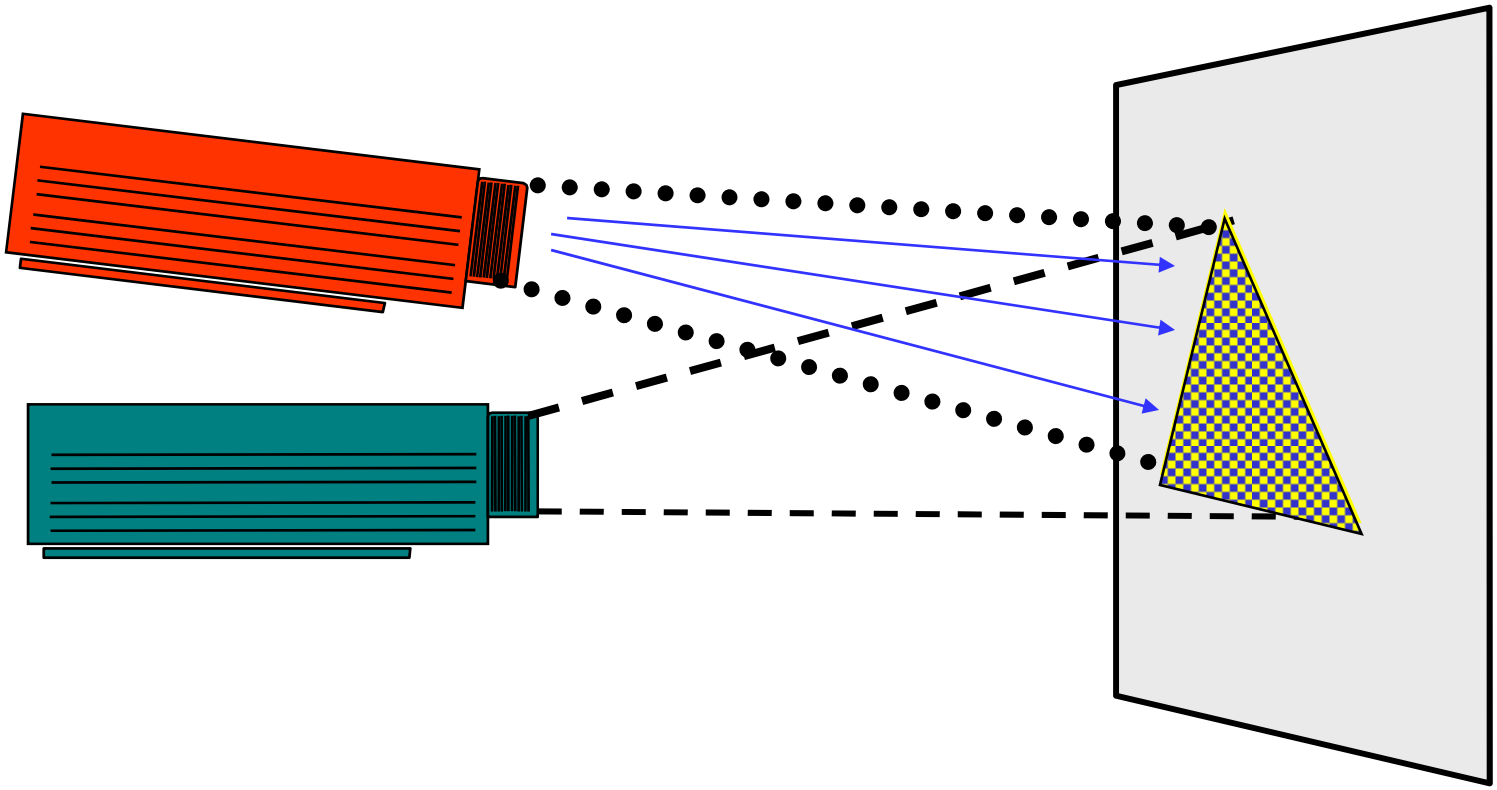
Now, imagine initially you build a model (the upper projecter),
based on which you "generate" your real software (the lower projecter)

# Model-Based Development



Now, imagine initially you build a model (the upper projecter),
based on which you "generate" your real software (the lower projecter),
which implements the functionalities in your model

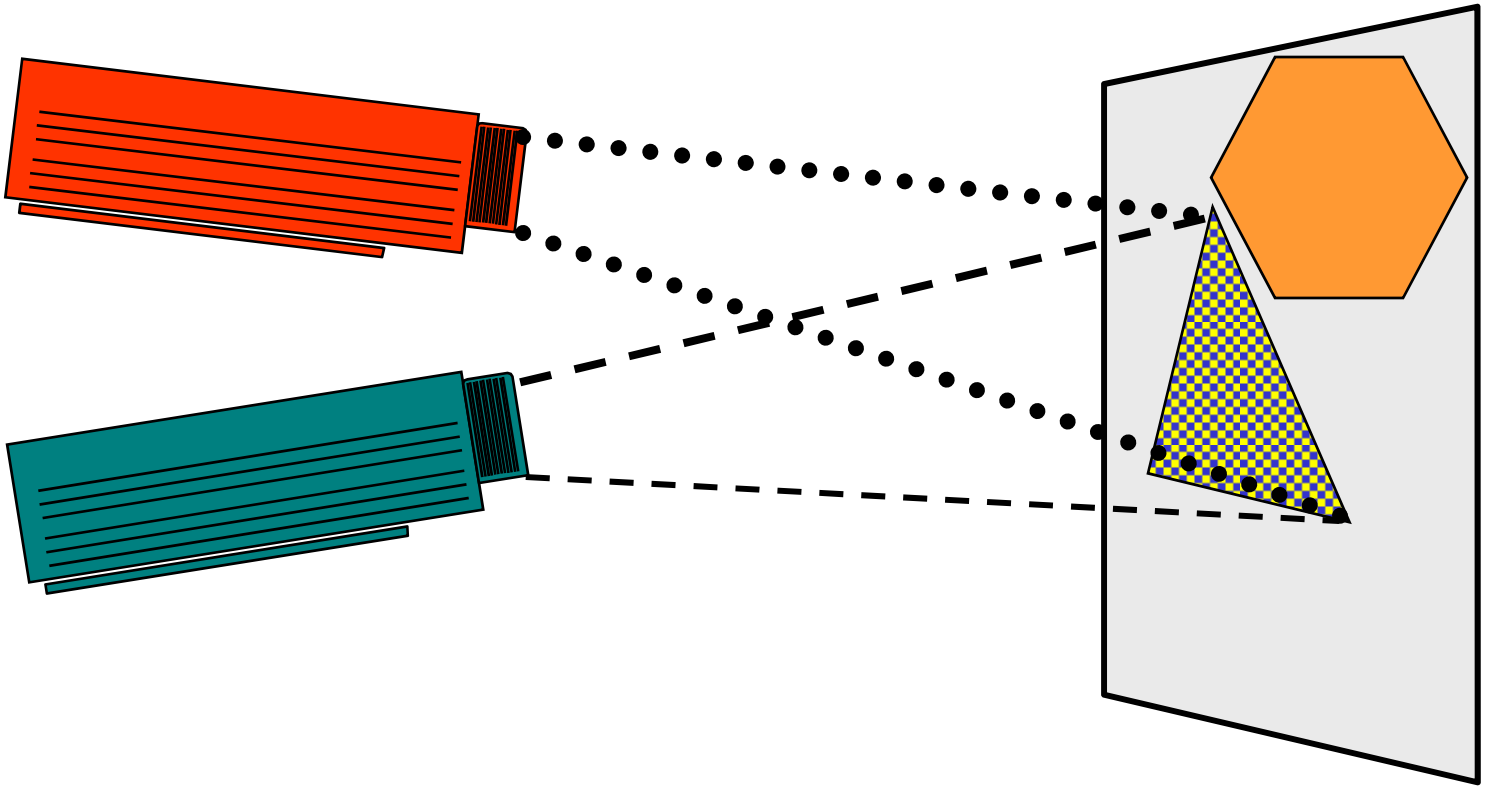
# Model-Based Testing



From the model you generates tests to cover the behavior of the real software in a **rigorous** and **systematic** manner

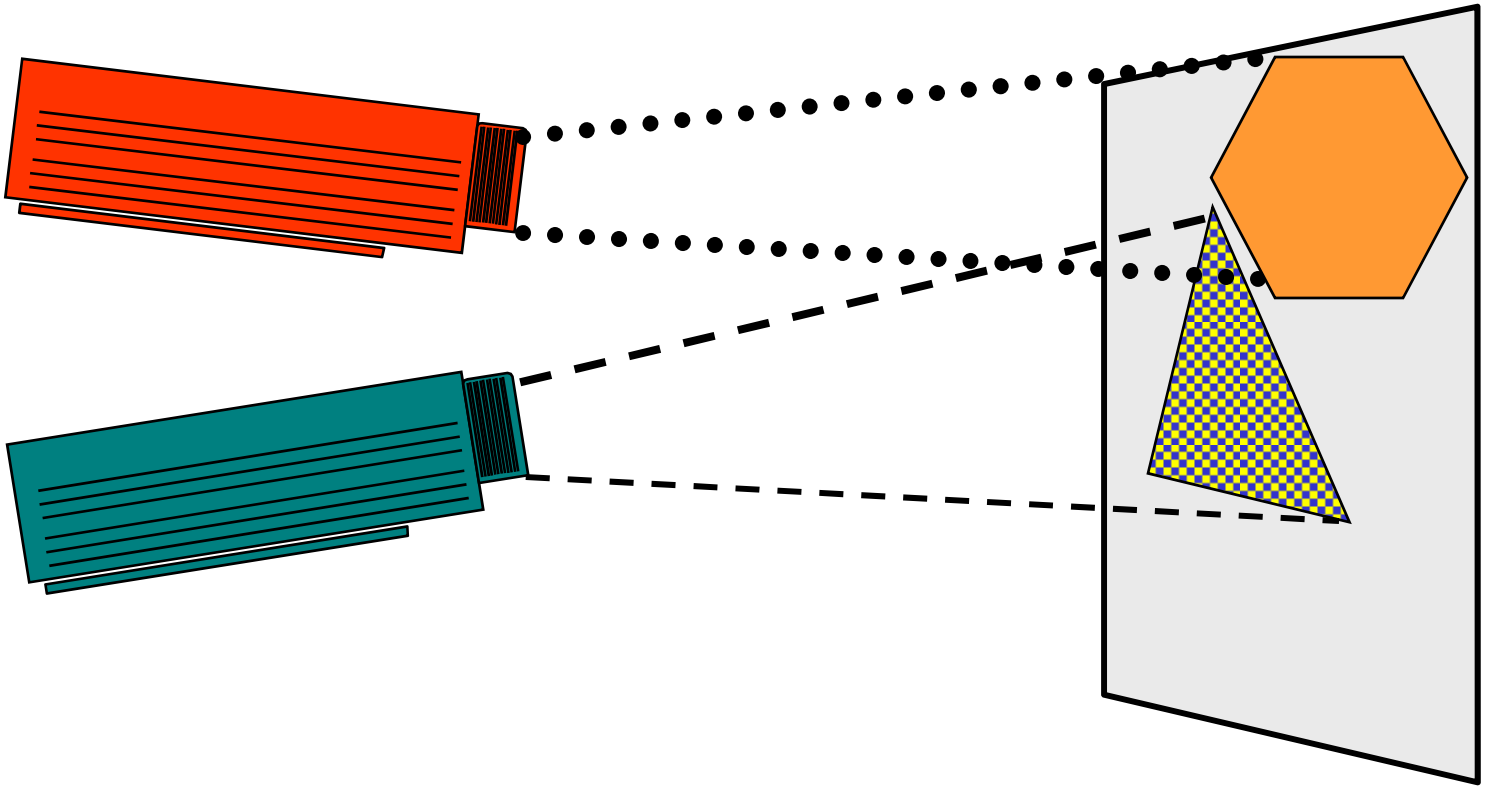
that's **much easier** than from the real software

# Model-Based Testing



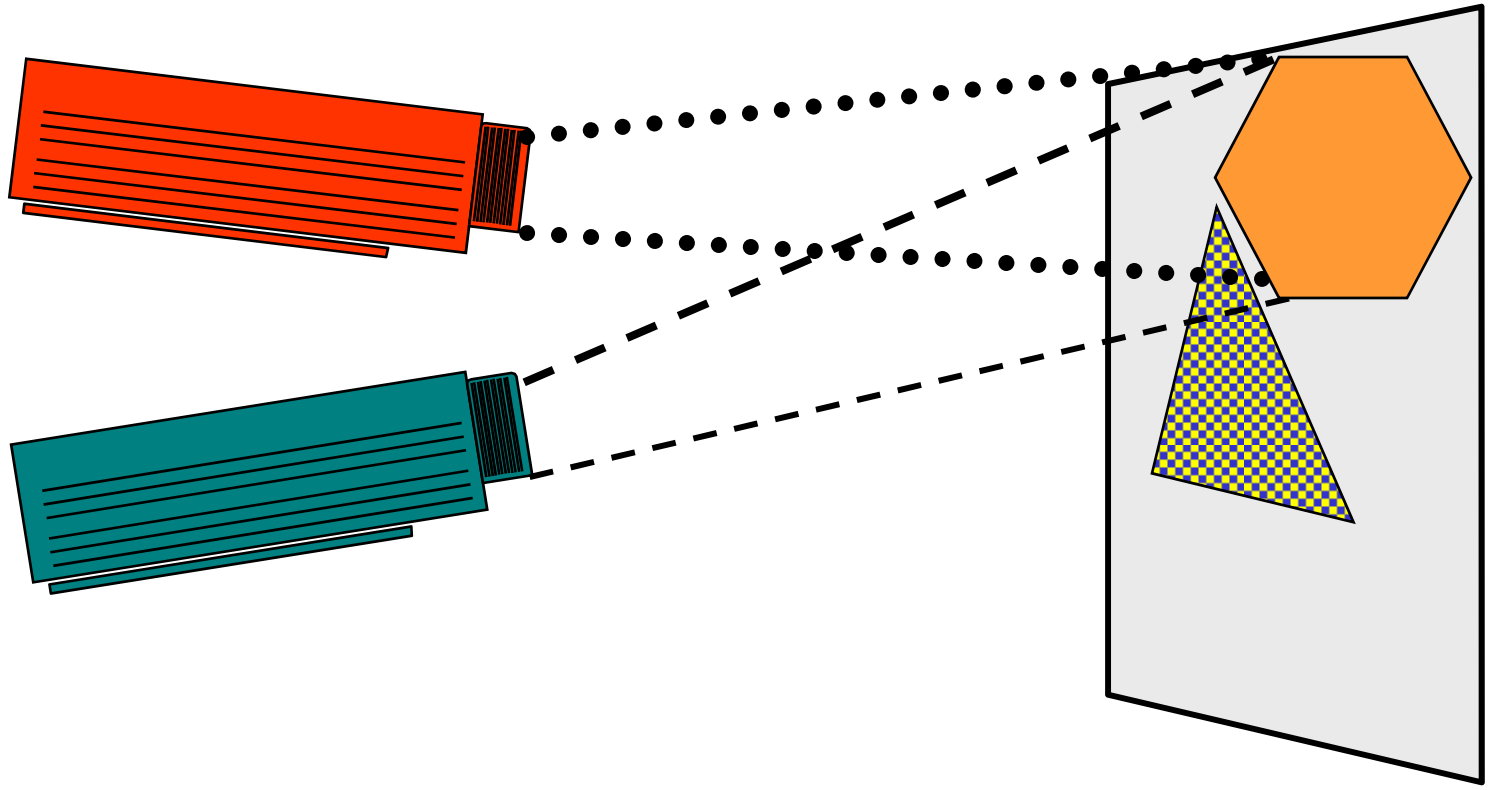
… and when there is a requirement change…

# Model-Based Testing



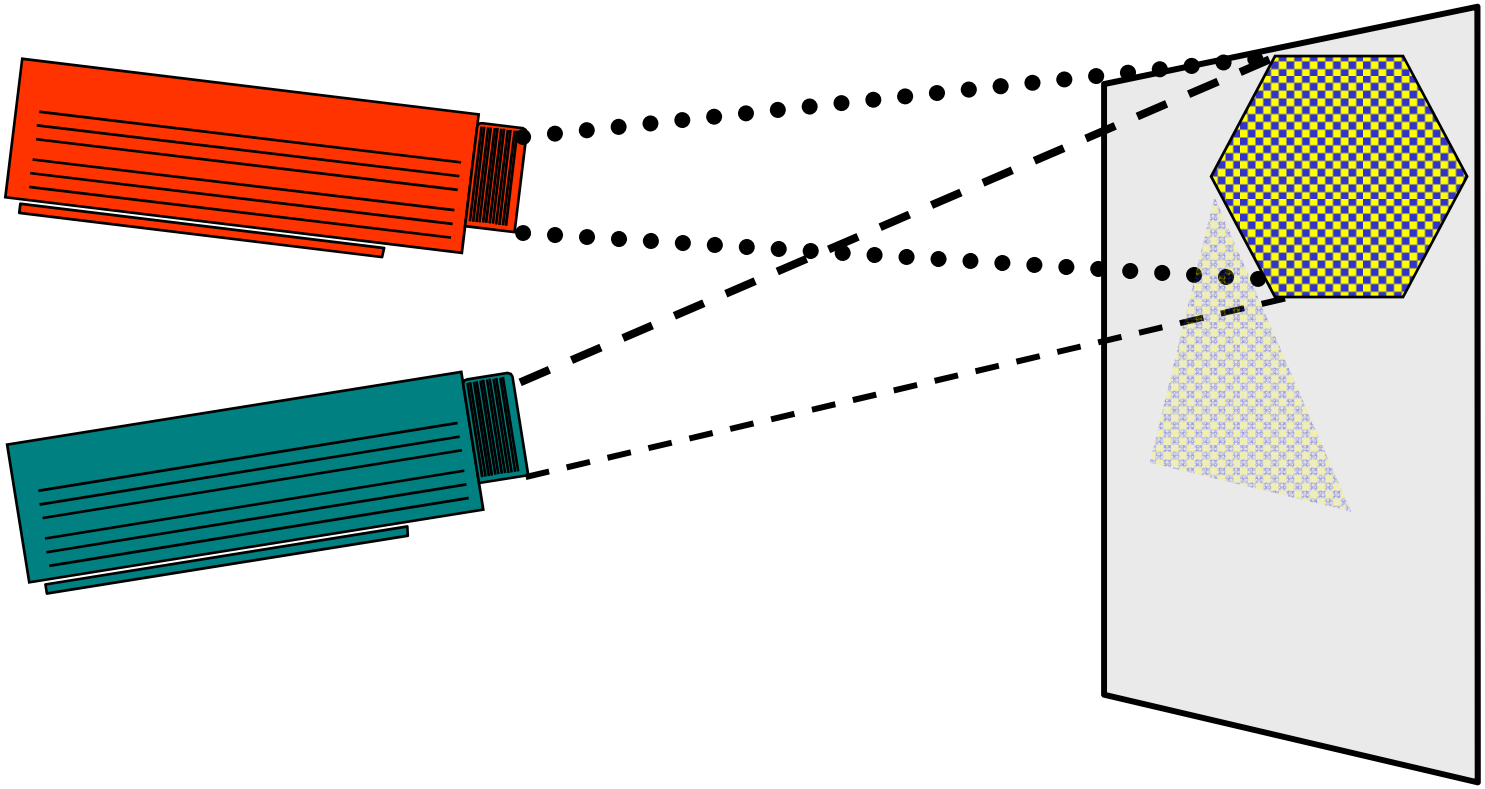
… you change the model…

# Model-Based Testing



… and re-generate the real software from the new model…

# Model-Based Testing



… and derive new tests from the new model….

# So What's the Benefit of a Model?

A model is a formal or semi-formal description of a system's behavior.

- Models are (much) **simpler** than the systems they describe
- Models help us **understand** and **predict** the system's behavior

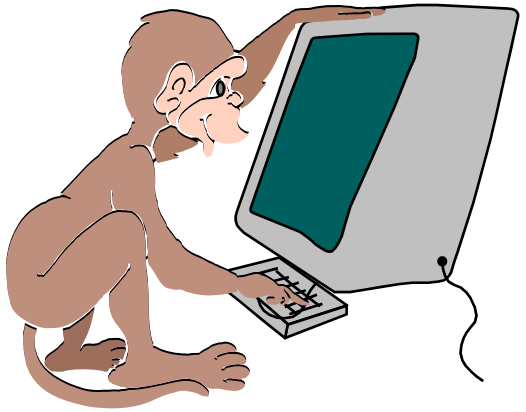
Formal models:
Finite State Machines (FSM) aka Automata, LTS, TA, CSP, CCS, Z, B, guarded command language, Message Sequence Charts, LSC, . . .

Semi-formal models:
UML, E-R Diagram, Data Flow Diagram, . . .

# Approaches to Automated Testing

Static Tests
(based on tester-written scripts)

(static tests)
(generated tests)

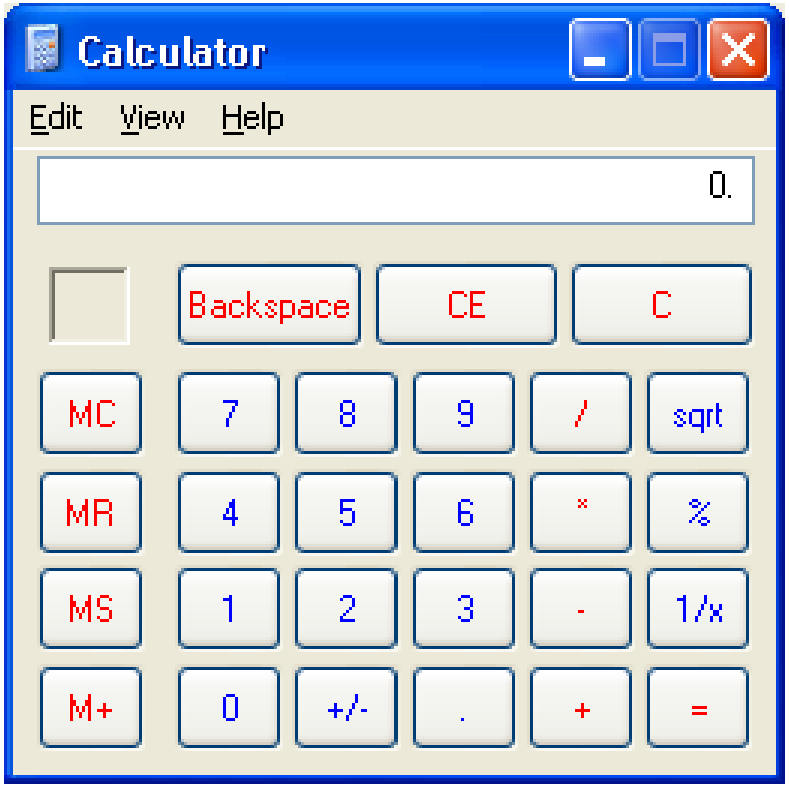


Monkey Tests
(constant repetition of simple, isolated actions against the IUT)

Model-Based Tests

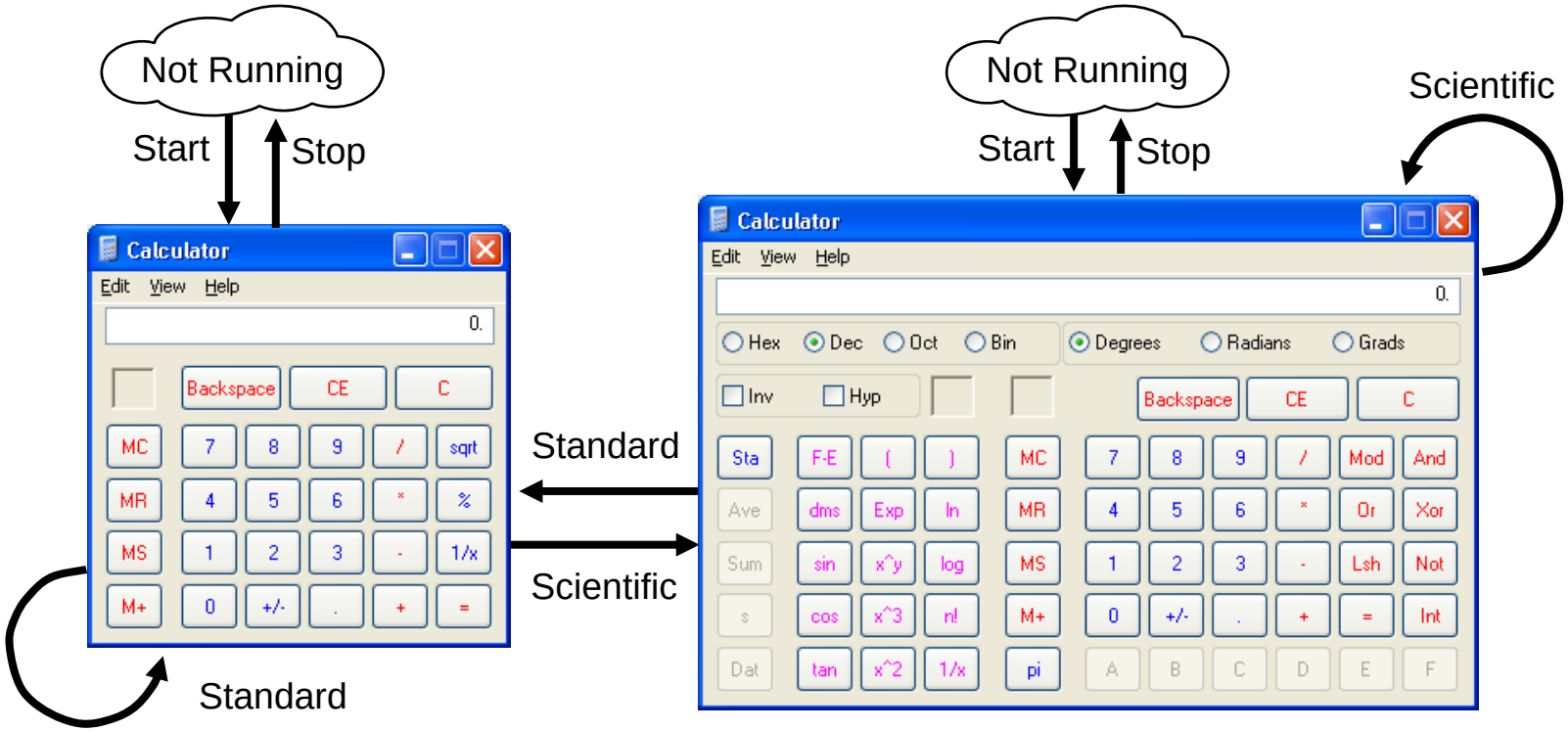
To go with a military analogy, **static tests** are like battlements: they are fairly cheap to build and maintain, and they can help keep you from losing ground you have already won. **Generated tests** are like tanks or ground troops: they need more thought in their design, and you need them if you want to win new territory, but they work best when they are *on the move*.

# Calculator: A Fairly Typical GUI



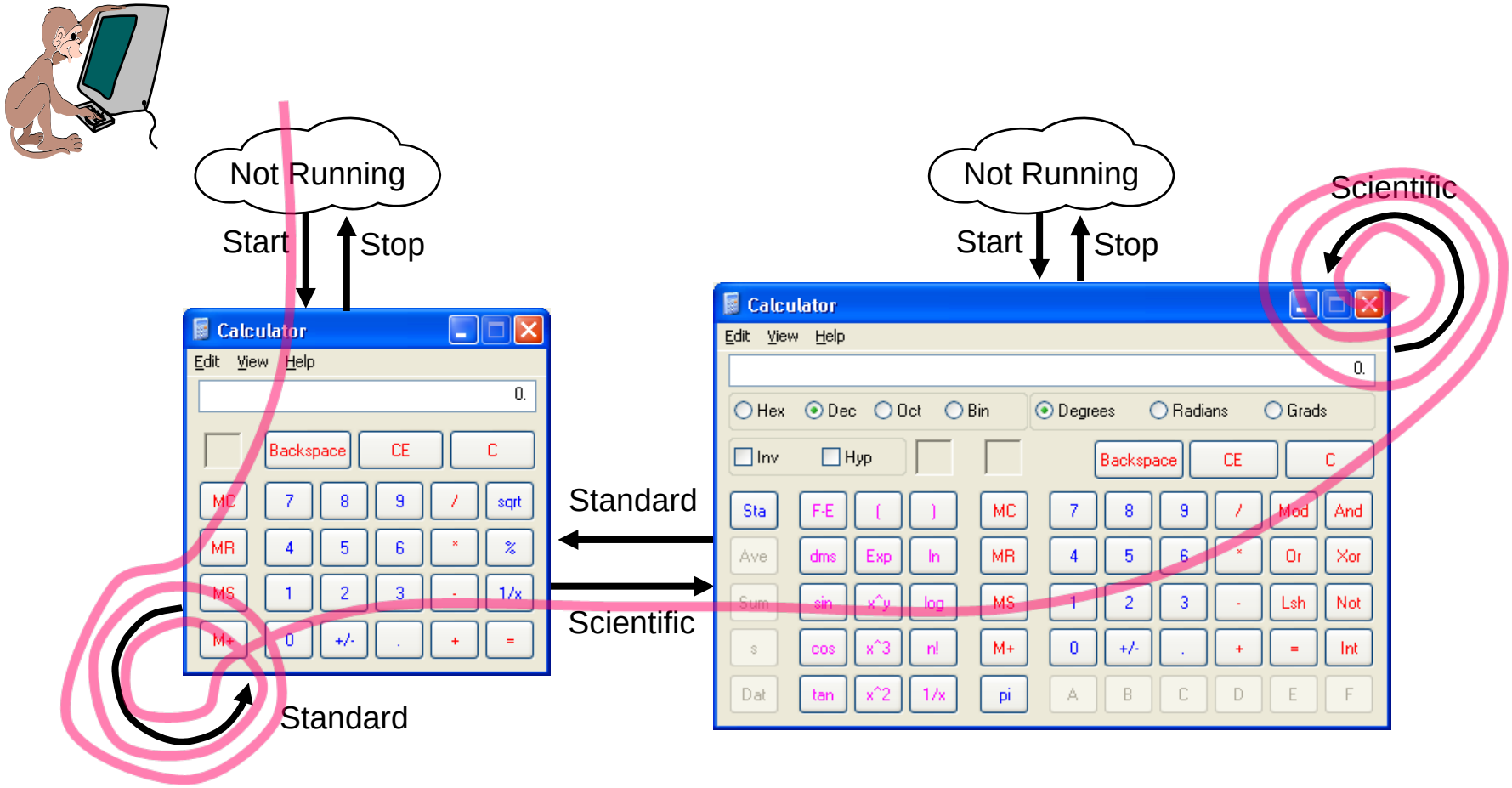

- Familiar enough
- Simple enough
- Complex enough
- Hard to test thoroughly

# Calculator GUI Behavior



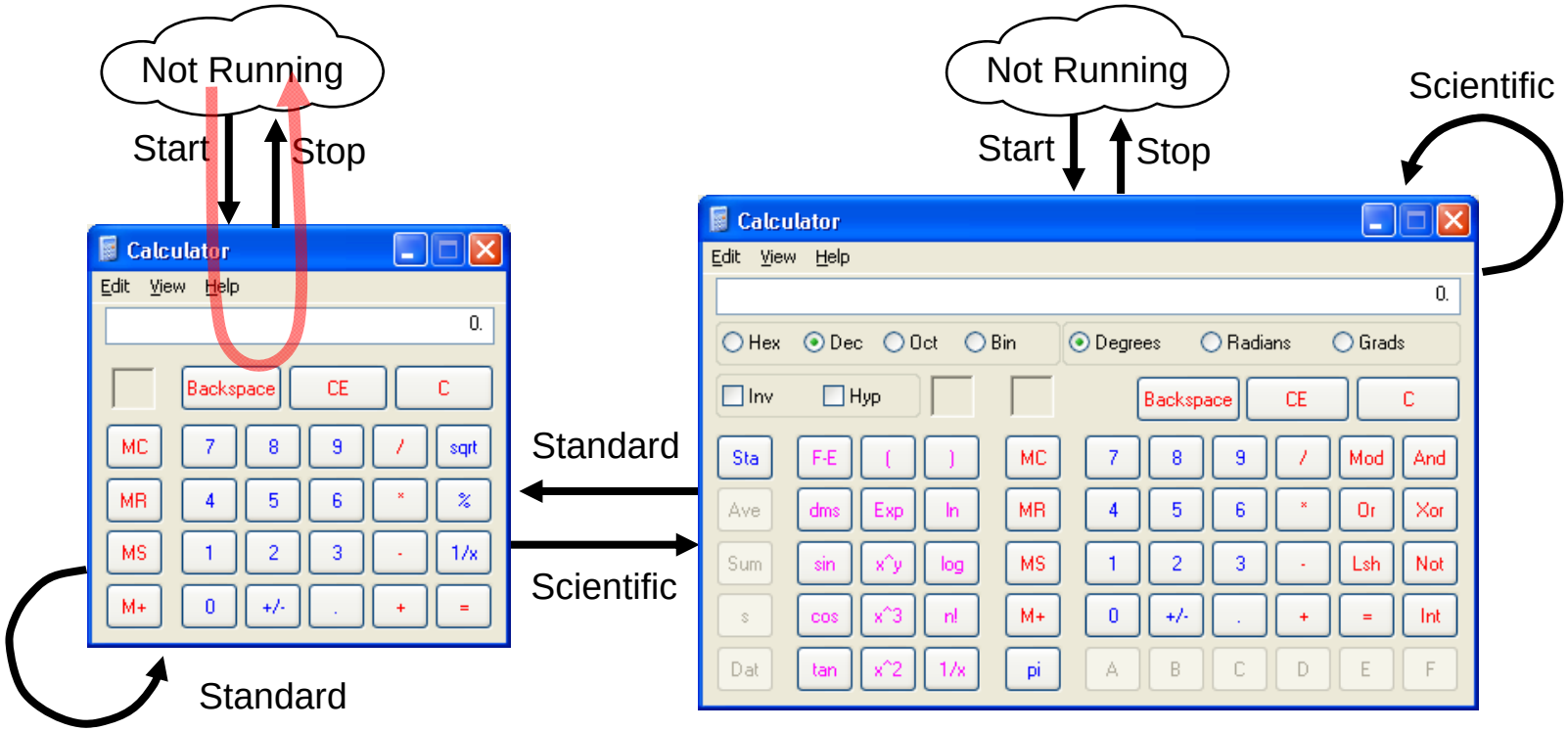
# Monkey Tests vs. The Calculator

Test: Start-Standard-Standard-Standard-Scientific-Scientific-Scientific-Scientific ...



# Static Tests vs. The Calculator

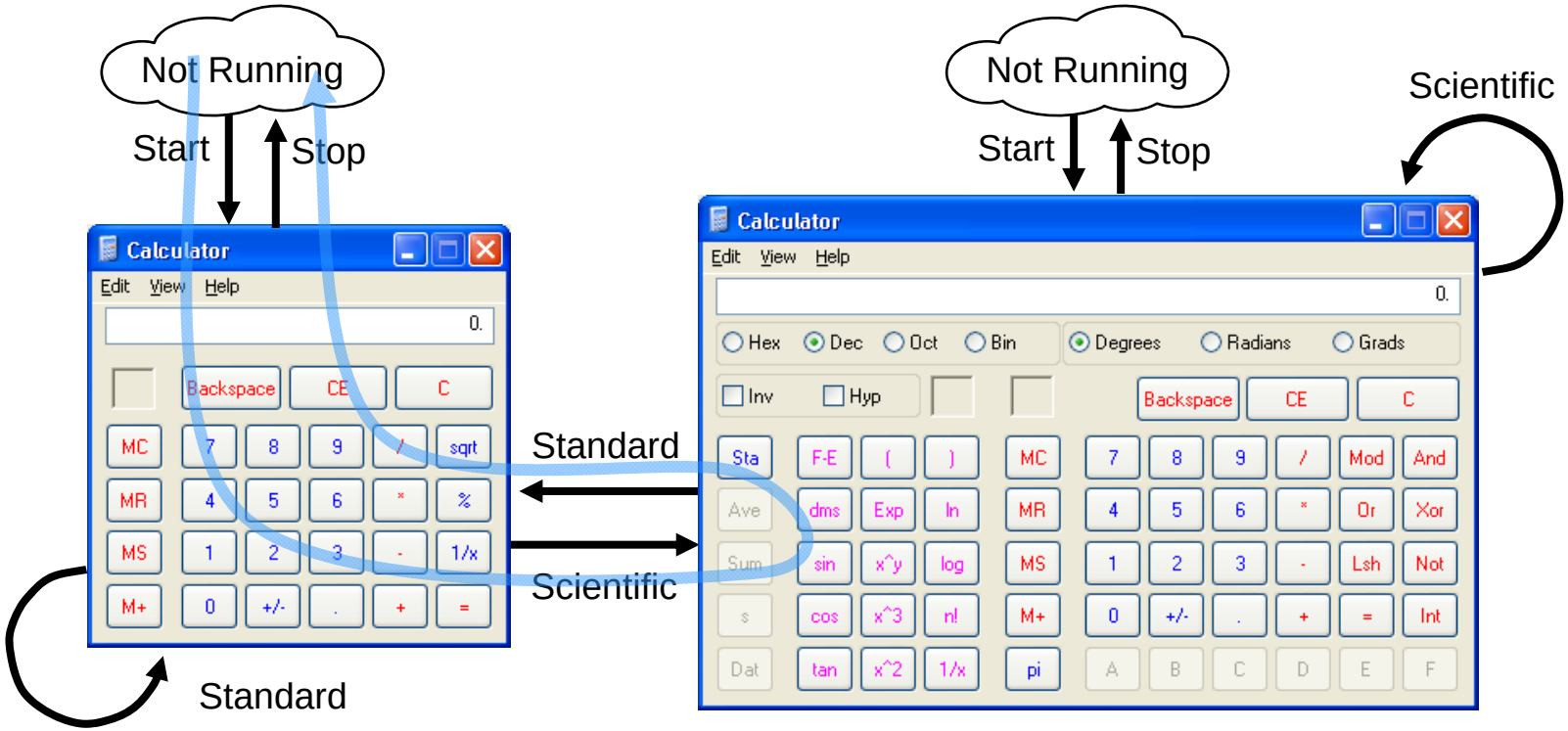
Test Case 1: Start Stop



# Static Tests vs. The Calculator

Test Case 1: Start Stop

Test Case 2: Start Scientific Standard Stop

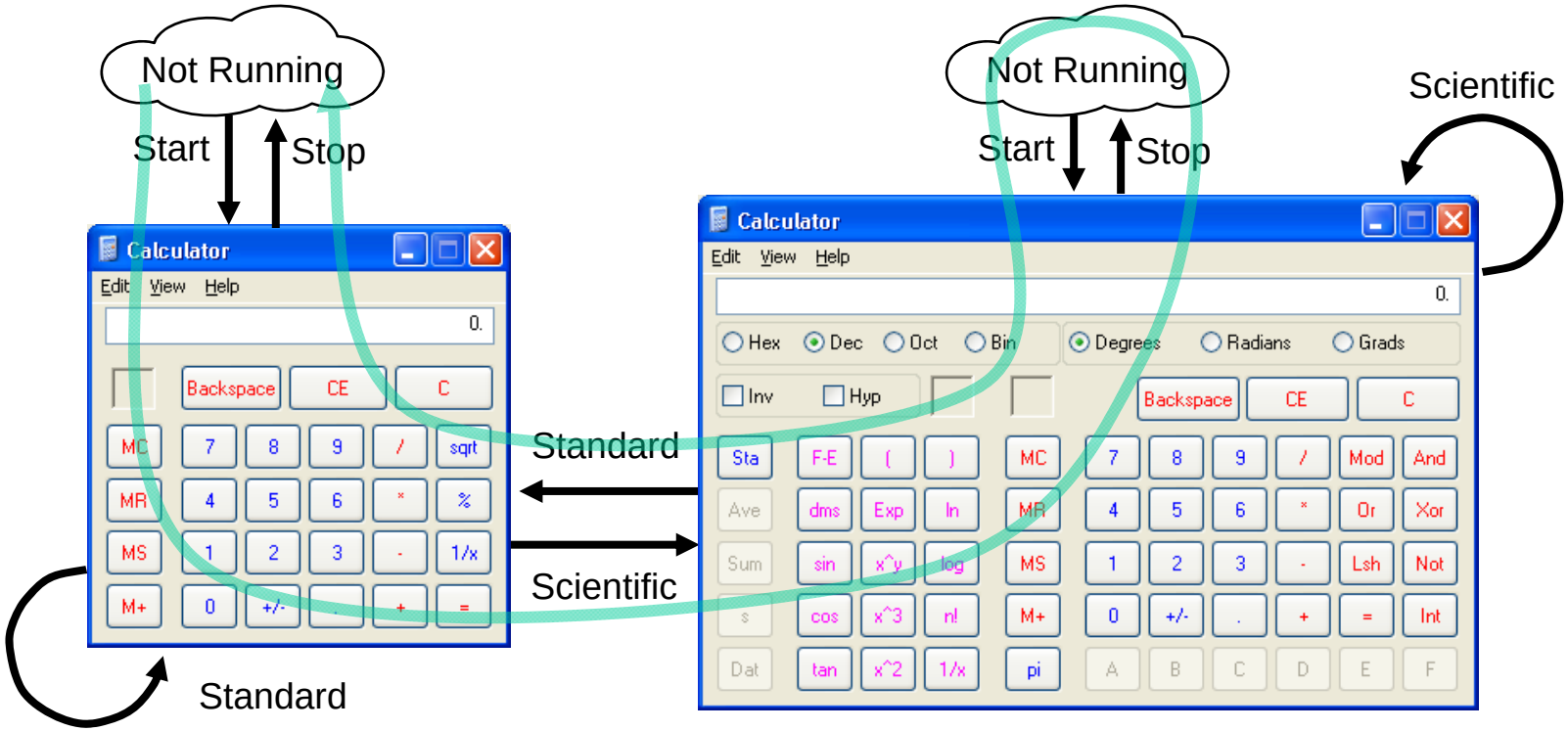


# Static Tests vs. The Calculator

Test Case 1: Start Stop

Test Case 2: Start Scientific Standard Stop

Test Case 3: Start Scientific Stop Start Standard Stop



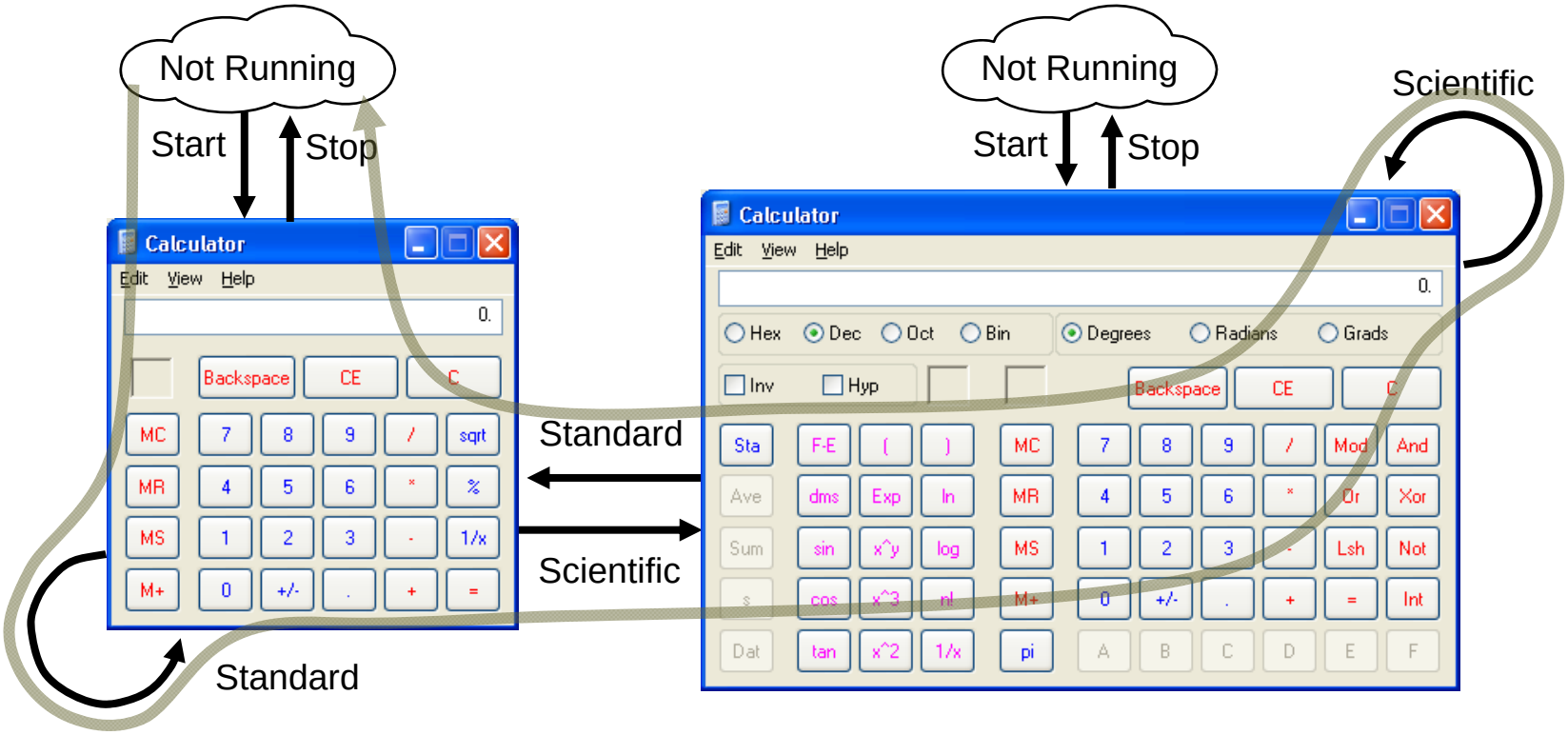
# Static Tests vs. The Calculator

Test Case 1: Start Stop

Test Case 2: Start Scientific Standard Stop

Test Case 3: Start Scientific Stop Start Standard Stop

Test Case 4: Start Standard Scientific Scientific Standard Stop



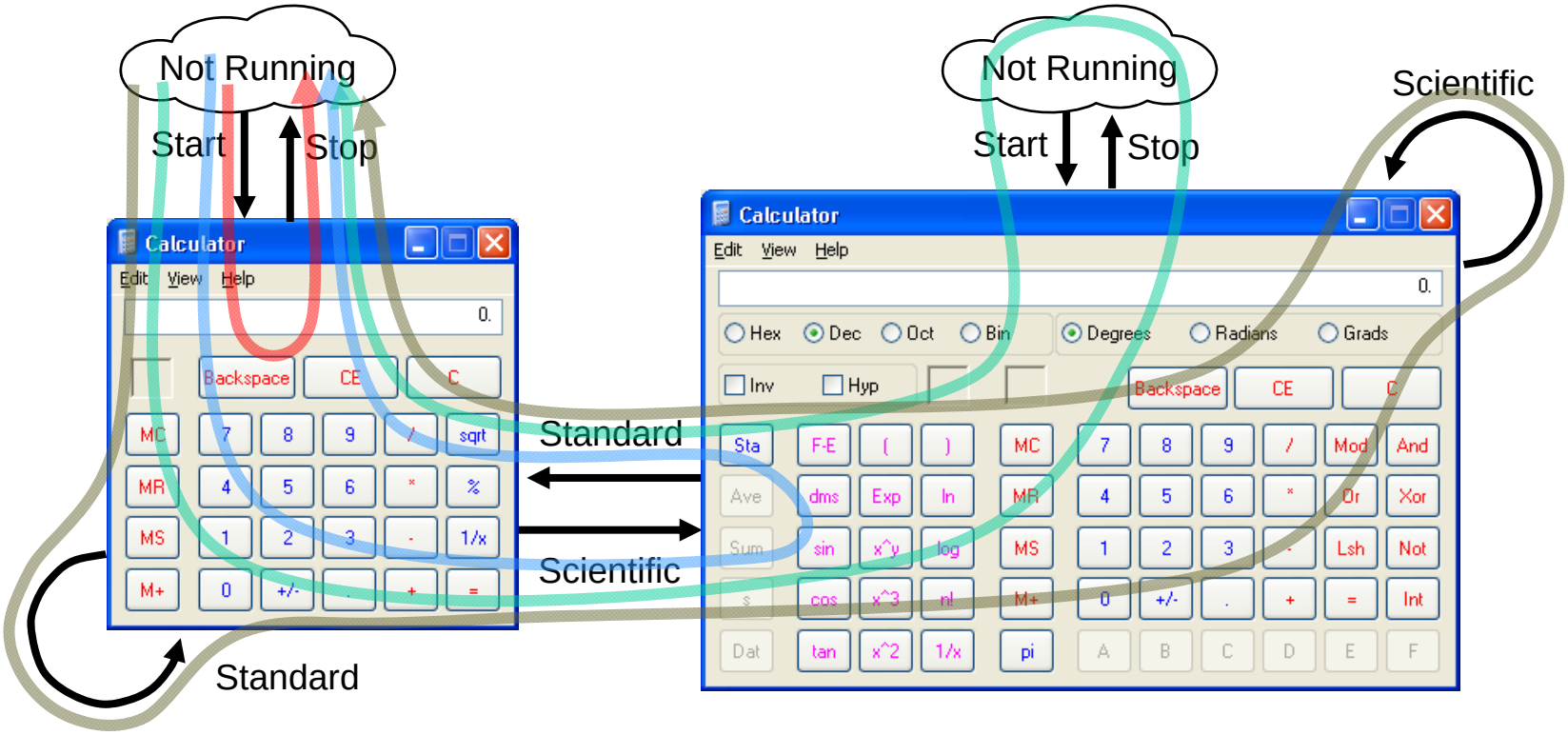
# So, here's your **test case library**

Test Case 1: Start Stop

Test Case 2: Start Scientific Standard Stop

Test Case 3: Start Scientific Stop Start Standard Stop

Test Case 4: Start Standard Scientific Scientific Standard Stop

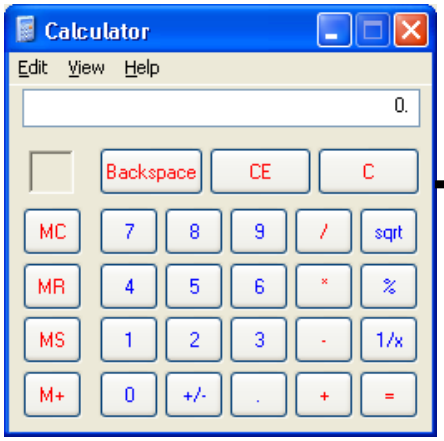


# But, really, what are you left with?

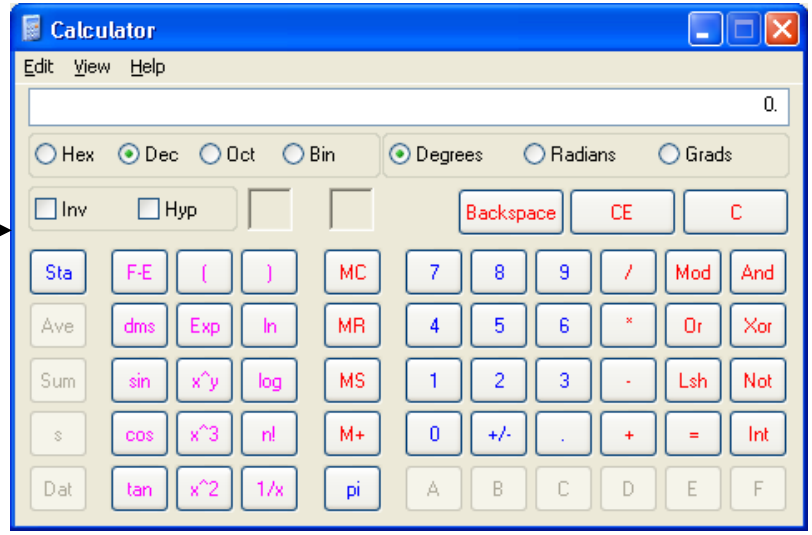
- Hard-coded test cases
- Tests that do only what you told them to
- Tests that wear out due to pesticide paradox

The more you test software, the more immune it becomes to your tests.

# MBT vs. The Calculator




Scientific

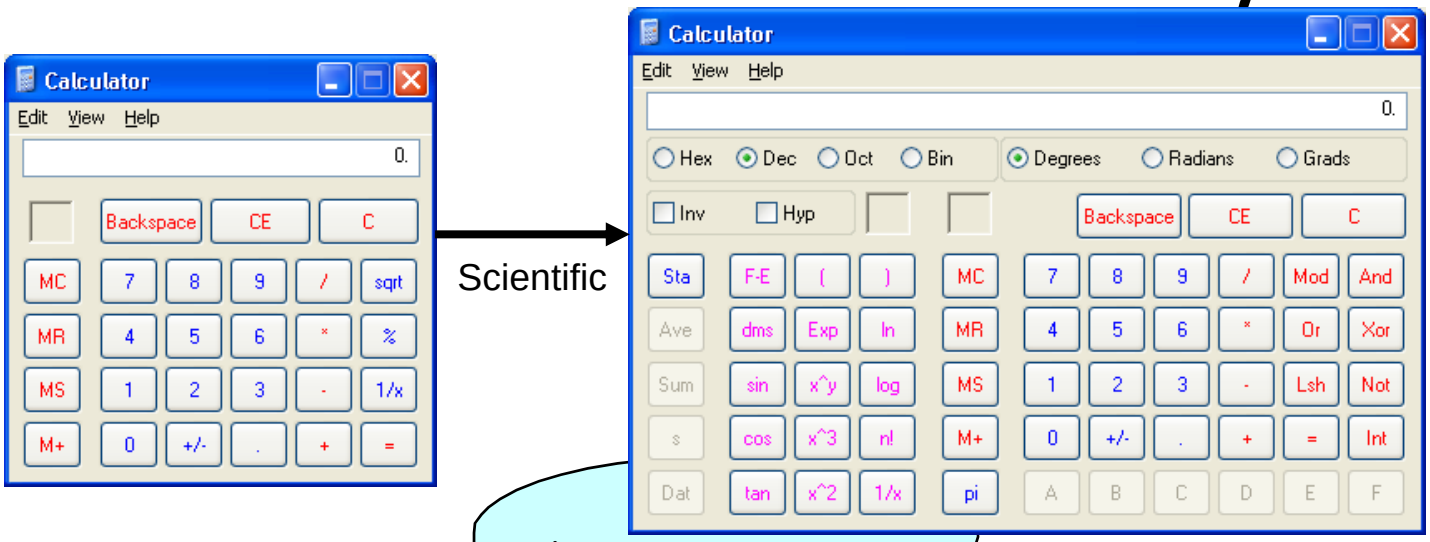


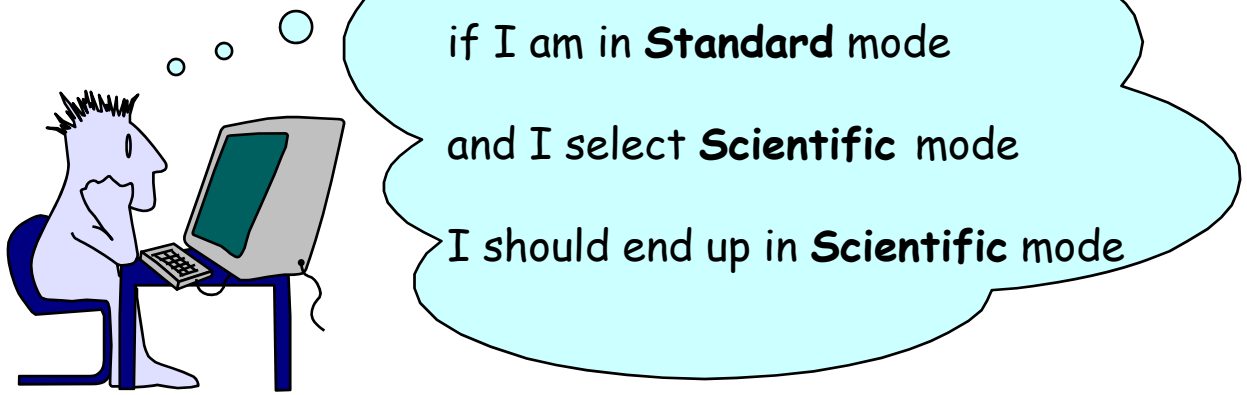

Setup: Calculator is running in Standard mode

Action: Select "Scientific" mode

Outcome: Did Calculator go correctly to "Scientific" mode?

# We all Use Models Already



# Steps for Creating a Model

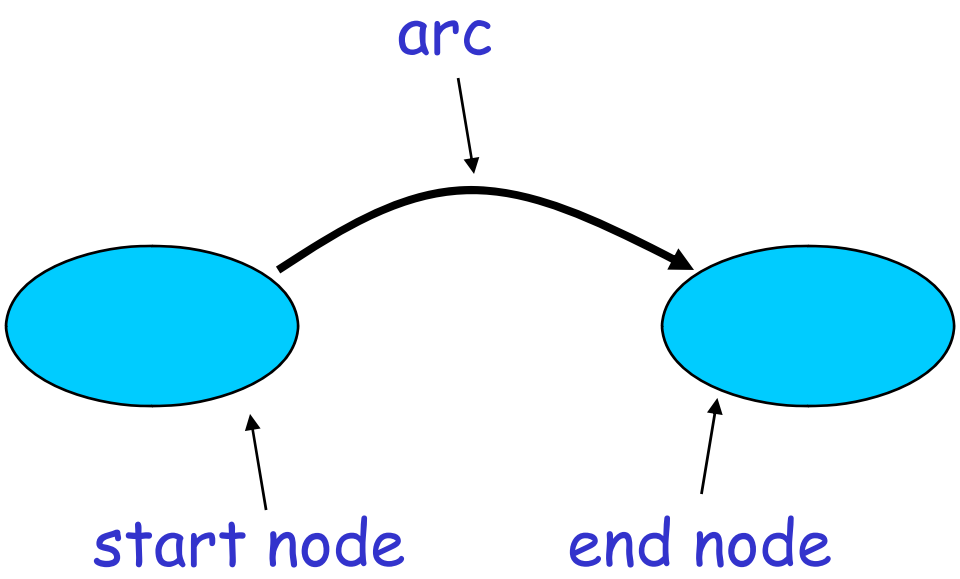
1. Walk through some scenarios
   a. What model do you have in your head?
   b. How do you know what you expect to see?

2. Figure out your scope:
   a. What are you testing?
   b. What are you ignoring?

3. Figure out a useful representation

# A Graph is a Type of Model

A Few Quick Graph Theory Terms



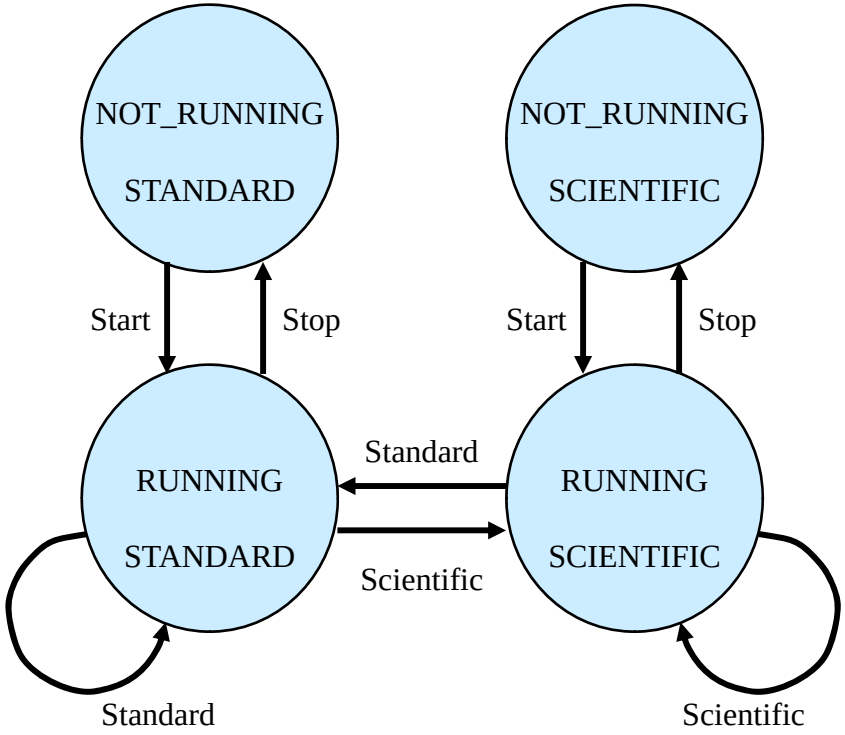
# State Variables in the Calculator GUI

The System is either

- NOT_RUNNING, or
- RUNNING

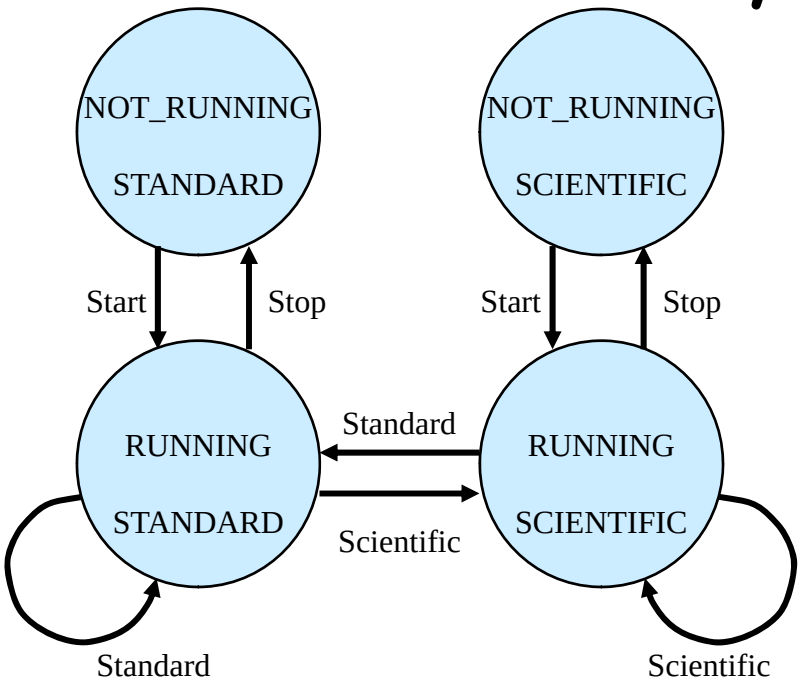
The Working Mode is either

- STANDARD, or
- SCIENTIFIC




Finite State Machine (FSM) model

# All Actions Aren't Always Available




Rule: You <u>cannot</u> execute the "Stop" action if the Calculator is not running

# Finding the Rules

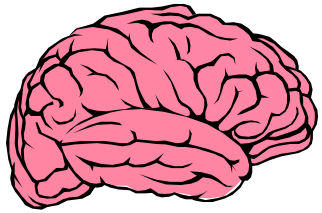
**Stop**

- When the System is NOT_RUNNING, the user cannot execute the **Stop** action.
- When the System is RUNNING, the user can execute the **Stop** action.
- After the **Stop** action executes, the System is NOT_RUNNING.

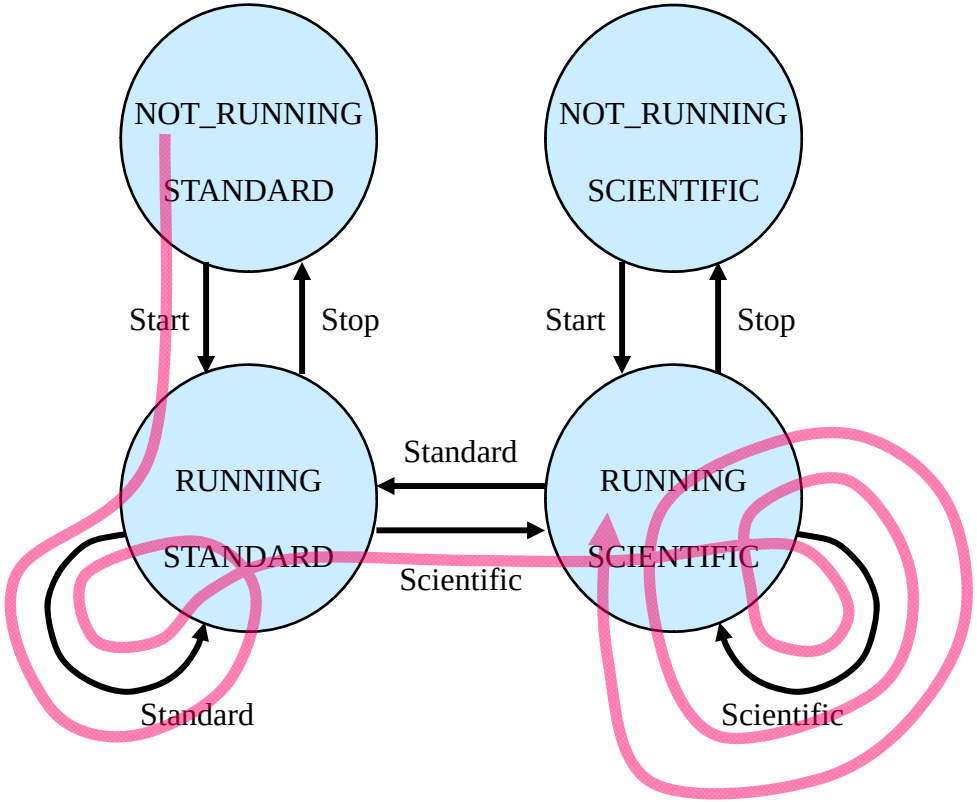
# The Generated Finite State Table

| Beginning State | Action | Ending State |
|---|---|---|
| NOT_RUNNING.STANDARD | Start | RUNNING.STANDARD |
| NOT_RUNNING.SCIENTIFIC | Start | RUNNING.SCIENTIFIC |
| RUNNING.STANDARD | Stop | NOT_RUNNING.STANDARD |
| RUNNING.SCIENTIFIC | Stop | NOT_RUNNING.SCIENTIFIC |
| RUNNING.STANDARD | Standard | RUNNING.STANDARD |
| RUNNING.STANDARD | Scientific | RUNNING.SCIENTIFIC |
| RUNNING.SCIENTIFIC | Standard | RUNNING.STANDARD |
| RUNNING.SCIENTIFIC | Scientific | RUNNING.SCIENTIFIC |

# A Random Walk

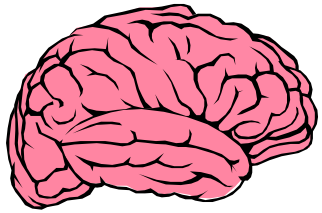


Start
Standard
Standard
Scientific
Scientific
Scientific
Scientific
…

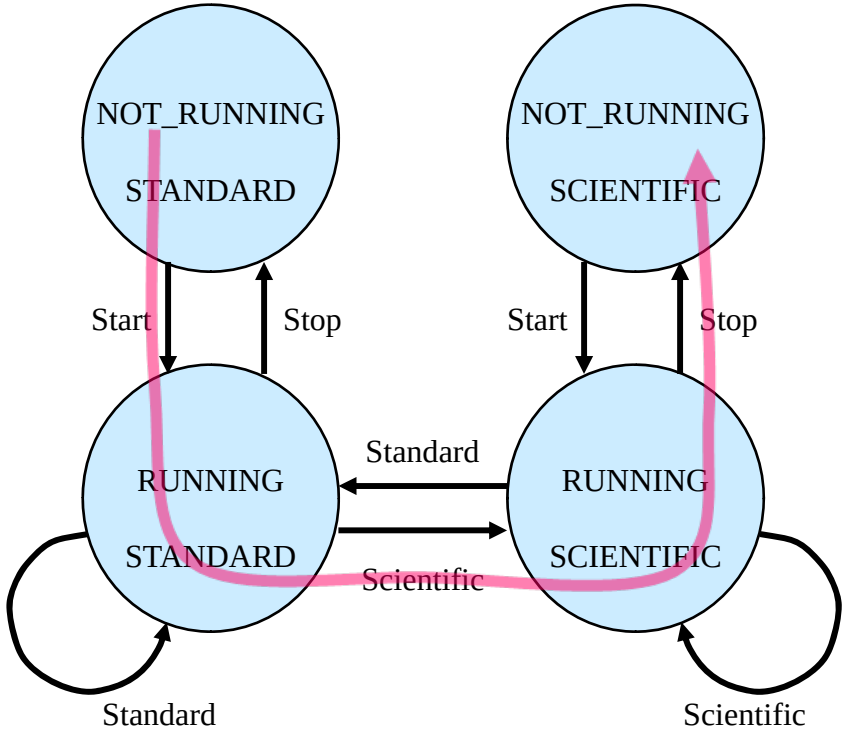



re-inventing the monkey

# All States ("salesman")

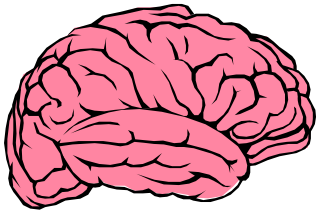


Start
Scientific
Stop
Start
Standard
Stop

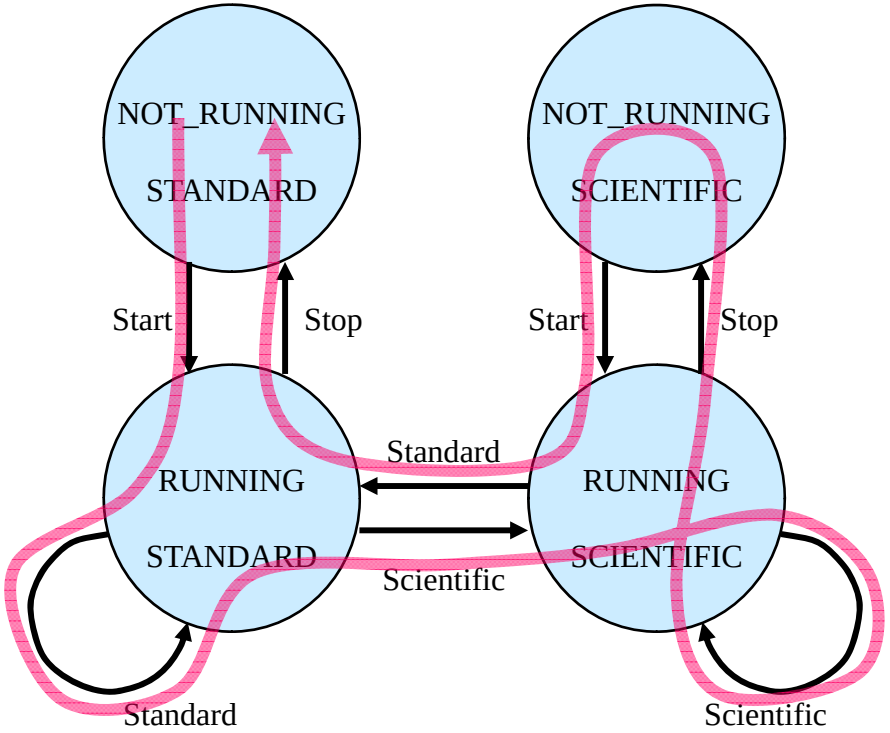



to reach every state in the model

# All Transitions ("postman")

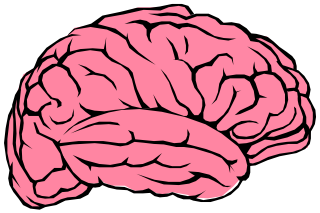


Start
Standard
Scientific
Scientific
Stop
Start
Standard
Stop

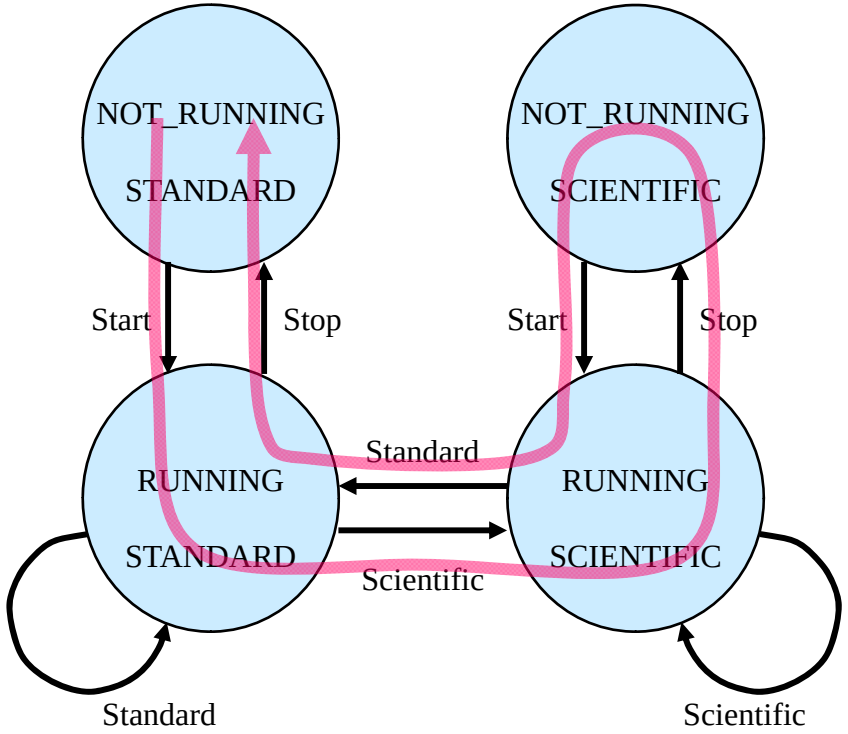



to execute every action

# All State-Changing Transitions

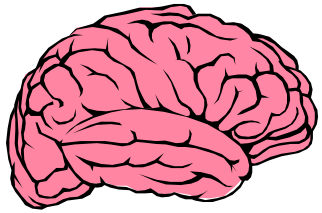


Start
Scientific
Stop
Start
Standard
Stop




to execute every state-changing action

# Shortest Paths First

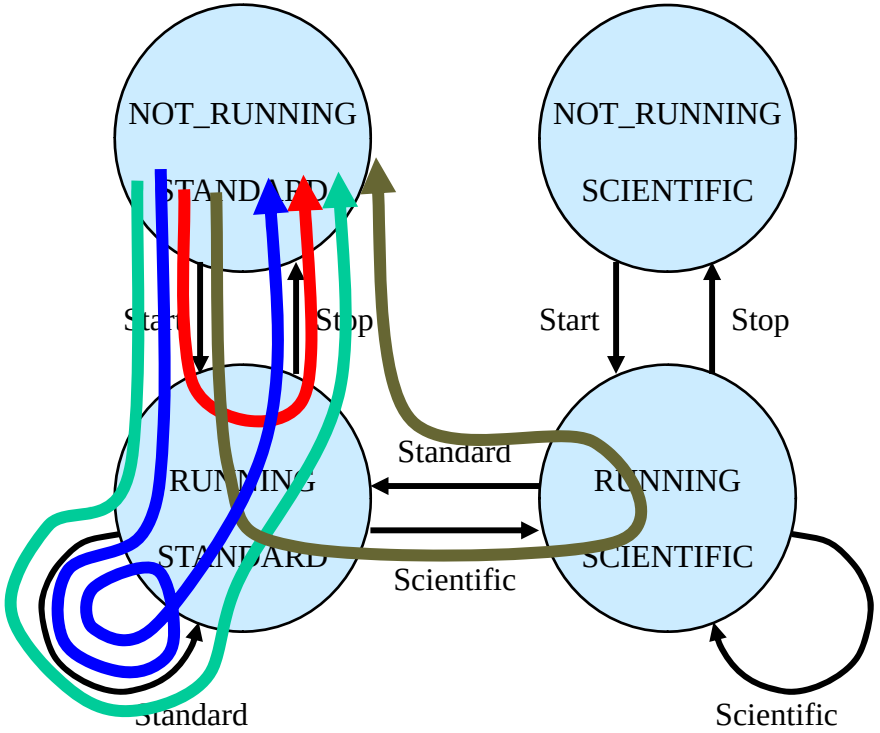


Length = 2
Start Stop

Length = 3
Start Standard Stop

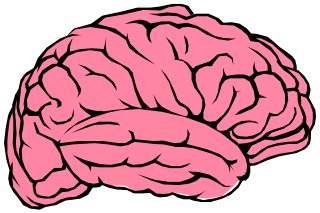
Length = 4
Start Standard Standard Stop
Start Scientific Standard Stop

and so on …




to execute every path (eventually!)

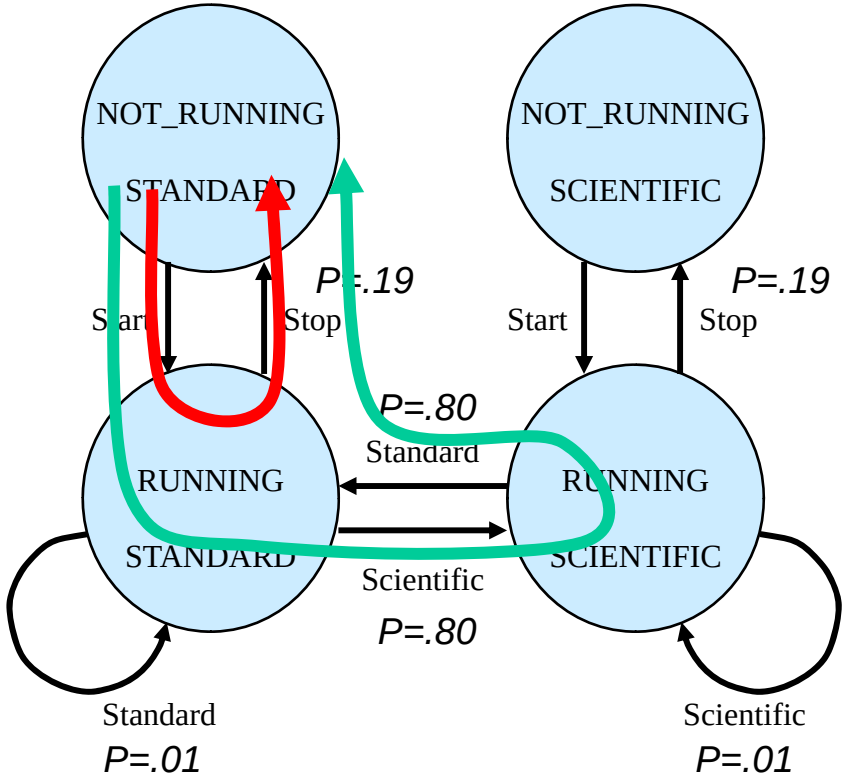
# Most Likely Paths First



Probability = 0.19
Start Stop

Probability = 0.1216
Start Scientific Standard Stop

and so on …



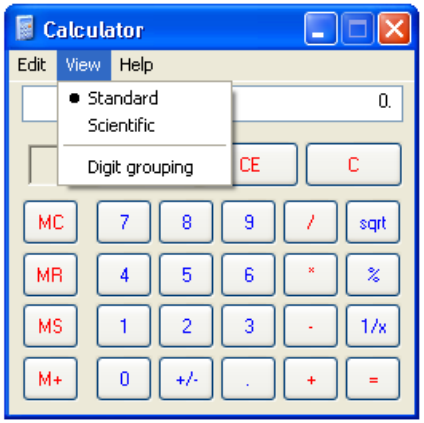

to execute favored paths in order

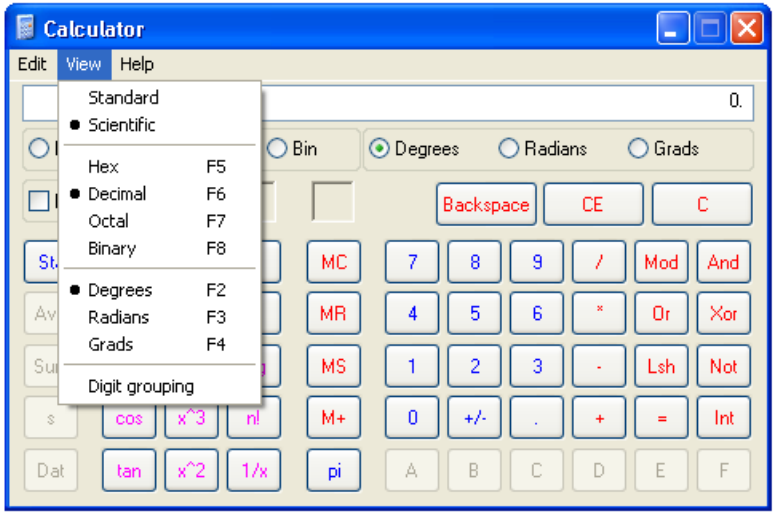
# Executing the Test Actions

```
open "test_sequence.txt" for input as #infile

while not (EOF(infile))

    line input #infile, action

    select case action

    case “Start“
        run("C:\WINNT\System32\calc.exe”)

    case “Standard“
        WMenuSelect(“View\Standard")

    case “Scientific“
        WMenuSelect(“View\Scientific")

    case “Stop“
        WSysMenu (0)
        WMenuSelect ("Close")

    end select

wend
```

```
‘get the list of test actions



‘read in a test action



‘ Start the calculator
‘ VT call to start calculator

‘ choose Standard mode
‘ VT call to select Standard

‘ choose Scientific mode
‘ VT call to select Scientific

‘ Stop the calculator
‘ VT call to bring up system menu
‘ VT call to select Close
```

# Use Rules as Heuristic Test Oracles

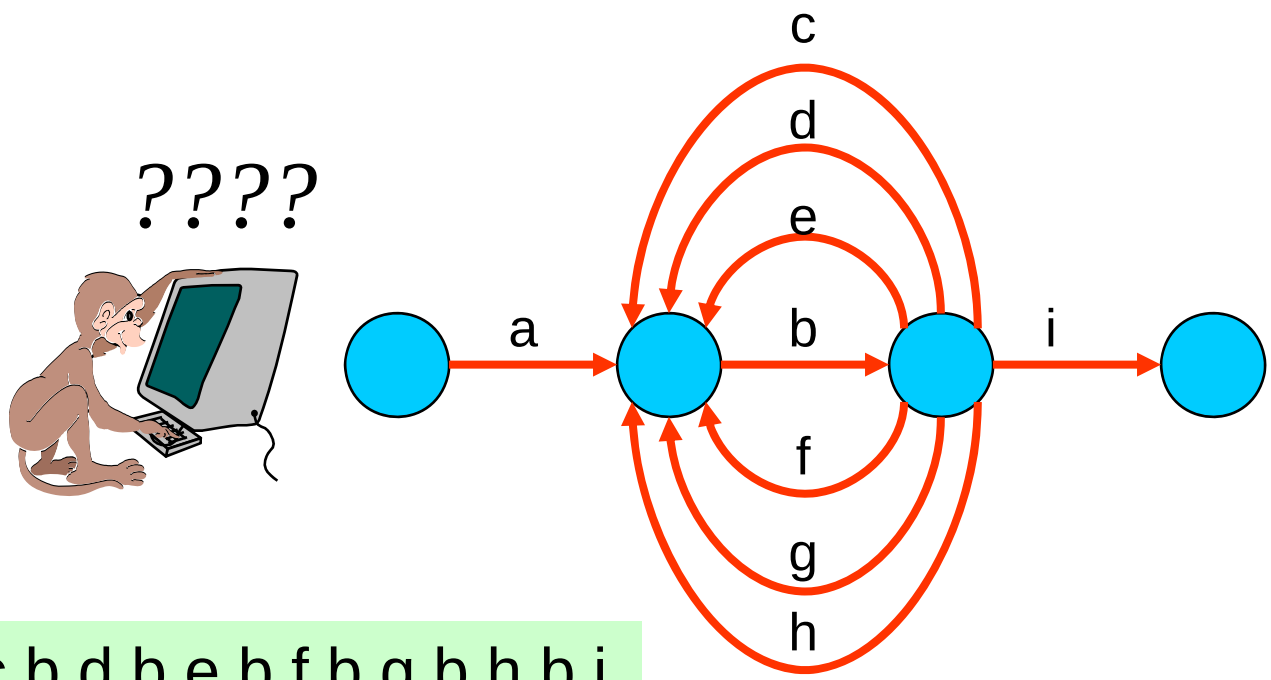



```
if ( (setting_mode = STANDARD) _

AND NOT WMenuChecked(“View\Standard") ) then

 print "Error: Calculator should be Standard mode“
 stop

endif
```

```
‘if we are in Standard mode

‘but Standard is not check-marked

‘alert the tester
```

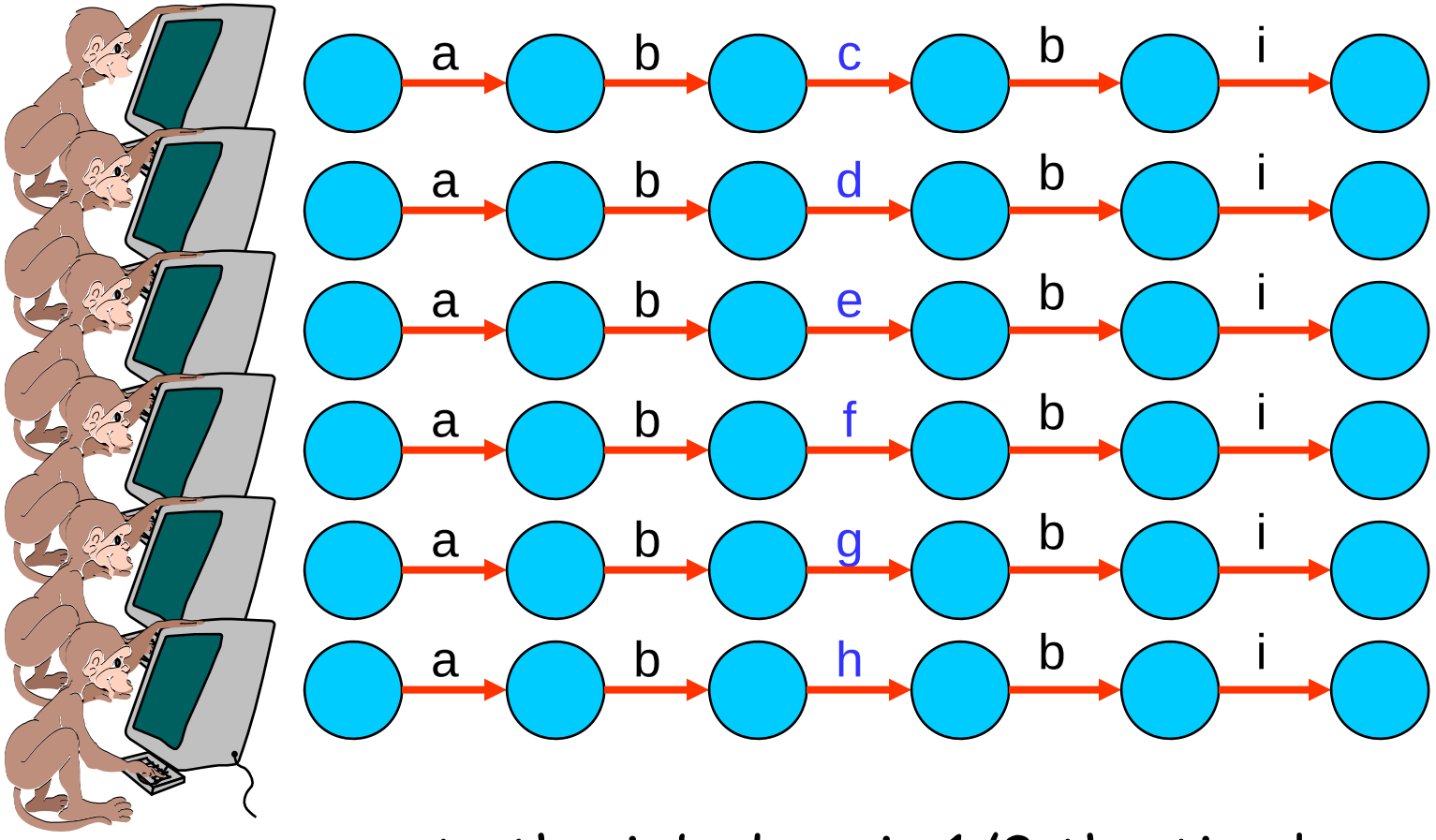
# Executing tests quickly




a b c b d b e b f b g b h b i

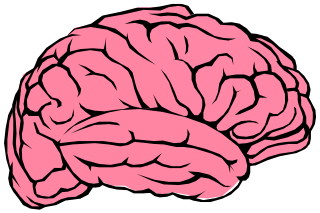
A single test machine approach takes 15 time units.

# But distributing the work ...




... gets the job done in 1/3 the time!

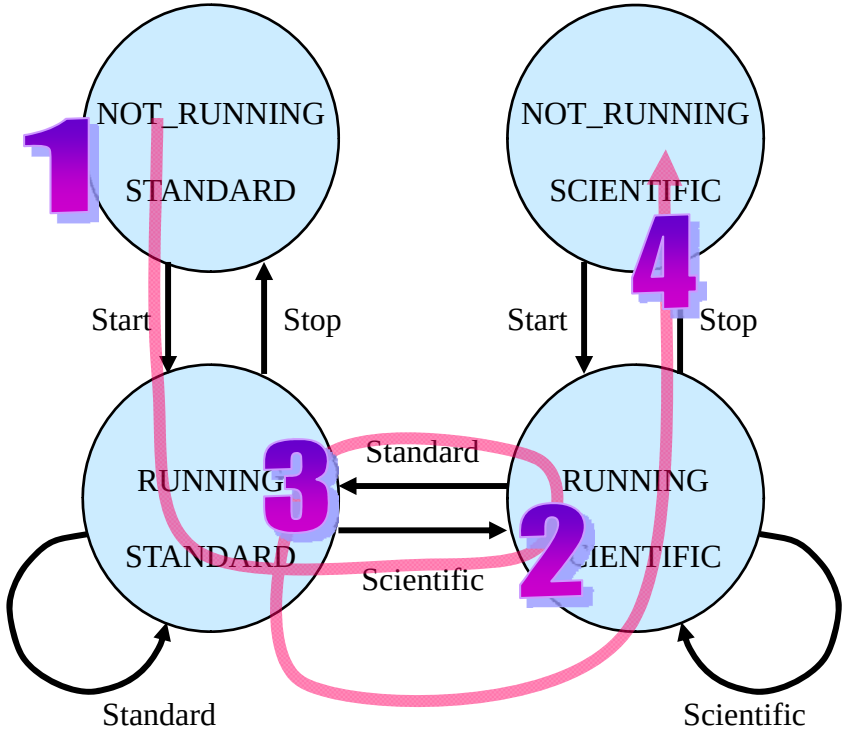
# An Anti-Random Walk



Start
Scientific

Standard

Scientific
Stop

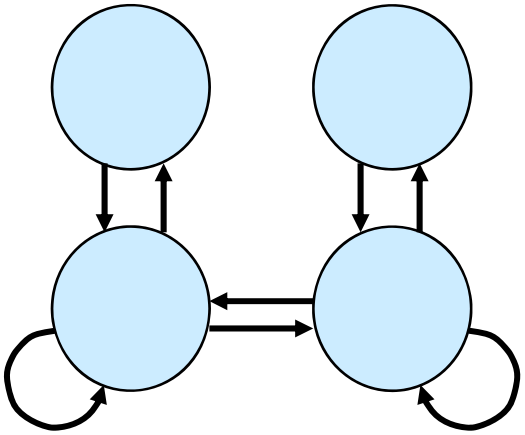



to visit states most different from where you've been

Here the most different state of (NOT_RUNNING, STANDARD) is (RUNNING, SCIENTIFIC).

# Models + Traversals = Model-Based Testing

- State models are good at representing system behavior
- You can use models to generate tests
- Different algorithms can provide tests to suit your needs:



- Random walk
- All states
- All transitions
- State-changing transitions
- Shortest paths first
- Most likely paths first
- Anti-random walks

# Q & A