Flow-Based Programming:
Why You Should Care
Even If You Never Plan To Use It

OpenWest 2015

Samuel M Smith PhD
sam@ioflo.com

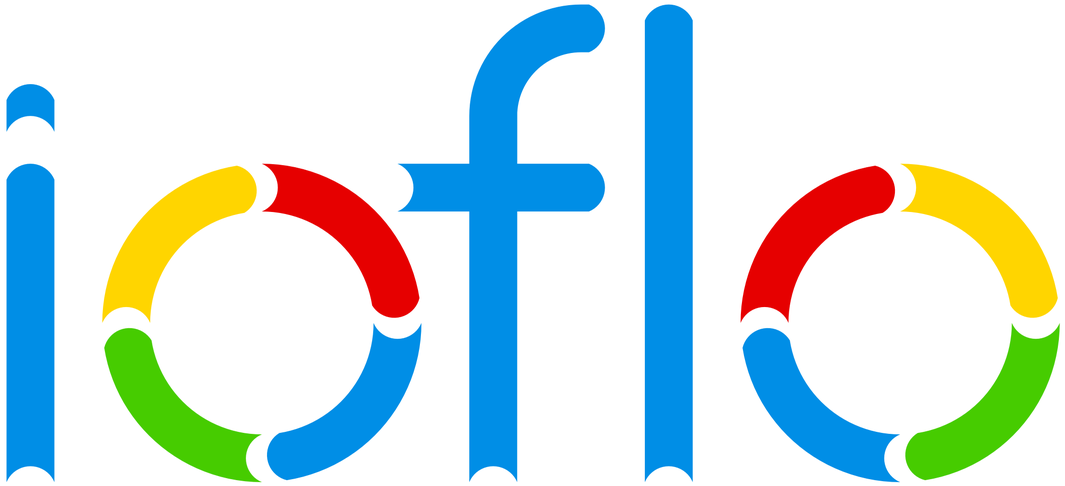
Reputation on the blockchain - it's time to get real.

worldtable.co
sam@worldtable.co

Computational reputation on the blockchain
to modulate the internet of interactions.

Open source decentralized platform

openreputation.net
https://github.com/OpenReputation



Flow-Based Programming Framework

github.com/ioflo/ioflo

ioflo.com

Flow-Based Programming (FBP)

- Originated in 1970's by J.P. Morrison, contemporary with OOP & FP
- Relatively unknown but a lot of interest recently
- Think general-purpose data-flow programming
- Use it via a programming style, pattern, paradigm, or framework, not a language
- FBP is a simplifying unifying paradigm
- Distributed concurrent applications benefit most from FBP
- An FBP architecture may still be really useful even when not using an FBP Framework
- An FBP mindset may provide unique solution insights even when using OOP or FP

Flow-Based Programming Resources

Flow-Based Programming, 2nd Ed. May 14, 2010

http://www.jpaulmorrison.com/fbp/

http://www.jpaulmorrison.com/fbp/links_external.html

https://flowbasedprogramming.wordpress.com/article/flow-based-programming/

Port Automata/ Port Based Objects

Port Automata and the Algebra of Concurrent Processes, Steenstrup & Arbib 1982

SoftwareComponentsForRealTime, Stewart 2000

Flow-Based Programming Frameworks

Javascript

NoFlo

Flux

constructables.es

Python

ioflo

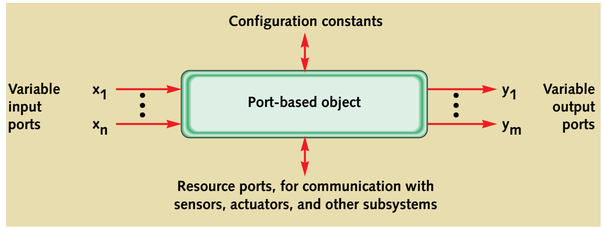
Pypes

PyF

Other

Expecco

PBO



More or less FBP

Java VM

Apache STORM

IBM InfoSphere Streams

Microsoft Azure Event Hubs

Python

ROS

Open Source Robotics Foundation

ERLANG

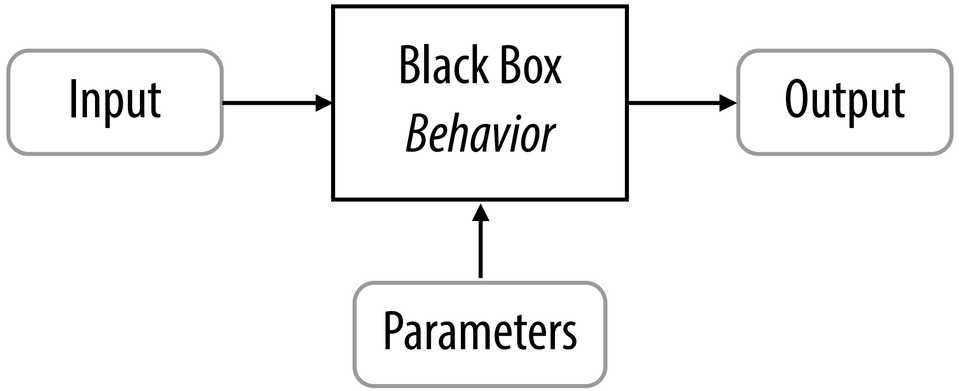
Other

MatLab Simulink

NATIONAL INSTRUMENTS LabVIEW

What is Flow-Based Programming (FBP)

A behavior transforms its input(s) into its output(s)

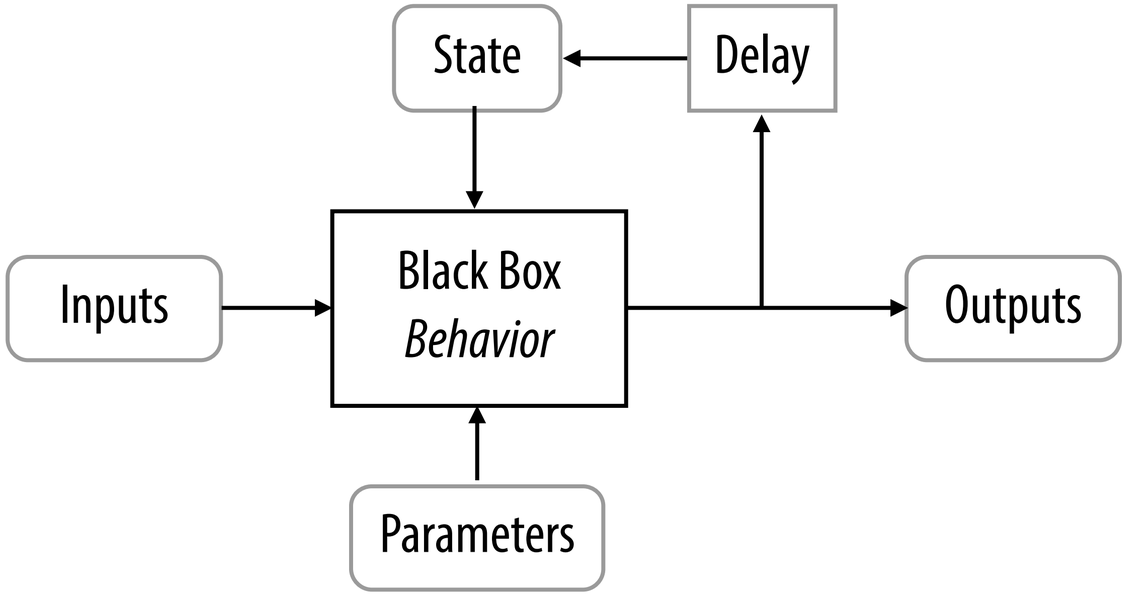


Inputs may also be parameters that modify the transformation

A behavior transforms its inputs governed by its parameters into its outputs

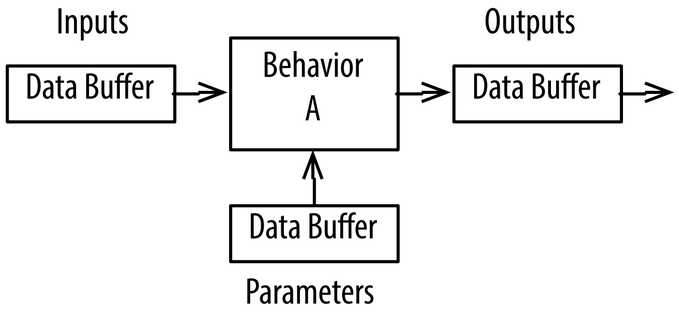
What is Flow-Based Programming (FBP)

Outputs may be fed back as state to modify the transformation

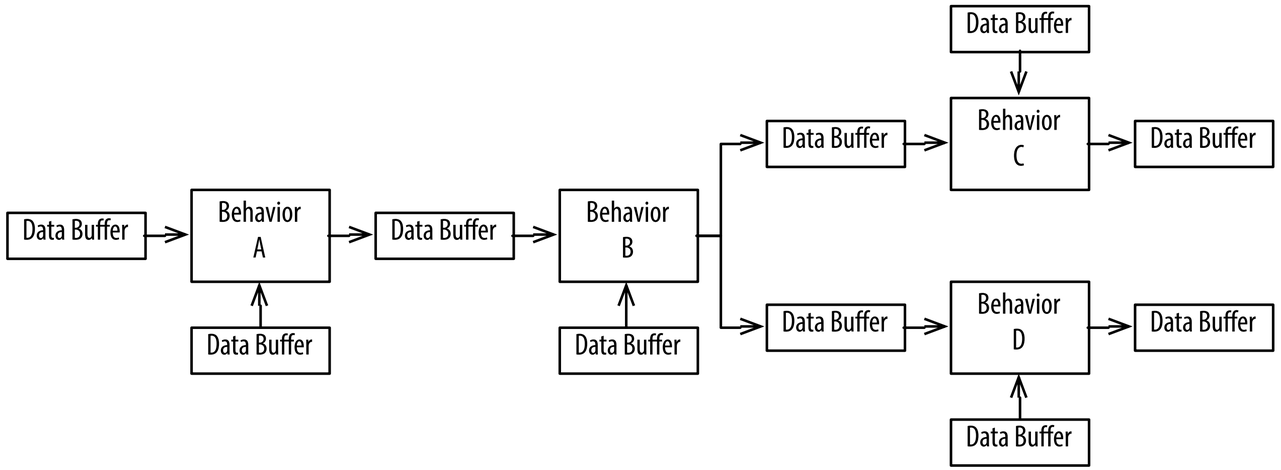


A behavior transforms its inputs and past outputs as governed by its parameters into its outputs

What is Flow-Based Programming (FBP)

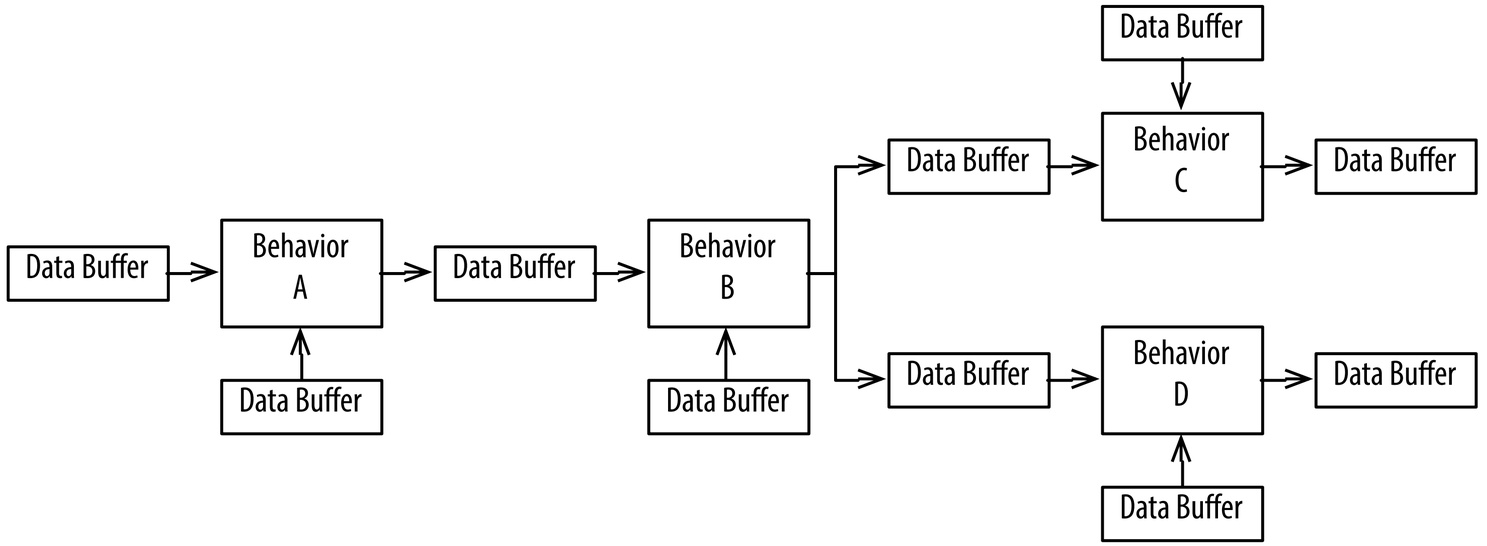


Behaviors can be reconnected endlessly in different networks without any internal changes



FBP applications (programs) are networks of asynchronous behaviors
which exchange data across externally defined connections

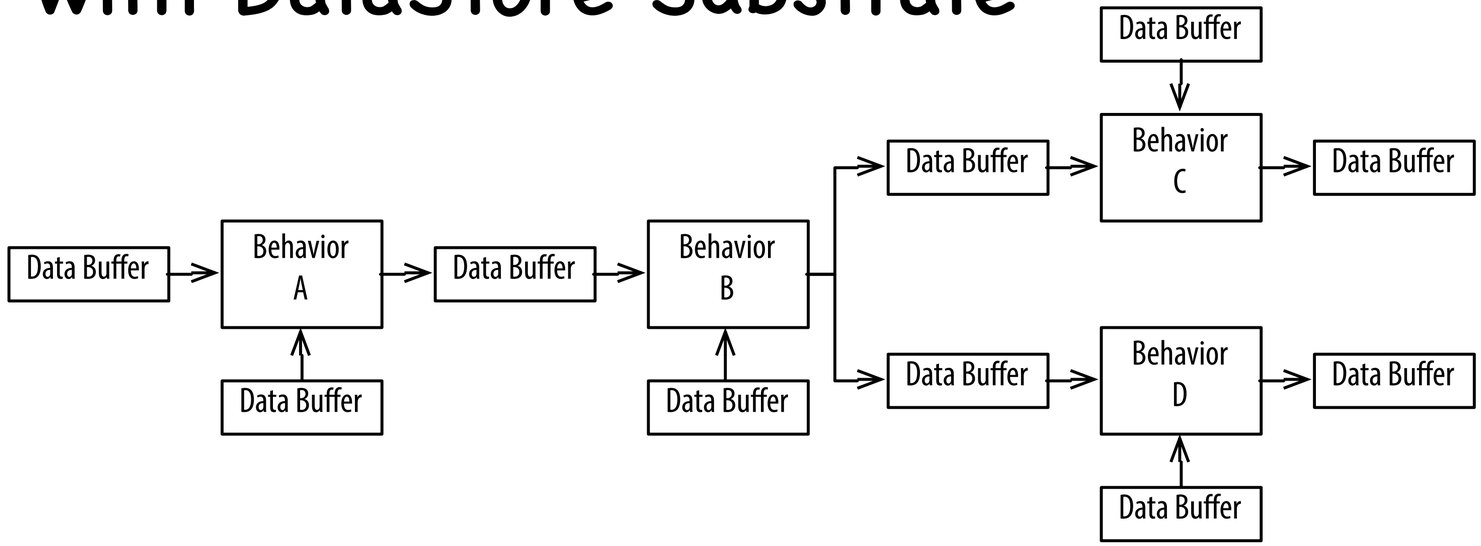
What is Flow-Based Programming (FBP)



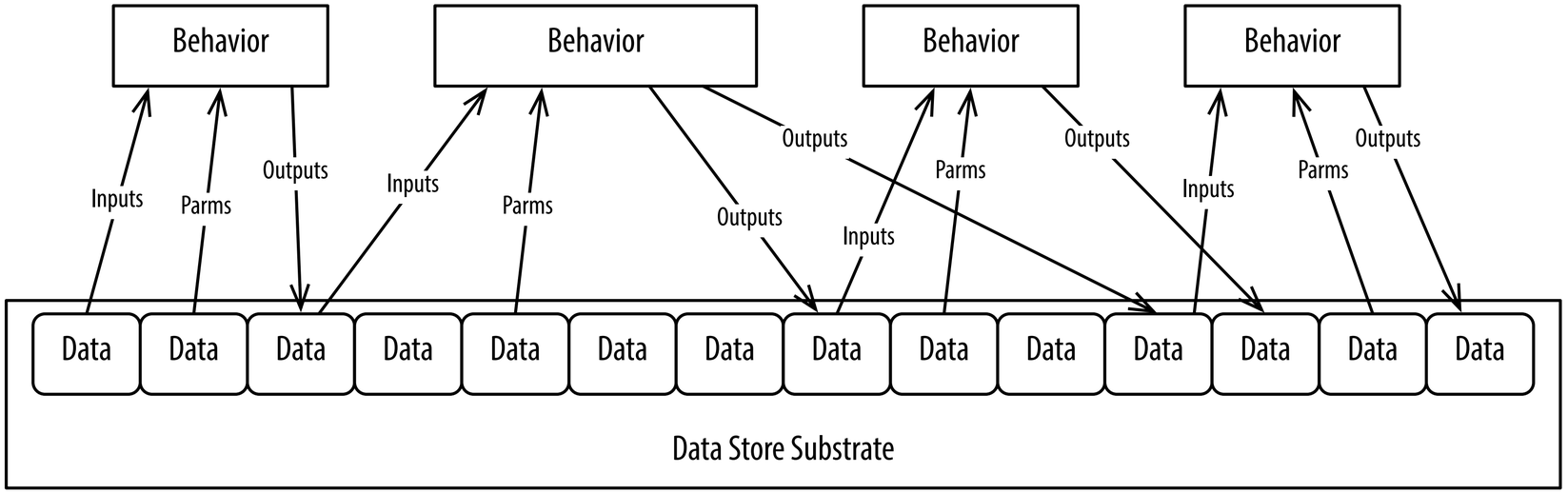
- Programming is the declarative composition of networks of behaviors
- FBP = Data Flow Oriented + Component Oriented
- FBP = FP-ish + OOP-ish

FBP Variant with DataStore Substrate

From this



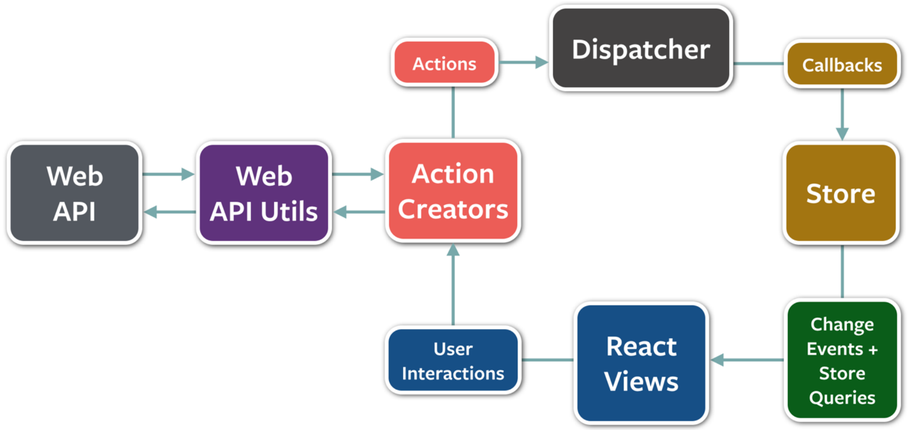
To this



- Adds configurability, observability, traceability, replayability

What is a Flow-Based Programming Framework

- Analogous to web application framework.
- Provides syntactic sugar and/or graphical editors to facilitate the composition and scheduling of behavior networks/graphs



- Begins where many other distributed application architectures are striving to end up.

```
house box1
   framer vehiclesim be active first vehicle_run
      frame vehicle_run
         do simulator motion uuv

   framer mission be active first northleg
      frame northleg
         set elapsed to 20.0
         set heading to 0.0
         set depth to 5.0
         set speed to 2.5
         go next if elapsed >= goal

      frame eastleg
         set heading to 90.0
         go next if elapsed >= goal

      frame southleg
         set heading to 180.0
         go next if elapsed >= goal

      frame westleg
         set heading to 270.0
         go next if elapsed >= goal

      frame mission_stop
         bid stop vehiclesim
         bid stop autopilot
         bid stop me

   framer autopilot be active first autopilot_run
      frame autopilot_run
         do controller pid speed
         do controller pid heading
         do controller pid depth
         do controller pid pitch
```

Dependency Inversion Principle

Dependency Inversion Principle, Martin 1996

Bad Software Design: Software that fulfills its requirements but exhibits any or all of:

Rigidity: Hard to change because each change affects other parts of the system.

Fragility: Making a change causes other parts of the system to break.

Immobility: Hard to disentangle in order to reuse in another application.

DIP:

HIGH LEVEL MODULES SHOULD NOT DEPEND UPON LOW LEVEL MODULES.

BOTH SHOULD DEPEND UPON ABSTRACTIONS.

ABSTRACTIONS SHOULD NOT DEPEND UPON DETAILS.

DETAILS SHOULD DEPEND UPON ABSTRACTIONS.

Its all about dependency management, duh !!!

Dependency Inversion Principle Transcendence

Bad Software Design: Software that fulfills its requirements but exhibits any or all of:

Rigidity: Hard to change because each change affects other parts of the system.

Fragility: Making a change causes other parts of the system to break.

Immobility: Hard to disentangle in order to reuse in another application.

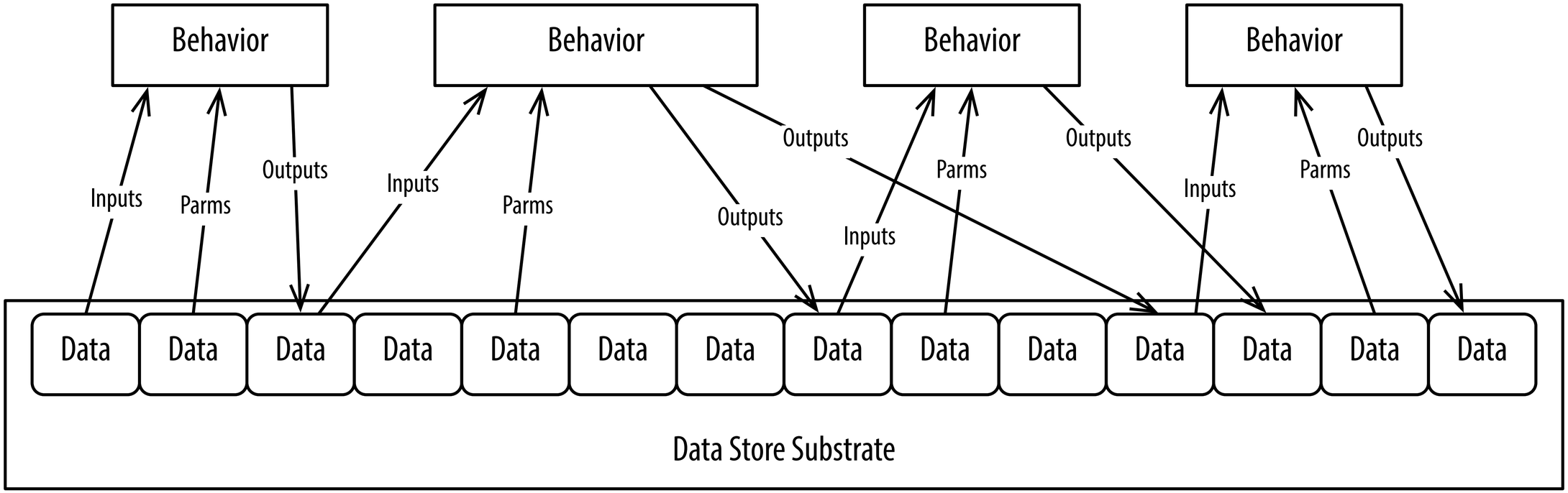
Flow-Based Programming transcends the DIP thusly:

THERE ARE NO MODULES, JUST COMPONENTS

THERE ARE NO ABSTRACTIONS OR DETAILS JUST DATA

COMPONENTS DEPEND ON DATA, NOT OTHER COMPONENTS

One Dependency: DATA



Replacement Independence

Behaviors (components) can be externally connected without any internal changes.

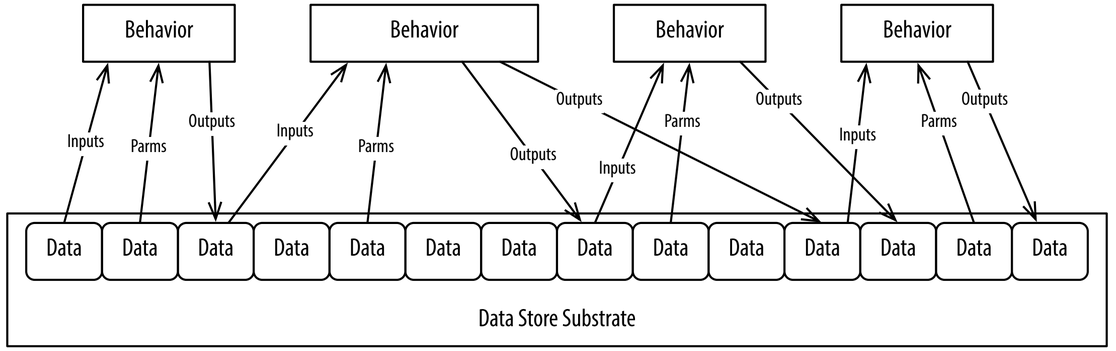
Composition of complex networks/graphs is conceptually simple

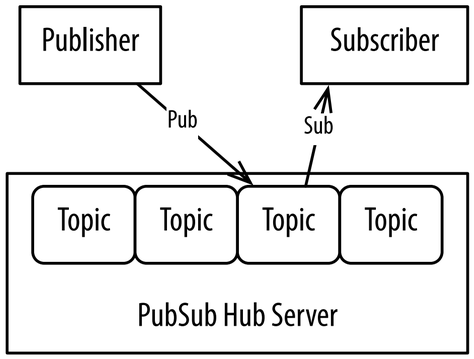
Because partitioning occurs intra-process/intra-host instead of inter-process/inter-host, distribution of behaviors across processor resources does not change behavior internals

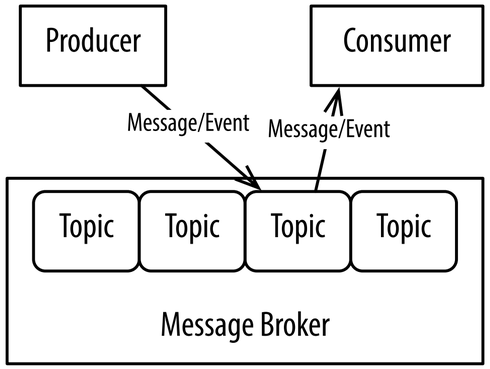
Replacement Independence = Dependency Minimization

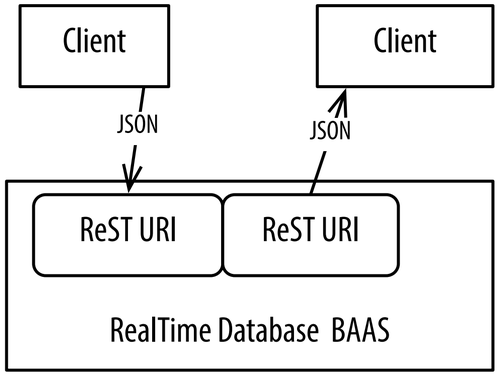
Replacement Independence = Flexibility, Robustness, Mobility

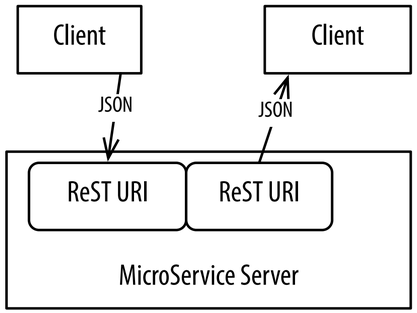
Meta Architecture Pattern

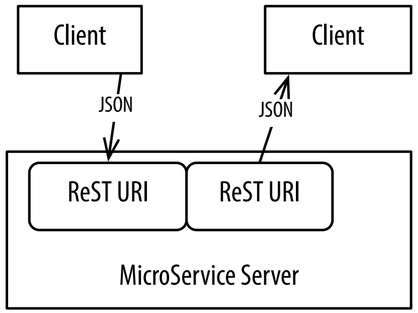


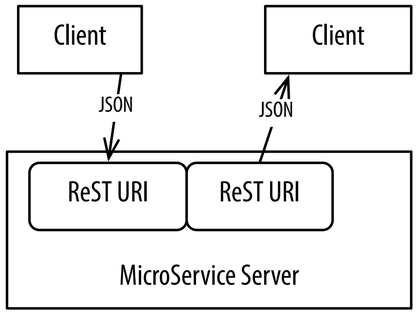


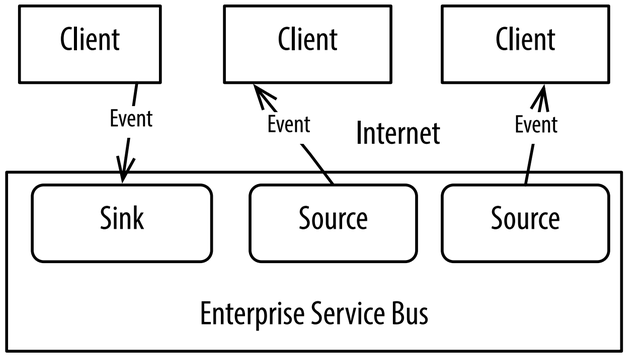












Complexity Management

Real Complexity = number of dependencies between elements of a software system

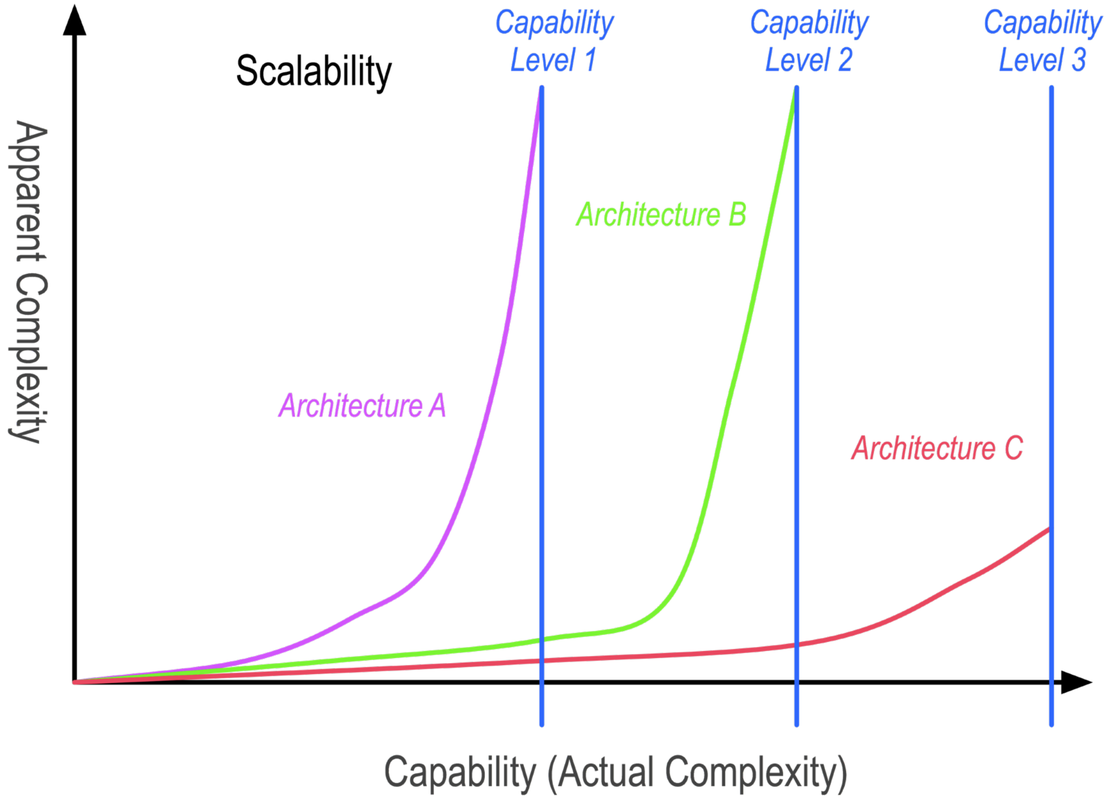
Apparent Complexity = number of dependencies that programmers must manage in order to make meaningful enhancements to software functionality

Perceived Risk = peril the programmer faces when attempting to add meaningful enhancements to software functionality.

Scalability

Higher levels of capability increase *real complexity* and may increase *apparent complexity*.

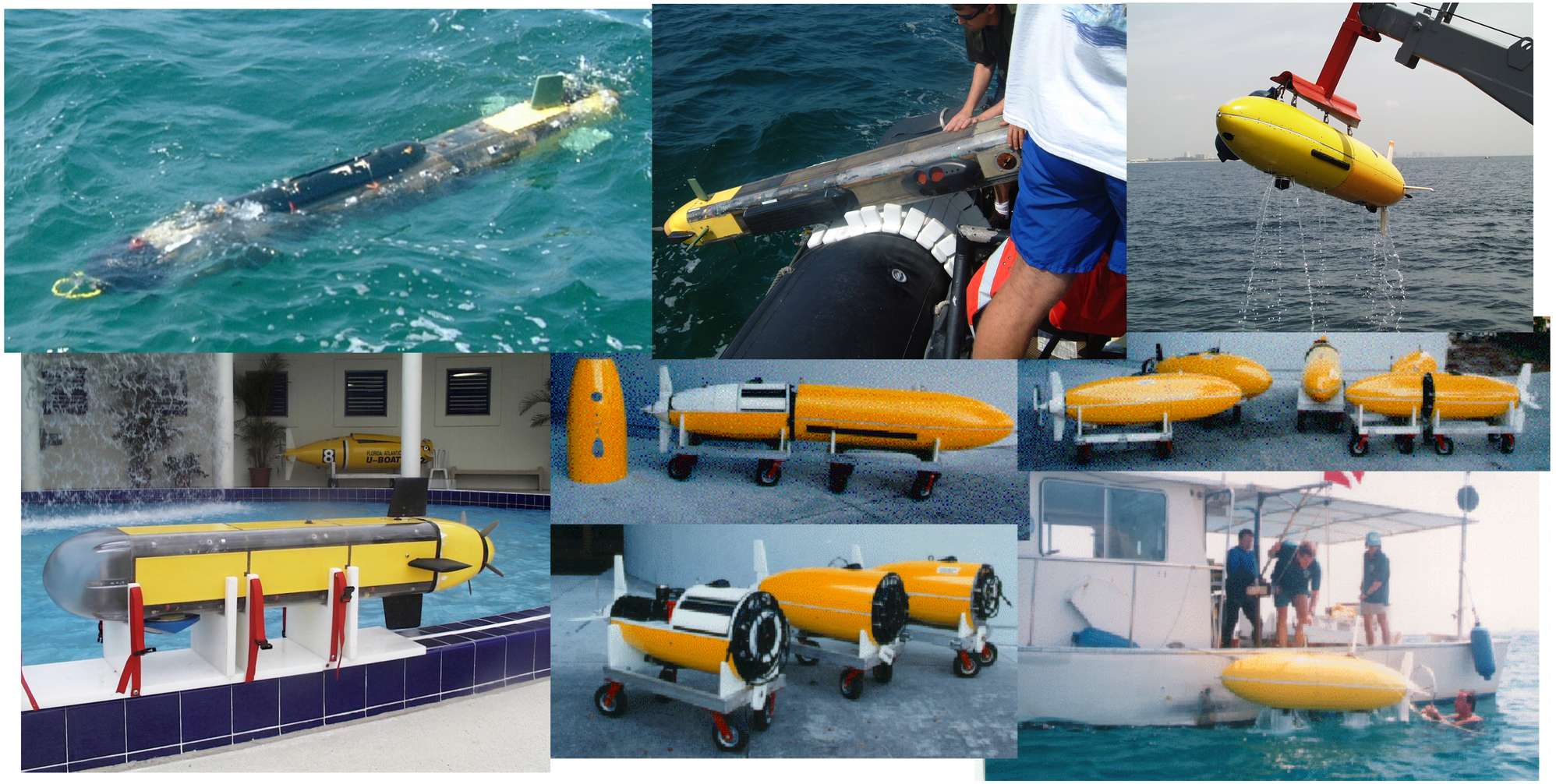
The principle limitation is programmer capacity not computational capacity



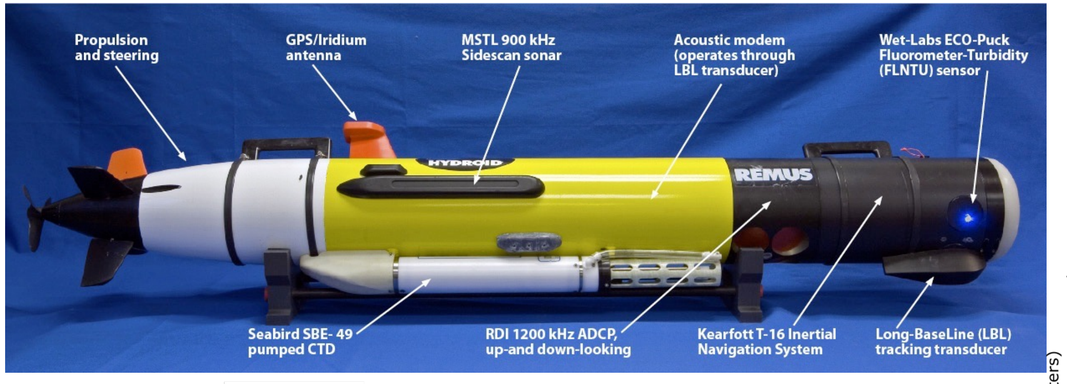
Distributed Application Menagerie

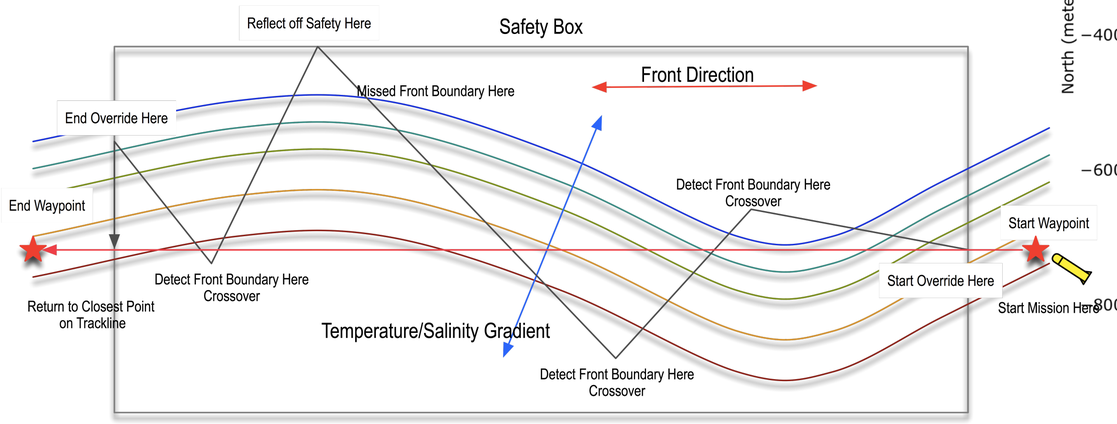
- Pub/Sub Message Broker (Rabbit MQ, AMQP, ZeroMQ)
- Task Scheduler (Celery, BeanStalk)
- Key Value Store, Database (Reddis, Couch, Mongo, River, ...)
- Resource Manager (Zookeeper)
- Data Flow Processor (Storm, Elastic, ...)
- Services (ReST web, WebRTC, Soap, ...)

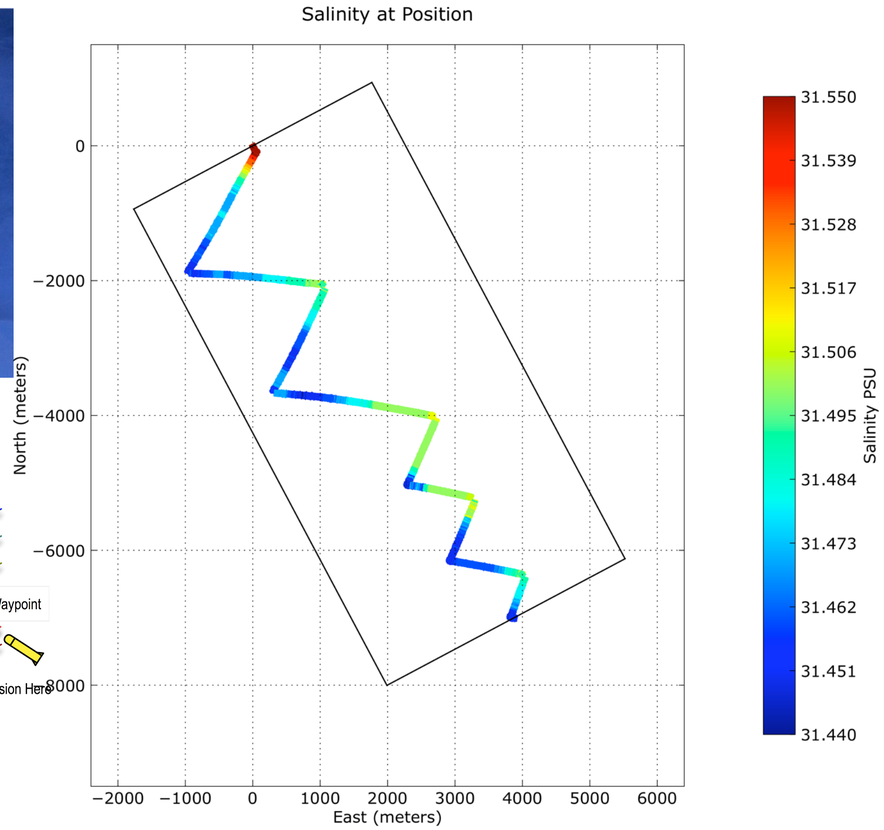
Autonomous Underwater Vehicles



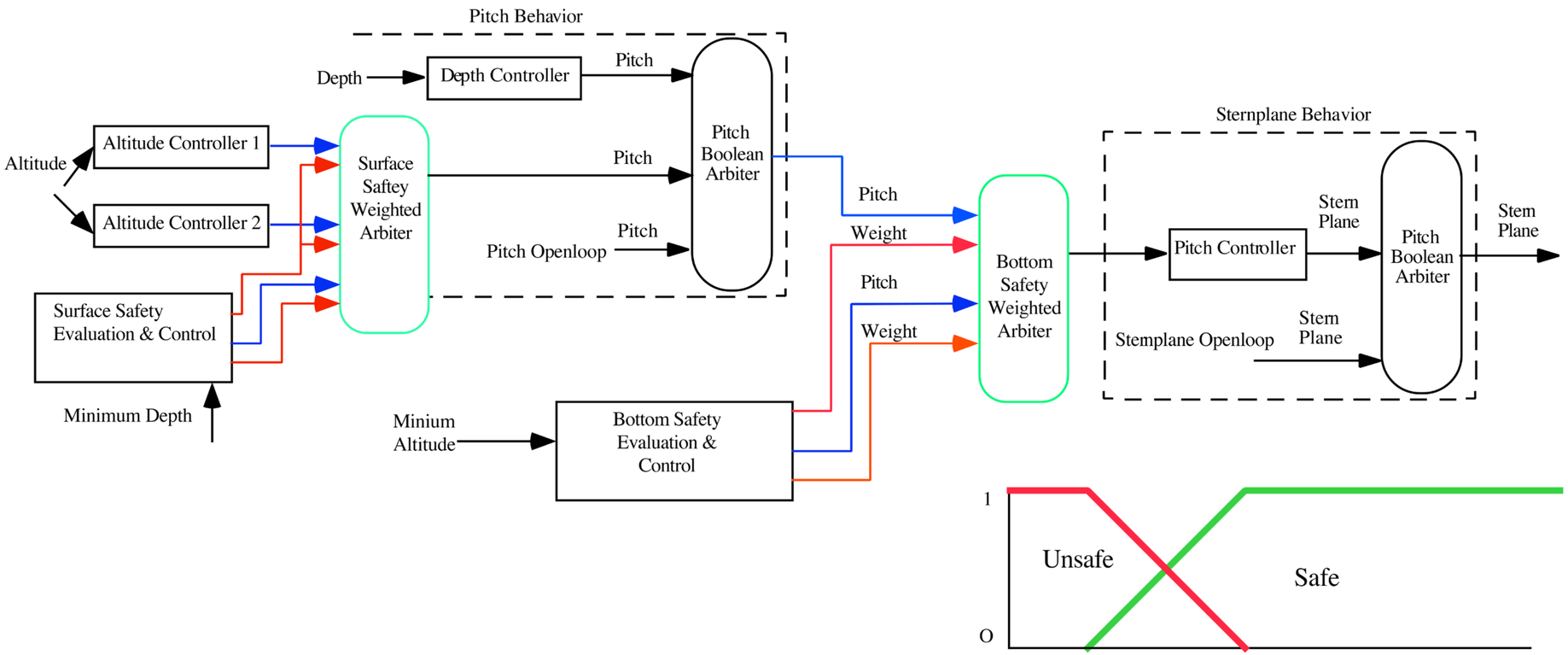
Autonomous Underwater Vehicles







Shipboard & Building Automation


Pitch Behavior
Depth
Depth Controller
Pitch
Pitch Boolean Arbiter
Altitude
Altitude Controller 1
Altitude Controller 2
Surface Saftey Weighted Arbiter
Pitch
Pitch Openloop
Pitch
Surface Safety Evaluation & Control
Minimum Depth
Minium Altitude
Bottom Safety Evaluation & Control
Pitch
Weight
Pitch
Weight
Bottom Safety Weighted Arbiter
Sternplane Behavior
Pitch Controller
Stern Plane
Pitch Boolean Arbiter
Stem Plane
Stemplane Openloop
Stern Plane
1
Unsafe
Safe
O

DSL

Marshaling, Configuration, Logic, Flow, Execution, and Scheduling

all in one place

Convenient Declarative Syntax (*3rd Generation*)

- Unified Scheduling and Execution
- Integrated Pub/Sub, Messaging,
- Observable/Traceable
- Nested Concurrent Contexts

FloScript Line Oriented, Contextual, Declarative Configuration Language

not block oriented

Declaration Sentence: `verb [object] [prepositional-phrases]`

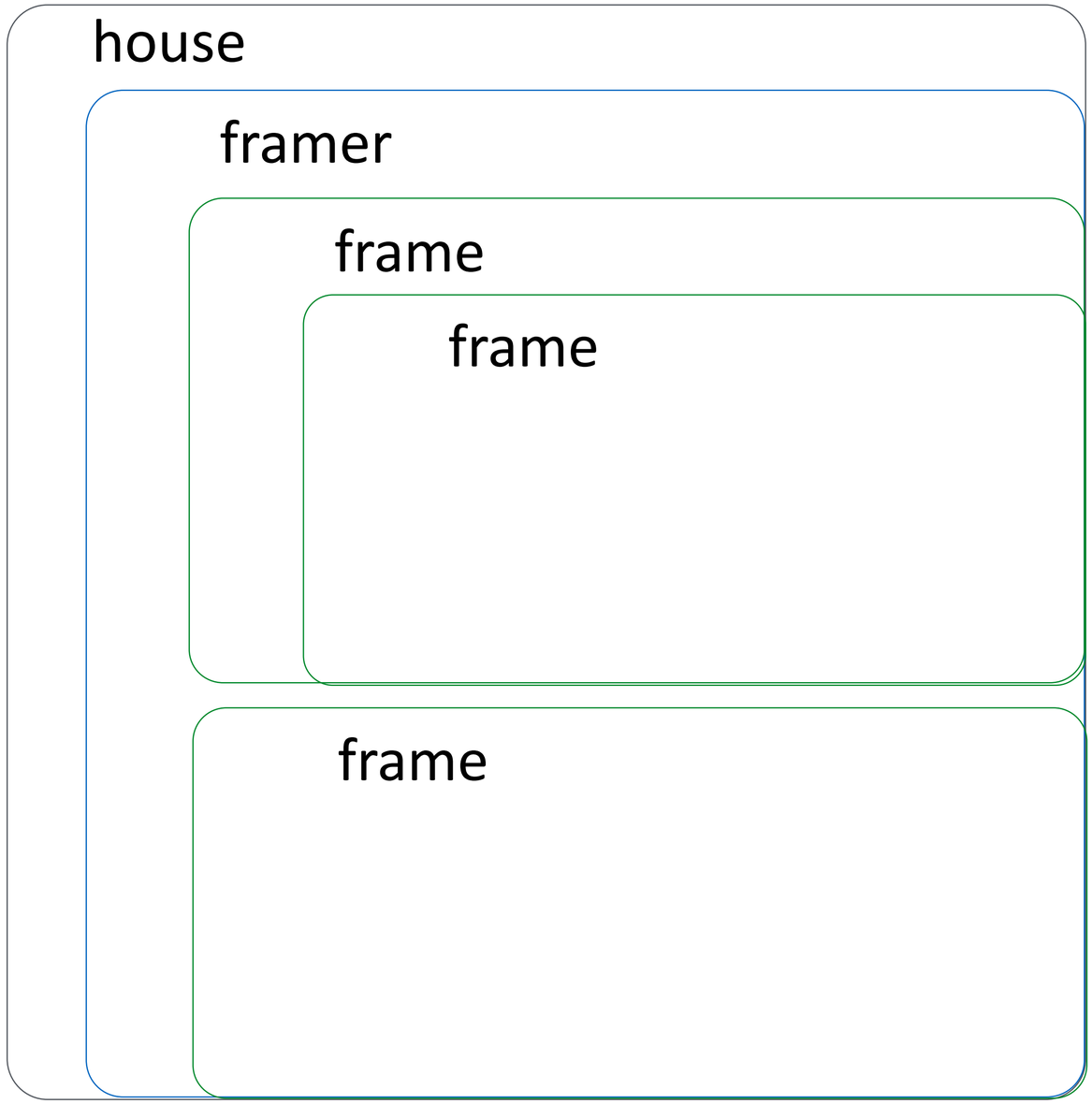
```
done
frame build in setup
set speed to 5
framer create at 0.5 be active first build
```

`[adjectives …] kind`

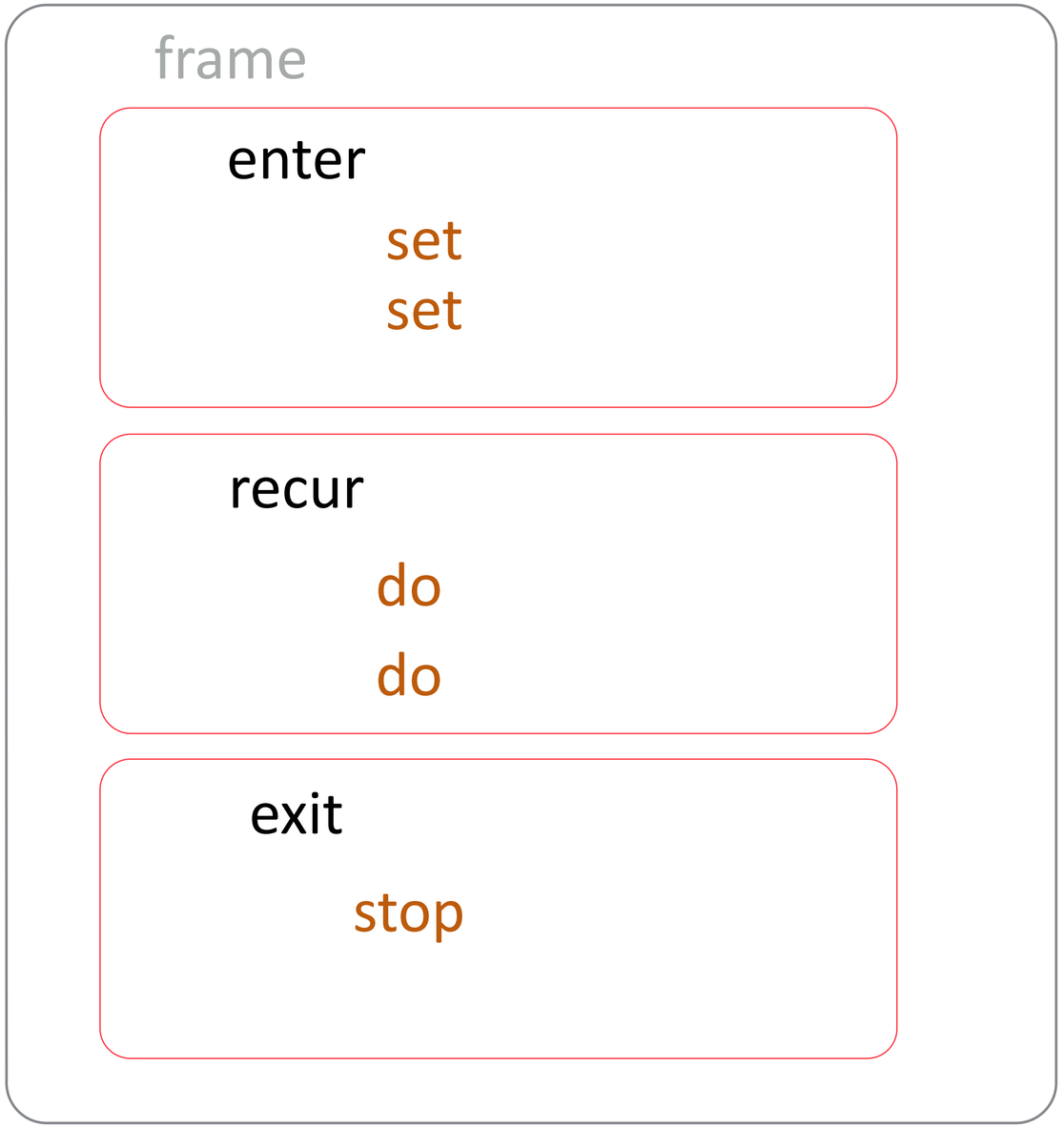
Verb Object: `do salt eventer`

Contexts:

Frame of Reference "*Framing*"

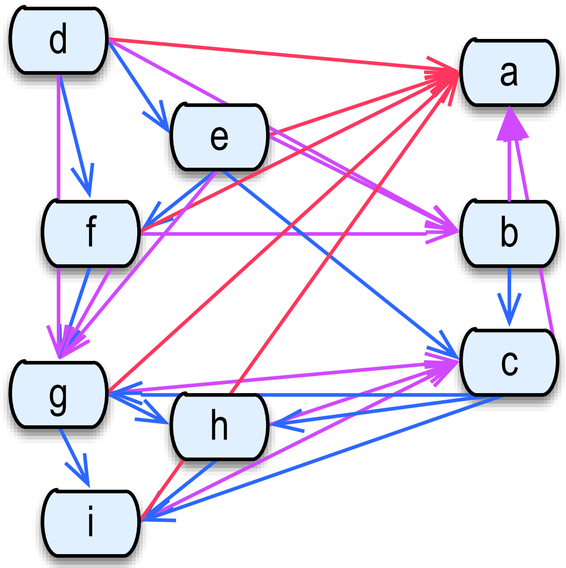


Action Execution "*Actioning*"

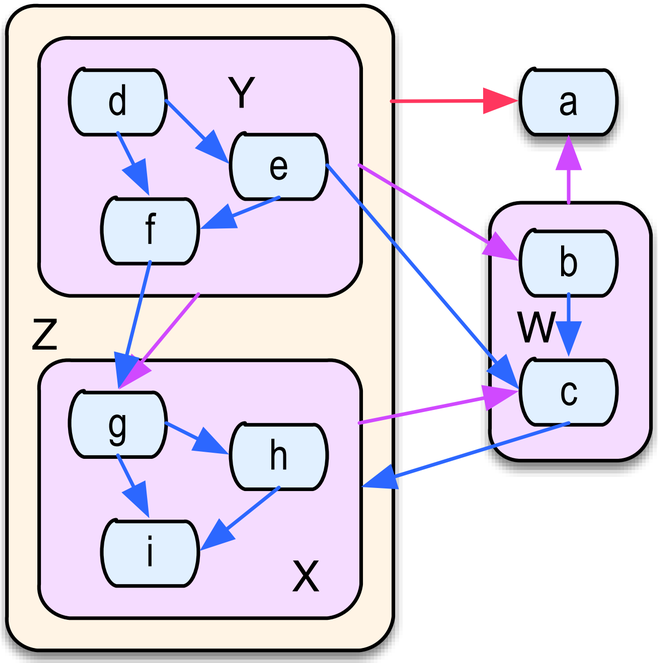


Hierarchical State

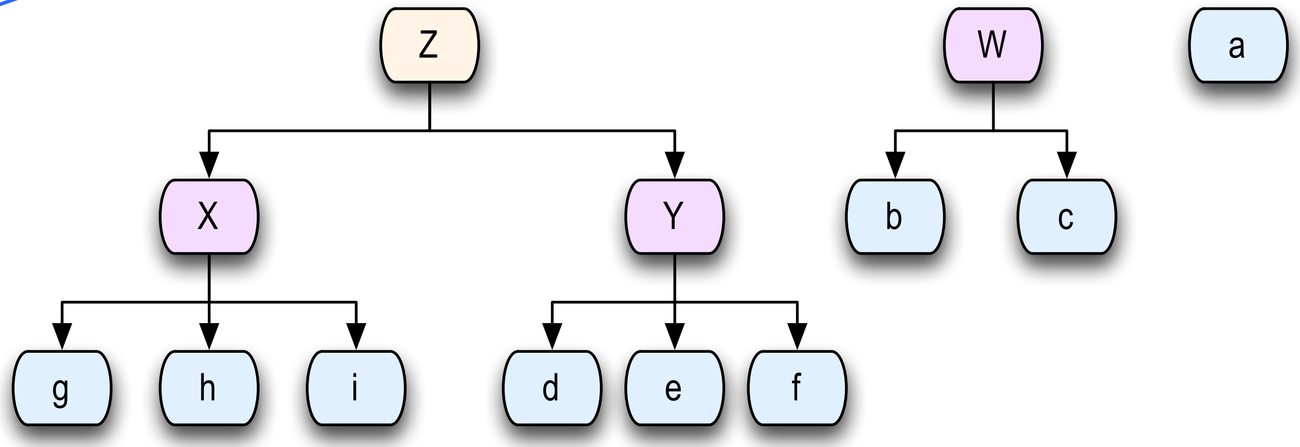
Flat State Machine
Relatively High Apparent Complexity



Hierarchical State Machine
Relatively Low Apparent Complexity

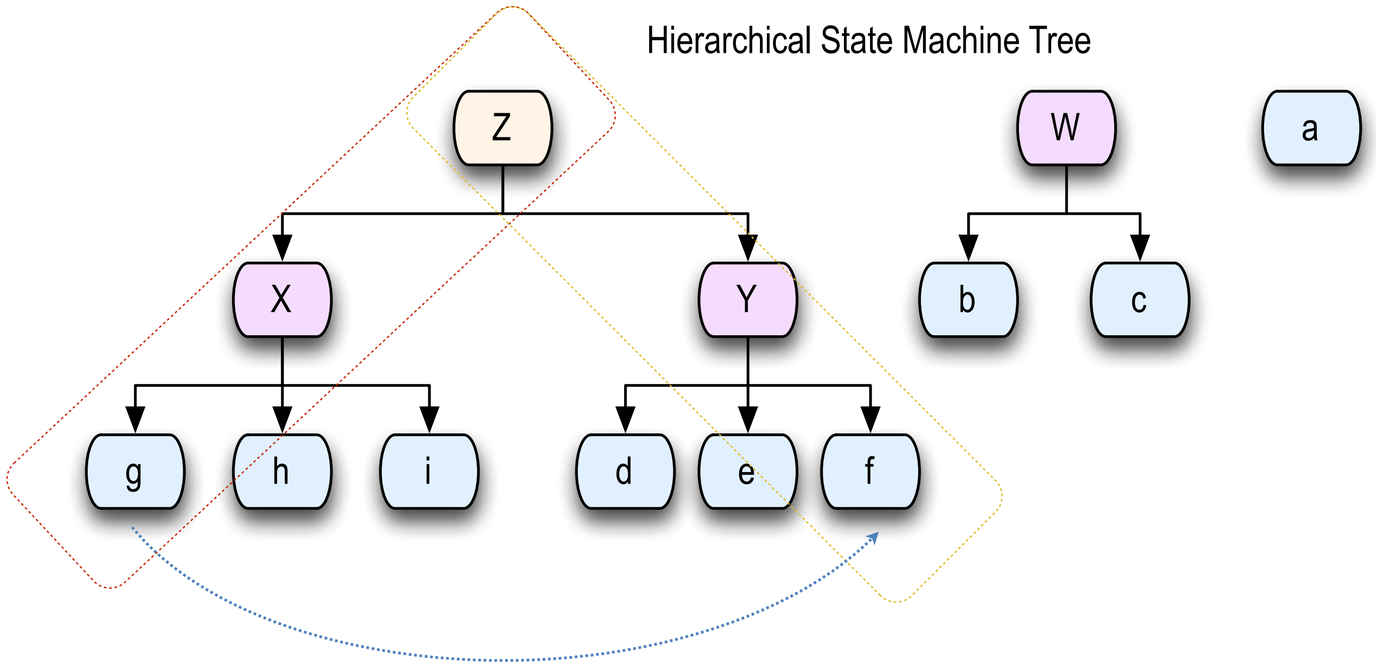


Hierarchical State Machine Tree



Transition = Change in Framing Context

```
go foobar if elapsed >= goal
```

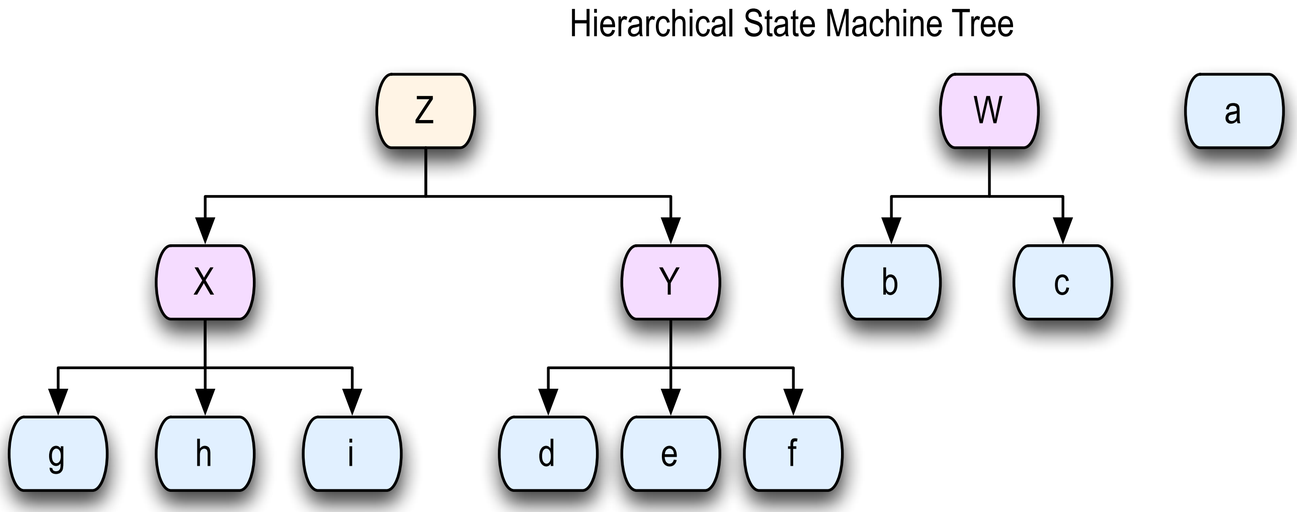


FloScript

Dichotomous Priorities

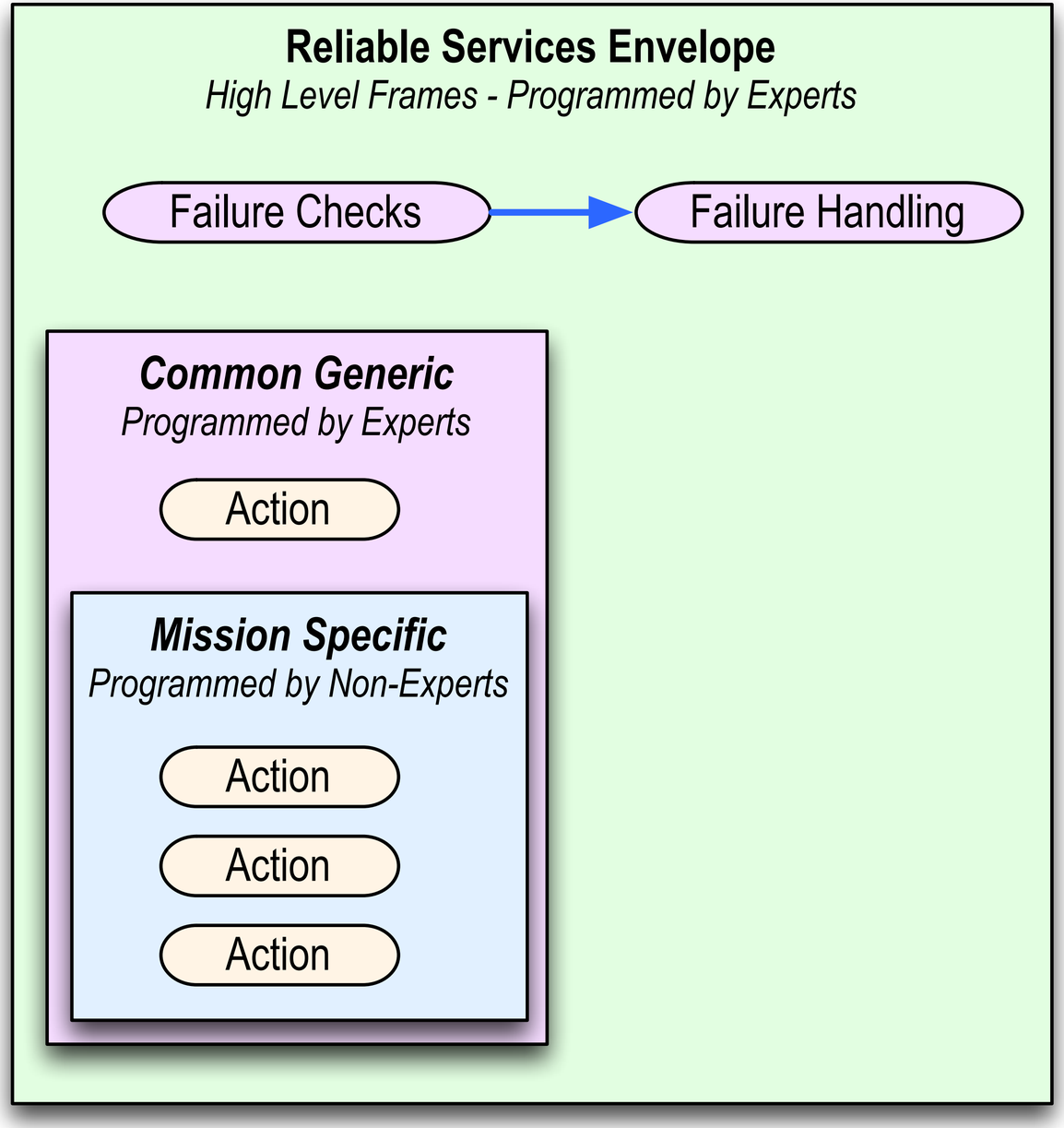
FloScript

Transitions
- Change Context, Propriety
- Priority is Top-Down



Actions
- Determine Contextual Behavior, Specificity
- Priority is Bottom-Up

Reliability



FloScript

Incremental Encapsulation

Framing *concurrency*

Framers

Auxiliary Framers

Master/Slave Framers

Nested Frames

Actioning *components*

FloScript Verbs

Ioflo library Python Actions/Behaviors for do verb objects

Custom Python coded do verb objects

Custom coded Python C Extensions for do verb objects

Universal Name-Spaced Pub/Sub Interface for Intra application communication

high replacement independence

Addressing Modes:

direct indirect-absolute

```
put name sam eyes blue into .person.detail
```

indirect-relative-implied indirect-relative-root

```
set speed by blue in myapp.setup
```

direct indirect-relative-frame

```
put name sam eyes blue into detail of frame start
```

direct indirect-relative-framer

```
put true into good of framer
```

FloScript

RAET Reliable Asynchronous Event Transport

https://github.com/RaetProtocol/raet

- RAET
  - Micro threaded architecture with non-blocking I/O
  - Micro threaded Event Pub/Sub separate from socket based transport layer
  - UDP sockets
  - Better observability and management of performance under load
  - Transactions
  - Unix domain sockets for interprocess communications

References

http://ioflo.com
https://github.com/ioflo
https://github.com/ioflo/ioflo_manuals

http://www.jpaulmorrison.com/fbp/
http://www.jpaulmorrison.com/fbp/links_external.html
https://flowbasedprogramming.wordpress.com/article/flow-based-programming/
http://www.amazon.com/Flow-Based-Programming-2nd-Application-Development/dp/1451542321/ref=sr_1_1?ie=UTF8&qid=1427910581&sr=8-1&keywords=flow+based+programming

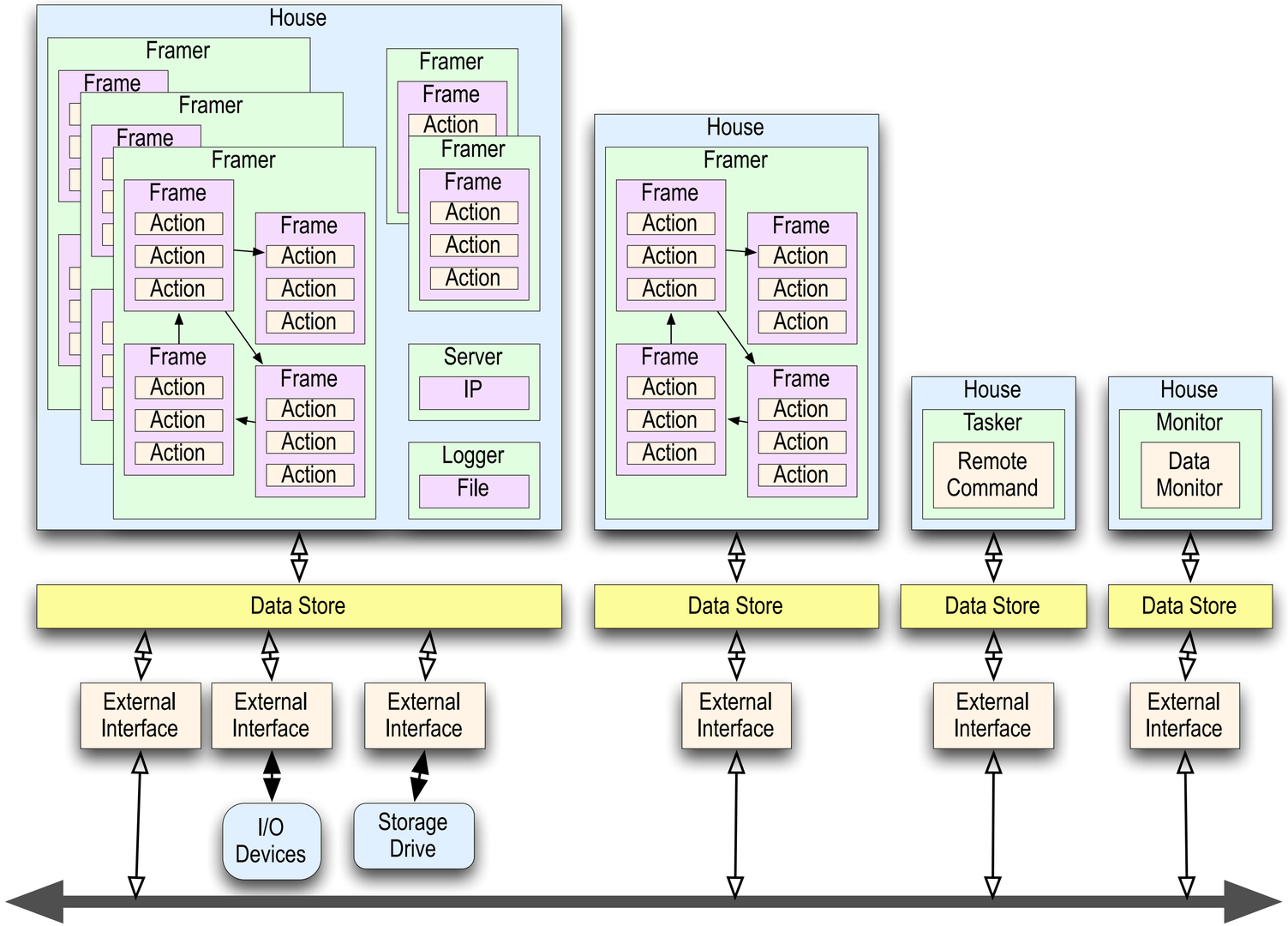
http://wiki.ros.org/ROS/Tutorials

Backup Slides

ioflo

FloScript

Big Picture



Example

```
$ pip install ioflo

$ ioflo -h

usage: ioflo [-h] [-v VERBOSE] [-p PERIOD] [-r] [-V] [-n NAME] [-f FILENAME]
             [-b [BEHAVIORS [BEHAVIORS ...]]] [-U USERNAME] [-P PASSWORD]

Runs ioflo. Example: ioflo -f filename -p period -v terse -r -h -b 'mybehaviors.py'

optional arguments:
  -h, --help            show this help message and exit
  -v VERBOSE, --verbose VERBOSE
                        Verbosity level.
  -p PERIOD, --period PERIOD
                        Period per skedder run in seconds.
  -r, --realtime        Run skedder at realtime.
  -V, --version         Prints out version of ioflo.
  -n NAME, --name NAME  Skedder name.
  -f FILENAME, --filename FILENAME
                        File path to FloScript file.
  -b [BEHAVIORS [BEHAVIORS ...]], --behaviors [BEHAVIORS [BEHAVIORS ...]]
                        Module name strings to external behavior packages.
  -U USERNAME, --username USERNAME
                        Username.
  -P PASSWORD, --password PASSWORD
                        Password.
```

```
house box1
   framer vehiclesim be active first vehicle_run
      frame vehicle_run
         do simulator motion uuv

   framer mission be active first northleg
      frame northleg
         set elapsed to 20.0
         set heading to 0.0
         set depth to 5.0
         set speed to 2.5
         go next if elapsed >= goal

      frame eastleg
         set heading to 90.0
         go next if elapsed >= goal

      frame southleg
         set heading to 180.0
         go next if elapsed >= goal

      frame westleg
         set heading to 270.0
         go next if elapsed >= goal

      frame mission_stop
         bid stop vehiclesim
         bid stop autopilot
         bid stop me

   framer autopilot be active first autopilot_run
      frame autopilot_run
         do controller pid speed
         do controller pid heading
         do controller pid depth
         do controller pid pitch
```

```
$ ioflo -v terse -f box1.flo


Starting mission from file box1.flo...
   Starting Framer vehiclesim ...
To: vehiclesim<<vehicle_run> at 0.0
   Starting Framer mission ...
To: mission<<northleg> at 0.0
   Starting Framer autopilot ...
To: autopilot<<autopilot_run> at 0.0
To: mission<<eastleg> at 20.0 Via: northleg (go next if elapsed >= goal)
      From: <northleg> after 20.000
To: mission<<southleg> at 40.0 Via: eastleg (go next if elapsed >= goal)
      From: <eastleg> after 20.000
To: mission<<westleg> at 60.0 Via: southleg (go next if elapsed >= goal)
      From: <southleg> after 20.000
To: mission<<mission_stop> at 80.0 Via: westleg (go next if elapsed >= goal)
      From: <westleg> after 20.000
   Stopping autopilot in autopilot_run at 80.000
   Stopping vehiclesim in vehicle_run at 80.125
   Stopping mission in mission_stop at 80.125
No running or started taskers. Shutting down skedder ...
Total elapsed real time = 0.2099
Aborting all ready taskers ...
   Aborting vehiclesim at 80.125
       Tasker 'vehiclesim' aborted
   Aborting mission at 80.125
       Tasker 'mission' aborted
   Aborting autopilot at 80.125
       Tasker 'autopilot' aborted
```

Intelligent Autonomy-Autonomic-Automation Programming Framework

Open Source: MIT License - ioflo.com - github.com/ioflo

Automation Operating System

Micro Threaded Concurrent Execution Engine With Non Blocking I/O

Automated Reasoning Engine

Flow Based Programming Framework

Hierarchical Action Framework

Discrete Event Simulation Framework

Dependency Injection Framework

Universal PubSub

FloScript: DSL for Convenient Configuration

Machine Learning - Machine Intelligence Infrastucture