Digital Twin Applied To Software Digital-TwinS

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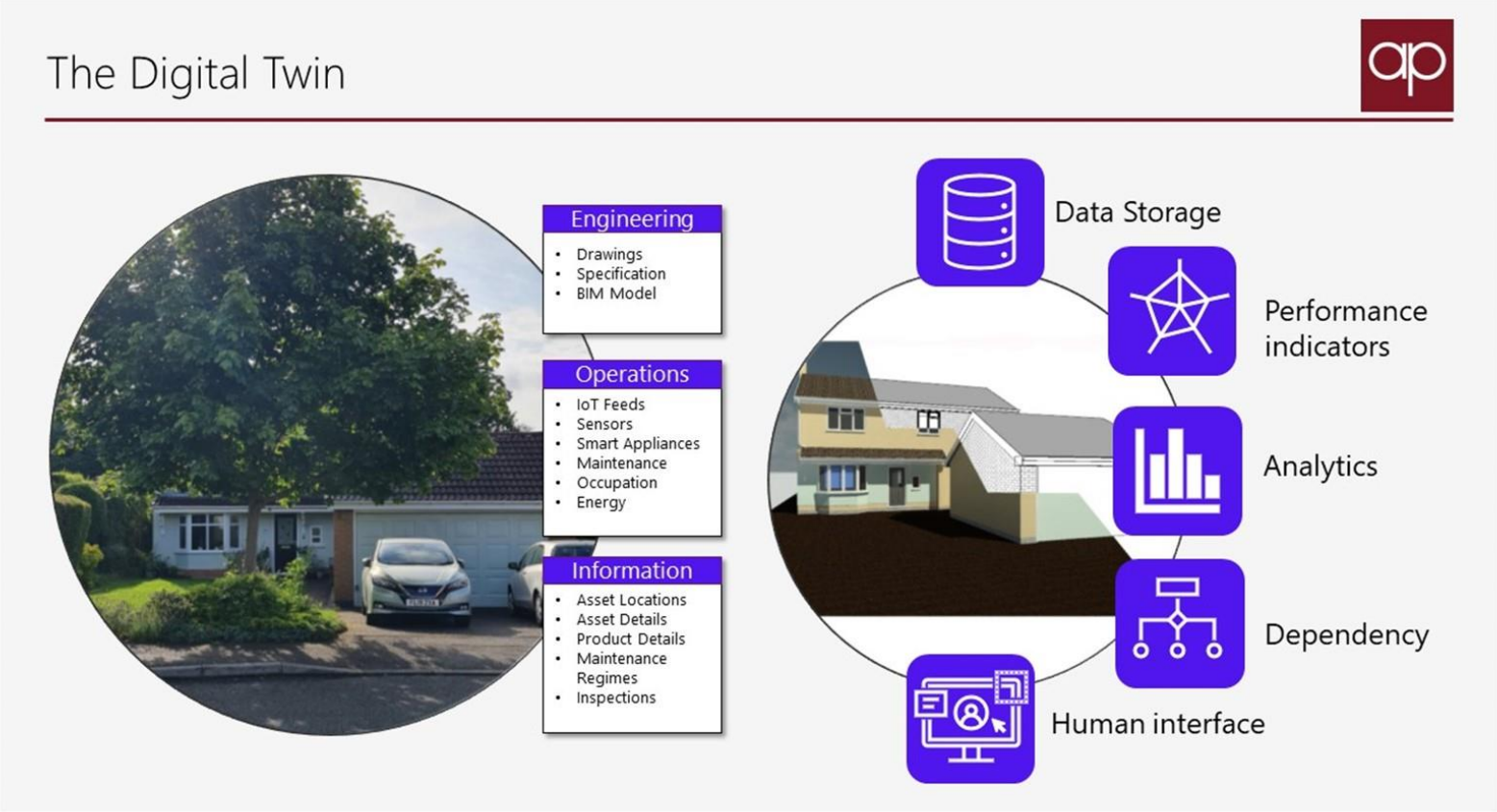
2023-06-20 Tue

Motivations

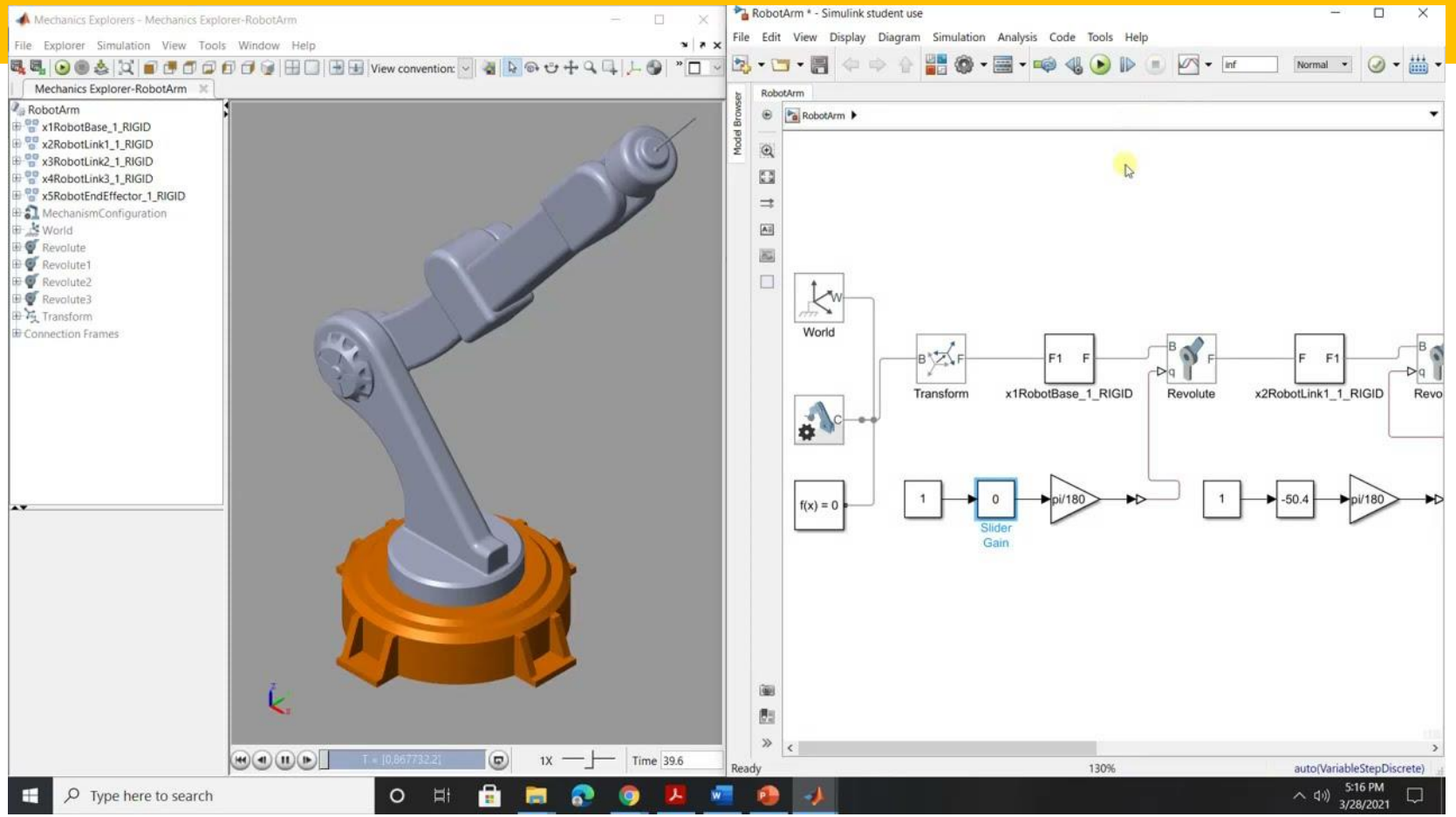
- How to understand complex software better?
- Combine best of static and dynamic languages
  - C++, Rust for speed;
  - Smalltalk, Python for flexibility
- Use redundancy to reduce bugs by orders of magnitude

Digital Twin Concept (2002)



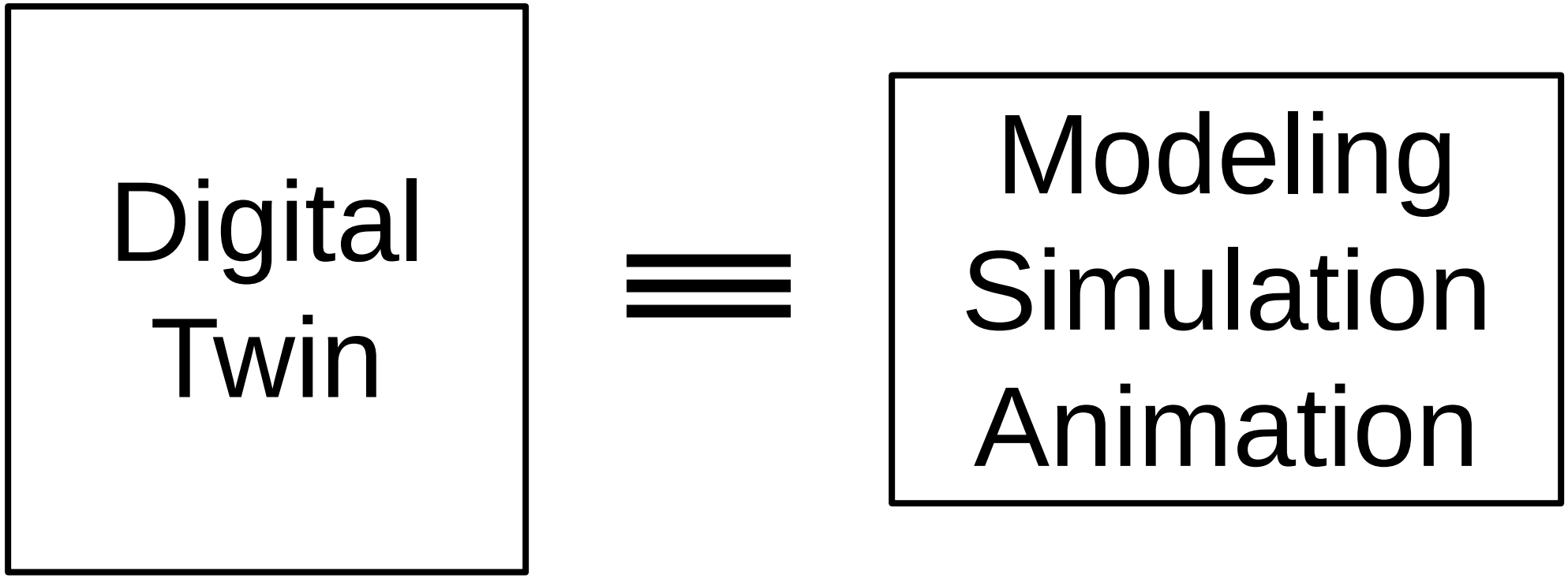
Physical Digital

Digital Twin Concept



Rigid Flexible

Digital Twin Concept

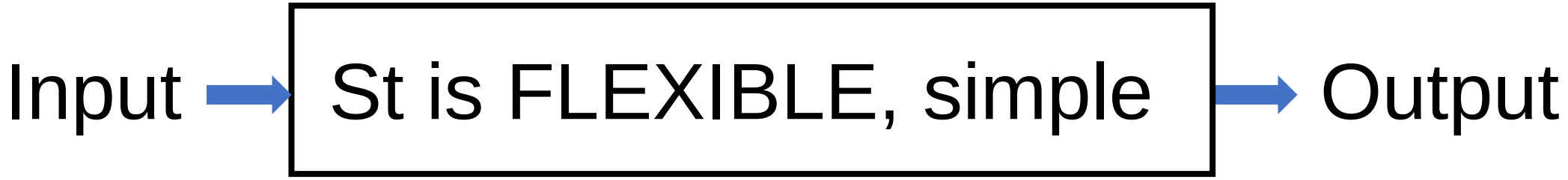


Digital-TwinS: Digital Twin applied to Software

- Combine best of static and dynamic languages
- TIOBE Index (Dec 2022) popularity ranking
  1. Python (dynamic)
  2. C (static)
  3. C++ (static)

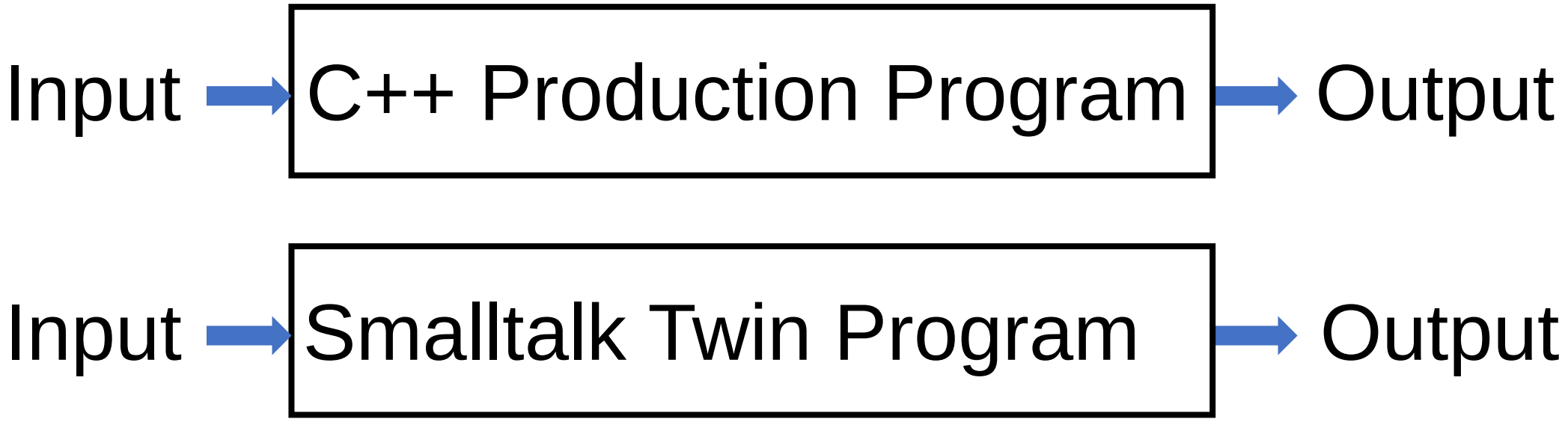
Why Digital-TwinS

C++ is best of FAST



Smalltalk is best of FLEXIBLE but not popular

Digital-TwinS: C++ and Smalltalk

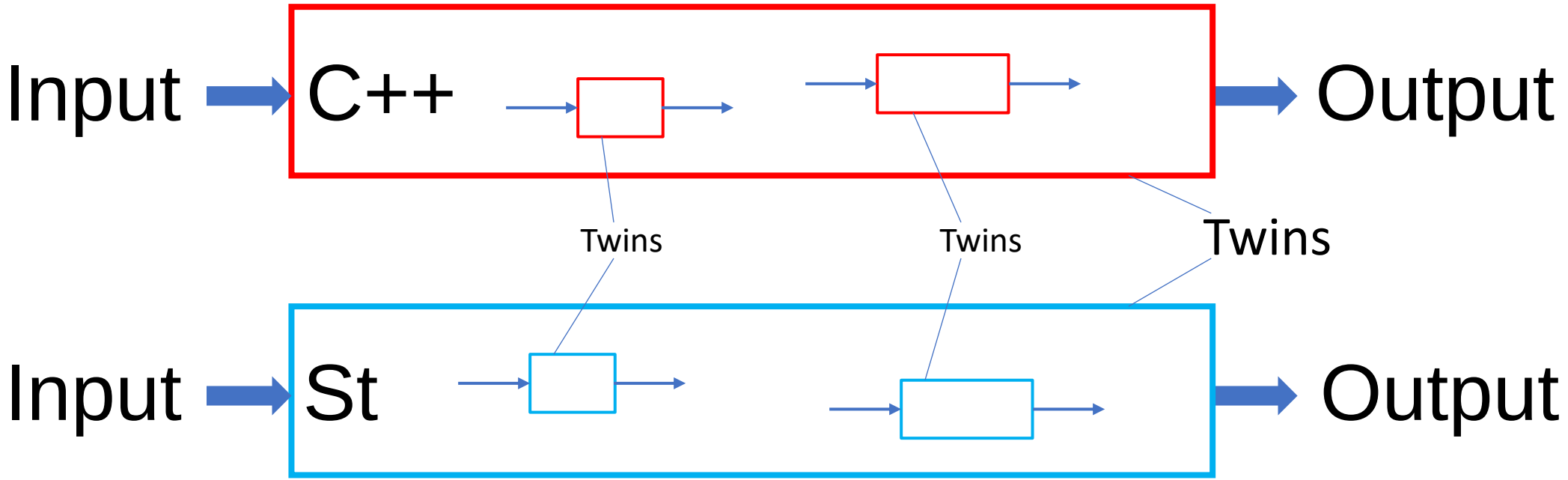


Same Input Same Output (SISO)

Fidelity improves by increasing SISO

Internals can be independent

Same Input Same Output (SISO)



Twins can be any size or any component

Internals can be partially dependent

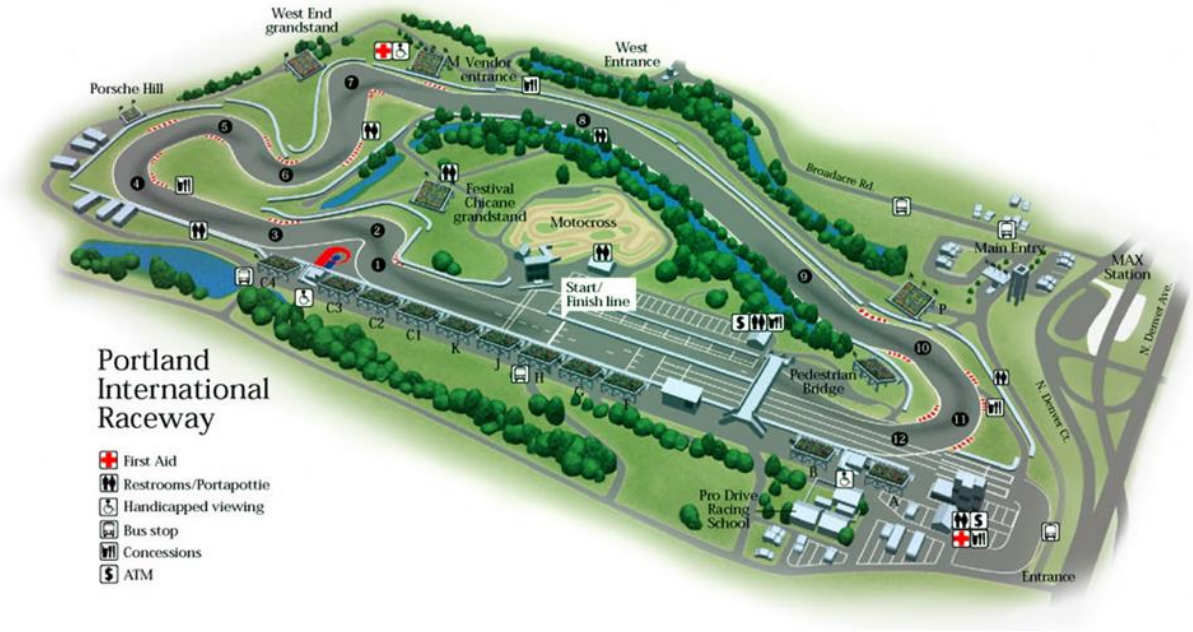
C++ is FAST at all cost

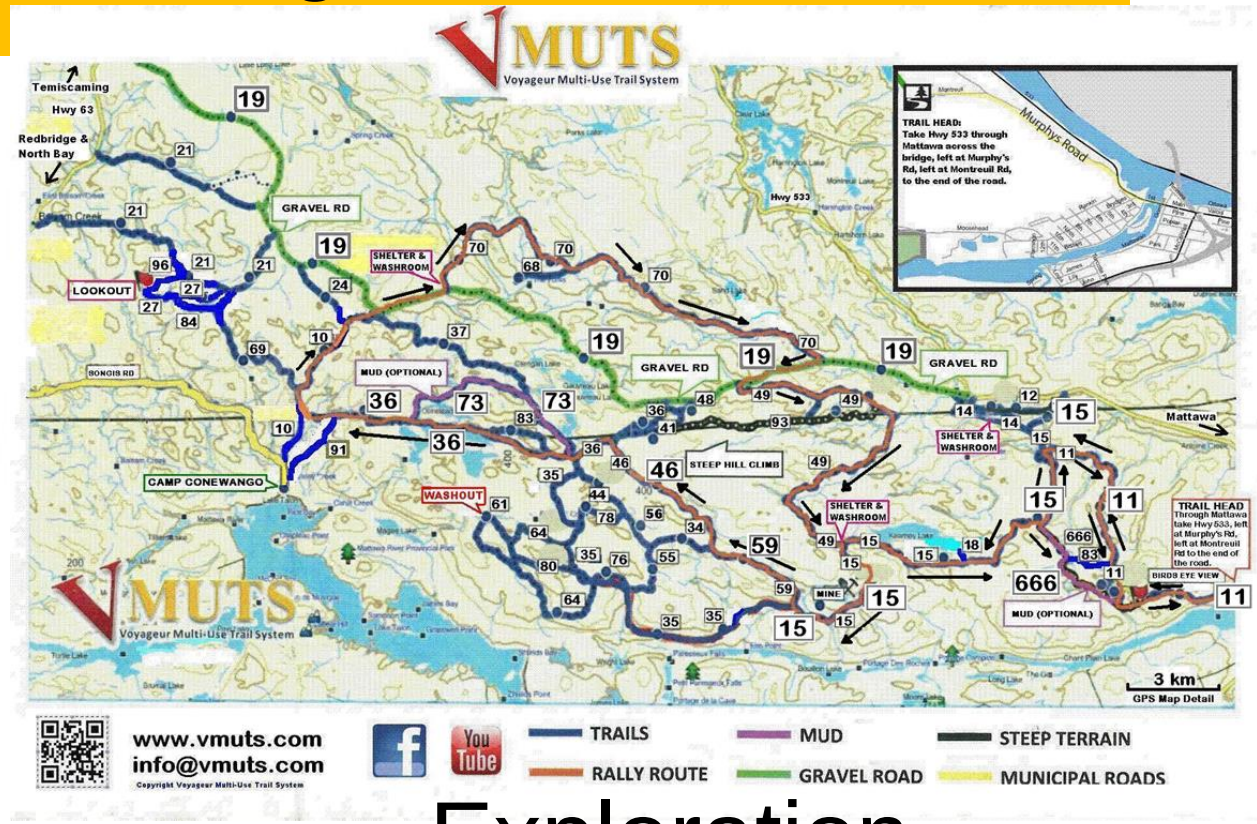
Smalltalk is NIMBLE and rugged
Low cost

A hybrid vehicle would have compromised capabilities
Java, C#, Obj C

C++ Heavy Infrastructure
Small area

Smalltalk Light Infrastructure
Large area



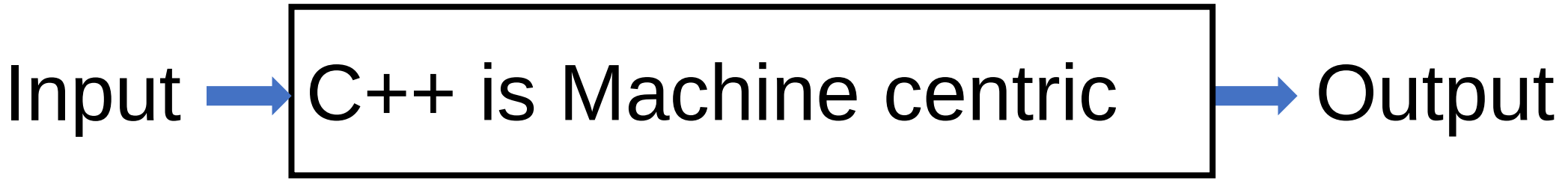


Execution

Exploration

We want to win in both settings

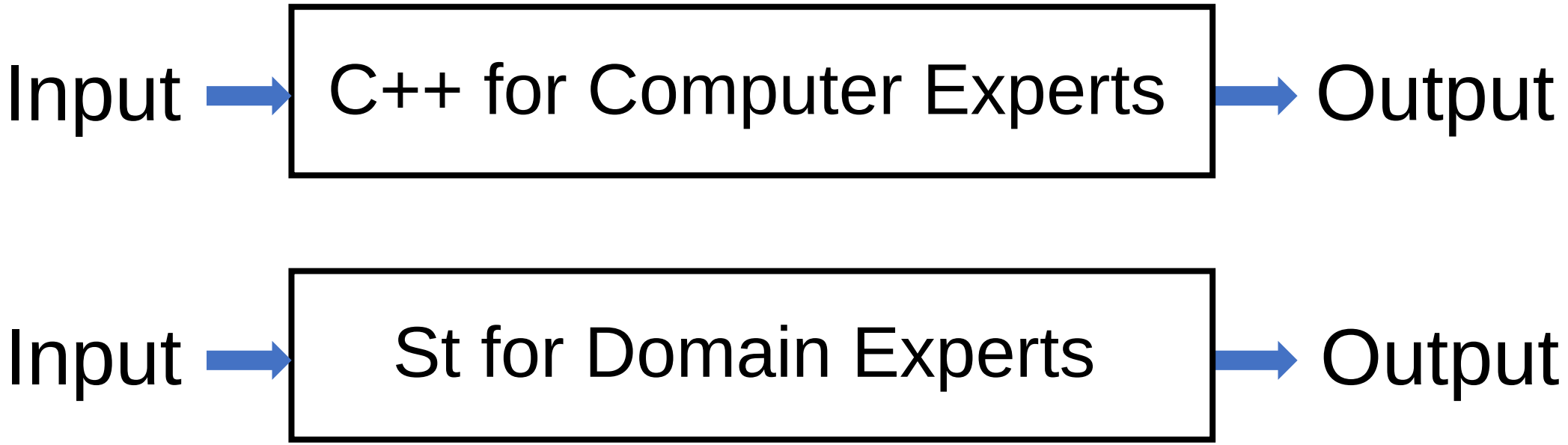
Why Digital-TwinS cont.



Humans think Objects

"Development at the speed of thought"

Why Digital-TwinS cont. 1



Synergy and feedback between experts

Why Digital-TwinS cont. 2

- Assume developing a brand-new feature.
- Smalltalk alone can do it in T days. But the feature is slow.
- C++ alone can do it in 5T days. But the feature is fast.
- Twins can do it in 3T days. Smalltalk development T days. Guided port to C++ is 2T days. Feature is fast and development is shorter.
- Twins cross-checking each other will reduce bugs in both greatly. This is a bonus.

Why Digital-TwinS cont. 3

- Twin can help documentation
- Twin could be substitute for documentation
  - Smalltalk is readable and less verbose than English
- Twins reduce bugs by checking each other
  - Probability of both making the same bug is product of Probabilities of each

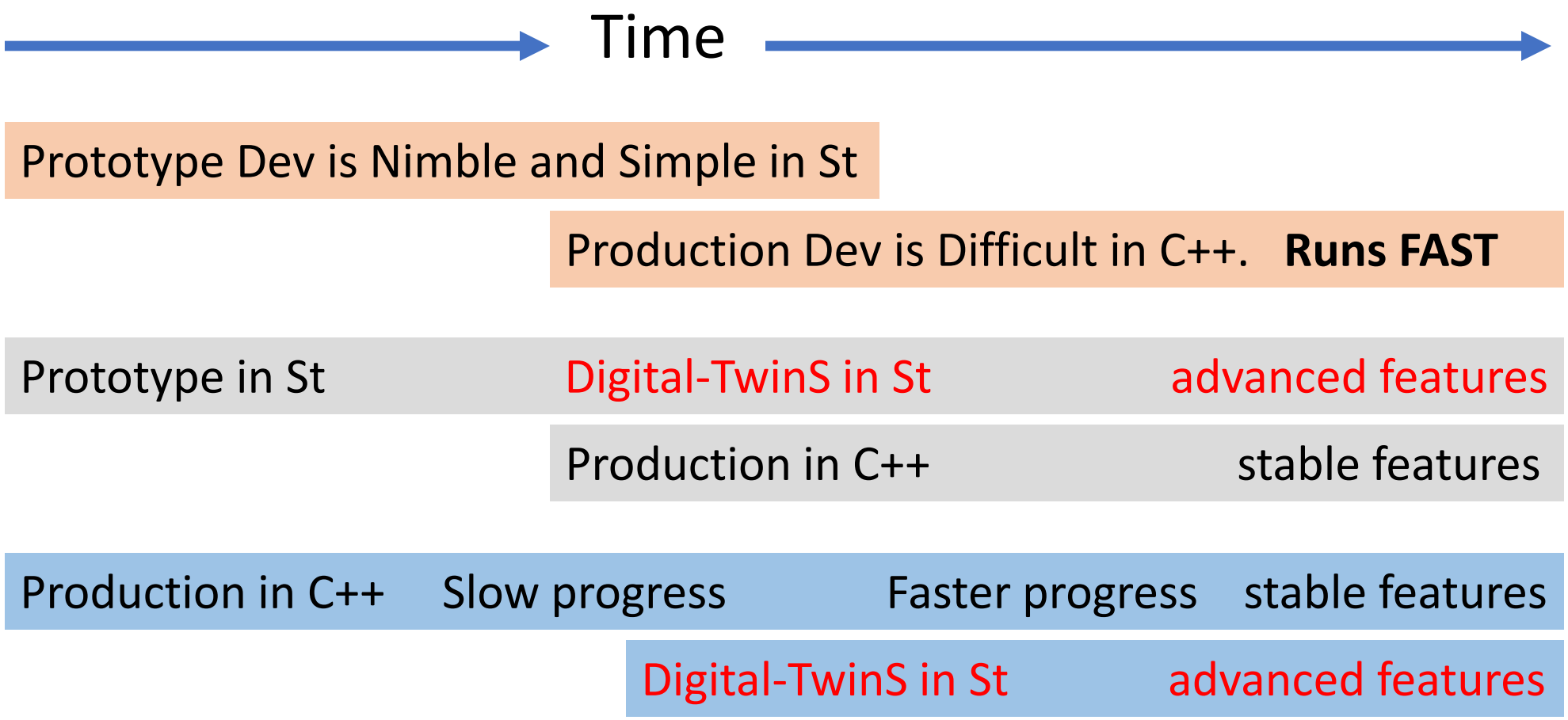
Strategy for Digital-TwinS

- Capture C++ algorithms in Smalltalk twin
  - Executable documentation
- Experiment in Smalltalk twin (superset program)
  - Fearless programming
- Transfer discoveries to C++ twin
  - Manually, automated or both
  - Strict testing
  - Iterate with twin
- Debug in Smalltalk twin
- Transfer fixes to C++ twin

Strategy for Digital-TwinS cont.

- Smalltalk explores, discovers, innovates
- Good discoveries are transferred to C++ twin
- C++ type checks, runs tests, runs fast
- Feedback and iterate
- Division of labor
- Twins cover each other completely

Prototype vs Digital-TwinS vs Production



Why Smalltalk

- Everything is an object all the time
  - Including IDE, Compiler, Debugger, Scheduler
  - Even when saved to disk on exit
- All operations are through message passing
  - Everything in Smalltalk is written in Smalltalk
    - Including Virtual Machine
  - Critical Smalltalk code are translated to C to be called
    - VM code is translated to C and compiled to executable

Why Smalltalk

- Everything is an object all the time
  - Pure OOP
  - 1, 1.0e2, $a, #b, ‘Hello’
  - true, false, nil, self, super, thisContext
  - Class, Block (lambda), Compiler, Debugger, etc
  - On exit, all objects are saved to disk
  - On startup, IDE returns to exact state before exit
  - Automatic garbage collection

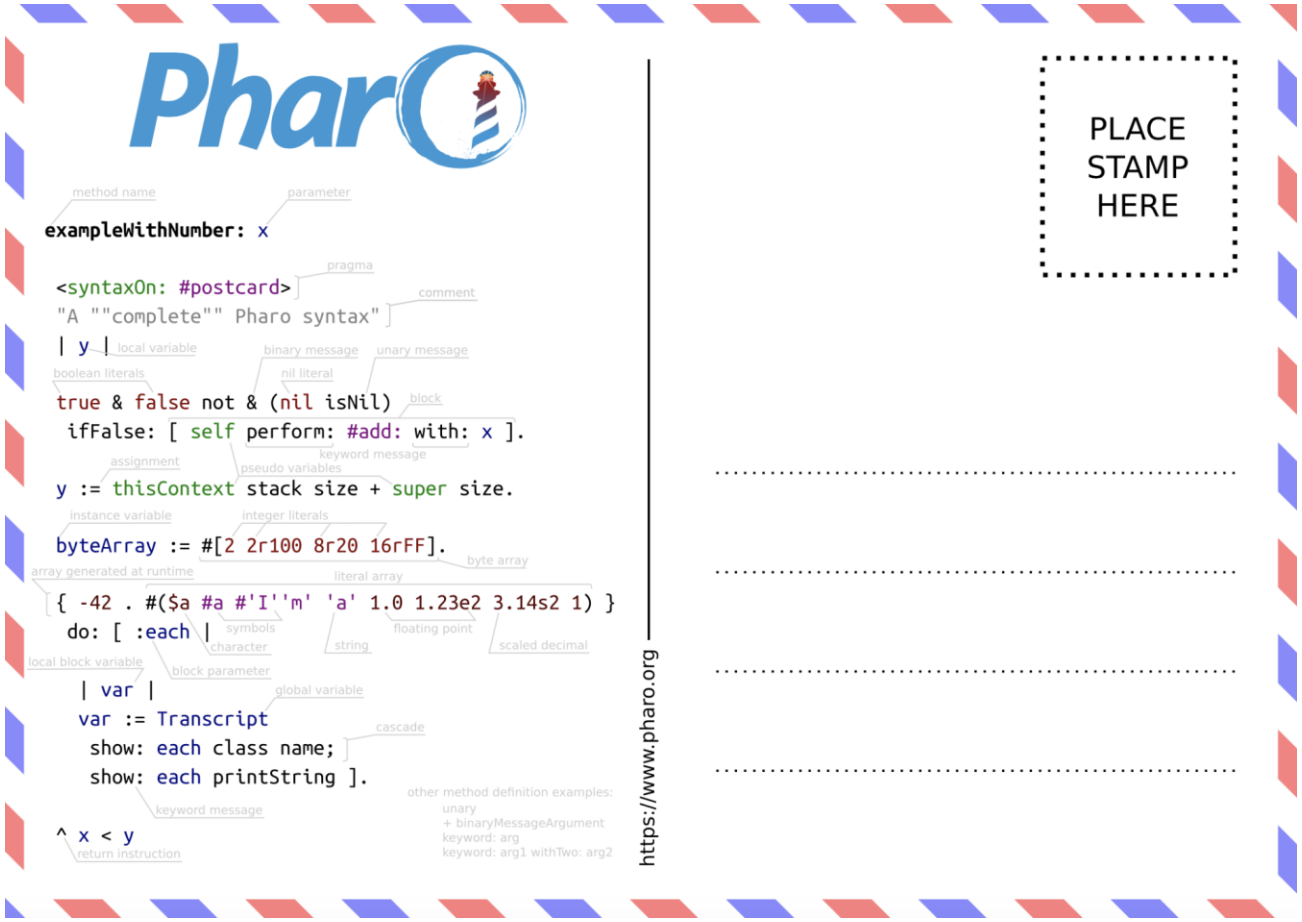
Why Smalltalk

- All operations are through message passing
  - Object message (like Subject predicate)
  - array isEmpty.
  - 4 + 3.
  - Transcript show: ‘Hello World’.
  - array do: [:each | each initialize. each run].

Why Smalltalk

- Smalltalk pioneered Pure OOP
- Influenced Objective-C, Java, Python, Ruby
- Pioneered MVC, GUI
- Xerox invented it for DARPA
- Xerox killed it
  - They wanted to sell printers and copiers
- It is free to be owned

Entire Syntax fits on a postcard



Smalltalk is Best of Flexible

- Edit and run anywhere
  - Zero build time
- Edit and continue in Debugger
- Inspect any object anytime
- Arbitrary levels of inspecting and debugging
- Save all objects and restart where you left off

Digital-TwinS: C++ and Smalltalk

Hybrid program would be a mediocre compromise

Digital-TwinS: OpenSmalltalk-VM and Production-VM

- OpenSmalltalk-VM is written in Smalltalk
- Production-VM is written in C
- Both VMs read the Smalltalk image file and run the Smalltalk IDE in which more Smalltalk programming is done
- Same Input Same Output
- OpenSmalltalk-VM has all the flexibility of Smalltalk
- Production-VM has all the speed of C

Smalltalk VM is written in Smalltalk and Translated to C

- Slang is subset of Smalltalk
- Slang mimics C
- VM is written in Slang in Smalltalk IDE
- VM is simulated in Smalltalk IDE to run another Smalltalk image
- Full debugging power of Smalltalk used on VM code
- VM Slang code is then translated to C code
- VM C code is compiled to make runtime executable VM

Slang to C translation

Slang (subset of Smalltalk)	C
instanceVariableNames: 'foregroundColor backgroundColor'	sqInt foregroundColor, backgroundColor;
classVariableNames: 'MemorySize'	#define MemorySize 10
^a+b	return (a+b);
a bitShift: 4	a >> 4;
now := FooBar foo: x bar: y	now = foobar(x,y);
^self bigEndian ifTrue: [16r6502] ifFalse: [16r0265]	return bigEndian() ? 0x6502 : 0x0265;
1 to: 10 by: 2 do: [:i | a at: 1 put: (i*2)]	for(i=1; i = 10; i += 2) { a[i] := (i*2); }
flag whileTrue: [self check]	while (flag) { check(); }

getName
  <returnTypeC: 'char *'>
  | newStr |
  <var: #newStr type: 'char*'>
  newStr := 'hello'
  ^newStr
	char *getName(void)
	{
	  char*newStr = "hello";
	  return newStr;
	}

Slang to C translation

Slang	C

defaultWidth
  <inline: true>
  ^10
 	
width
  <inline: false>
  ^width ifNil: [width := defaultWidth].
	static sqInt width(void)
	{
	  return width == nilObj ? (width = 10) : width;
	}

https://wiki.squeak.org/squeak/2267

Smalltalk VM written in JavaScript

- https://caffeine.js.org/beatshifting/
- https://pharojs.org/demo.html

Digital-TwinS Conclusion

- C++ for speed, strict safety
  - Industry is good at it
- Smalltalk for flexibility, experimentation, fun
  - “Development at the speed of thought”
- Twins reduce bugs by checking each other
- Smalltalk was invented right
- Anyone can “own” Smalltalk for free