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The Evolution of the VA Smalltalk Virtual Machine

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- Why am I giving the presentation instead of a real VM guy?

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- Because the real VM guy is busy!!
    - Seth and Kate's daughter Adelyn, born June 19

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Agenda

- Driving forces
- VAST VM history
- Do we need a new VM?
- Challenges
- How we did it
- Results
- Demo
- Still to do
- Q&A

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Driving Forces

- 64-bit support required
  - Dramatically expands available memory space
  - Interface with 64-bit DLLs/SOs
- Simplify maintenance and enhancement of the VAST VM
  - Enables use of modern tool chains
  - Replaces current proprietary modeling language with C

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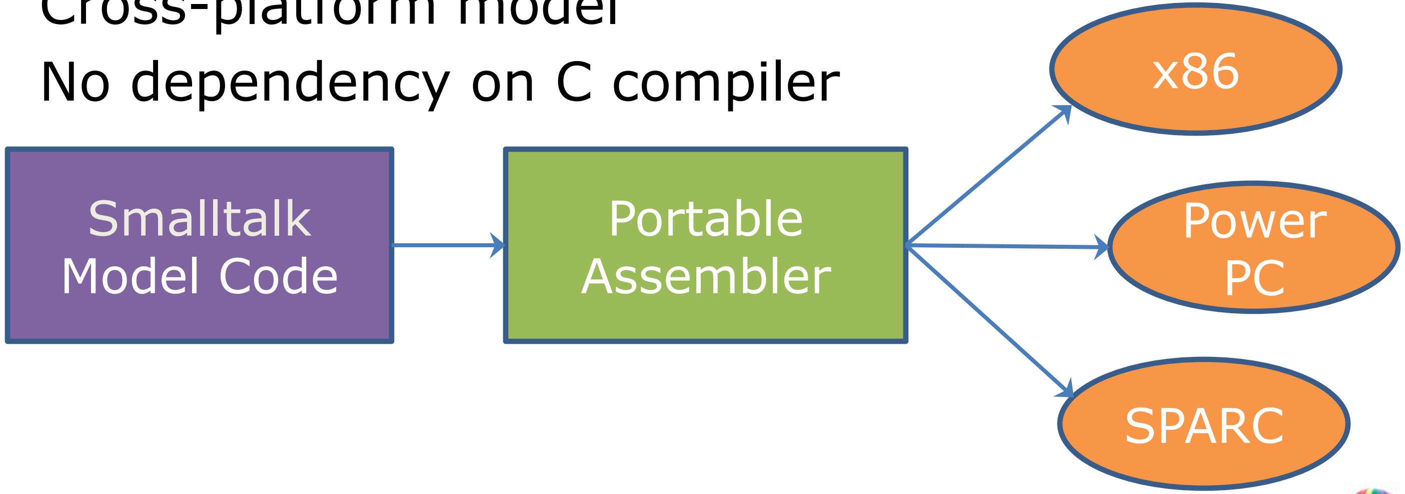
VAST VM History

- Extremely stable - basically unchanged in 25+ years
- Developed using proprietary Smalltalk VM Modeling Language
    - Maximize efficiency on constrained hardware
    - Cross-platform model
    - No dependency on C compiler



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Do We Need a NEW VM?

- Smalltalk Modeling Language
  - Obscure – hard to learn/extend
  - Obfuscates the algorithms
- Portable Assembler
  - Does not take advantage of new machine architectures
- Generated machine code
  - Non-standard calling conventions
  - Standard debuggers don’t work
  - Hard to map performance tools result back to model
- JIT
  - Must be hand-built to match machine architecture

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Sample Smalltalk Model code

```
VMprCharacterTestBit
  self
    systemPrimitive: 'VMprCharacterTestBit'
    receiverClass: Character
    body: [| receiver byteArray bit addr |
      receiver := registerModel allocateDataRegister.
      byteArray := registerModel allocateAddressRegister.
      bit := registerModel allocateDataRegister.
      byteArray gets: (self parm: 1 of: 1).
      ([self isImmediate: byteArray] || [(self isBytes: byteArray) not]) do: [
        self failAsmPrimitiveViaCache: PrimErrInvalidClass arg: 1].
      receiver gets: (self receiverForParms: 1).
      self convertToCharacter: receiver.
      bit gets: receiver.
      bit &= 7.
      receiver shiftRightLogical: 3.
      (receiver greaterThanOrEqualUnsigned: (byteArray at: (constant field: 'size' of: K8ObjectHeader))) do: [
        self failAsmPrimitiveViaCache: PrimErrInvalidSize arg: 1].
      registerModel region: [
        addr := registerModel allocateAddressRegister asBytePointer.
        addr gets: (constant addressOfLabel: (label global data named: 'K8SetBits')).
        bit loadUnsigned: (addr indexedBy: bit)].
      receiver loadUnsigned: ((byteArray asBytePointer at: constant objectHeaderSize) index: receiver).
      and setFlags source: bit dest: receiver.
      condition zero do: [receiver gets: false] else: [receiver gets: true].
      self return: receiver parms: 1]
```

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Sample C code

```
EsPrimitive(VMprCharacterTestBit)
{
    U_16 value;
    EsObject byteArray;
    U_8 bit;

    byteArray = EsPrimitiveArgument(1, 1);
    if (!EsIsBytes(byteArray))
            EsPrimitiveFailed(EsPrimErrInvalidClass, 1);
    value = EsCharacterToU16(EsPrimitiveReceiver(1));
    bit  = (U_8)(value & 7);     /* 0 to 7  bit number within byte */
    value = (value >> 3) + 1; /* 1 to (MAX_CHARACTER_VALUE/8)+1  byte number within table */
    if (value > (byteArray->size))
            EsPrimitiveFailed(EsPrimErrInvalidSize, 1);
    EsPrimitiveSucceed((((EsByteAt(byteArray, value)) & (1<<bit)) ? EsTrue : EsFalse), 1);
}
```

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Challenges

- Minimal existing test cases
  - If the basic image tests run, the VM is OK
- ‘VM in C’ performance
  - 32-bit x86 VM loses an available register (-)
  - C compilers produce far superior code; example: instruction reordering (+)
  - Many benchmarks (both micro and macro) ported and developed
- Tool chain convergence
- Image conversion
- Impedance mis-match
  - “Jump where ever I want to”, stack and register mgmt

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How We Did It

- Moved to cmake and gcc based tool chain
  - Use ‘register intrinsics’ for performance
  - Nightly build and test
- Minimal assembler
  - Low-level arithmetic, exception handling, OLE support
- Incremental changes
  - Shim code developed to cross old/new boundary
    - VM always works
  - 64-bit ‘clean’ changes as we go
  - Detour from plan: Interpreter was done all in one piece

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How We Did It

- Example: Garbage Collector
  - 3 major components: Scavenger, Mark-Compact, Allocator
  - Components converted one-at-a-time
  - Millions of lines of trace output produced to verify everything worked the same
  - Incremental changes means we always had a working VM to test the changes

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How We Did It

- Just in time image conversion (64-bit VM)
  - 32-bit images and image components (ICs) converted on first use
  - Image can be saved in 64-bit format
  - 32-bit ICs loadable from 64-bit image

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How We Did It

There’s no magic in software, just hard work with a result that may appear to be magic!

- The image has to change -- because 64-bitness shows through
  - Foreign Function Interfaces (FFI) aka PlatformFunctions
  - Memory mapping objects (OSObjects)
- Goal is to minimize changes in user code
  - So most of the changes are in VAST framework code

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How We Did It

- Elastic PlatformFunctions
  - Holds template for making FFI call
  - Parameter sizes and offsets *were* fixed
  - Changed parameter sizes and offsets from fixed to relative

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How We Did It

- Elastic OSStructures
  - Accessors *were* based on fixed size and structure offsets
  - Changed accessors from absolute to relative offset
  - Compute fixed offsets on image startup

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How We Did It

- Elastic OSStructure Example (C)

```
#ifdef _WIN32
#include <pshpack1.h>
#endif
typedef struct NMHDR
{
  HWND      hwndFrom;
  UINT_PTR  idFrom;
  UINT      code;         // NM_ code
};
typedef struct TVKEYDOWN {
  NMHDR hdr;
  WORD wVKey;
  UINT flags;
};
#ifdef _WIN32
#include <poppack.h>
#endif
```

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How We Did It

- Elastic OSStructure Example (Smalltalk)

```
"Define NMHDR Struct"
OSNmhdr members: #(#hwndFrom #idFrom #code) types: #(pointer pointer
uint32).

"Define TVKEYDOWN Struct - Pack1 if 32-bit"
OSTvKeydown members: #(hdr wVKey flags) types: #(OSNmhdr uint16 uint32).
System is64BitVM ifFalse: [OSTvKeydown updateAlignmentType: AlignNone]. "Pack
on byte boundary"


---------------------------------------------------------------------------------------
OSTvKeydown>>#flags
"Answer the member: UINT flags.
        32/64-bit compatible"
^ self uint32At: #flags
```

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How We Did It

- Additional Benefits of Elastic OSStructures
  - Custom Packing for data structures
    - OSStructure members: #(a b) types: #(int8 int8) alignment: Align2 "pack2"
  - Custom Padding
    - OSStructure members: #(a b) types: #(int8 pad[3] int32) alignment: AlignNone "pack1/manual pad�something"
  - Embedded OSStructures
    - OSStructureA members #(a) types: #(int8)
    - OSStructureB members #(a b) types: #(int8 OSStructureA)
  - Nested Anonymous Structures/Unions
    - OSStructure members: #(a (b c)) types: #(int32 ((int32 int32)))
      - struct { int a; struct { int b; int c; } }
    - OSStructure members: #(a (b c)) types: #(int32 (int32 double))
      - struct { int a; union { int b; double c; } }

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How We Did It

- Additional Benefits of Elastic OSStructures
  - Pointer Types
    - OSStructure members #(a b) types: #(pointer int32) "4 bytes on 32-bit, 8 bytes on 64-bit"
    - OSStructure members #(a b) types: #('uint8*' int32) "Also a pointer with additional type info"
  - Arrays
    - OSStructure members #(a b) types: #('int8[10]' int32) "Array types are supported
    - OSVariableStructure members: #(a b) types: #(int8 pointer[]) "Flexible array types supported

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How We Did It

- Additional Benefits of Elastic OSStructures
  - Dependency Analyzer
    - Don't need to define OSStructures in order of their dependencies
    - Invalid Circular dependencies will be detected
  - Extensible Base Types
    - You can add your own types, either globally or method override
    - We do a method override for TCHAR for future Unicode support
      - Currently a char8, but may later be a char32. Existing definitions using TCHAR are now future proofed for this change

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Results

- 64-bit VM is just a recompile
- No separate 32-to-64 bit image converter
- Interpreter benchmarks are > 80% of current VM
  - Before algorithm tuning
  - Before C tuning
- User code is largely unaware of change

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Demo

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Still To Do

- 80% done means more work to do
  - Performance tuning (algorithms and C)
  - JIT
  - 64-bit Packager
  - Improved garbage collector
  - Installation and setup
  - UNIX

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When can we have it?

- Windows - 3 delivery dates
  - Alpha
    - 1Q2016
    - Early customer involvement program; entry by invitation
  - Beta
    - 2Q2016
    - Open registration
  - Production
    - V9.0 on normal product delivery schedule
- UNIX later

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Thank you for your attention

Questions?