goto; conference aarhus

CHAKRA: UNDER THE HOOD

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Design Principles

- Security
- ECMAScript Compliance
- Balanced Performance
- Transparency

JIT Security

- Data Execution Protection
- Codebase Alignment Randomization
- Random NOP Insertion
- Constant Blinding
- JIT Code Allocation Cap
- JIT Page Randomization

```
int         3
int         3
push        ebp
mov         ebp, esp
...
xor         eax, eax
xor         ecx, ecx
lea         ecx, [ecx]
$enterLoop:
cmp         ecx, 0x0a
mov         edi, edi
jge         $exitLoop
mov         edx, 0x02EBCC90
xor         edx, 0x50A2B255
add         eax, edx
jo          $handleOverflow
inc         ecx
jmp         $enterLoop
$exitLoop:
shl         eax, 1
jo          $handleOverflow
inc         eax
mov         esp, ebp
pop         ebp
ret
```

JIT Hardening Comparison

ACCUVANT LABS

JIT Hardening Techniques	Chrome	Internet Explorer	Firefox
Codebase Alignment Randomization	✗	✓	✗
Instruction Alignment Randomization	✗	✓	✗
Constant Folding	✓	✓	✗
Constant Blinding	✓	✓	✗
Resource Constraints	✓	✓	✗
Memory Page Protection	✗	✓	✗
Additional Randomization	✓	●	✗
Guard Pages	✓ *	●	✗

* Chrome 14

✓ Technique was implemented

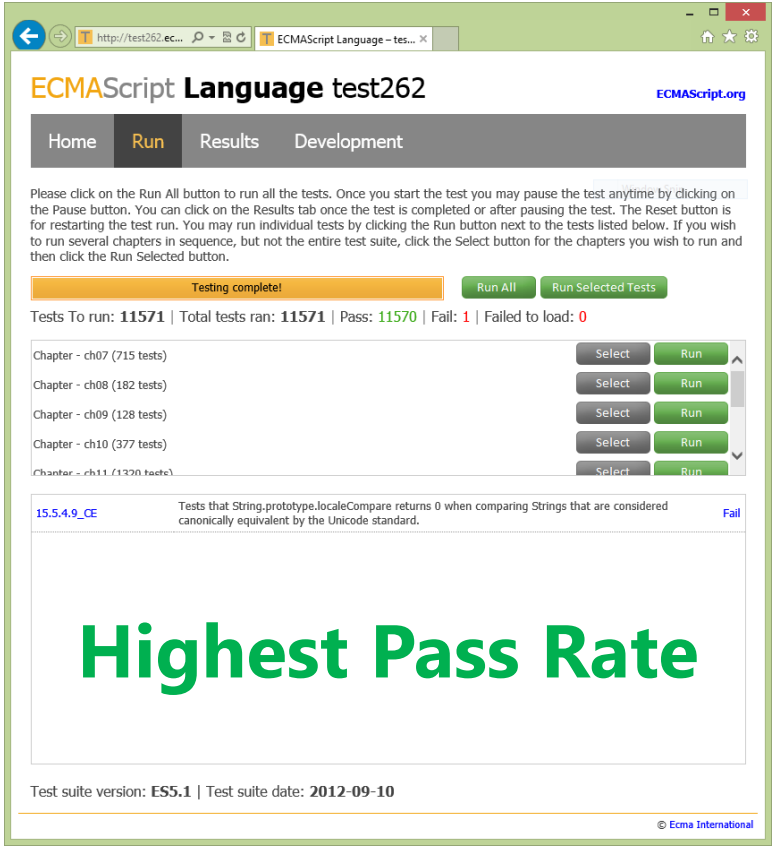
● Technique was not necessary

✗ Technique was not implemented

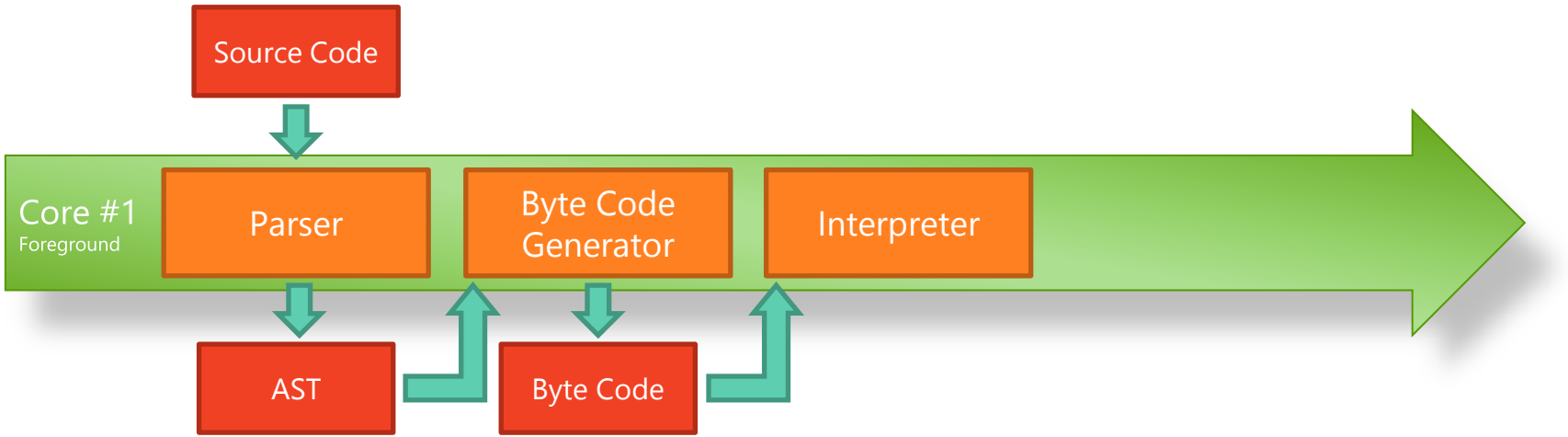
Figure 17. JIT hardening overview

http://www.accuvant.com/sites/default/files/images/webbrowserresearch_v1_0.pdf (12/2011)

ECMAScript Compliance



Balanced Performance:
Page Load




WORLD RECORD SPEED TEST
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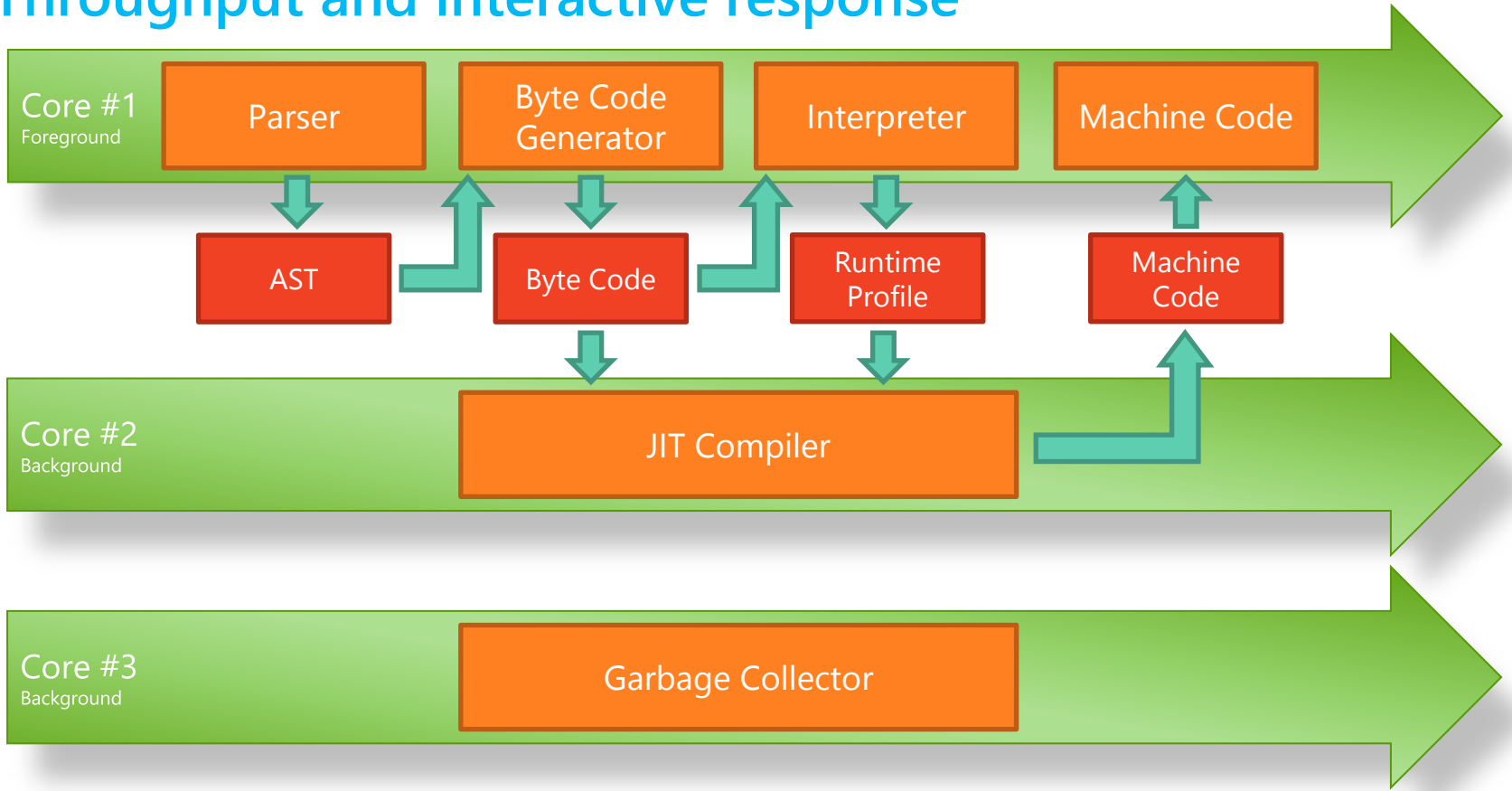
Page Load & App Start-Up

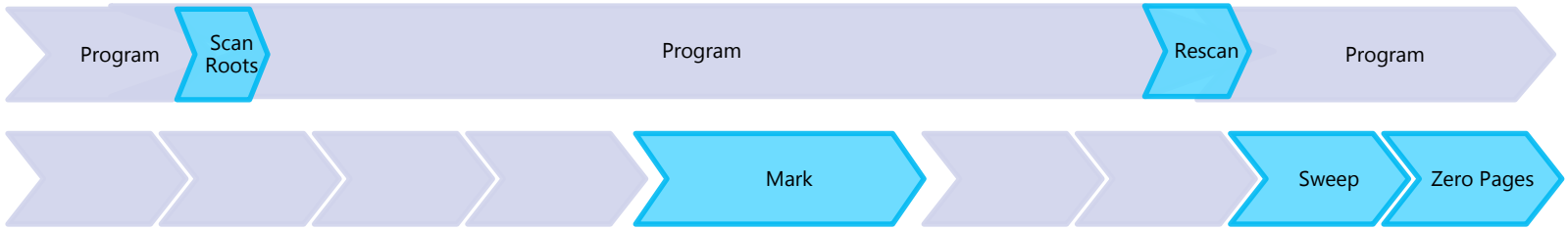
- One of the most visceral elements of user experience
- Internal and third-party reviews show IE has solid page load performance
  - Strangeloop: http://bit.ly/Sxcw2O
    - *"Internet Explorer 10 served pages faster than other browsers…"*
  - Tom's Hardware: http://bit.ly/OY3Bw0
    - *"Here, Microsoft's own IE9 takes the lead…"*
- Page load design points
  - Interpreter: start execution almost immediately
  - Deferred Parsing: avoid parsing unused code
  - Start-Up Profile Caching: remember which functions were called
  - Background code generation and garbage collection

Balanced Performance:
Throughput and interactive response

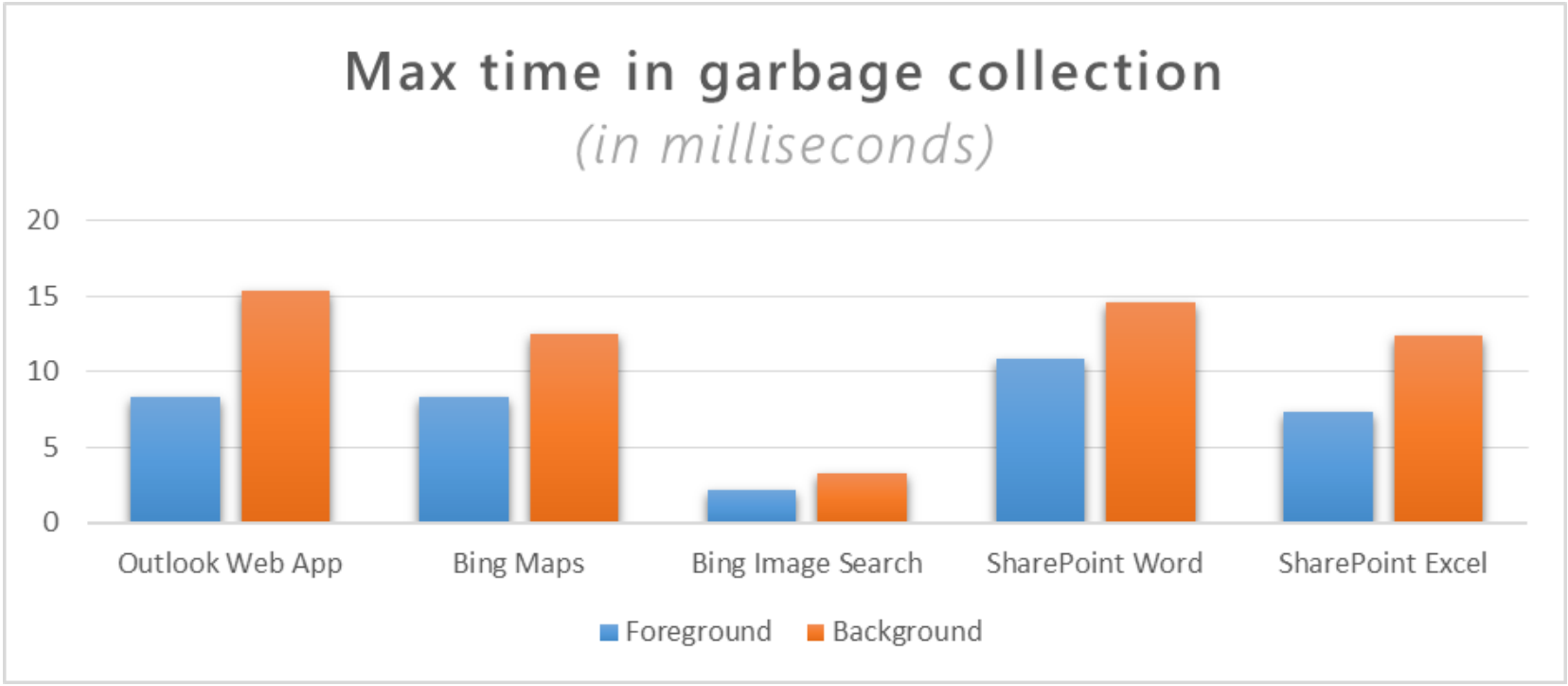


Chakra's Garbage Collector

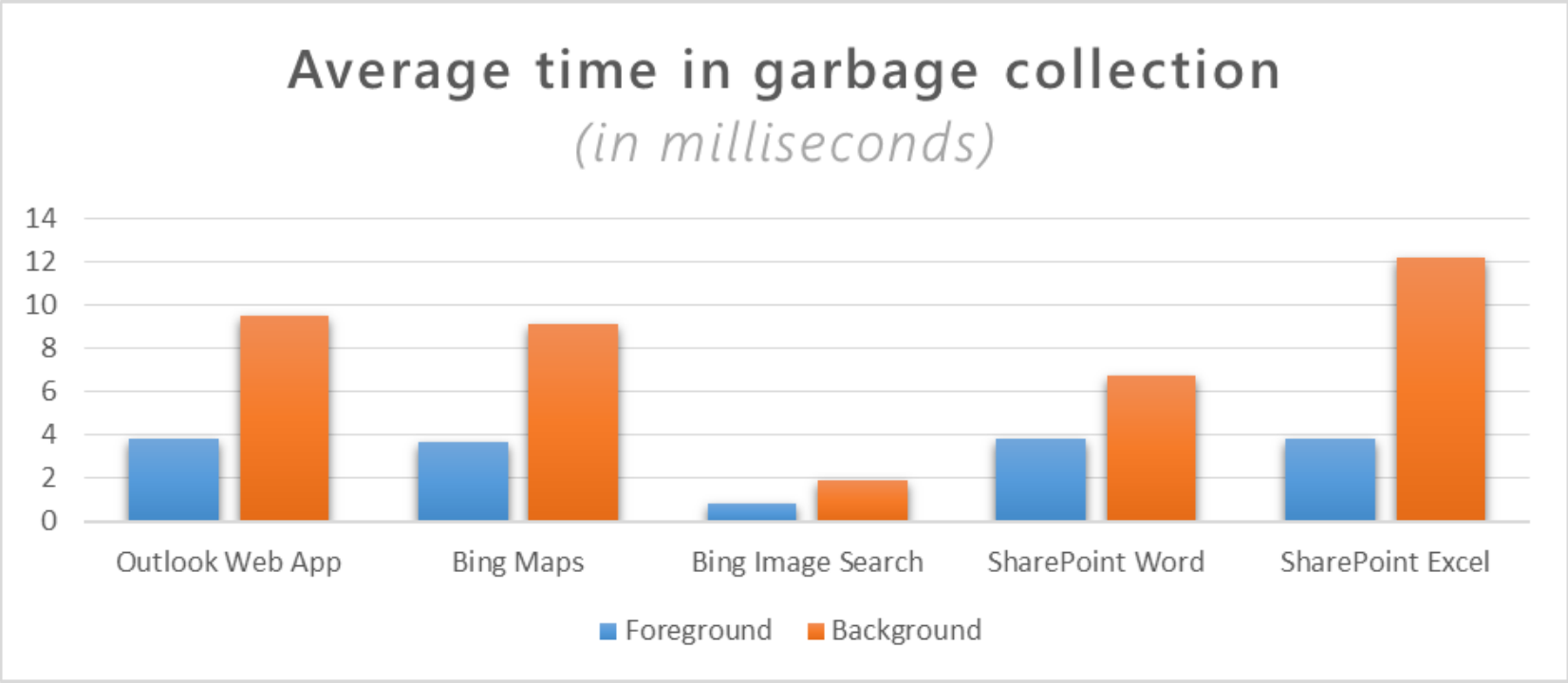
- Conservative
  - Can handle object pointers on the native stack; tagged integers lead to very low rate (0.02 per GC) of spurious object references
  - Simplifies interoperation with native code
- Generational
  - partial collections; no separate nursery space
- Mark and Sweep
  - small objects sorted by size into buckets for low fragmentation
  - free-list and bump allocation, currently no compaction or evacuation
- Concurrent



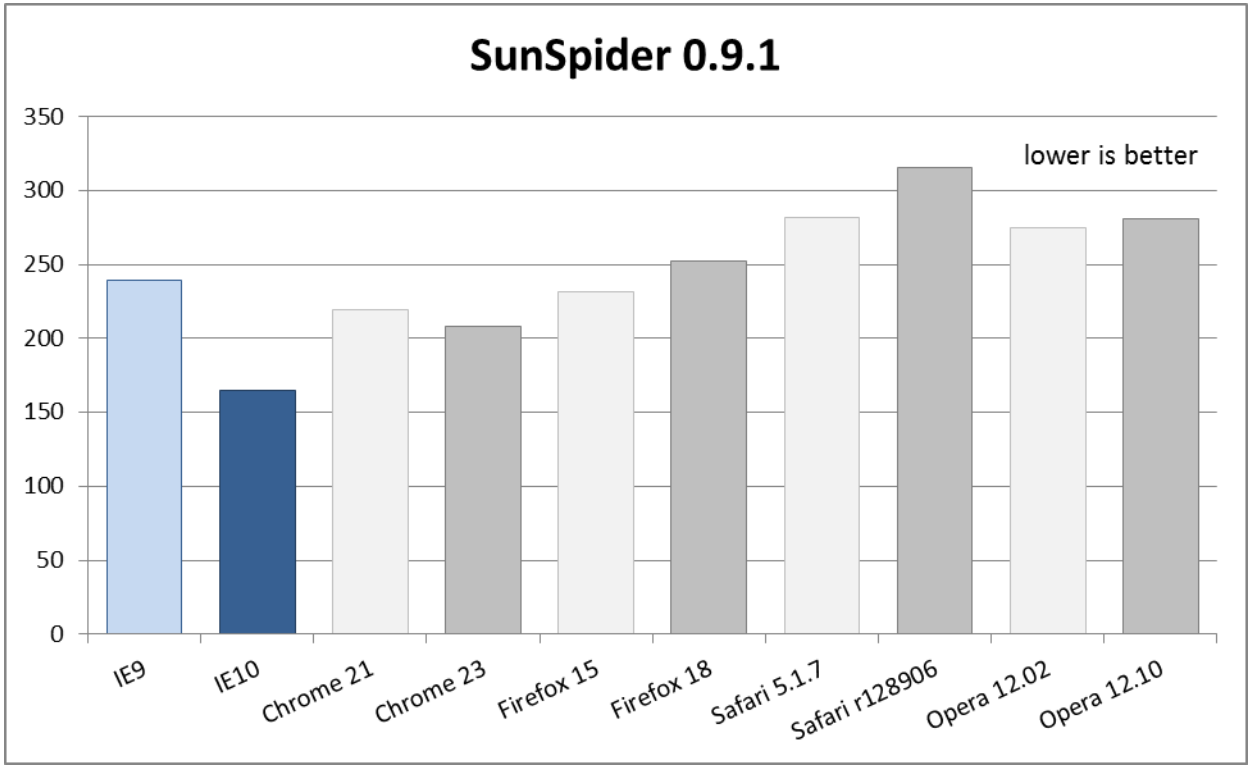
Interactive Response: Pause Times



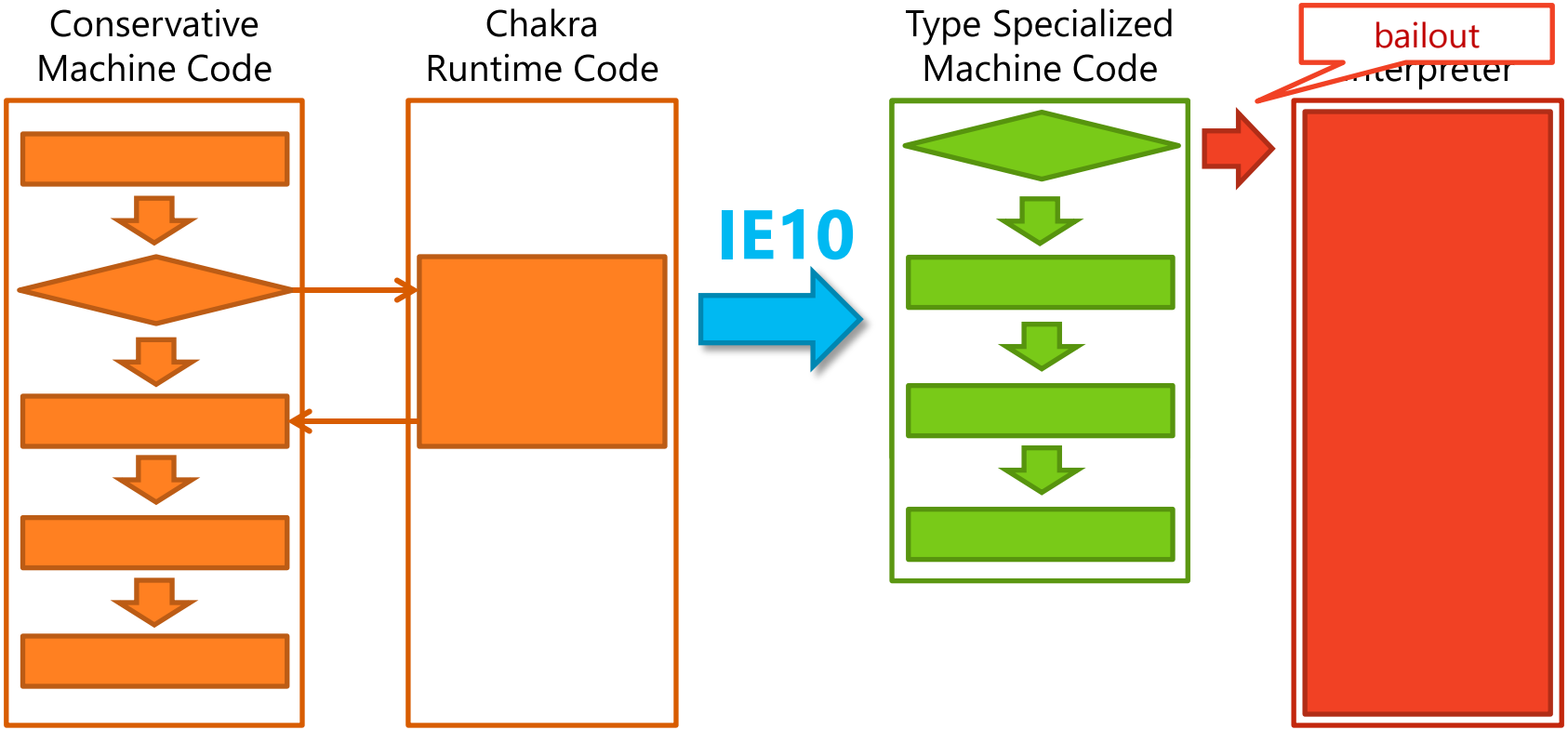
Interactive Response: Pause Times



WebKit SunSpider



Optimistic Profile-Based JIT



Type Specialized Integer Math in IE10

bitops-bits-in-byte.js

```
function bitsinbyte(b) {
    var m = 1, c = 0;
    while(m<0x100) {
        if(b & m) c++;
        m <<= 1;
    }
    return c;
}
```

```
$enterLoop:
  cmp         esi, 0x100
  jge         $exitLoop

  mov         ecx, eax
  and         ecx, esi
  test        ecx, ecx
  jeq         $l1

  add         edi, 1
  jo          $bailOut

$l1:
  shl         esi, 1
  jmp         $enterLoop
```

Type Specialized Float Math in IE10

3d-cube.js

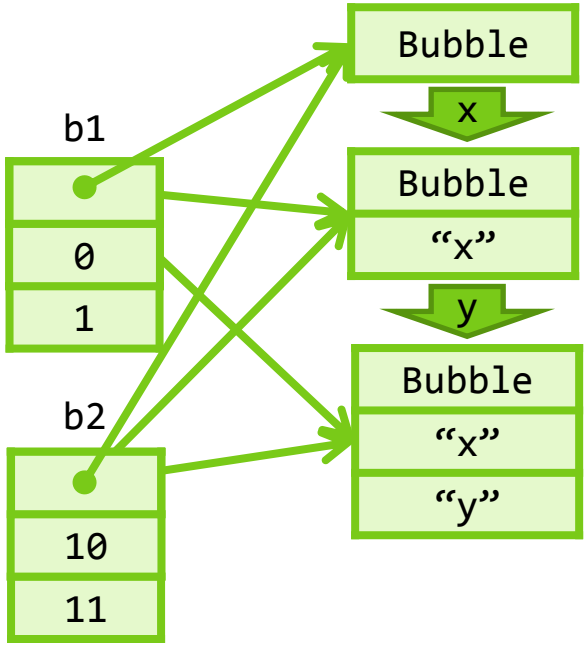
```
for (; i < NumPix; i++) {
    Num += NumAdd;
    if (Num >= Den) {
        Num -= Den;
        x += IncX1;
        y += IncY1;
    }
    x += IncX2;
    y += IncY2;
 }
```

```
$enterLoop:
  cmp         eax, edx
  jge         $exitLoop
  addsd       xmm7, xmm2
  comisd      xmm7, xmm6
  jb          $l2
  subsd       xmm7, xmm6
  movsd       xmm2, <-176>
  addsd       xmm0, xmm2
  addsd       xmm1, xmm3
$l2:
  addsd       xmm0, xmm4
  addsd       xmm1, xmm5
  add         eax, 1
  jo          $bailOut
  movsd       xmm2, <-192>
  jmp         $enterLoop
```

Fast Property Access in IE9

```
function Bubble(x, y) {
  this.x = x;
  this.y = y;
}
var b1 = new Bubble(0, 1);
var b2 = new Bubble(10, 11);
```

monomorphic

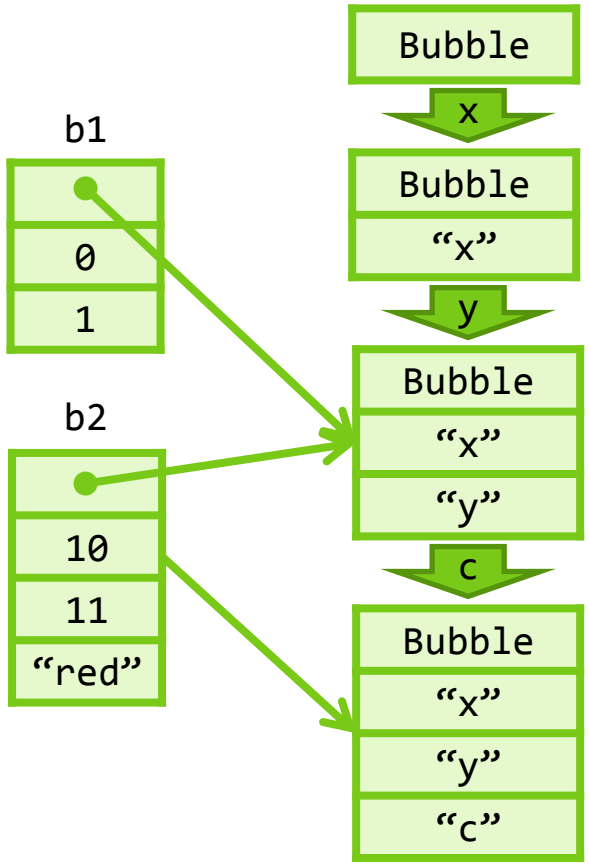


Fast Property Access in IE9

```
function Bubble(x, y) {
  this.x = x;
  this.y = y;
}
var b1 = new Bubble(0, 1);
var b2 = new Bubble(10, 11);
b2.c = "red";
```

b1.type ≠ b2.type

polymorphic



Faster Property Access in IE10

- Object type specialization
- Polymorphic property caches
- Field hoisting
- Copy propagation
- Streamlined object layout
- Function inlining

total += o.x + o.y + o.z

```
mov         edi,dword ptr [ebx+88h]
mov         eax,18BF198h
test        edi,1
jne         053F01D7
mov         ecx,dword ptr [edi+8]
cmp         ecx,dword ptr [eax]
jne         053F01D7
movzx       eax,word ptr [eax+6]
mov         eax,dword ptr [edi+eax*4]
mov         edx,18BF1A8h
test        edi,1
jne         053F01F5
mov         ecx,dword ptr [edi+8]
cmp         ecx,dword ptr [edx]
jne         053F01F5
movzx       edx,word ptr [edx+6]
mov         edx,dword ptr [edi+edx*4]
...
mov         eax,18BF1B8h
test        edi,1
jne         053F0231
...
```

o.x

IE10

o.y

o.z

```
mov         edi,dword ptr [ebp-0A8h]

test        edi,1
jne         $BailOut
mov         eax,dword ptr [edi+8]
cmp         dword ptr ds:[8E4F20h],eax
jne         $BailOut

mov         eax,dword ptr [edi+1Ch]

mov         ecx,dword ptr [edi+20h]
...

mov         eax,dword ptr [edi+24h]
...
```

```
for(…) {
  total += o.x + o.y + o.z;
}
```

```
test        esi, 1
jne         $bailOut
mov         eax, dword ptr [esi+8]
cmp         eax, [0x00480500]
jne         $bailOut
mov         eax, dword ptr [esi+28]
mov         ecx, dword ptr [esi+32]
mov         edx, dword ptr [esi+36]
...
add         eax, ecx
jo          $bailOut
...
add         eax, edx
jo          $bailOut
...
add         ebx, eax
jo          $bailOut
...
```

o is {x,y,z}?

o.x

o.y

o.z

t = o.x + o.y

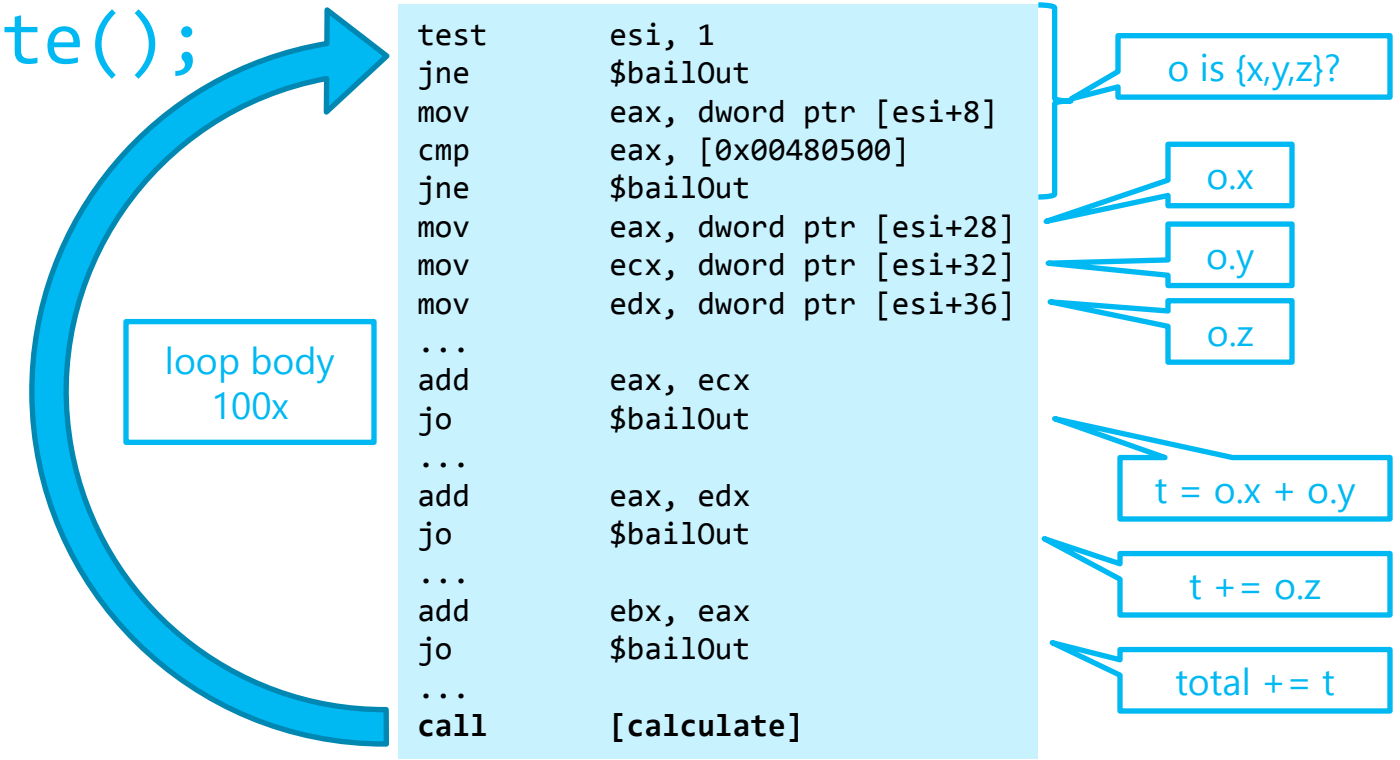
t += o.z

total += t

loop header
1x

loop body
100x

```
for(…) {
  total += o.x + o.y + o.z;
  calculate();
}
```



```
for(…) {
  total += o.x + o.y + o.z;
  calculate();
}
```

loop header
1x

loop body
100x

```
test        esi, 1
jne         $bailOut
mov         eax, dword ptr [esi+8]
cmp         eax, [0x00480500]
jne         $bailOut
mov         eax, dword ptr [esi+28]
mov         ecx, dword ptr [esi+32]
mov         edx, dword ptr [esi+36]
...
add         eax, ecx
jo          $bailOut
...
add         eax, edx
jo          $bailOut
...
add         ebx, eax
jo          $bailOut
...
$inlinedCalculate:
```

o is {x,y,z}?

o.x

o.y

o.z

t = o.x + o.y

t += o.z

total += t

Windows Store Applications

- Bytecode Caching
- GC on Idle/Suspend
- Fast marshaling to native code
  - Native calling conventions and exception handling
  - Generation and caching of method entry points (based on meta-data)

More work to do

- Throughput
  - Array operations; typed arrays
  - Polymorphism and function inlining
- Standards
  - ES6 features; ES5 accessor performance
- Improve GC for games and long-running applications
  - Precise pointers
  - Iterate between sequential and concurrent phases

Make web development work for any app

- Great JS engine performance
  - Multiple cores, GPU, continued optimization
- APIs, device capabilities, secure component model
- Build tools that enable construction of large-scale Javascript applications