Erlang Engine Tuning:
Know Your Engine
Part 2: The Beam

What is ERTS?

ERTS is the Erlang Runtime System.

ERTS as source code:

See: [OTP]/erts/
emulator/
beam/
hipe/
etc/

ERTS as components:

The BEAM interpreter

Processes

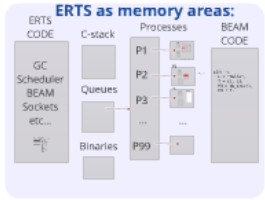
The Scheduler

HiPE

The Garbage Collector

I/O

ERTS as memory areas:



Sharing

Hibernation:
Do a GC to a temp area.
Check size
Allocate a minimal mem area
move live data

Erlang Engine Tuning: Know Your Engine Part 2: The Beam

Erik Stenman

Happi

- Programming since 1980
- Erlang since 1994
- First native code compiler for Erlang
- HiPE
- Project Manager for Scala 1.0
- 2005-2010 CTO @ Klarna
- Chief Scientist @ Klarna
- Writing a book about ERTS

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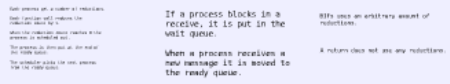
The Scheduler



The Garbage Collector


Processes

Conceptually: 4 memory areas and a pointer:

- A Stack
- A Heap
- A Mailbox
- A Process Control Block
  - A PID

HiPE

I/O

Processes

Conceptually: 4 memory areas and a pointer:

A Stack

A Heap

A Mailbox

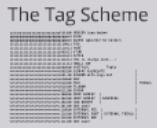
A Process Control Block

A PID

ERTS as memory areas:

ERTS CODE

GC
Scheduler
BEAM
Sockets
etc...



C-stack

Queues

Binaries

Processes

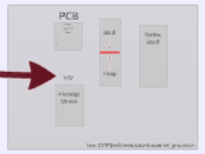
P1

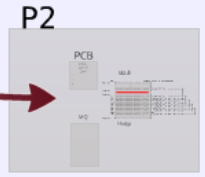
P2

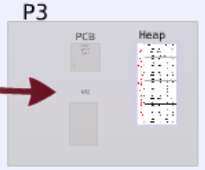
P3

...

P99



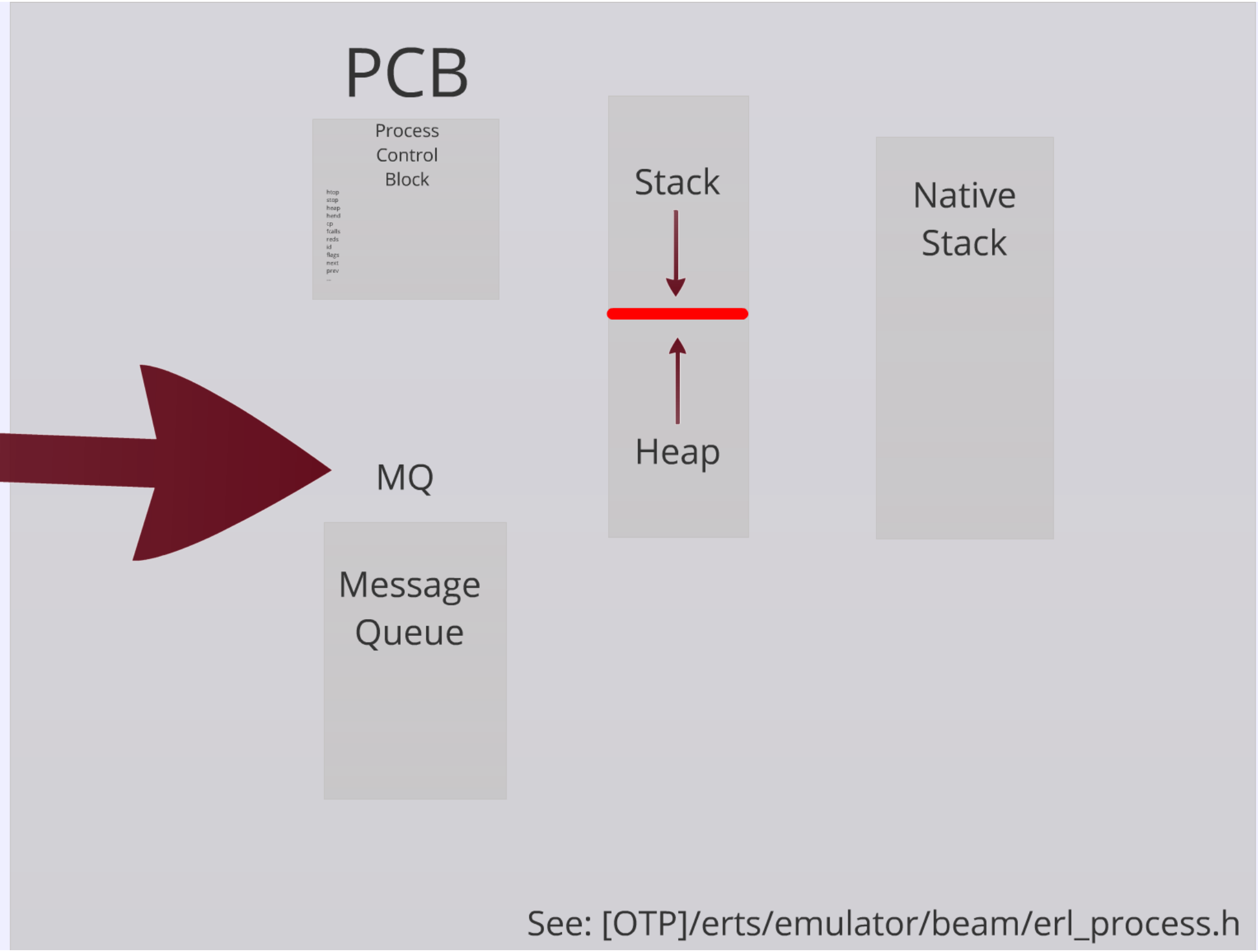




...

BEAM CODE

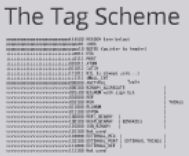
```
p2() ->
  L = "Hello",
  T = {L, L},
  P3 = mk_proc(),
  P3 ! T.
```


PCB
Process
Control
Block
htop
stop
heap
hend
cp
fcalls
reds
id
flags
next
prev
...
Stack
Heap
Native
Stack
MQ
Message
Queue
See: [OTP]/erts/emulator/beam/erl_process.h

ERTS as meme

ERTS CODE

GC
Scheduler
BEAM
Sockets
etc...



C-stack

Queues

Binaries

Proce

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...

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ERTS as memory areas:

ERTS CODE

GC
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BEAM
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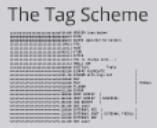


C-stack

Queues

Binaries

Processes

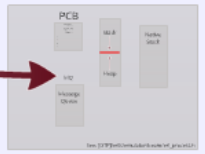
P1

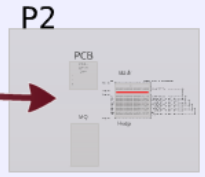
P2

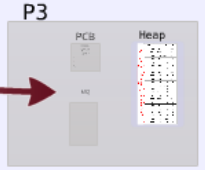
P3

...

P99







...

BEAM CODE

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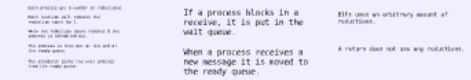
```

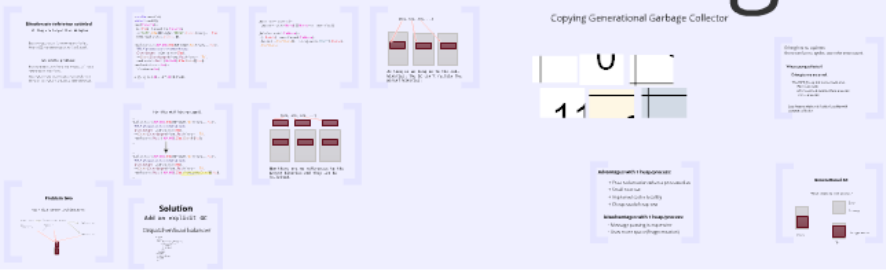
ERTS as components:

The BEAM interpreter

The Scheduler



The Garbage Collector



Processes

Conceptually: 4 memory areas and a pointer:

- A Stack
- A Heap
- A Mailbox
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HiPE

I/O

BEAM

- Garbage Collecting-
- Reduction Counting-
- Non-preemptive-
- Directly Threaded-
- Register-
- Virtual-

-Machine

BEAM is Virtually Unreal

The Beam is a virtual machine: it is implemented in software instead of in hardware.

There is no official specification of the Beam, it is currently only defined by the implementation in Erlang/OTP.

A Stack Machine - it is not

BEAM is a register machine

Advantage of a stack machine

- Easier to compile to
- Easier to implement

See my blog: http://stenmans.org/happi_blog/?p=194 for an example of a stack machine.

Advantage of a register machine

- More efficient (?)

- Two types of registers: X and Y-registers.
- X0 is the accumulator and mapped to a physical register, also called R0.
- Y registers are actually stack slots.

There are a number of special purpose registers: htop, stop, I, fcalls and floating point registers.

Dispatch: Directly Threaded Code

The dispatcher finds the next instruction to execute.

I: 0x1000

```
#define Arg(N) (Eterm *) I[(N)+1]
#define Goto(Rel) goto *((void *)Rel)
```

External beam format:

```
{move,{x,0},{x,1}}.
{move,{y,0},{x,0}}.
{move,{x,1},{y,0}}.
```

Loaded code*:

```
0x1000: 0x3000
0x1004: 0x0
0x1008: 0x1
0x100c: 0x3200
0x1010: 0x1
0x1014: 0x1
0x1018: 0x3100
0x101c: 0x1
0x1020: 0x1
```

*This is a lie... beam actually rewrites the external format to different internal instructions....

beam_emu.c **:

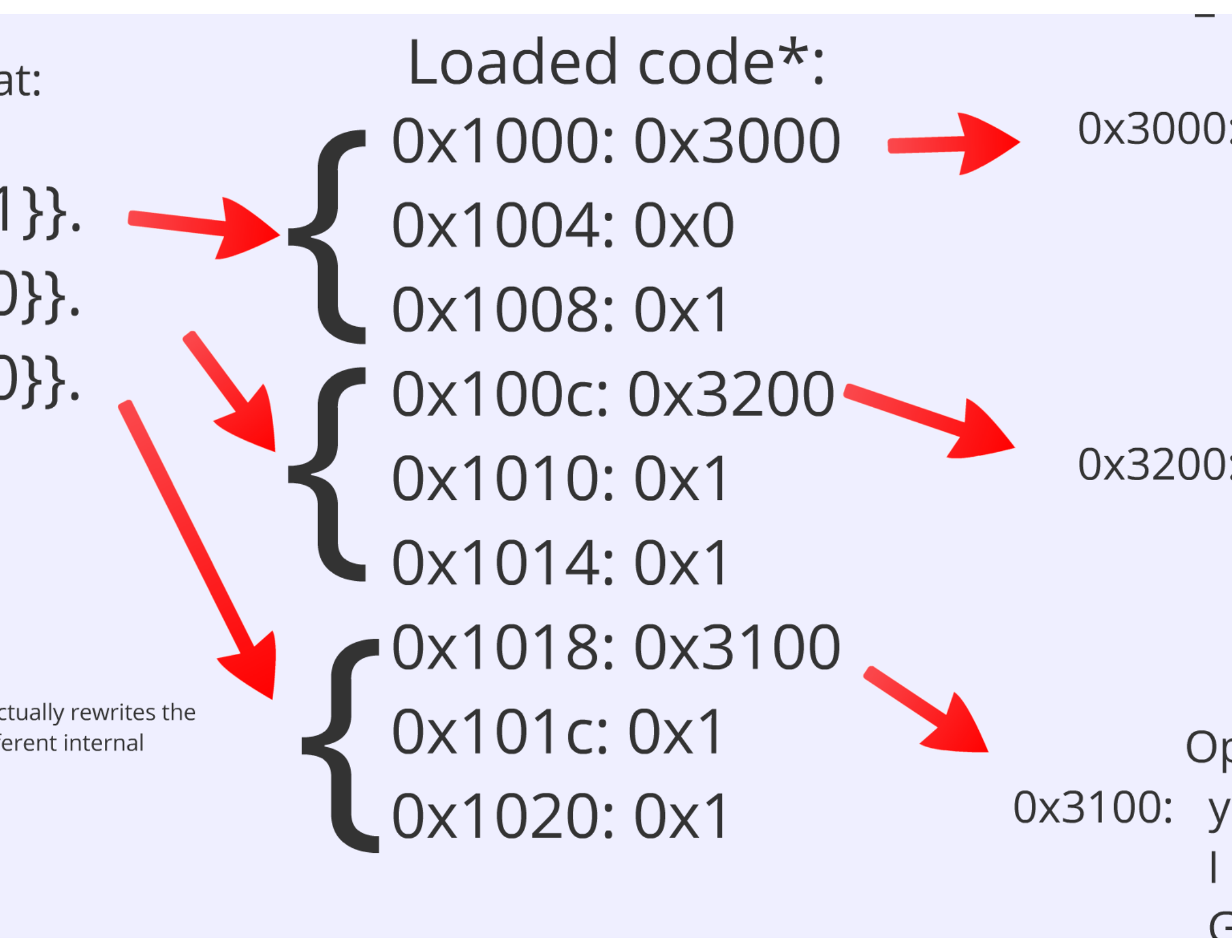
```
        OpCase(move_xx): {
0x3000:   x(Arg(1)) = x(Arg(0));
          I += 3;
          Goto(*I);
        }

        OpCase(move_yx): {
0x3200:   x(Arg(1)) = y(Arg(0));
          I += 3;
          Goto(*I);
        }

      OpCase(move_xy): {
0x3100:   y(Arg(1)) = x(Arg(0));
          I += 3;
          Goto(*I);
        }
```

External beam format:

{move,{x,0},{x,1}}.
{move,{y,0},{x,0}}.
{move,{x,1},{y,0}}.


at:
1}}.
0}}.
0}}.
Loaded code*:
0x1000: 0x3000
0x1004: 0x0
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0x100c: 0x3200
0x1010: 0x1
0x1014: 0x1
0x1018: 0x3100
0x101c: 0x1
0x1020: 0x1
0x3000
0x3200
0x3100:
ctually rewrites the
ferent internal

beam_emu.c **:

```
            OpCase(move_xx): {
0x3000:       x(Arg(1)) = x(Arg(0)):
              I += 3;
              Goto(*I);
            }

            OpCase(move_yx): {
```

** This is another lie, there are no such instructions in beam_emu, but you can't handle the truth.

e:

```
#define Arg(N) (Eterm *) I[(N)+1]
#define Goto(Rel) goto *((void *)Rel)
```

beam_emu.c **:

```
        OpCase(move_xx): {
0x3000:   x(Arg(1)) = x(Arg(0)):
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        }
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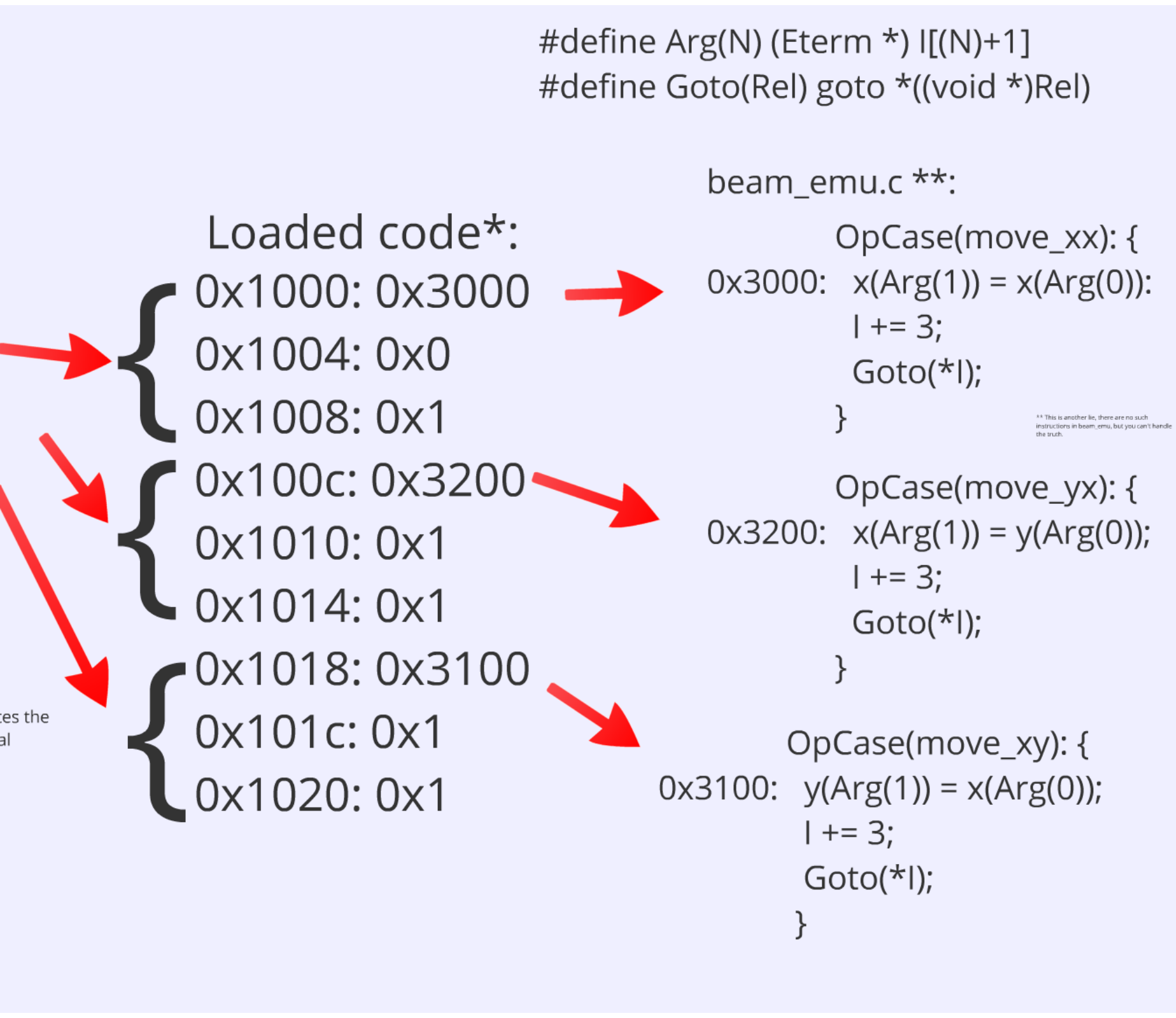
```
        OpCase(move_yx): {
```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I += 3;
Goto(*I);
}
OpCase(move_xy): {
0x3100: y(Arg(1)) = x(Arg(0));
I += 3;
Goto(*I);
}

Scheduling:

`Non-preemptive, Reduction counting`

- Each function call is counted as a reduction
- Beam does a test at function entry: if (reds < 0) yield
- A reduction should be a small work item
- Loops are actually recursions, burning reductions

A process can also yield in a receive.

Memory Management:

`Garbage Collection`

- On the Beam level the code is responsible for:
  - checking for stack and heap overrun.
  - allocating enough space

- "test_heap" will check that there is free heap space.
- If needed the instruction will call the GC.
- The GC might call lower levels of the memory subsystem to allocate or free memory as needed.

BEAM

- Garbage Collecting-
- Reduction Counting-
- Non-preemptive-
- Directly Threaded-
- Register-
- Virtual-

-Machine

world.hrl

```
-define(GREETING, "hello world").
```

world.erl

```
-module(world).
-export([hello/0]).

-include("world.hrl").

hello() -> ?GREETING.
```

```
1> c(world, ['P']).
** Warning: No object file created - nothing loaded **
ok
```

world.P

```
-file("world.erl",1).
-module(world).
-export([hello/0]).
-file("world.hrl", 1).
-file("world.erl", 4).
hello() ->
    "hello world".
```

1> c(world, 'S').

```
{module, world}.
%% version = 0
{exports, [{hello,0}, {module_info,0},
{module_info,1}]}.
{attributes, []}.
{labels, 7}.


{function, hello, 0, 2}.
{label,1}.
{func_info, {atom,world}, {atom,hello}, 0}.
{label,2}.
{move,{literal,"hello world"},{x,0}}.
return.

{function, module_info, 0, 4}.
{label,3}.
{func_info, {atom,world}, {atom,module_info},0}.
{label,4}.
{move,{atom,world},{x,0}}.
{call_ext_only, 1,
                {extfunc, erlang, get_module_info, 1}}.

{function, module_info, 1, 6}
{label,5}.
{func_info,{atom,world},{atom,module_info},1}.
{label,6}.
{move,{x,0},{x,1}}.
{move,{atom,world},{x,0}}.
{call_ext_only, 2,
                {extfunc, erlang, get_module_info, 2}}.
```

1> compile:file(world, ['S', binary]).

world.hrl

```
-define(GREETING, "hello world").
```

world.erl

```
-module(world).
-export([hello/0]).

-include("world.hrl").

hello() -> ?GREETING.
```

```
hello() -> ?GREETING.
```

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1> c(world, ['P']).
** Warning: No object file created - nothing loaded **
ok
```

world.P

```
file("world.erl",1)
```

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{func_info, {atom,world}, {atom,module_info},0}.
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{move,{atom,world},{x,0}}.
{call_ext_only, 1,
                    {extfunc, erlang, get_module_info, 1}}.

{function, module_info, 1, 6}
{label,5}.
{func_info,{atom,world},{atom,module_info},1}.
{label,6}.
{move,{x,0},{x,1}}.
{move,{atom,world},{x,0}}.
{call_ext_only, 2,
                    {extfunc, erlang, get_module_info, 2}}.
```

ed **

```
{label,5}.
{func_info,{atom,world},{atom,module_info},1}.
{label,6}.
{move,{x,0},{x,1}}.
{move,{atom,world},{x,0}}.
{call_ext_only, 2,
                    {extfunc, erlang, get_module_info, 2}}.
```

```
1> compile:file(world, ['S', binary]).
```

Beam Instructions

An Added Example

```
-module(add).
-export([add/2]).

add(A,B) -> id(A) + id(B).

id(I) -> I.
```

```
{allocate,1,2}.
 {move,{x,1},{y,0}}.
 {call,1,{f,4}}.
 {move,{x,0},{x,1}}.
 {move,{y,0},{x,0}}.
 {move,{x,1},{y,0}}.
 {call,1,{f,4}}.
 {gc_bif,'+',{f,0},1,[{y,0},{x,0}],{x,0}}.
 {deallocate,1}.
 return.
```

Lessons learned:

- BEAM is a
  - Garbage Collecting-
  - Reduction Counting-
  - Non-preemptive-
  - Directly Threaded-
  - Register-
  - Virtual- -Machine
- Use the option ['S', binary] to get beam code.


QUESTIONS?