The New Call Graph Based Performance Consultant

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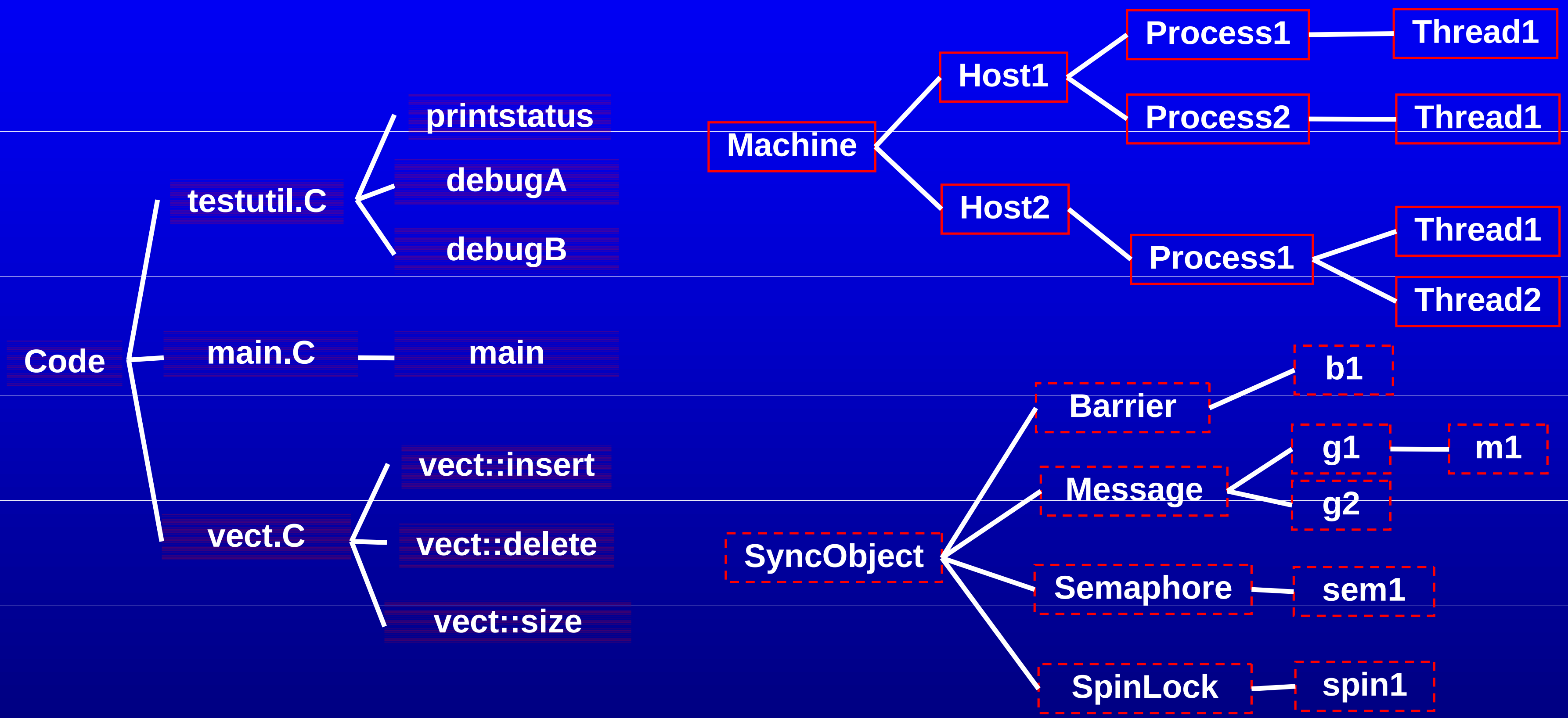
The Performance Consultant (PC)

- Uses two main Paradyn technologies
  - Dynamic instrumentation
  - Automated bottleneck search
- Original version had difficulty searching large applications
- Our solution: direct PC search using application call graph

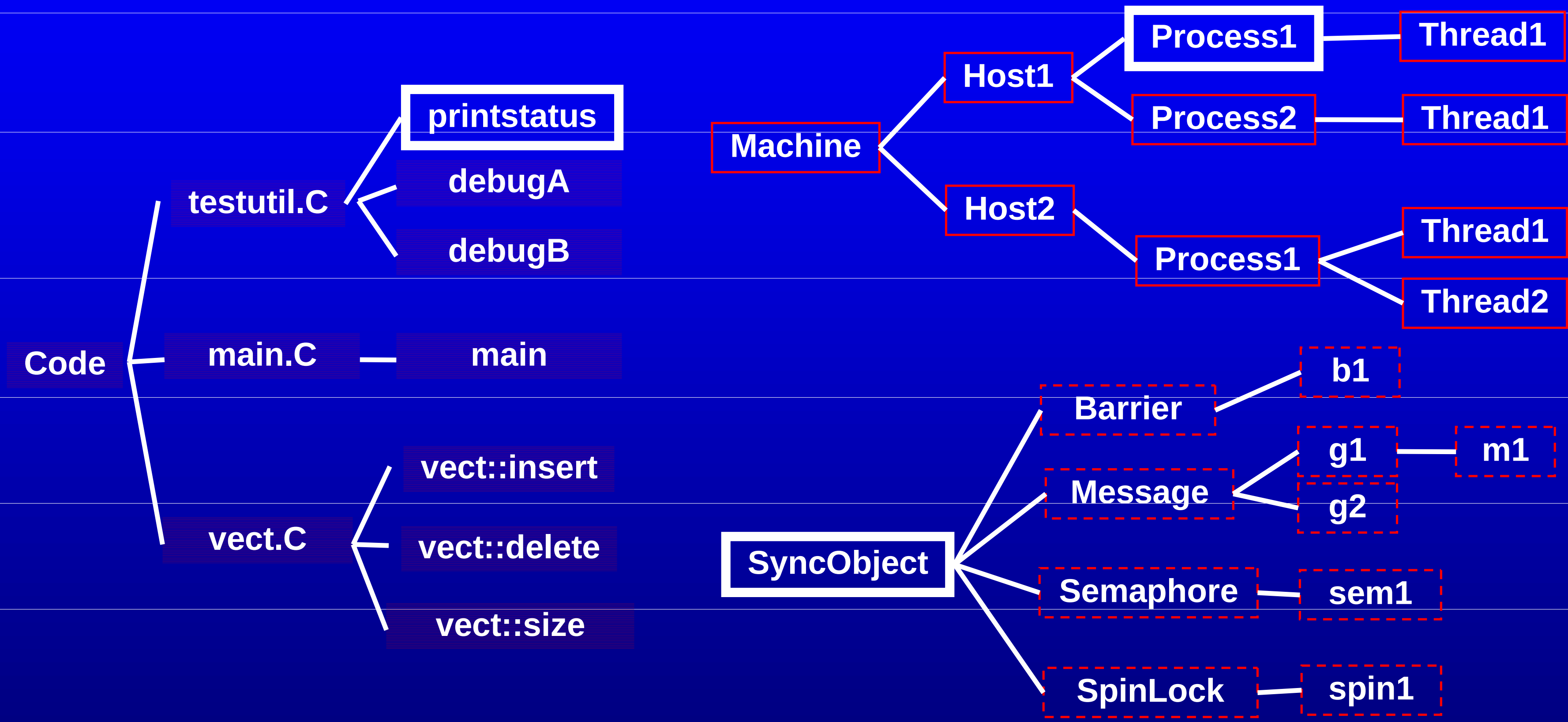
Outline

- Paradyn Basics
- Original Search Strategy
- Call Graph Based Search Strategy
- Dynamic Call Site Instrumentation
- Performance Comparison
- Conclusion

Paradyn Basics: Resource Hierarchies



Paradyn Basics: Resource Hierarchies



Example Focus: {/Code/testutil.C/printstatus, /Machine/host1/process1, /SyncObject }

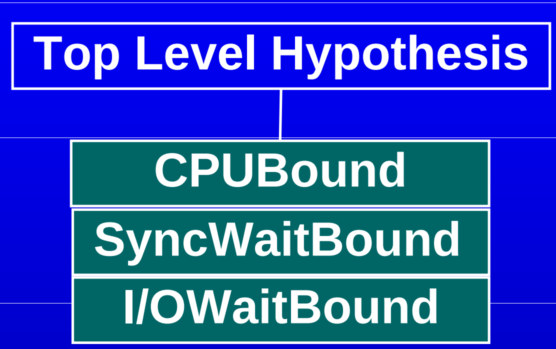
Paradyn Basics: Performance Metrics

- Metrics are measurable performance characteristics such as CPU time, function calls, I/O bytes transferred
- Performance data collected for metric/focus pair
- Example metric/focus pairs:
  - cpu:{/Code/mod1/func1 }
  - msgs:{/Code/mod1/func1, /Machine/host1/proc4/thread2, /SyncObject/Message/1/0}

Performance Consultant Basics

- Why is the application running slowly?
  - Test bottleneck hypotheses
    - CPU Bound?
    - I/O Wait Bound?
    - Synchronization Wait Bound?
    - Memory Bound?
  - Performance metric associated with each hypothesis
- Which part of the application is slow?
  - Isolates bottleneck to part of resource hierarchy

Original PC Example



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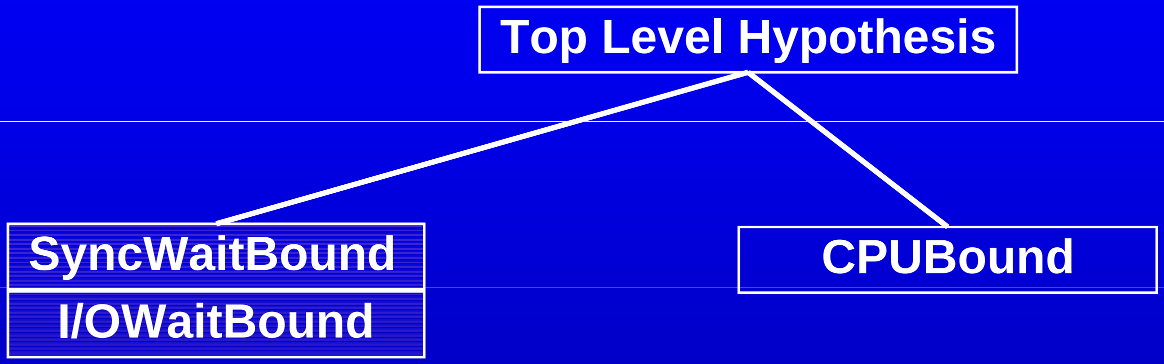

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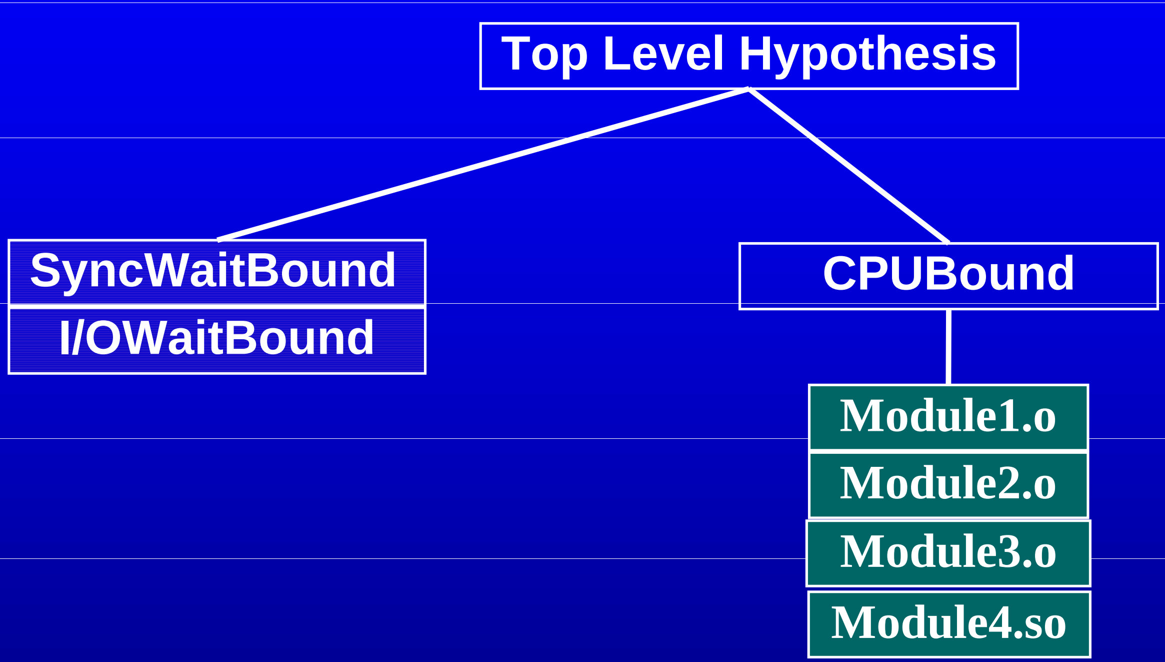

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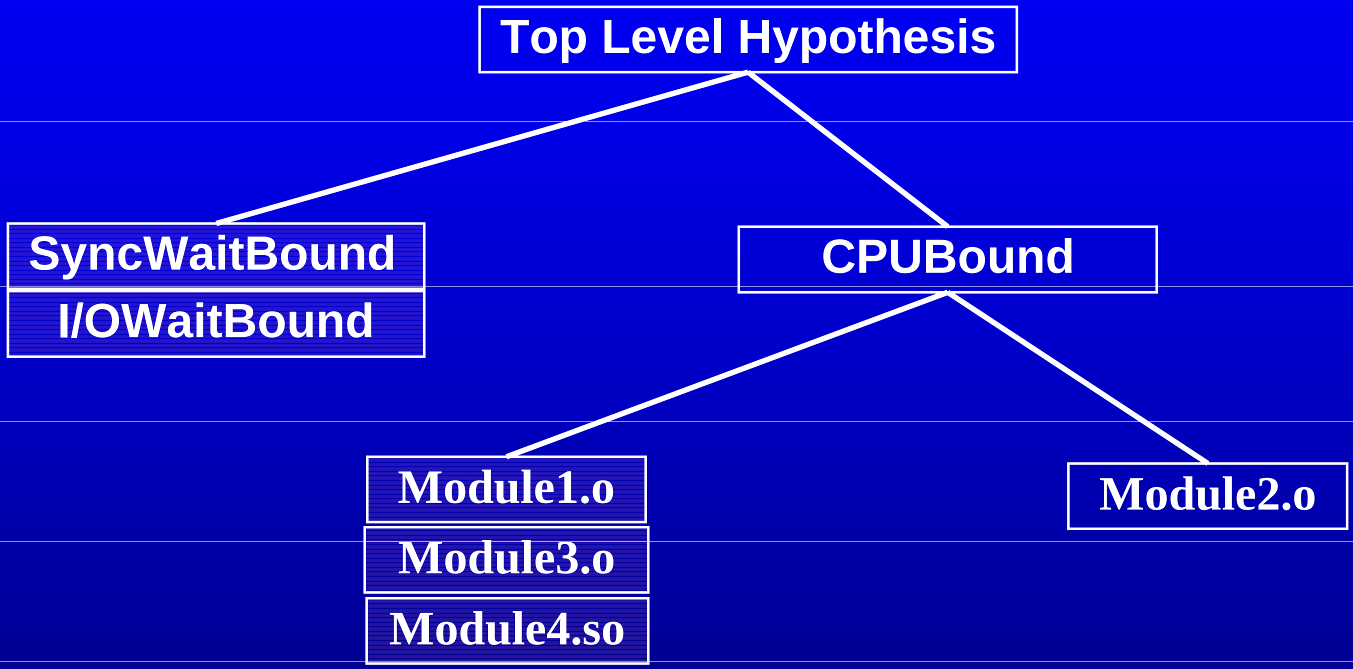

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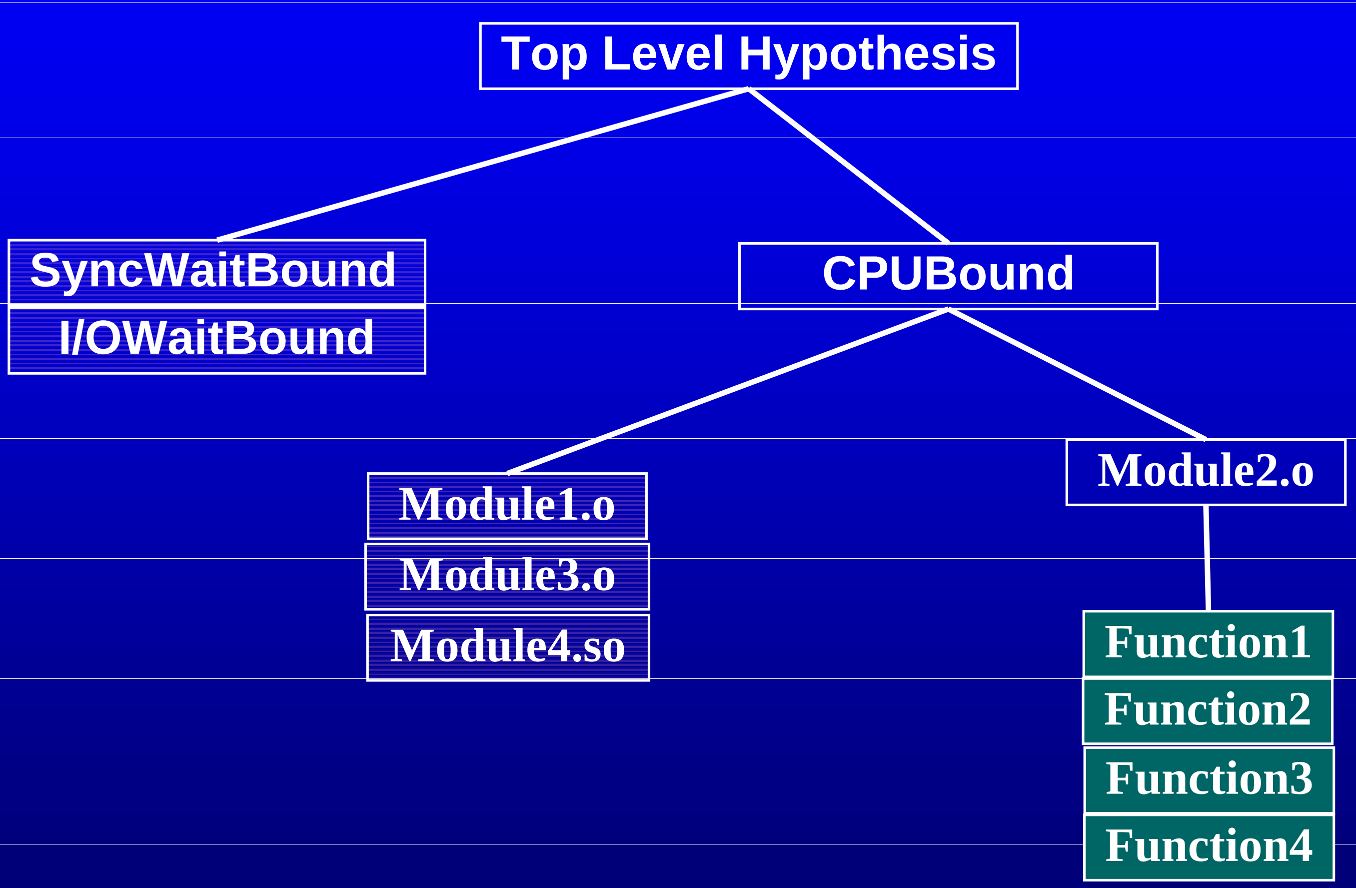

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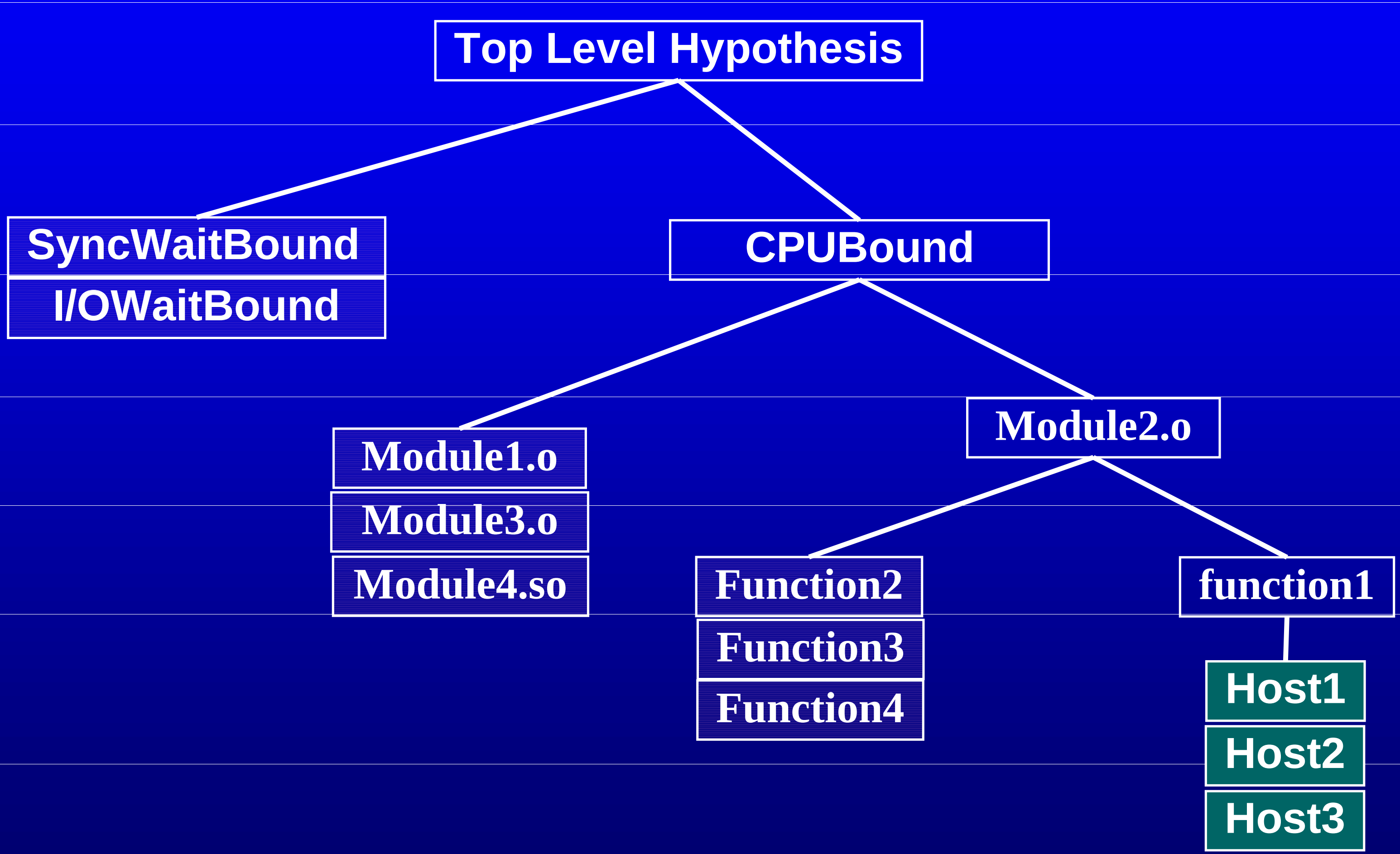
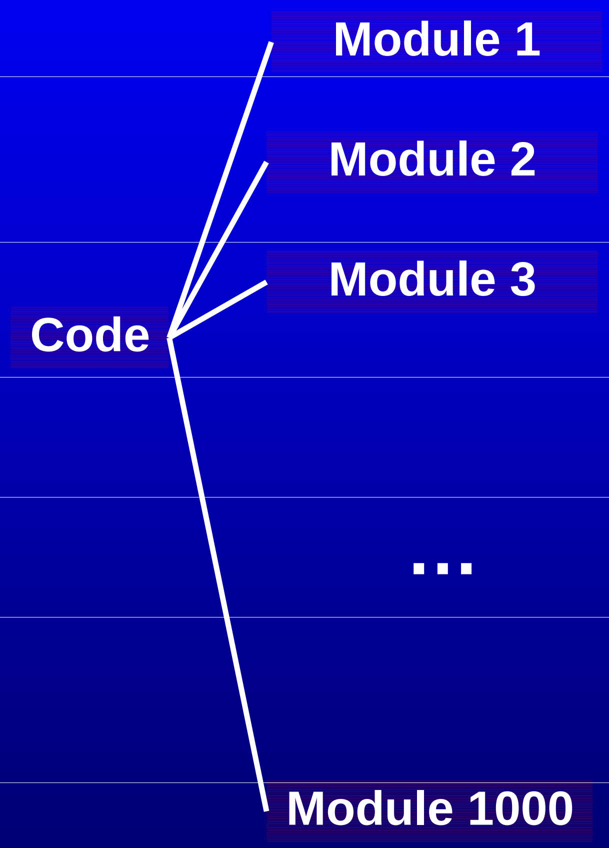


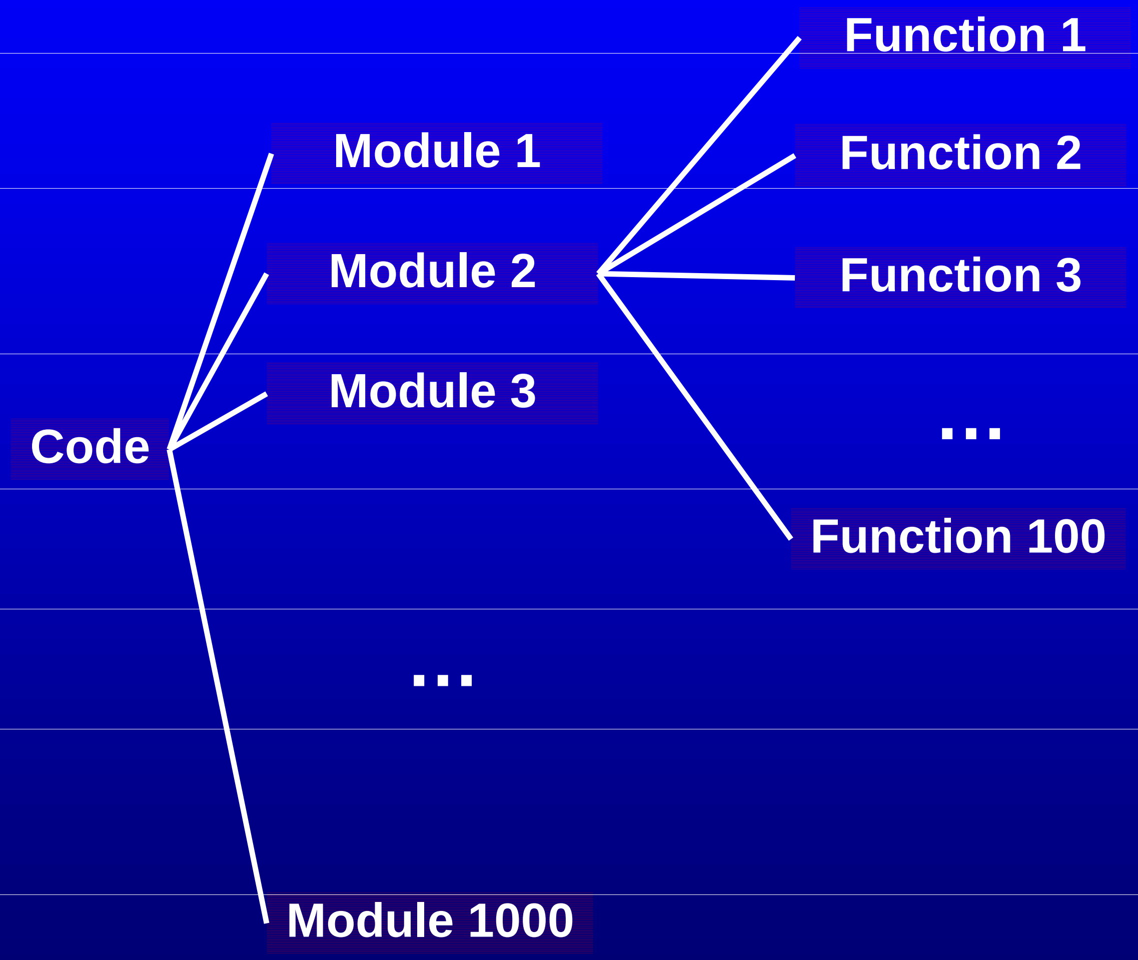
Original Performance Consultant

- Problem: Traversing the code hierarchy does not scale
  - Search space too large: too many modules, too many functions
  - Module instrumentation is not cheaper than instrumenting all of module's functions
  - Exclusive metrics are costly
- We would like to avoid excessive instrumentation

Too many modules and functions



Too many modules and functions



PC Timing Metrics

- Performance Consultant based on the idea that coarse grained instrumentation is cheaper than fine grained…
- But instrumenting a module has the same cost as instrumenting each function in the module individually.

Exclusive vs. Inclusive Metrics

```
foo() {

    bar();

     car();

}
```

Exclusive Timer

Exclusive vs. Inclusive Metrics

```
startTimer(t) ---->  foo() {

stopTimer(t)  ---->
                        bar();
startTimer(t) ---->

stopTimer(t)  ---->
                        car();
startTimer(t) ---->

stopTimer(t)  ---->
                     }
```

Exclusive Timer

Exclusive vs. Inclusive Metrics

```
startTimer(t) →  foo() {
stopTimer(t)  →
startTimer(t) →      bar();
stopTimer(t)  →
startTimer(t) →      car();
stopTimer(t)  →  }
```

Exclusive Timer

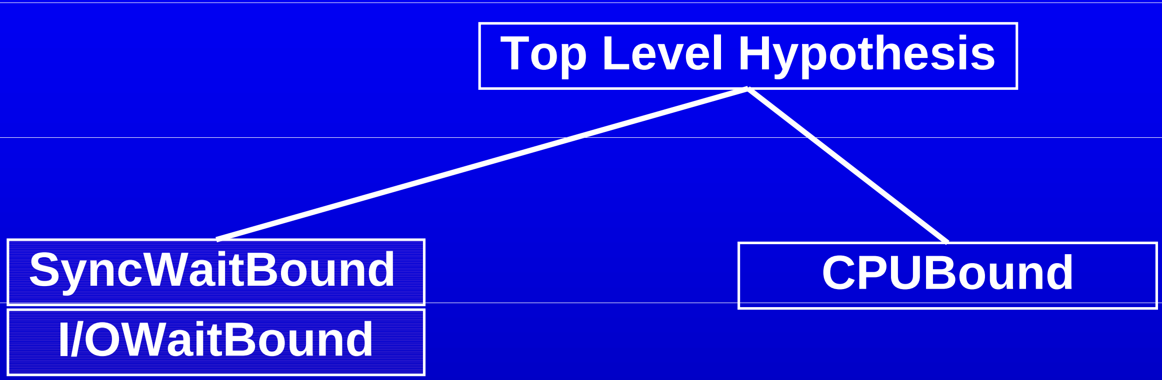
```
startTimer(t) →  foo() {
                     bar();
                     car();
stopTimer(t)  →  }
```

Inclusive Timer

Call Graph Based Performance Consultant

- Based on application's call graph
- Code hierarchy search starts at function `main`, search continues to `main`'s children
- Advantages: Lots!
  - It's Scalable: Natural hierarchical refinement from course grained search to fine grained search
  - Uses less costly inclusive metrics
  - Functions which are not part of call graph will never be instrumented

Call Graph Based PC Example



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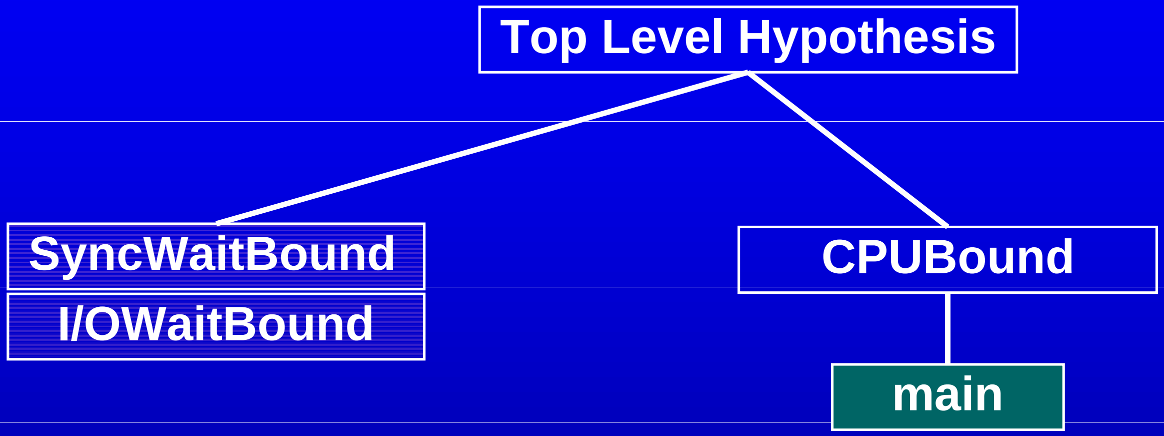

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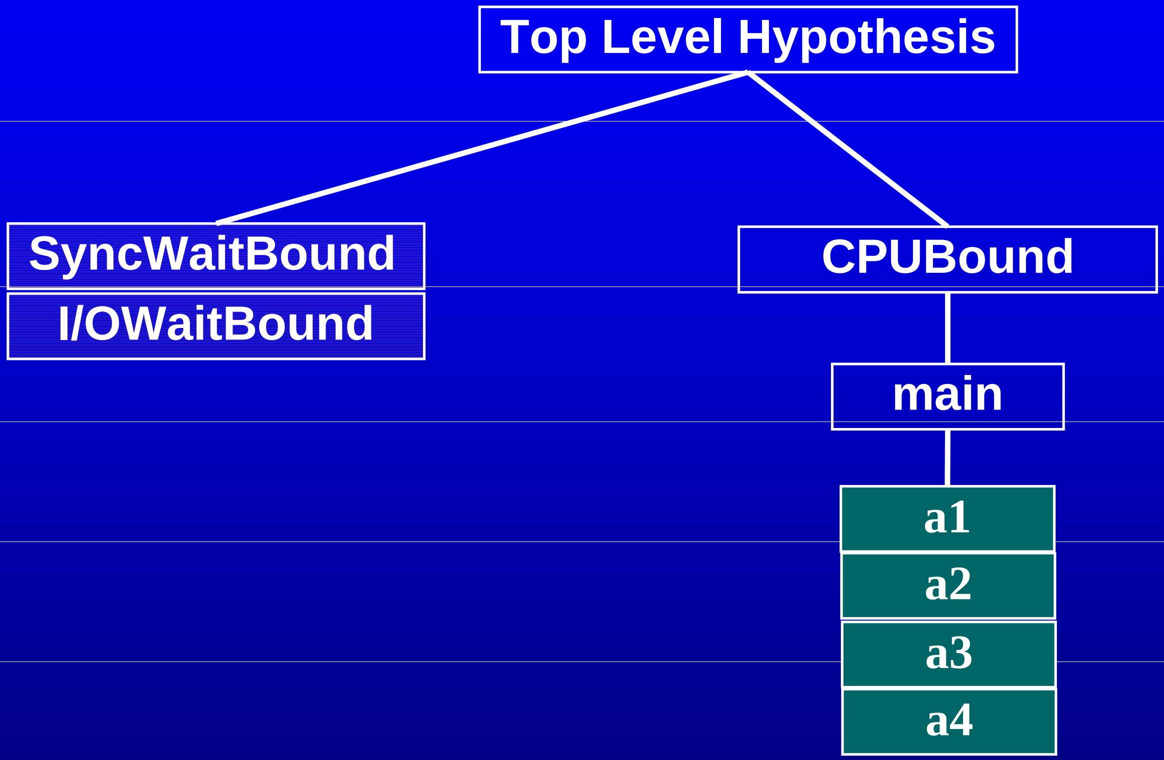

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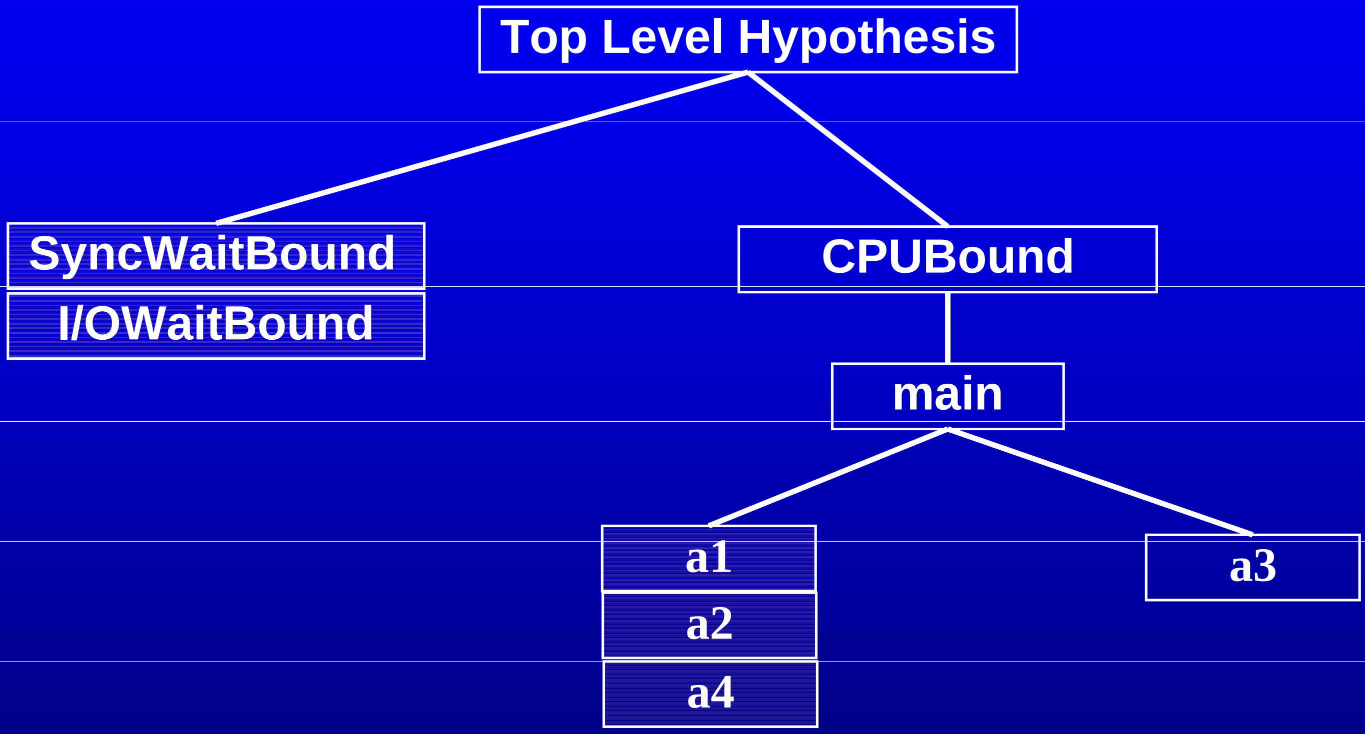

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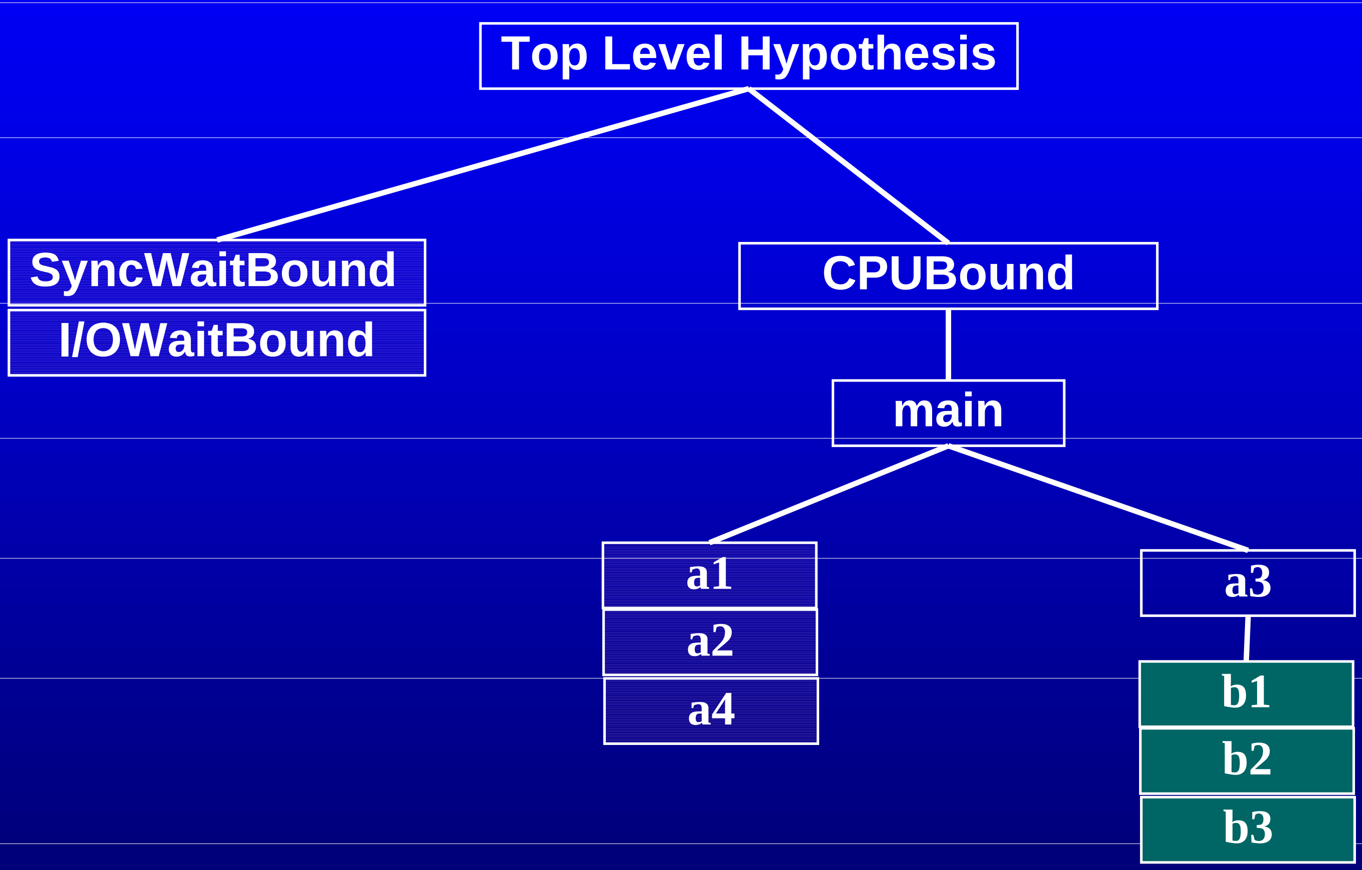

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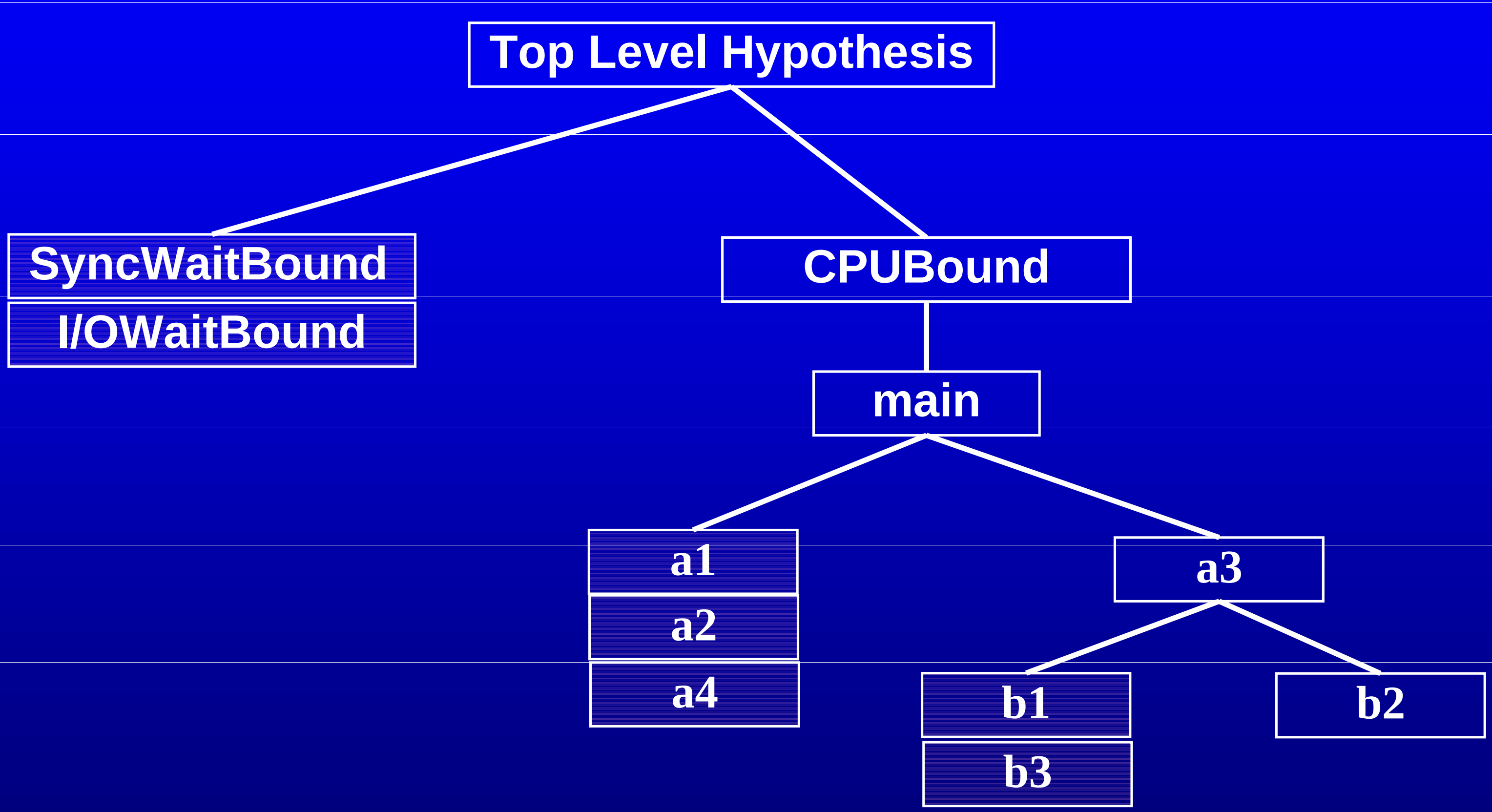


Call Graph Construction

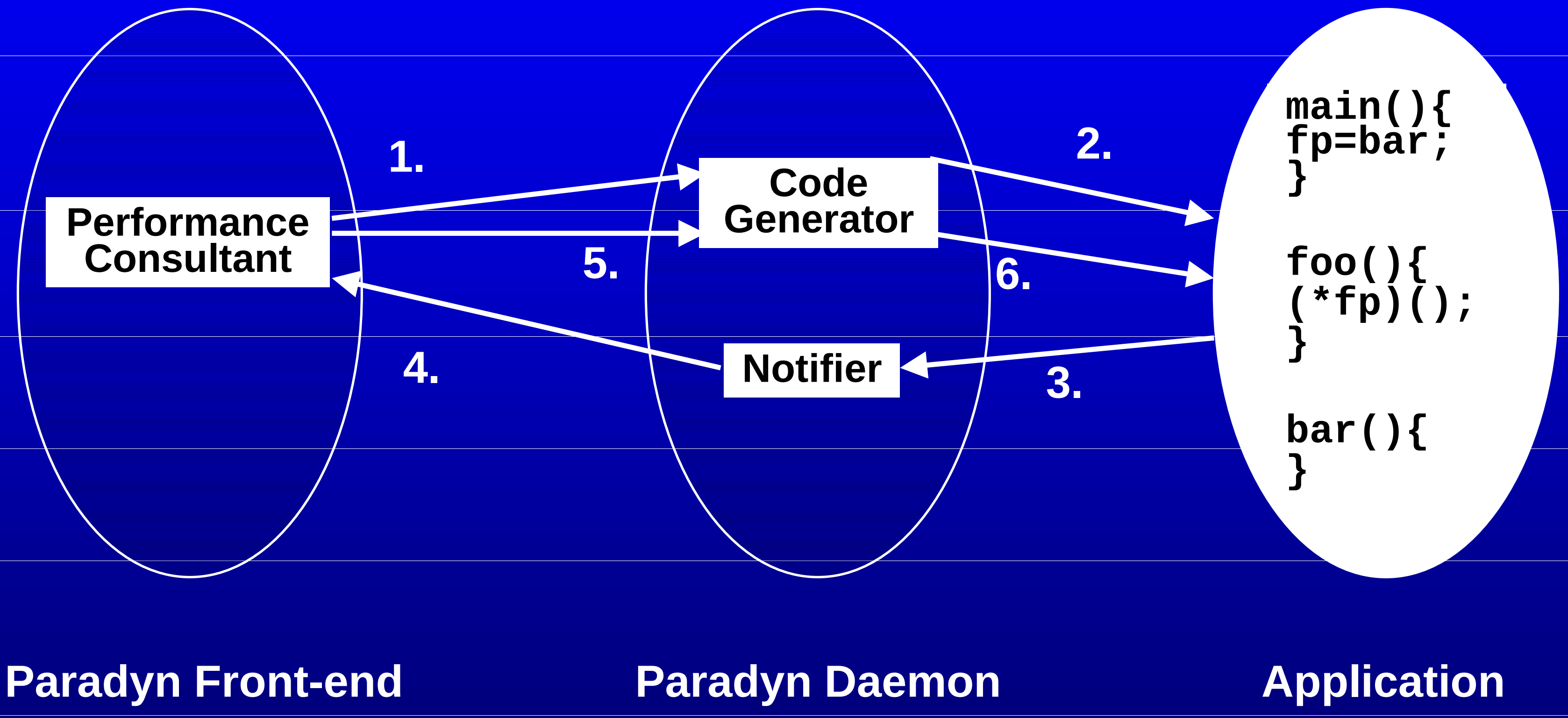
- Problem: targets of calls using function pointers and virtual functions are not statically determinable.
- Unknown callees in static call graph may cause blind spots in new PC search
- We resolve dynamic callee addresses at run time
- Strategy:
  - Build static call graph at program start
  - Fill in dynamic call graph on demand.

Dynamic Call Sites

- Characterized by keeping the address of a callee in a register or memory location
- New type of instrumentation necessary to determine callee
- Examples:

Instruction Set	Call Instruction
MIPS	`jalr $t9`
X86	`call [%edi]`

Call Site Instrumentation: Chain of Events



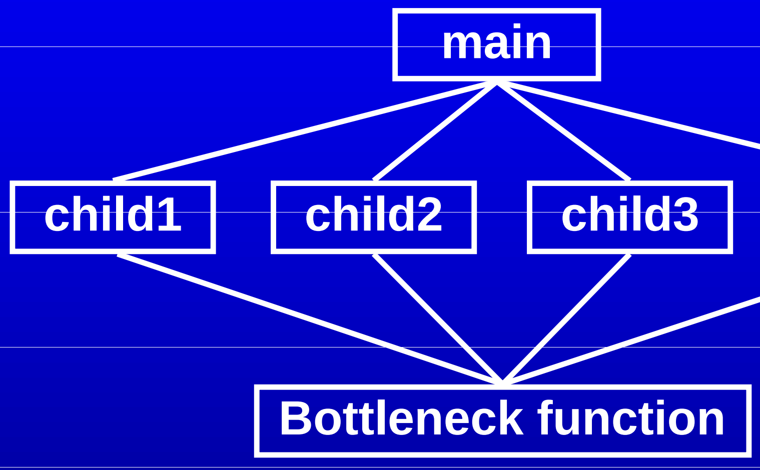
Performance Results

	Bottlenecks found in complete search		Instrumentation Mini-tramps Used		Required Search Time (seconds)	
Application	Original	Call Graph	Original	Call Graph	Original	Call Graph
Draco	3	5	14,317	228	1,006	322
go	2	4	12,570	284	755	278
Fpppp	3	3	474	96	141	186
ssTwod (MPI)	9	9	43,230	11,496	461	316
OM3 (MPI)	13	16	184,382	60,670	2,515	957

Conclusion

- Call graph based search strategy perturbs application less than old search
- New search also faster than old search
- New version of PC available in Paradyn 3.0
- Room for future work…
  - Exclusive bottleneck verification
  - Finding a way to avoid potential blind spots.

Potential Blind Spot for New PC



A rare scenario: we haven't seen it happen yet.

Retroactive Instrumentation

- Problem: Find CPU Time for a function if we are executing in one of its children.
- When do we start the timer for the entry to function?
- Need mechanism to trigger instrumentation code.
- Retroactive instrumentation walks stack, triggering outstanding timers