

Principles of Real-Time Programming

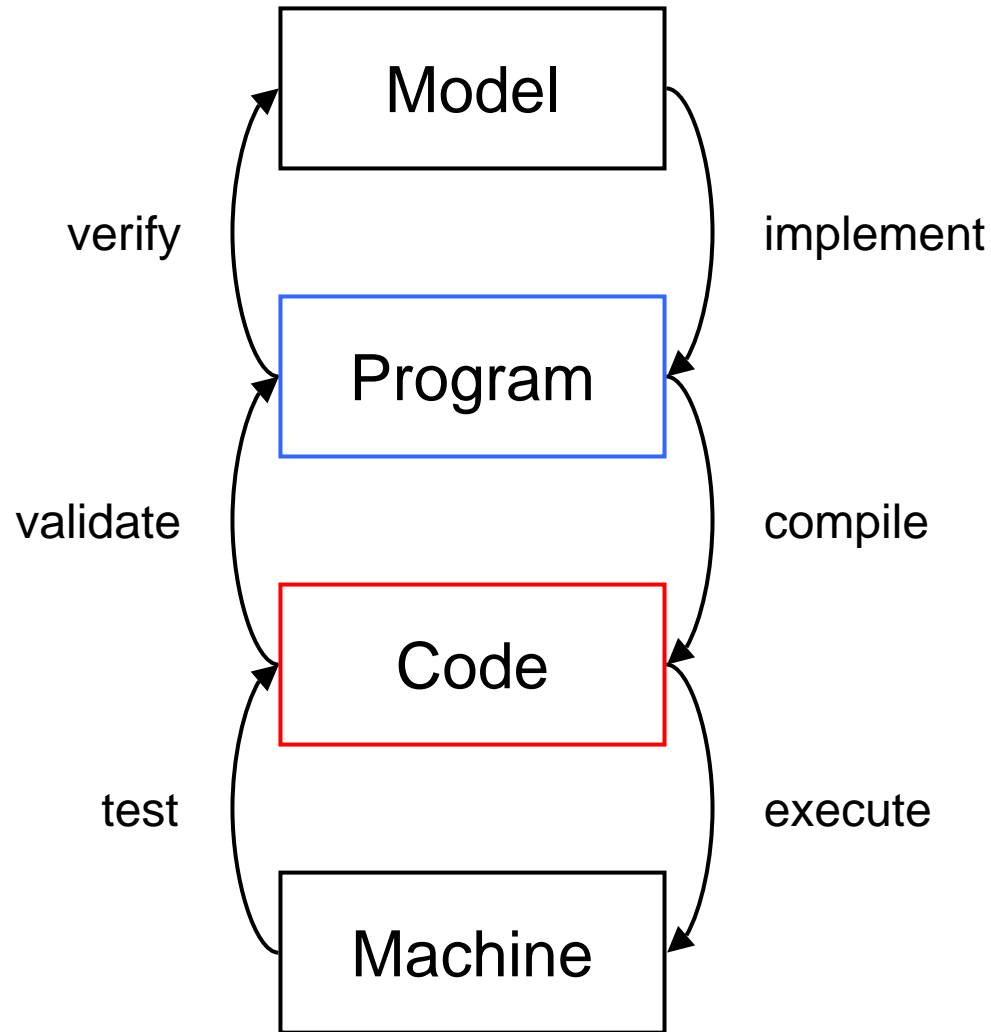
EMSOFT 2002

Christoph M. Kirsch

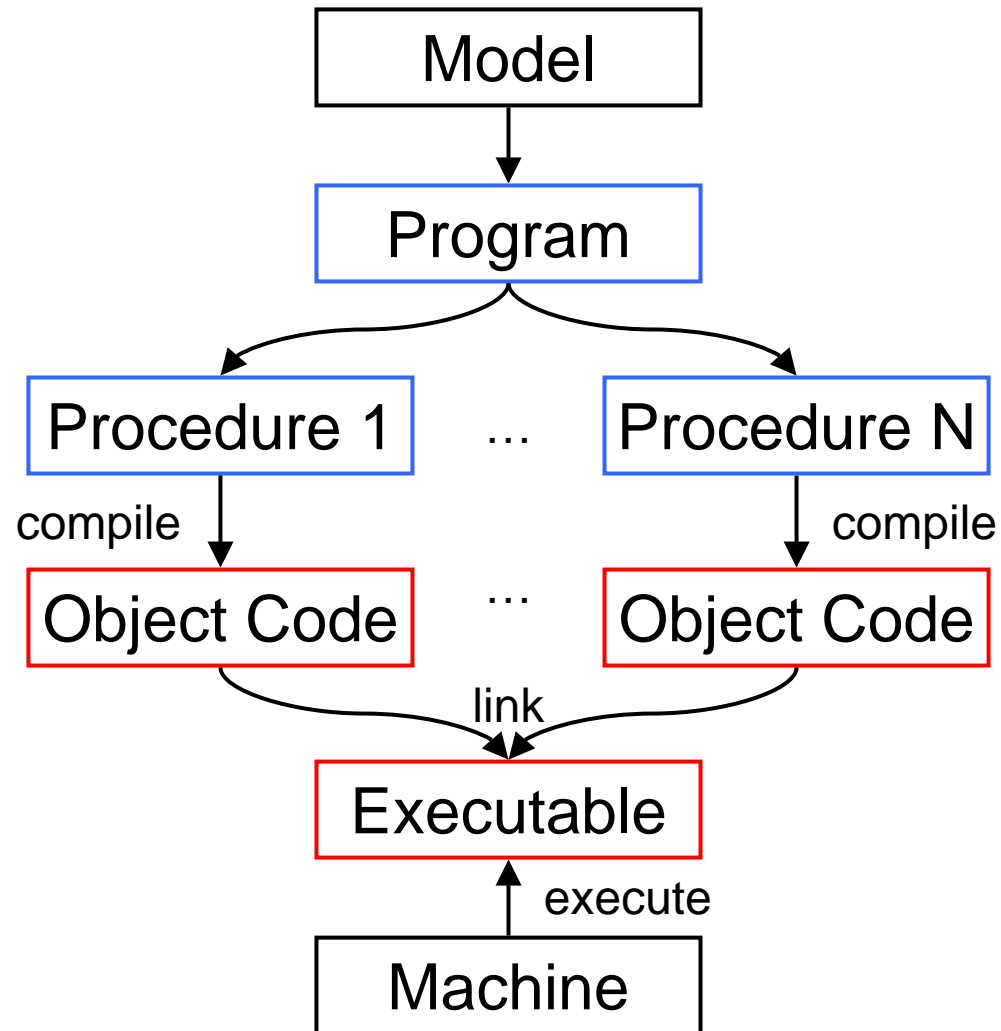
UC Berkeley

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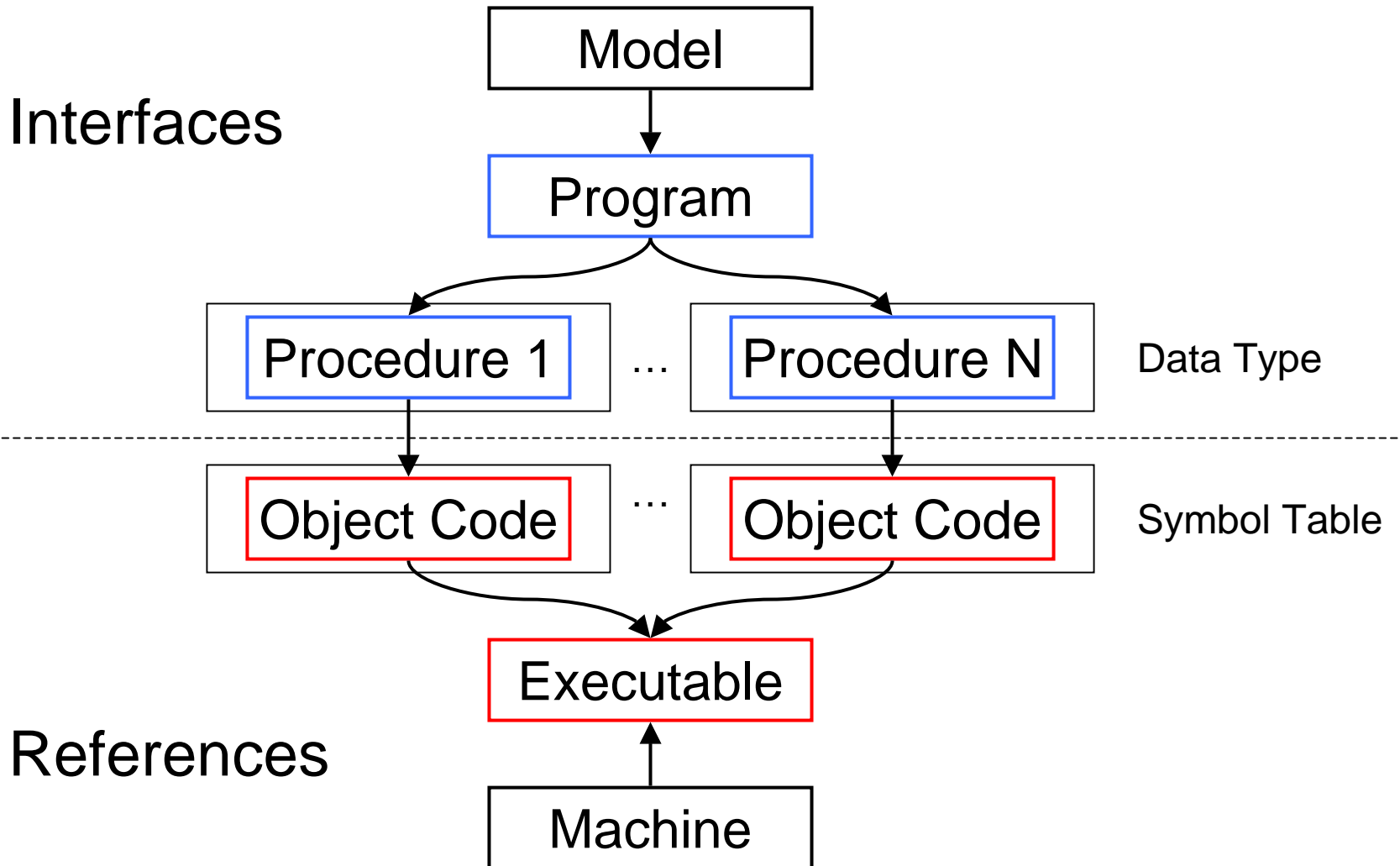
Sequential Programming



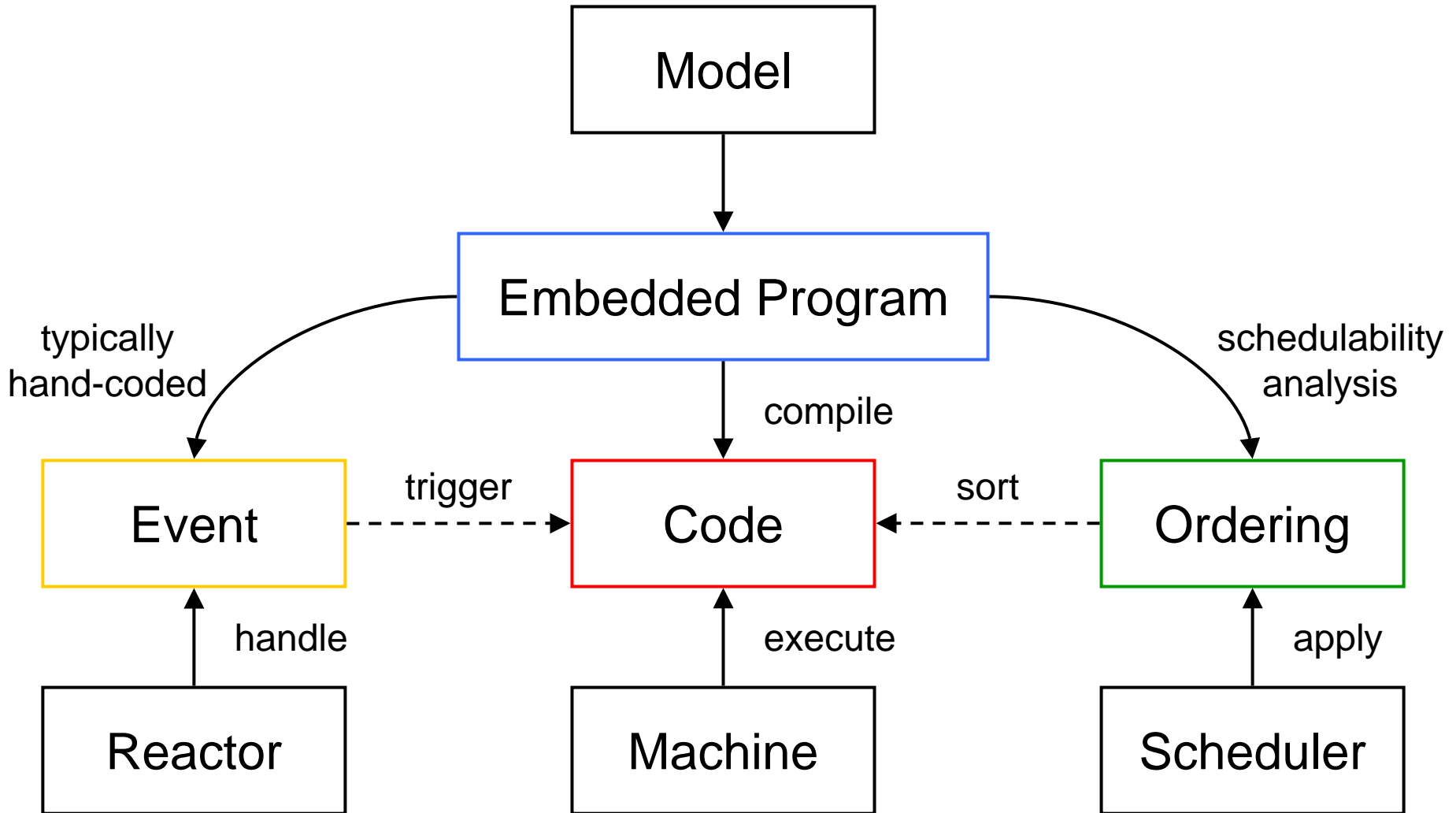
Composability and Type Safety



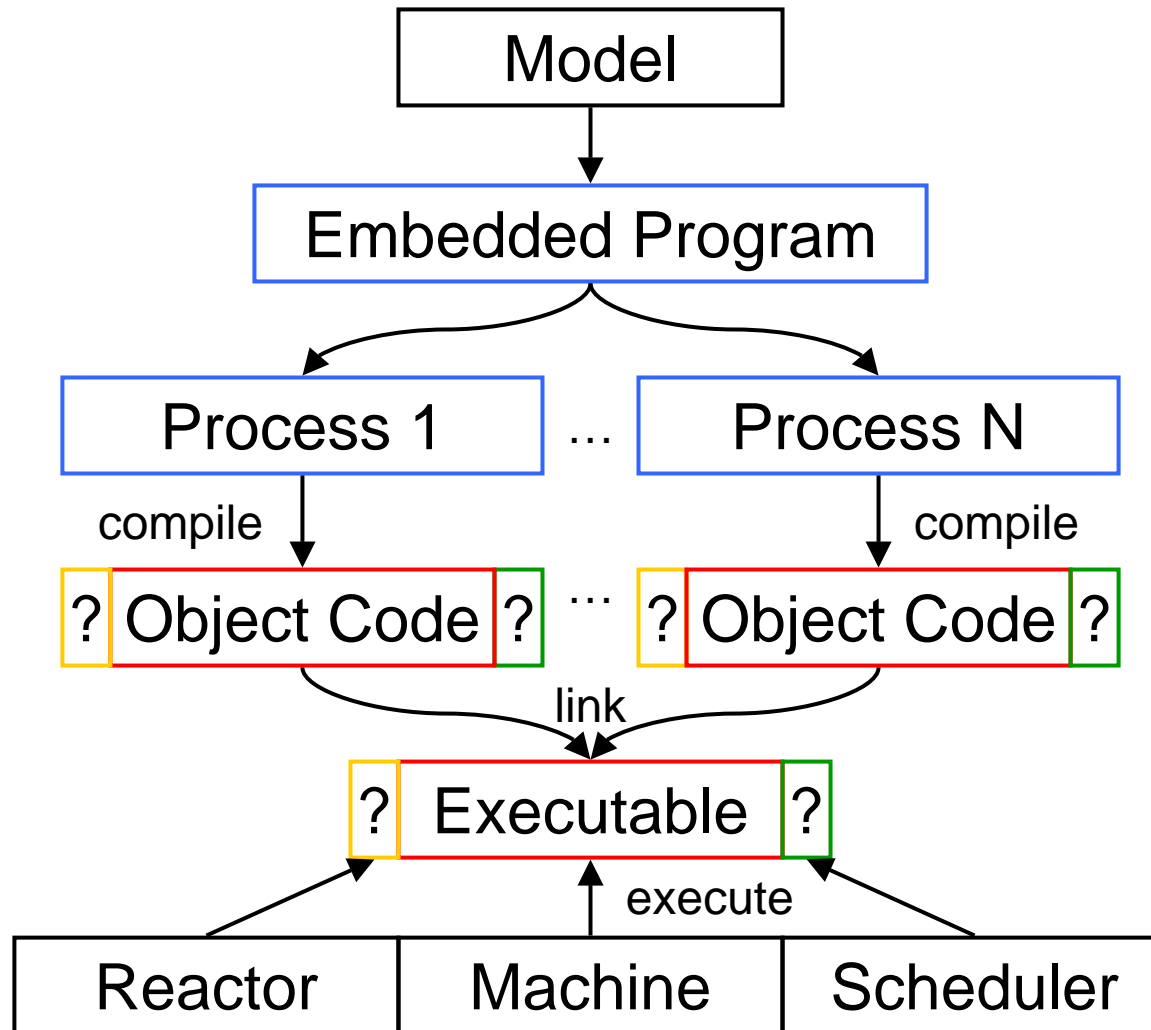
Type Safety



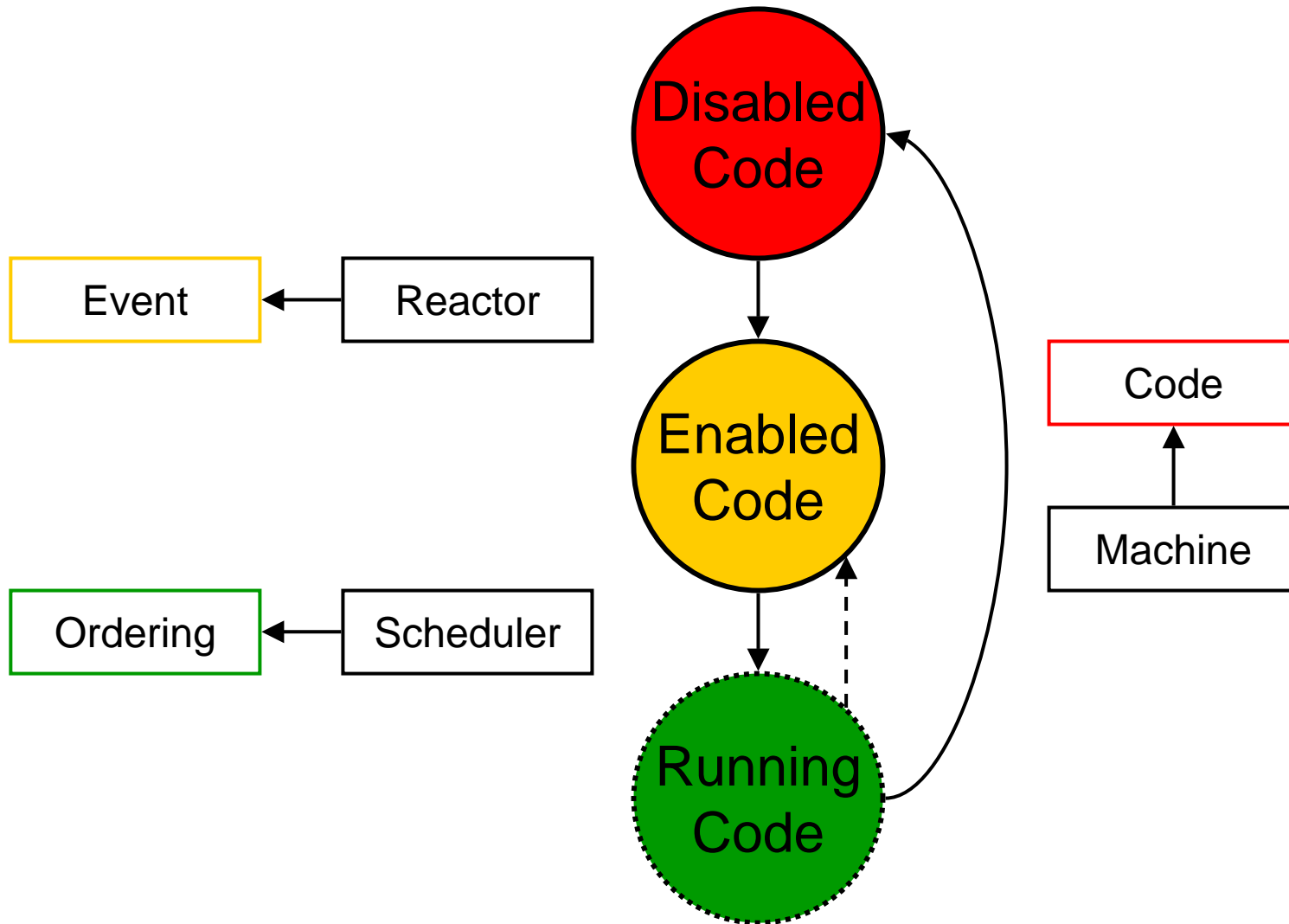
Embedded Programming



Composability and Time Safety



A Real-Time Process Model



Embedded Software



Environment

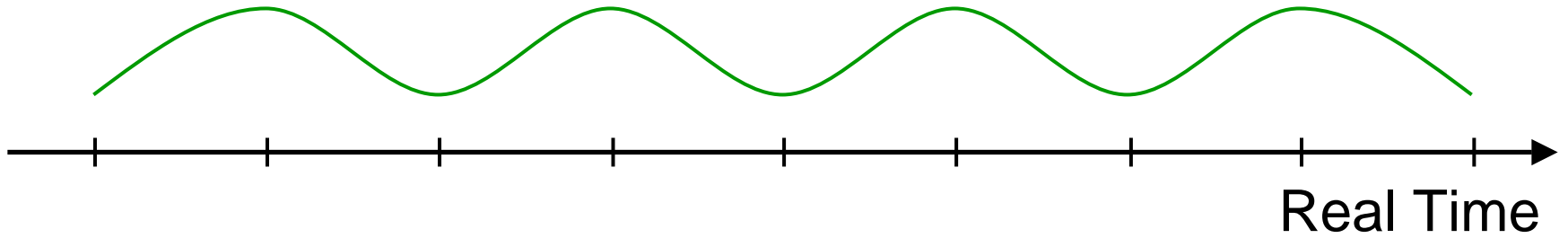
Environment Processes

Software Processes

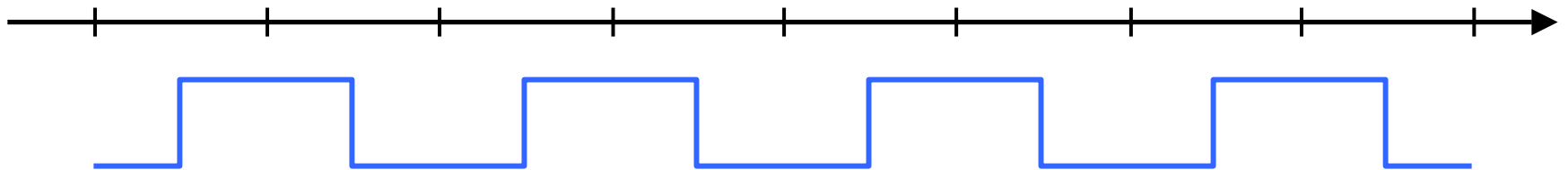
Software

Real Time vs. Soft Time

Environment

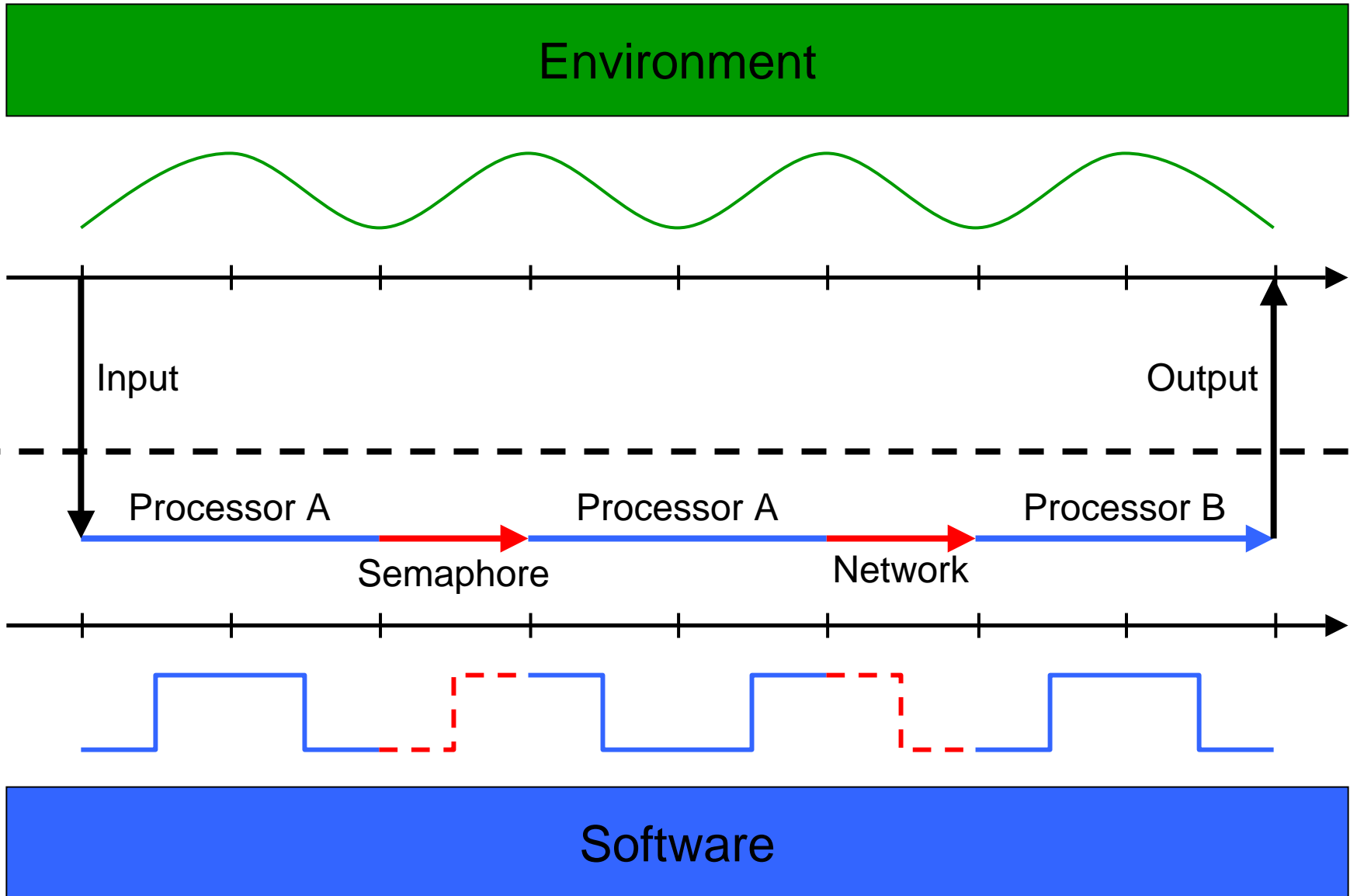


Soft Time

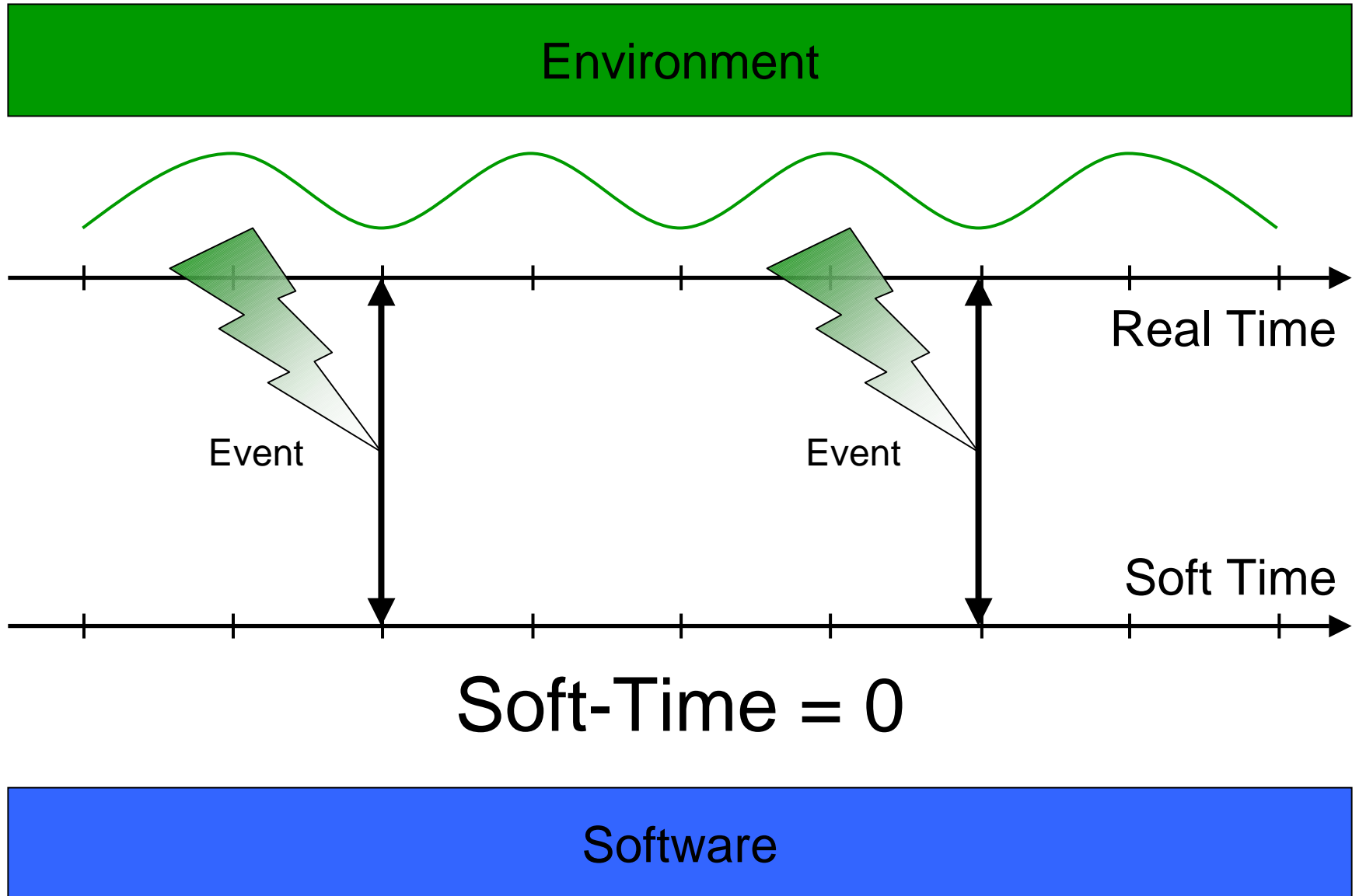


Software

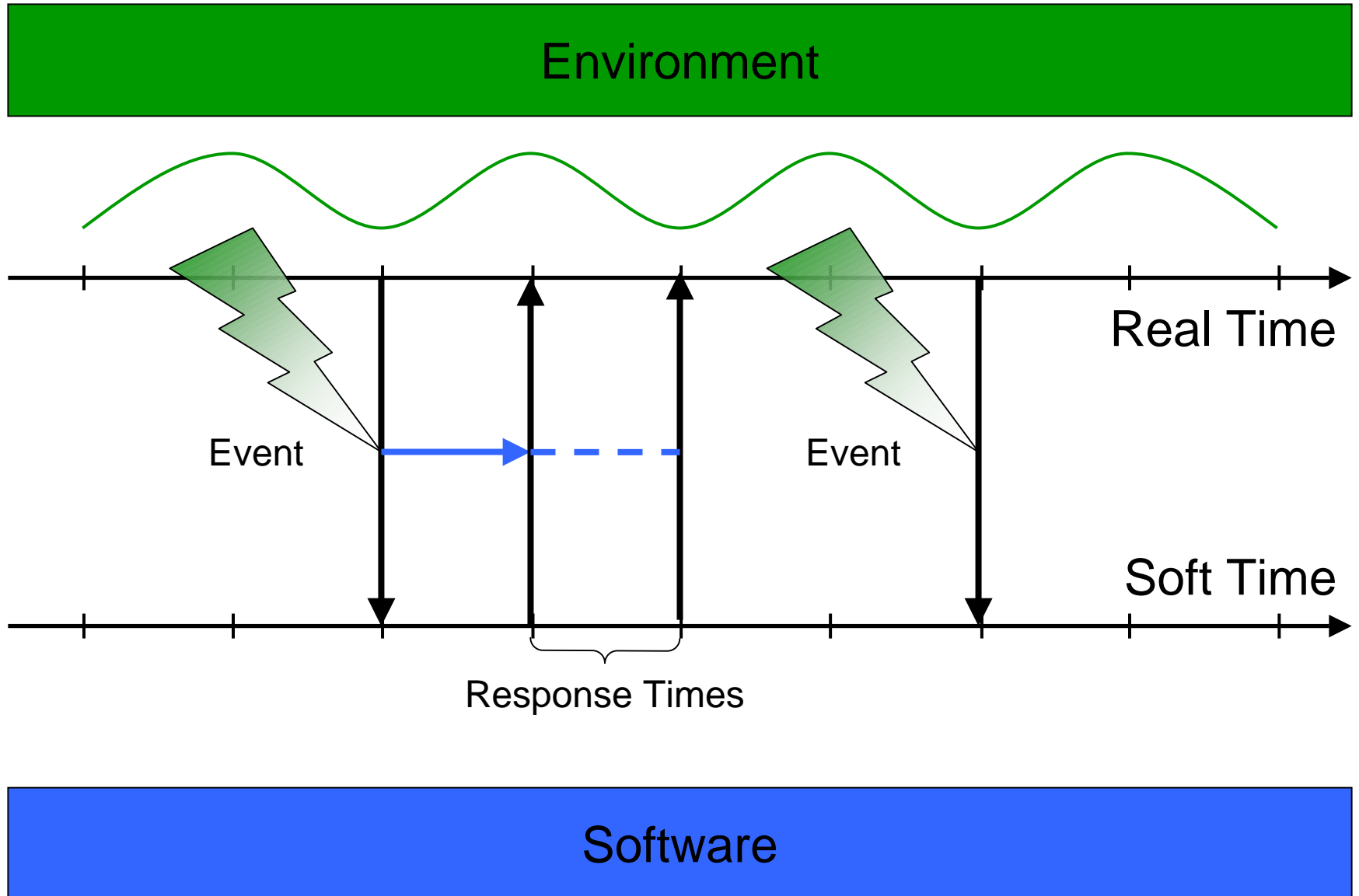
Soft Time



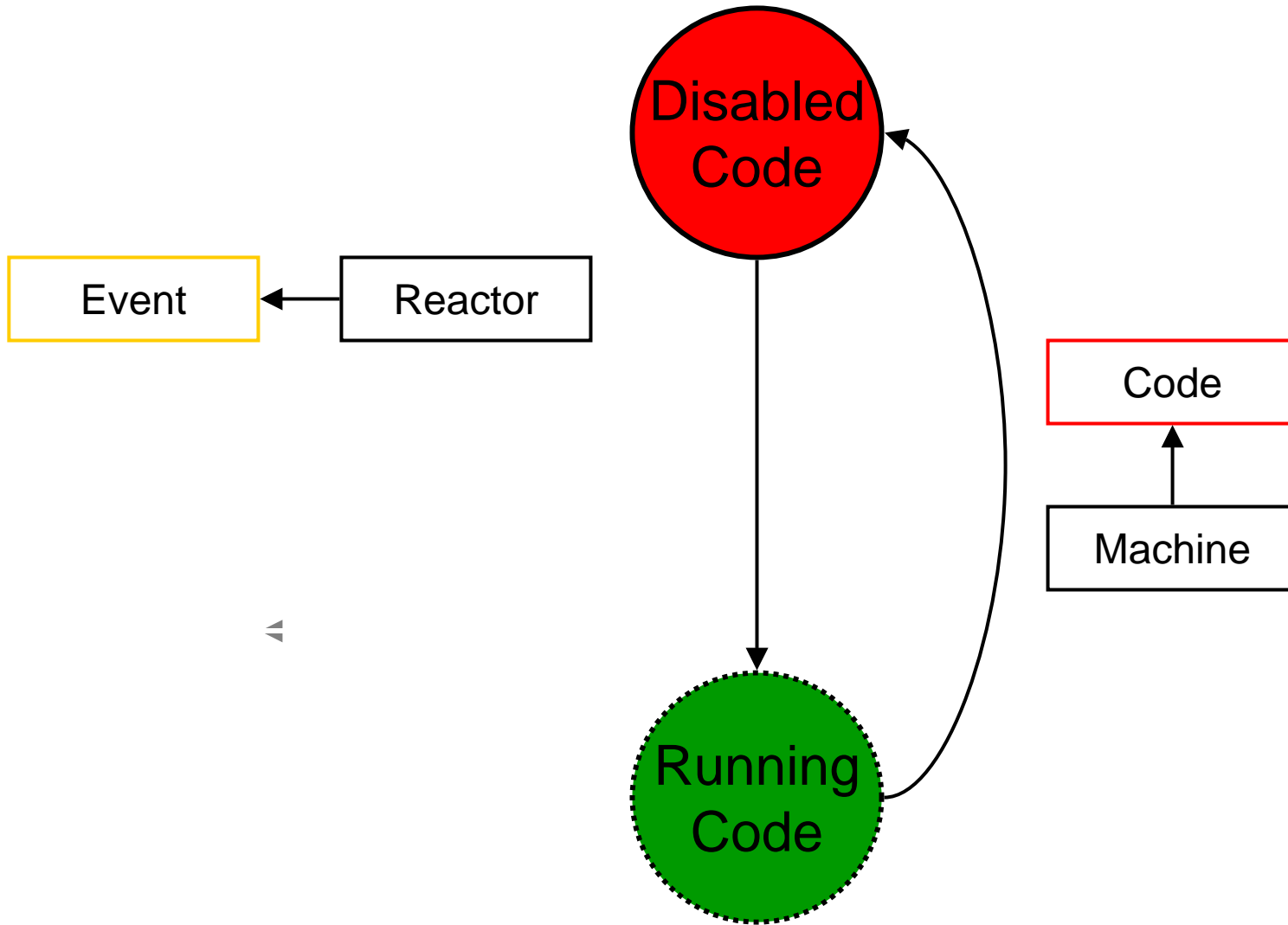
The Synchronous Model



A Synchronous Implementation



Event Safety



Synchrony

Environment

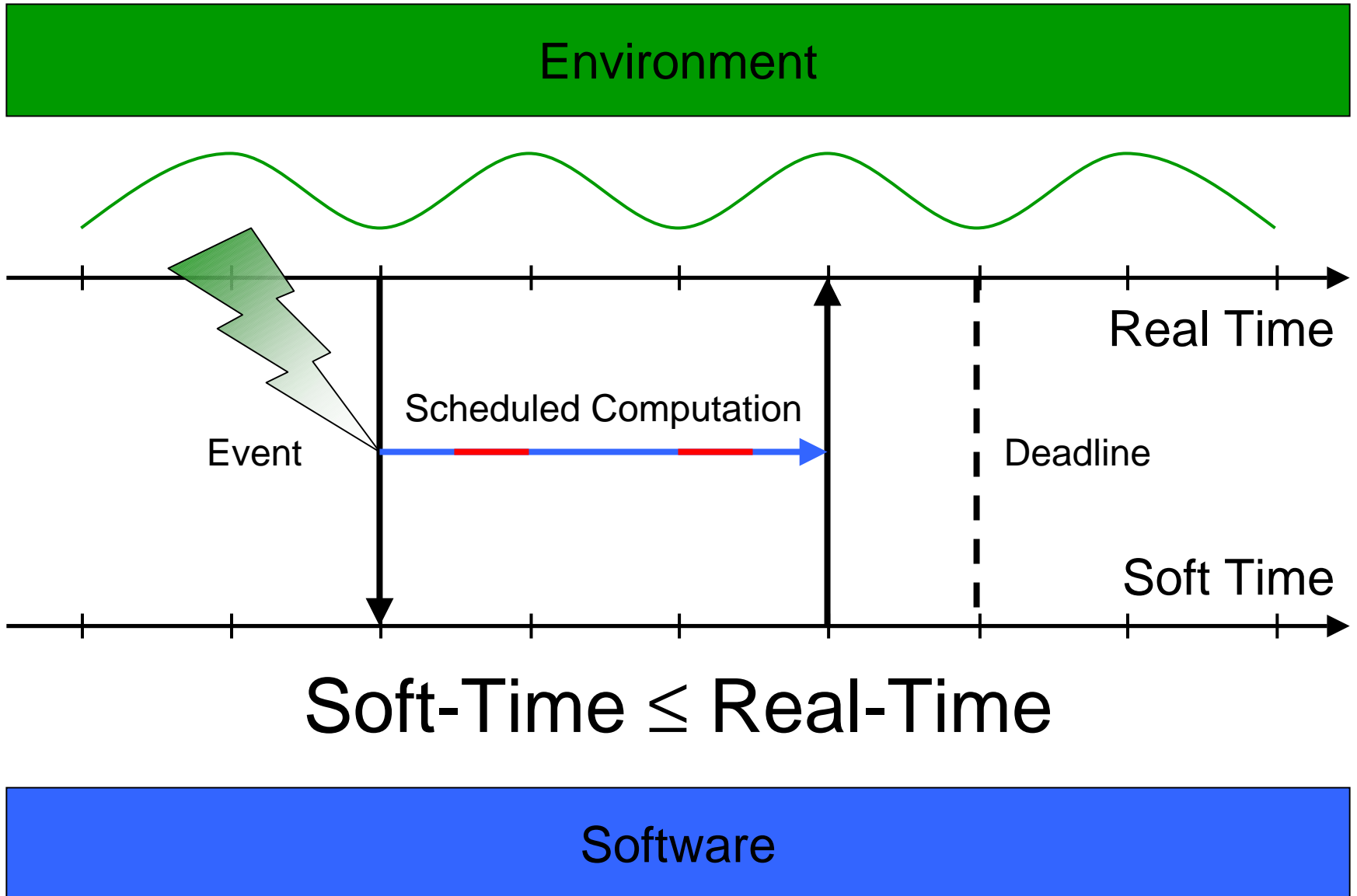
Real Time

Input

Output

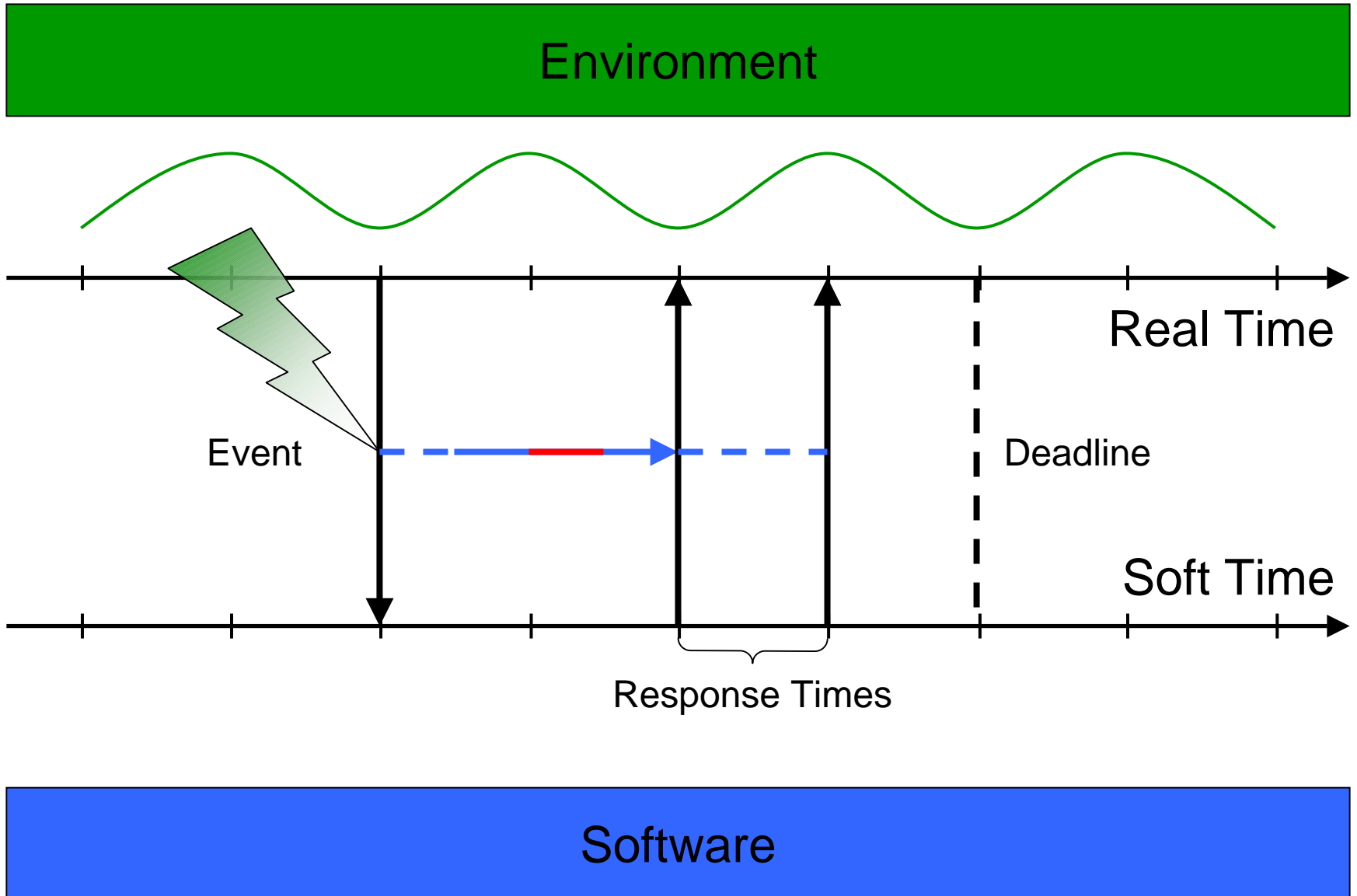
Software

The Scheduled Model

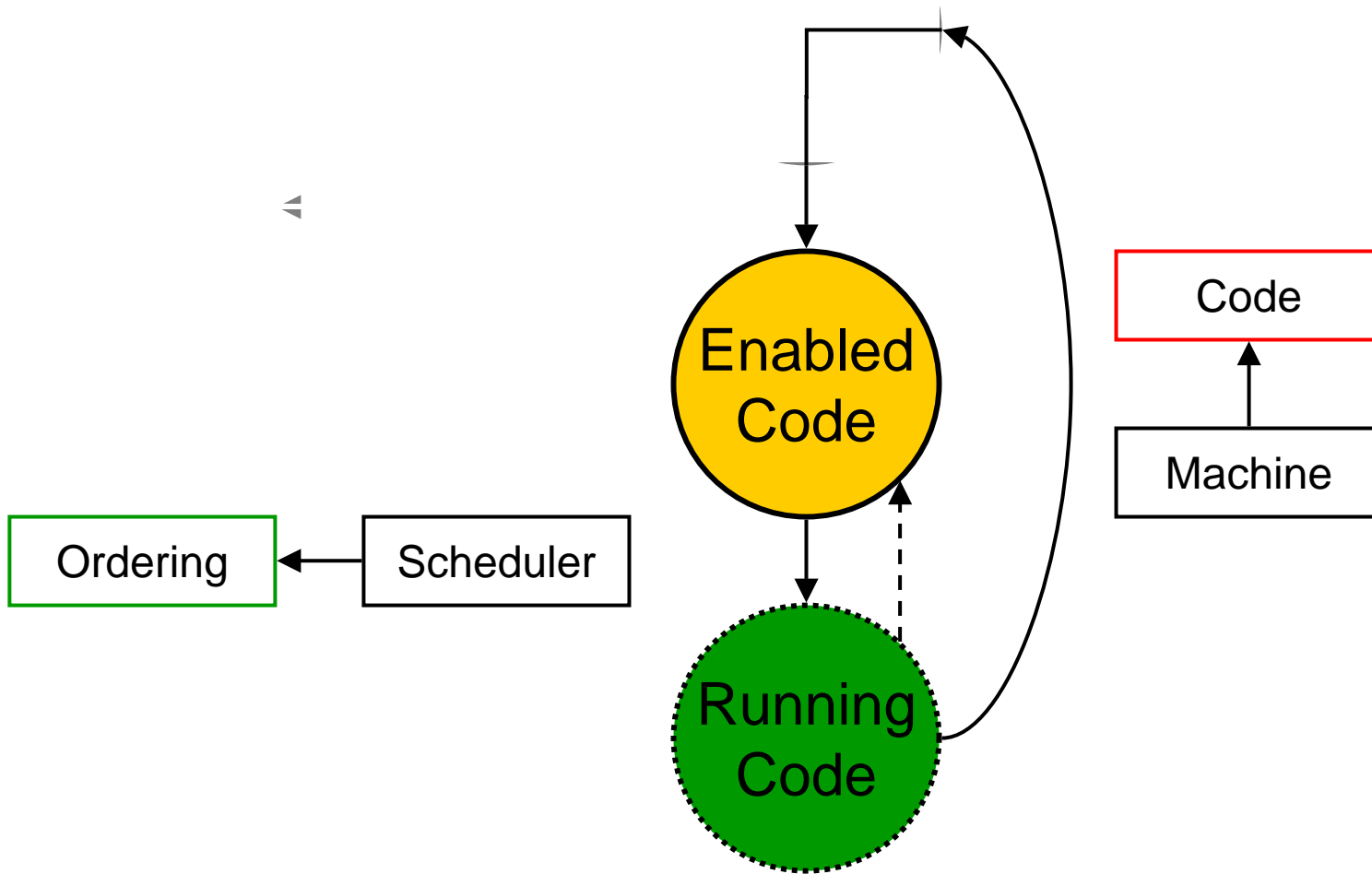


$$\text{Soft-Time} \leq \text{Real-Time}$$

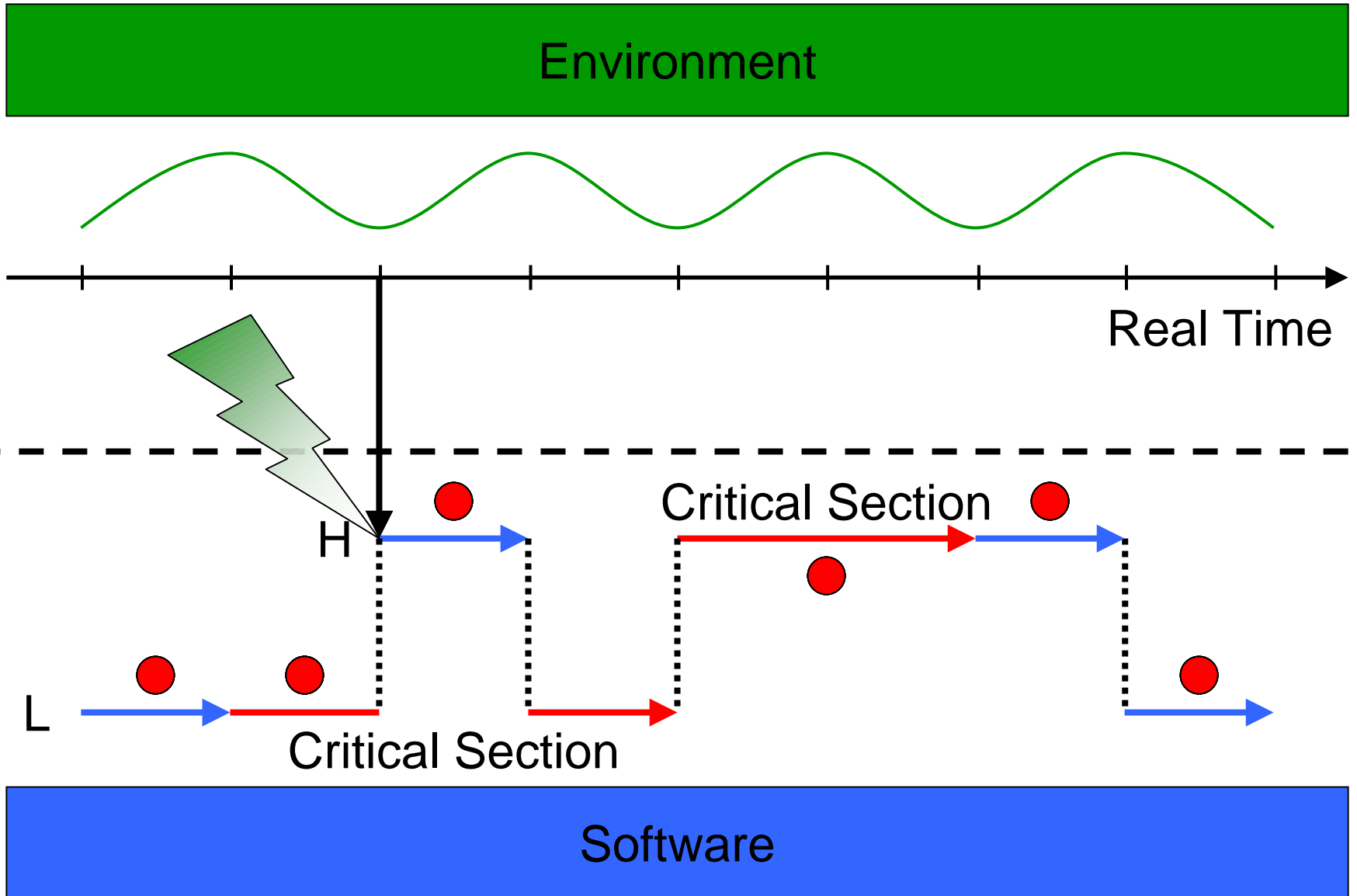
A Scheduled Implementation



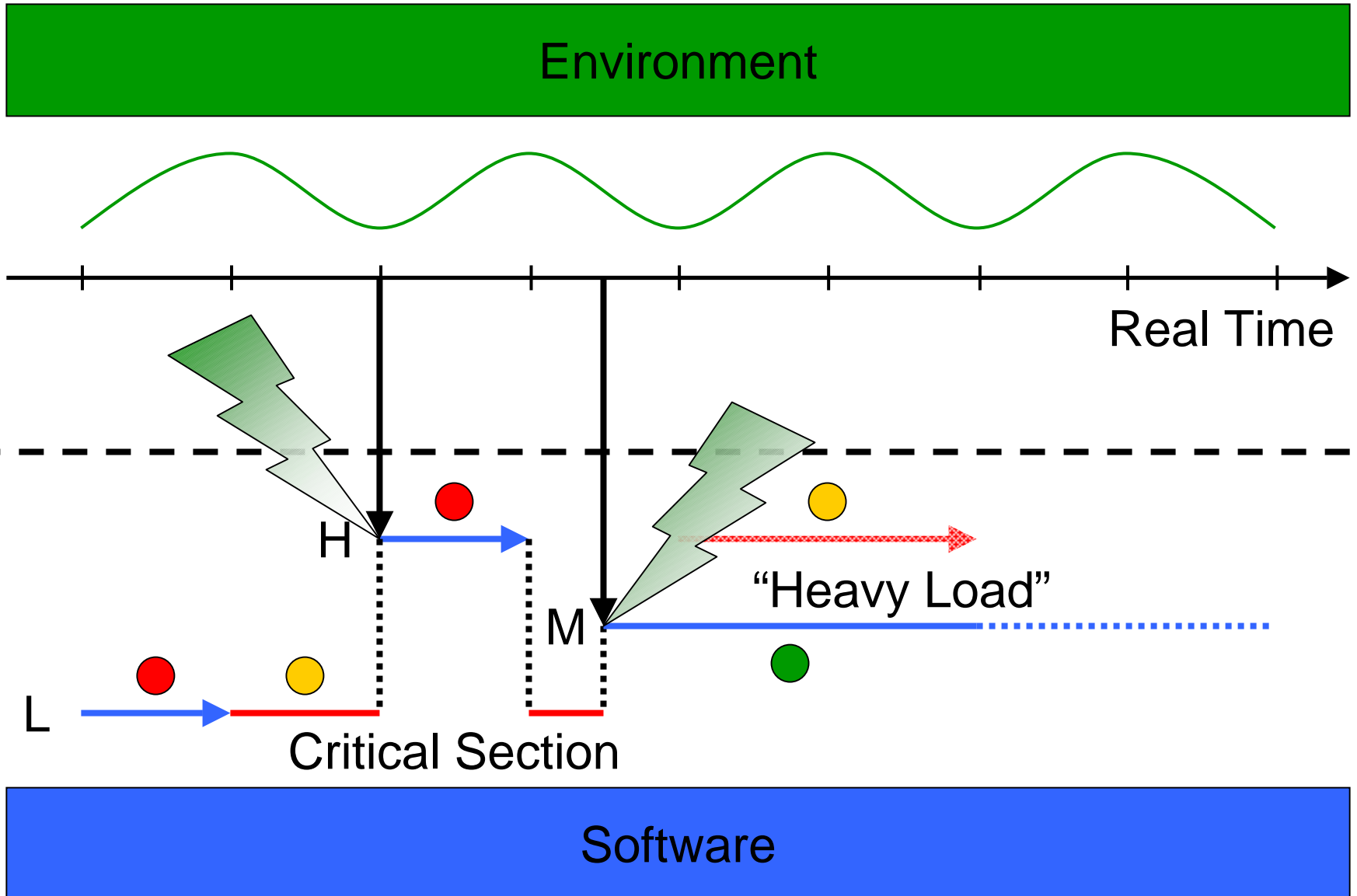
Space Safety



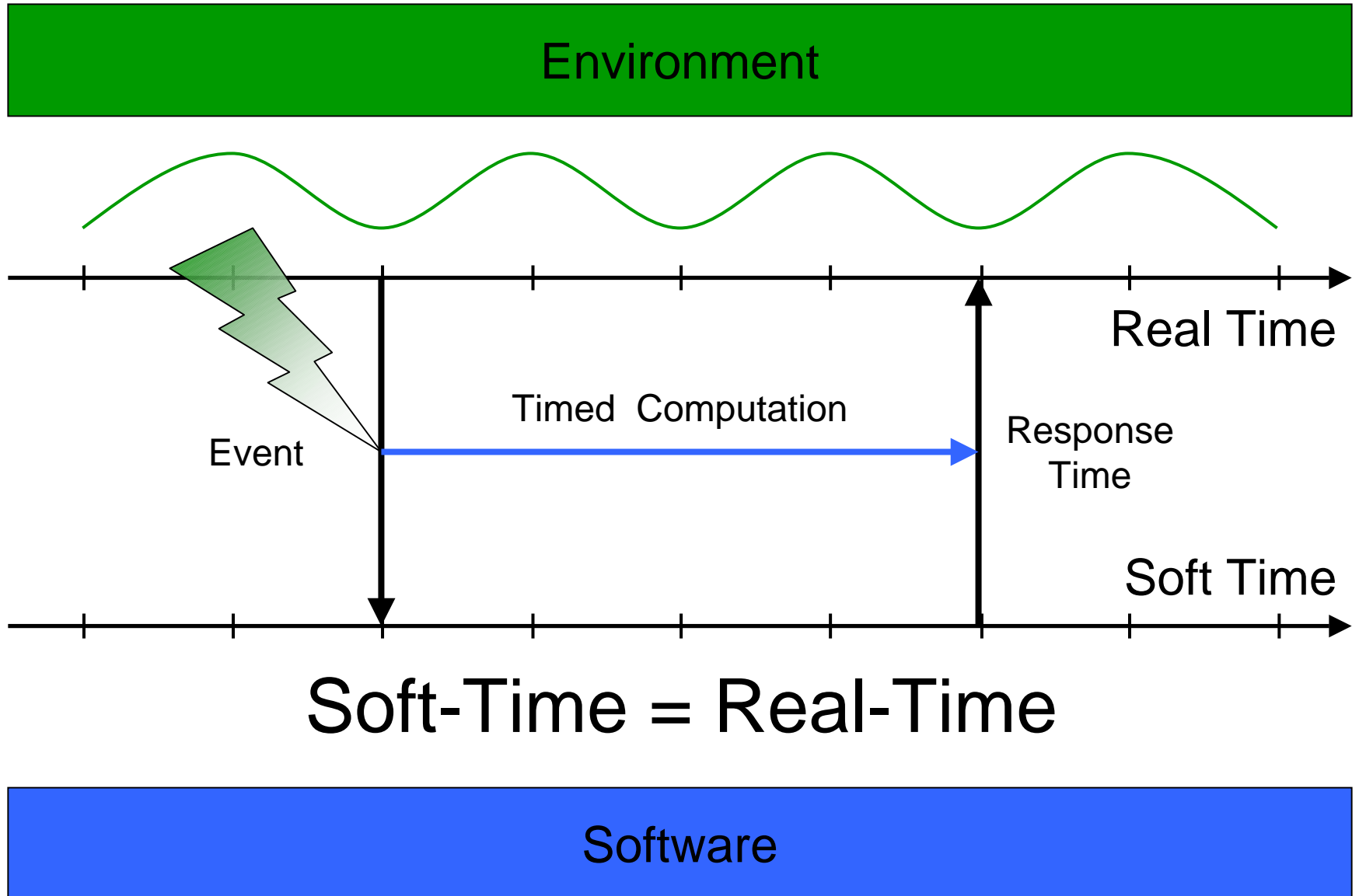
Priority Inversion



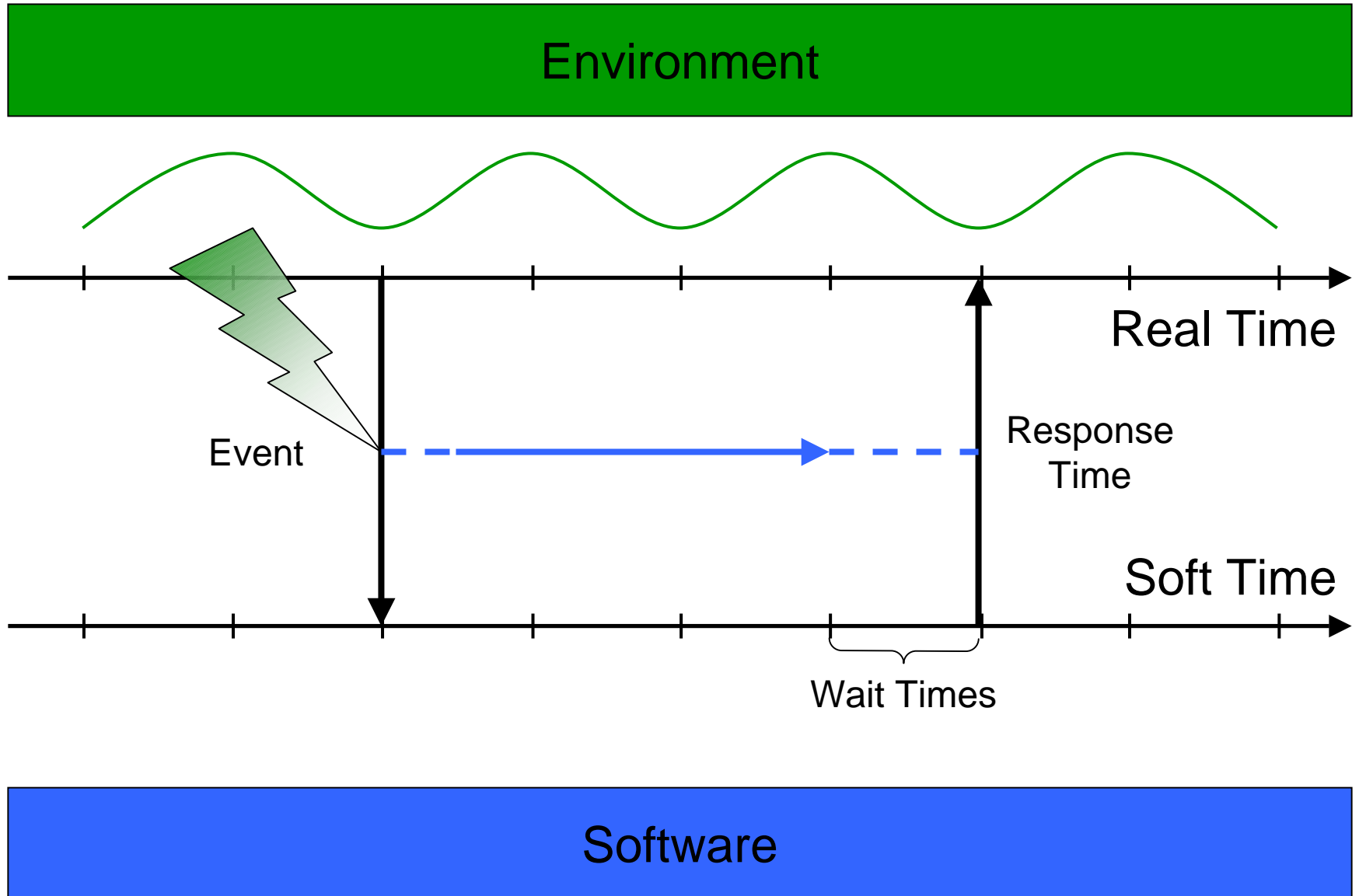
Unbounded Soft Time



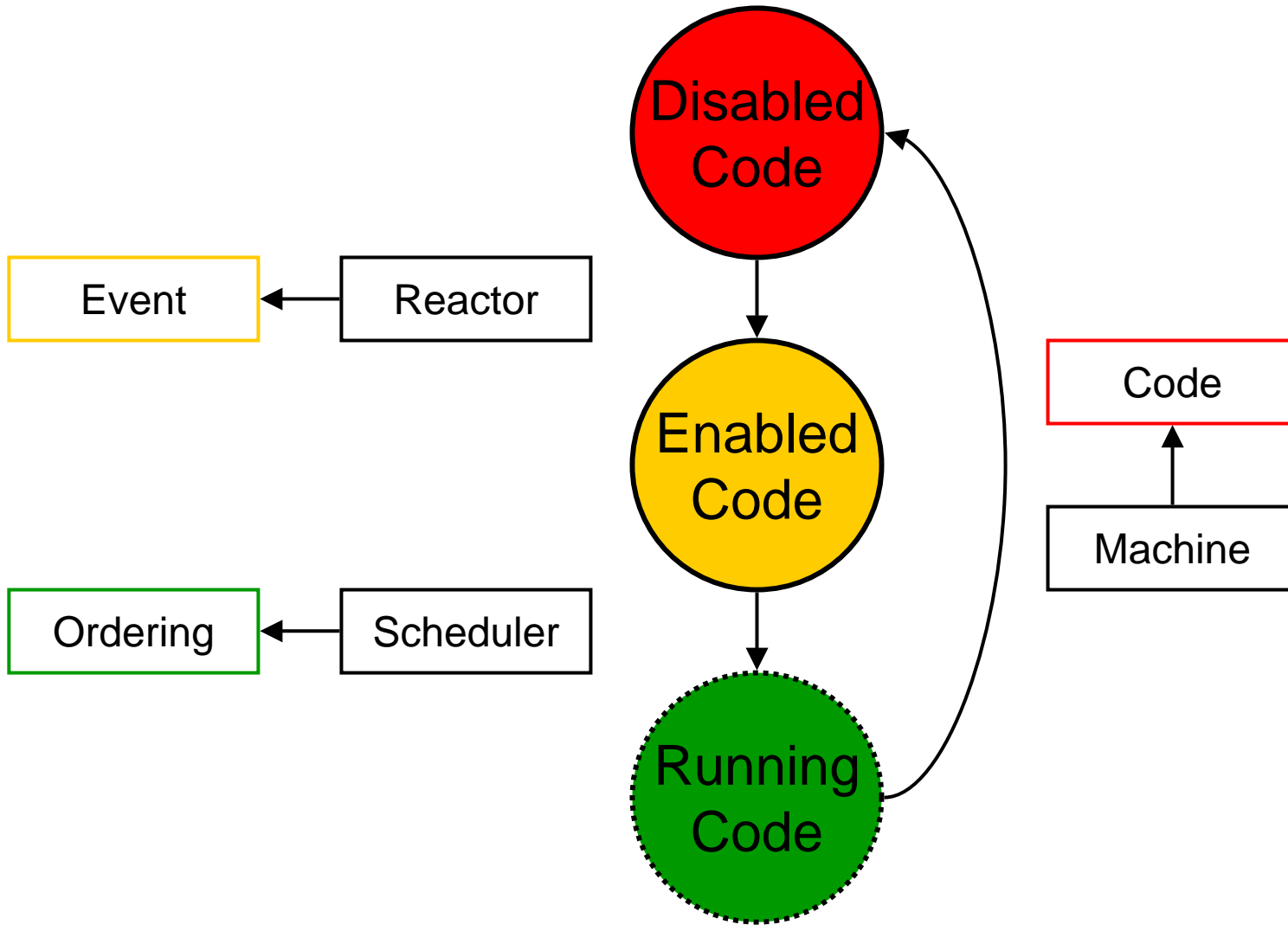
The Timed Model



A Timed Implementation

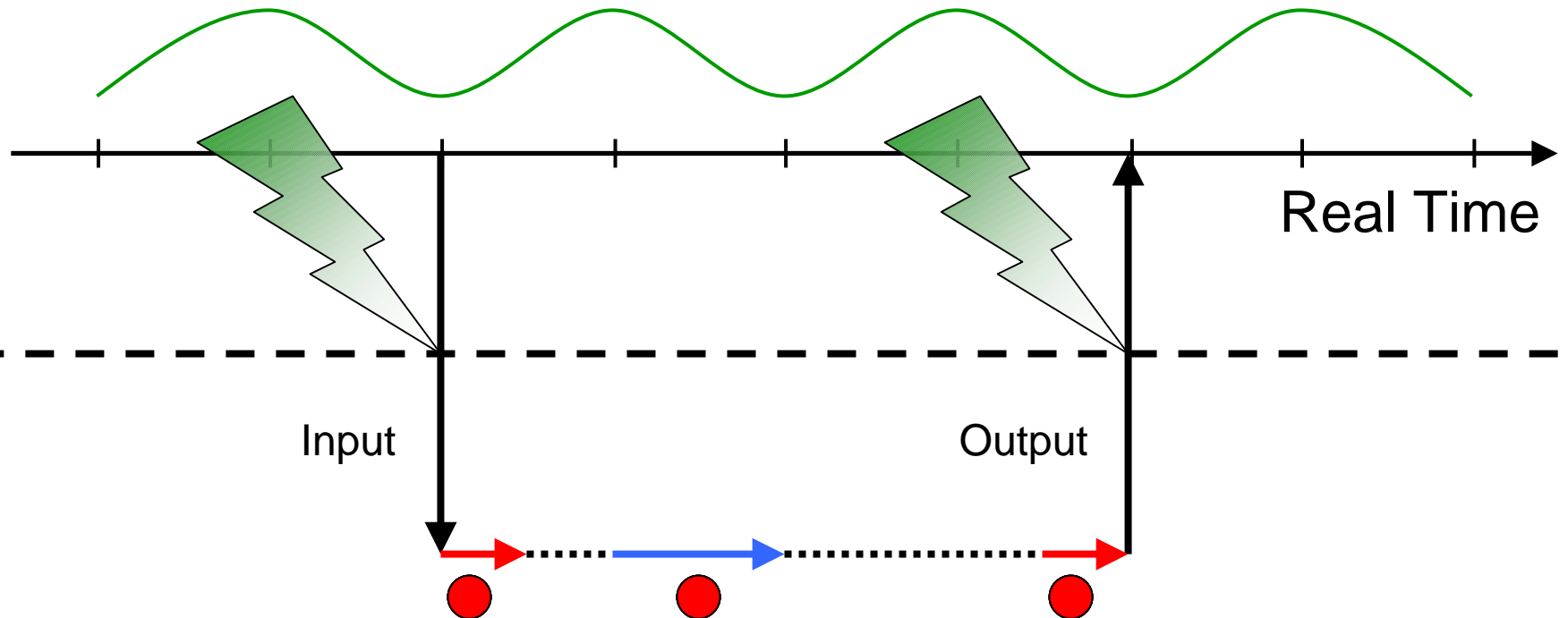


Time Safety



Software vs. Environment Event

Environment



Software

E Code

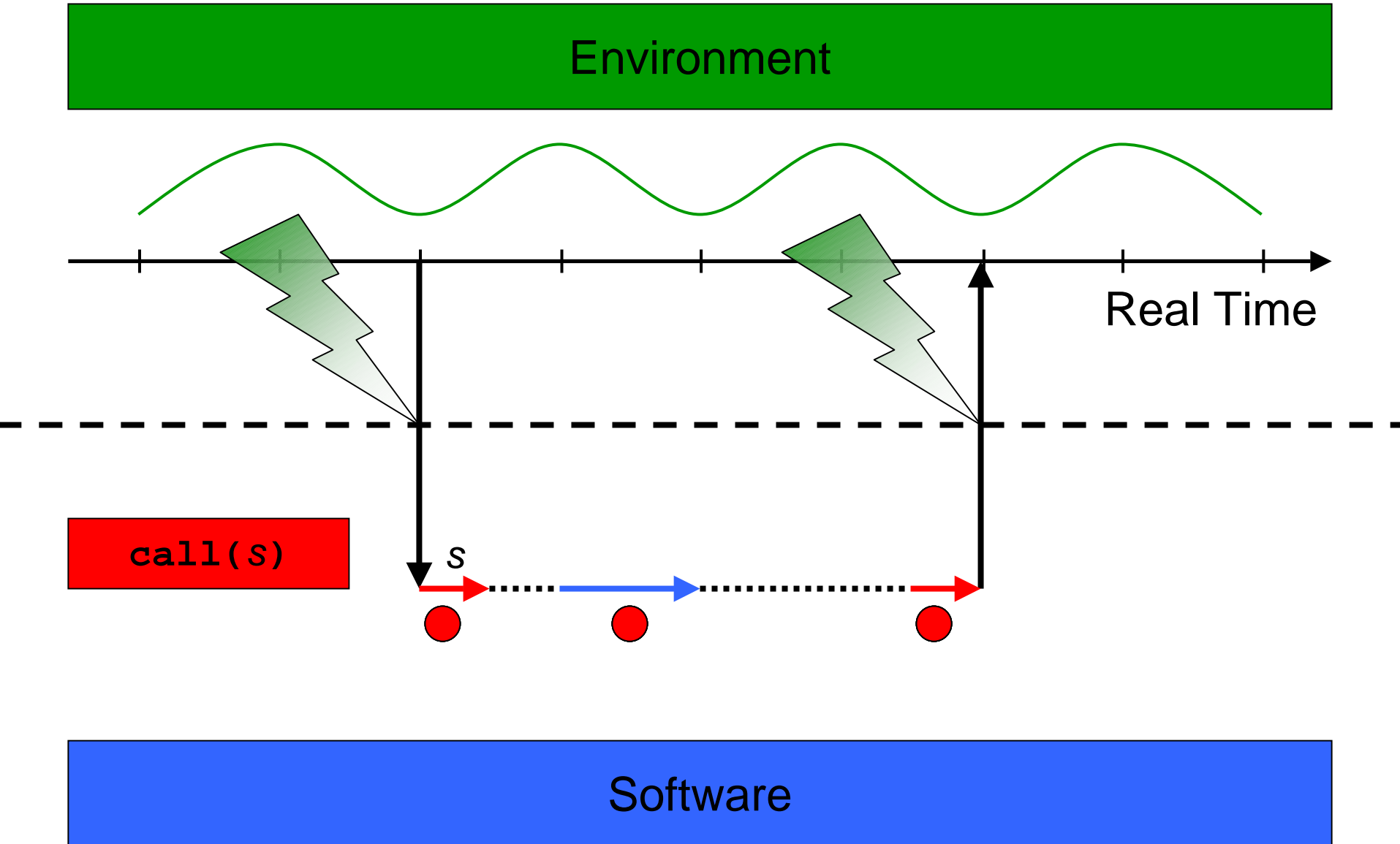
Environment

Real Time

`call(s)`

`s`

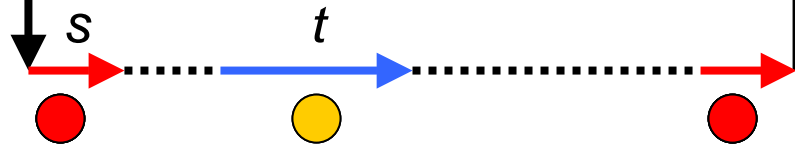
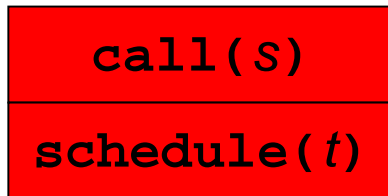
Software



E Code

Environment

Real Time



Software

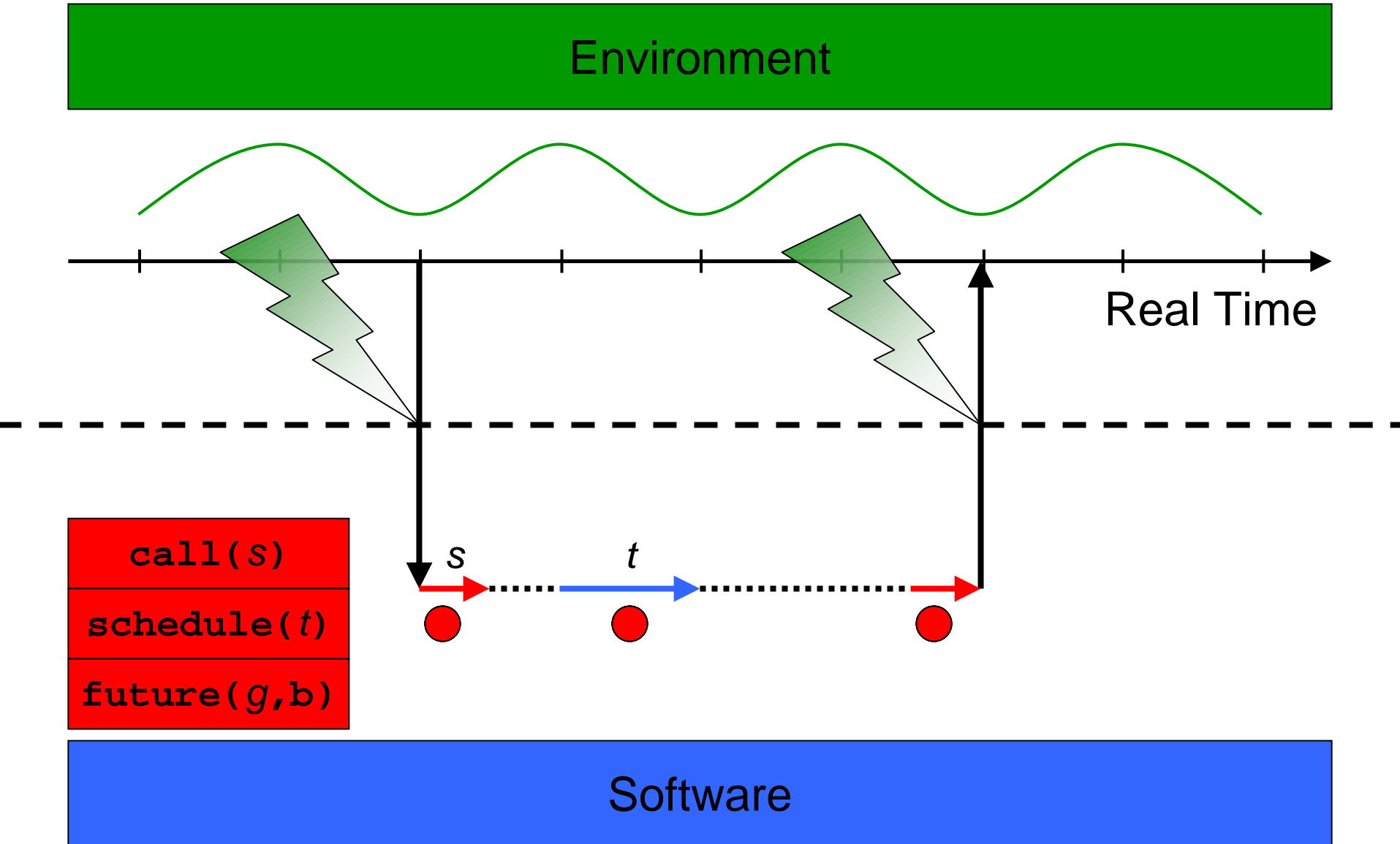
E Code

Environment

Real Time

<code>call(s)</code>
<code>schedule(t)</code>
<code>future(g,b)</code>

Software



E Code

Environment

Real Time

b:

`call(a)`

`call(s)`

`schedule(t)`

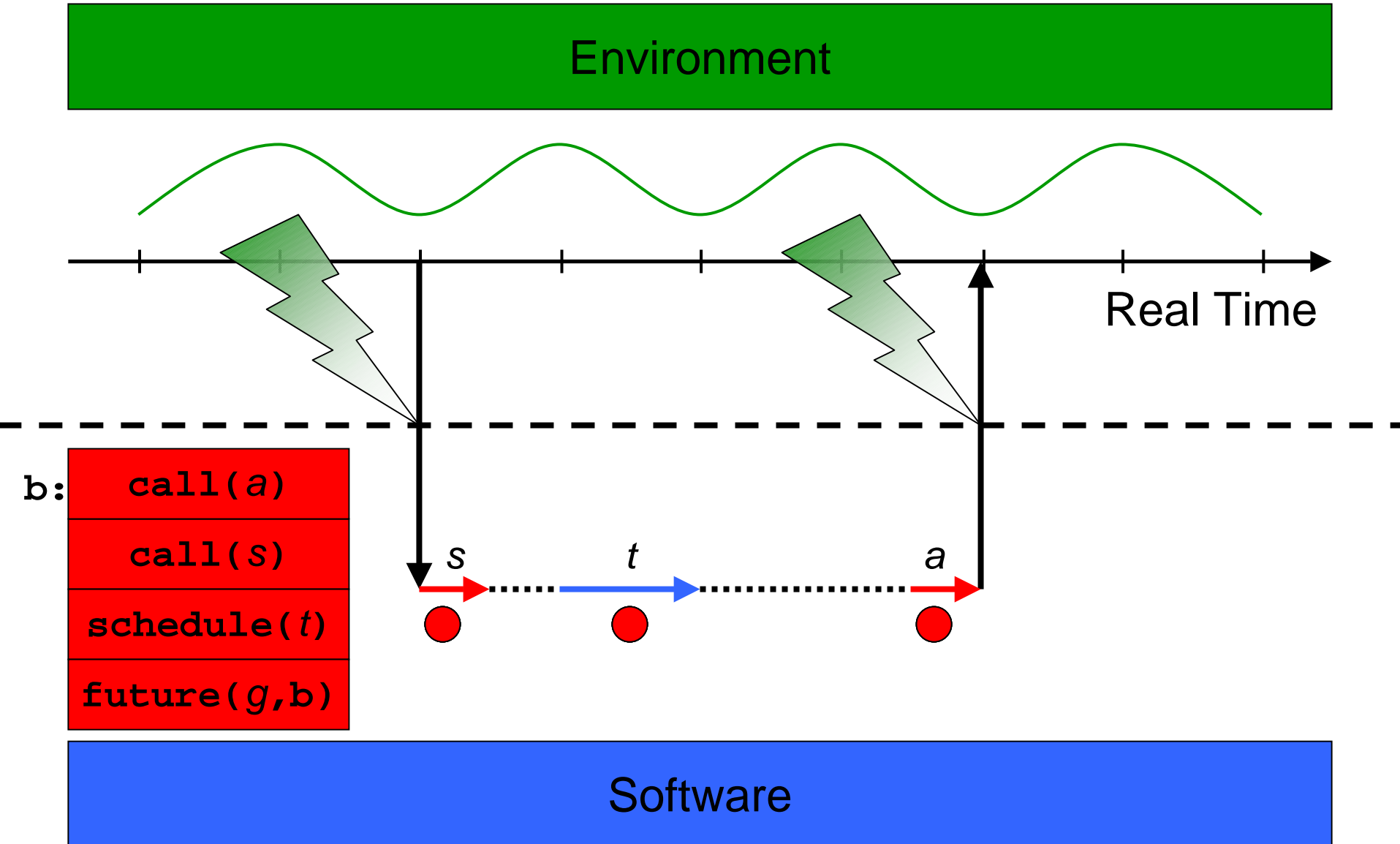
`future(g,b)`

s

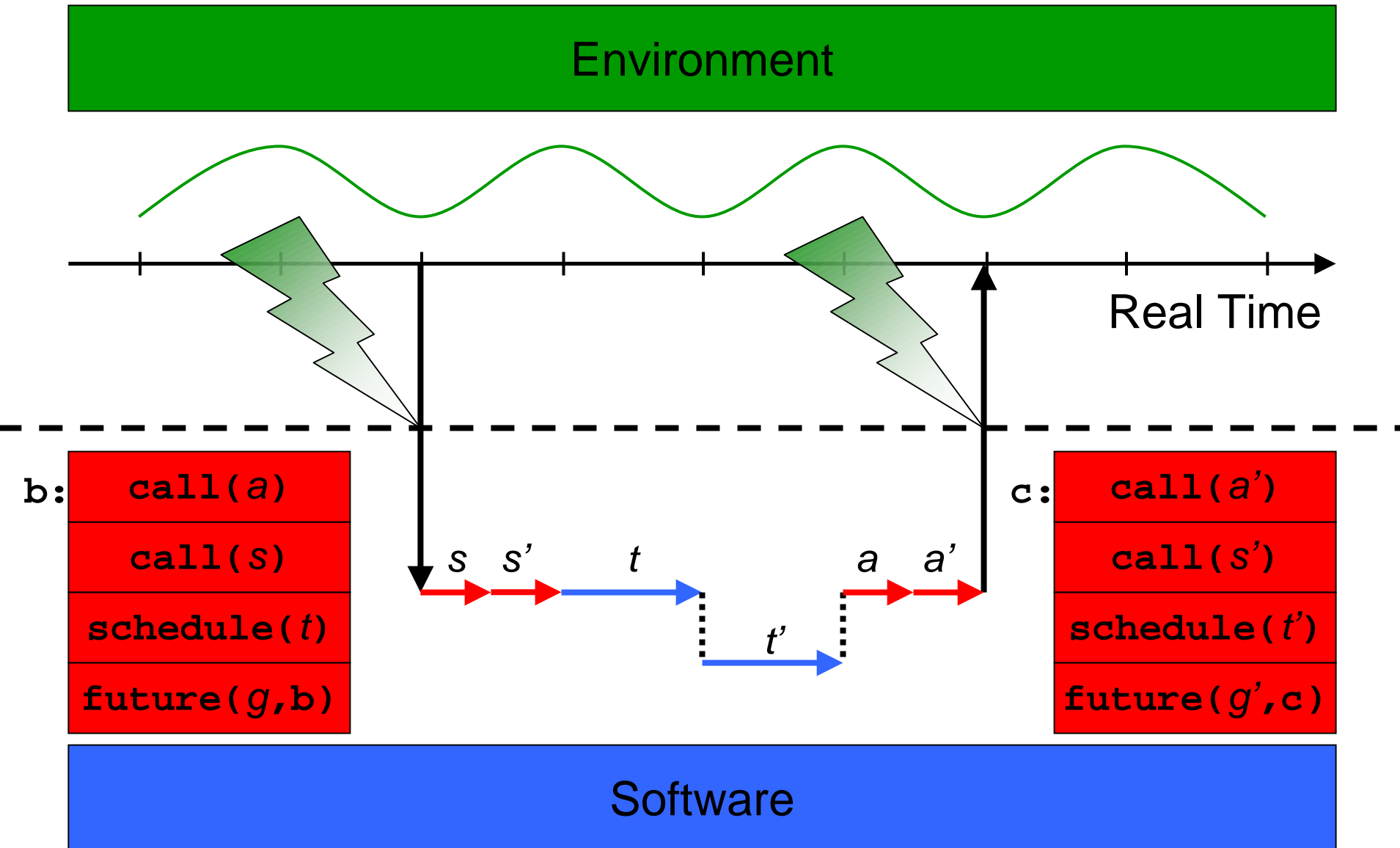
t

a

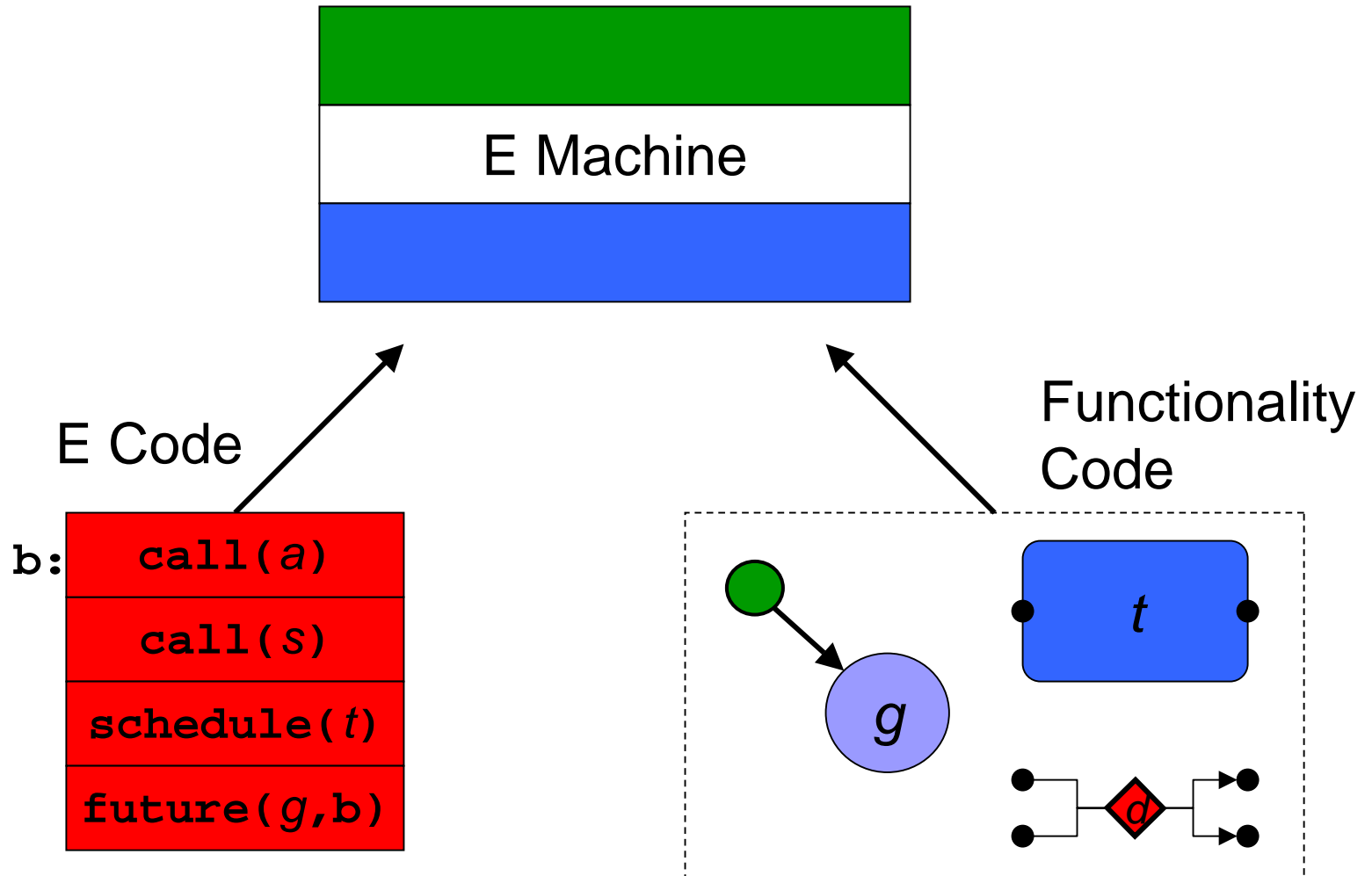
Software



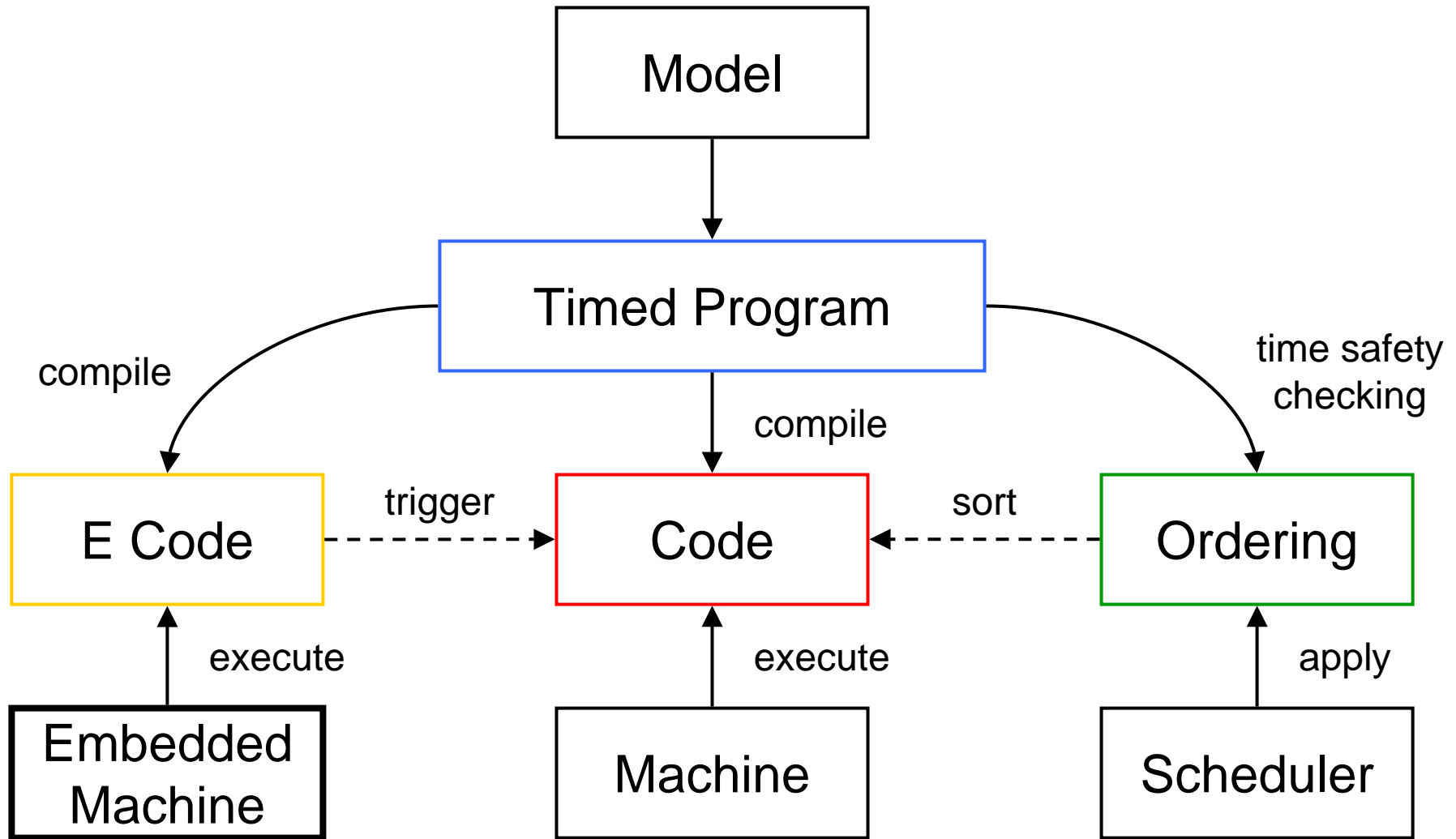
Composability and Time Safety



Dynamic Linking



The Embedded Machine



Credits

- Synchronous Programming:
 - Esterel
 - Lustre
 - Signal
 - and many more
- Scheduled Programming:
 - Real-Time Operating Systems
 - Real-Time Scheduling Theory
 - Real-Time Communication Protocols
- Classical Compiler Technology:
 - Modular/Incremental Compilation
 - Abstract Machines