What Happened on Mars?

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What Happened On Mars?

- Mars Pathfinder probe (1997)
- Nice launch
- Nice transit
- Nice de-orbit
- Nice thump-down (inflatable air-bag)
- Nice rover disembarkation
- Nice rover ***spontaneous reboots***

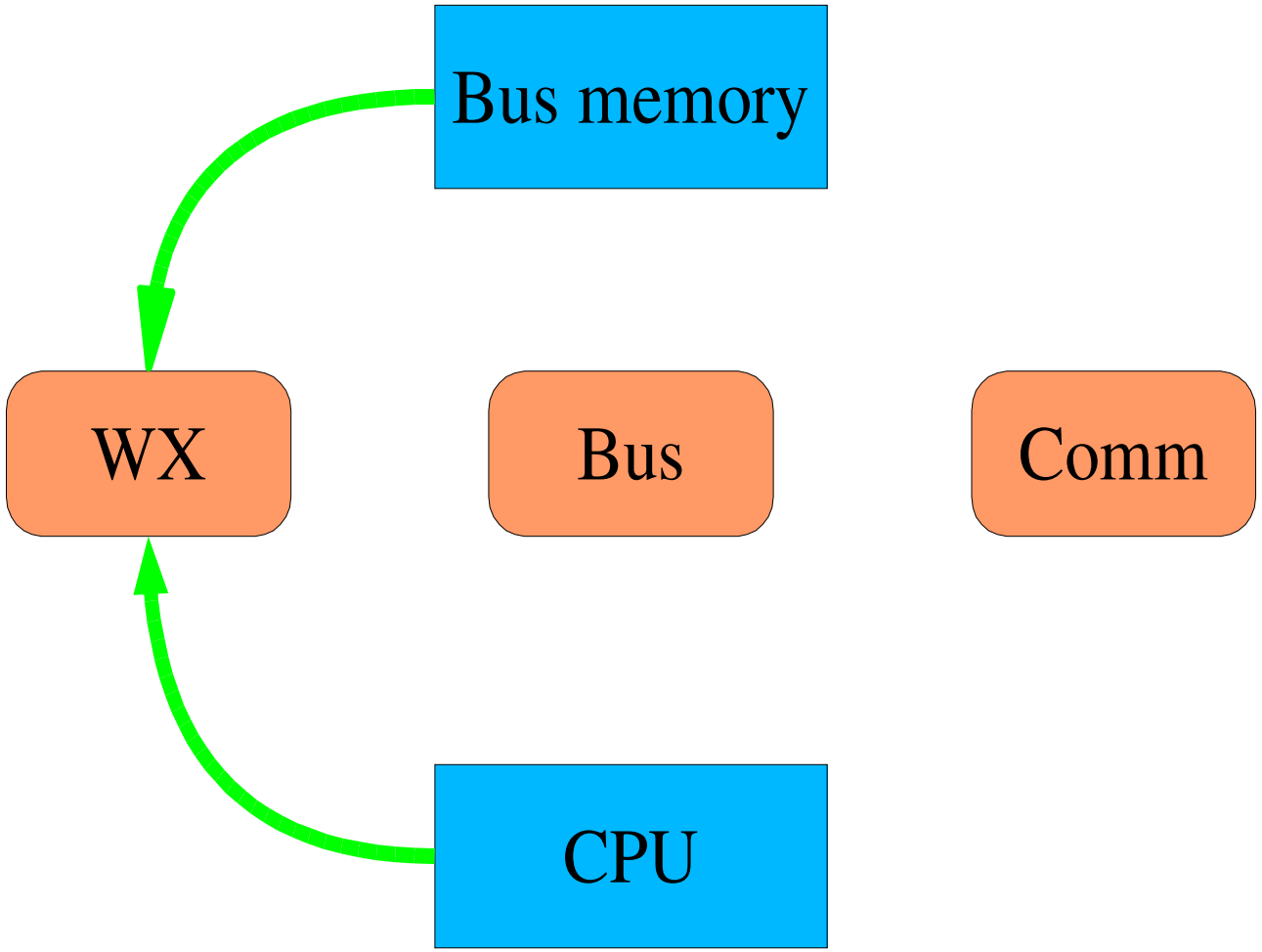
Internal Architecture

- "Information bus" (blackboard/whiteboard/...)
  - High-priority bus manager thread
- Meteorological data gathering
  - Occasional activity
  - Low-priority weather data thread
- Communication with Earth
  - Medium-priority communication thread
- Watchdog thread: "too quiet"? ***Reboot***

What could go wrong?

- Weather data locks “bus” memory to publish
- High-priority bus manager must wait

What could go wrong?



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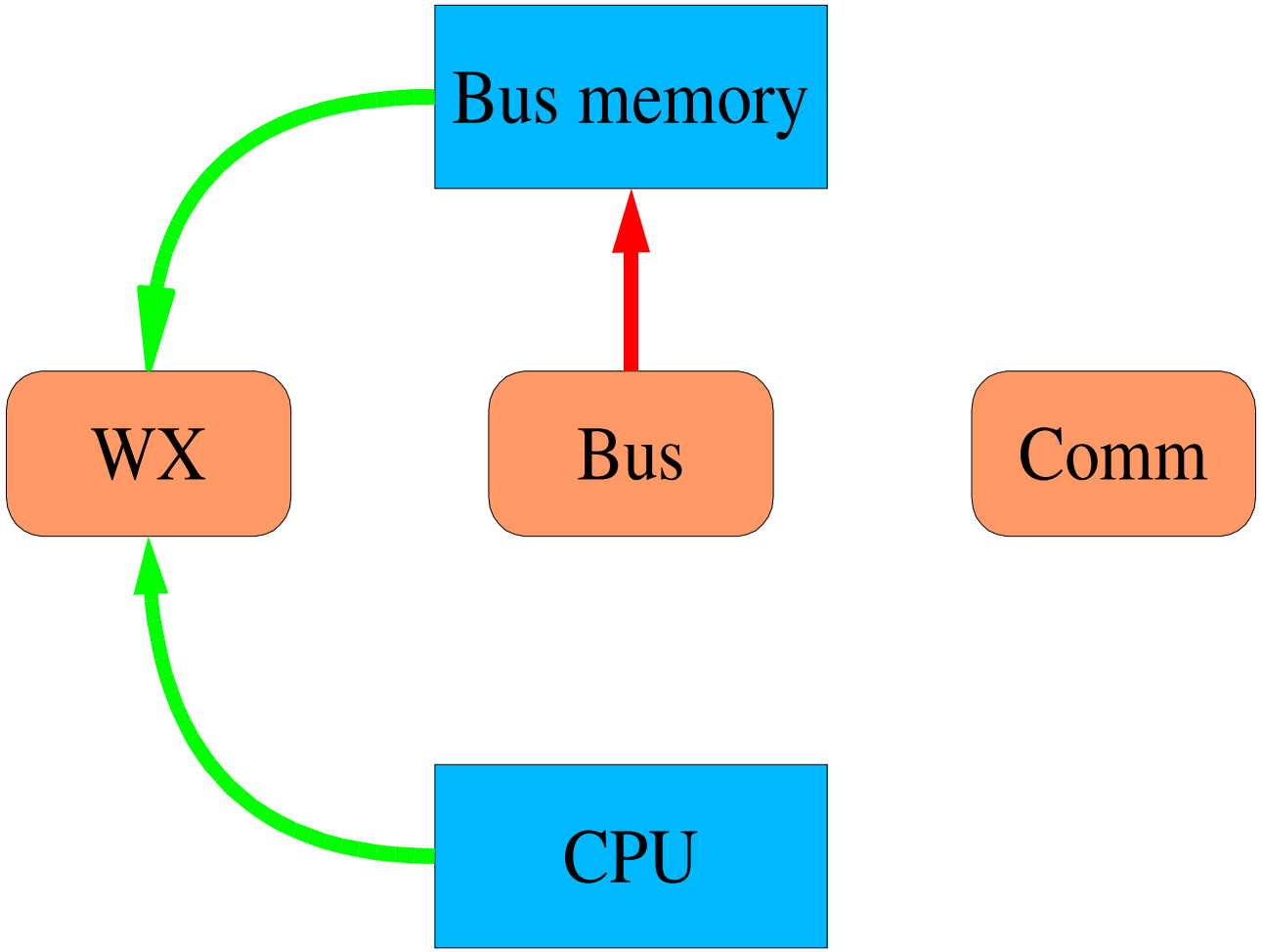

What could go wrong?

- Weather data locks "bus" memory to publish
- High-priority bus manager must wait
- ***Interrupt*** makes communication runnable
  - "Medium" priority, so preempts weather data
  - communication then attempts to lock bus
  - Highest-priority runnable task, so it spin-waits

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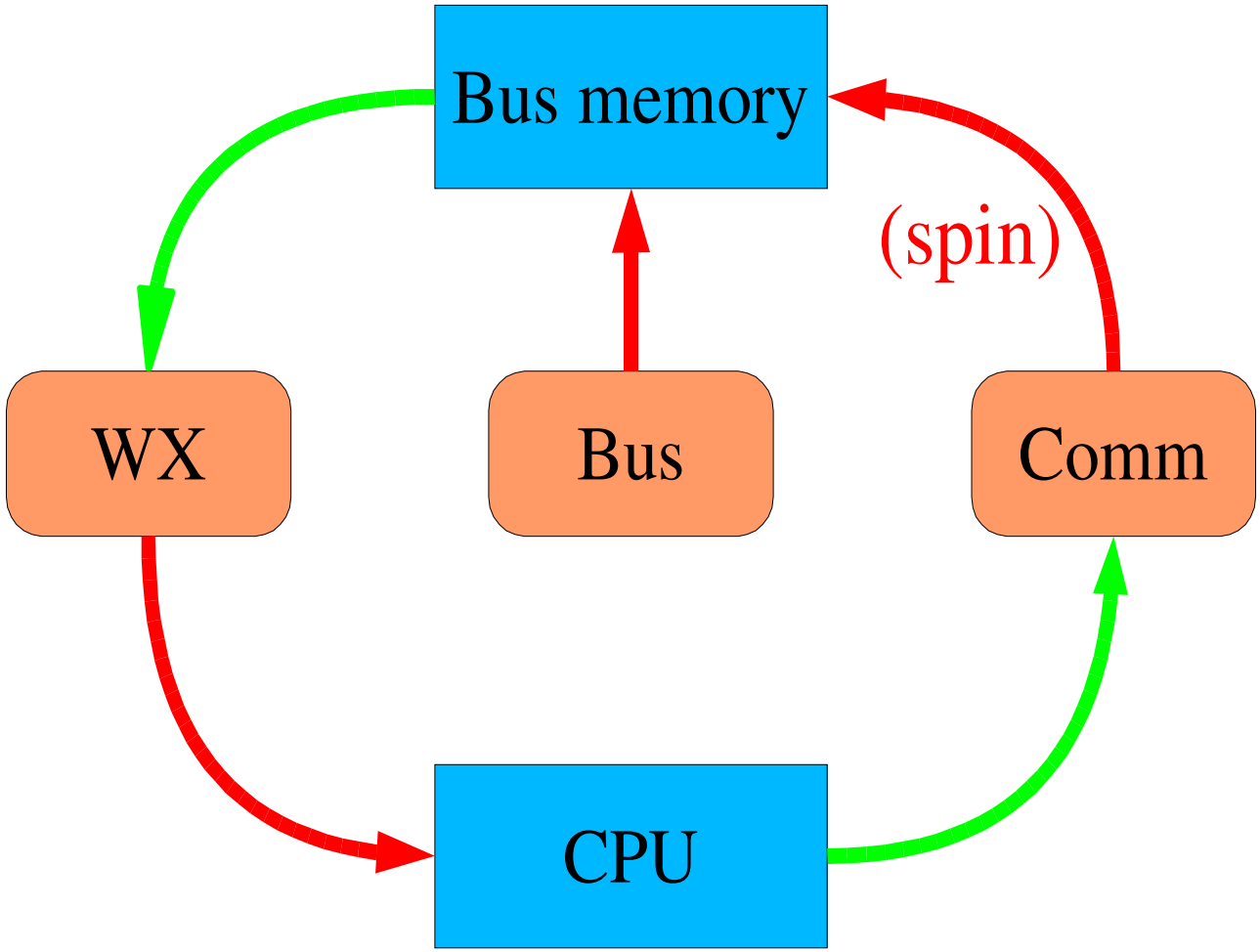

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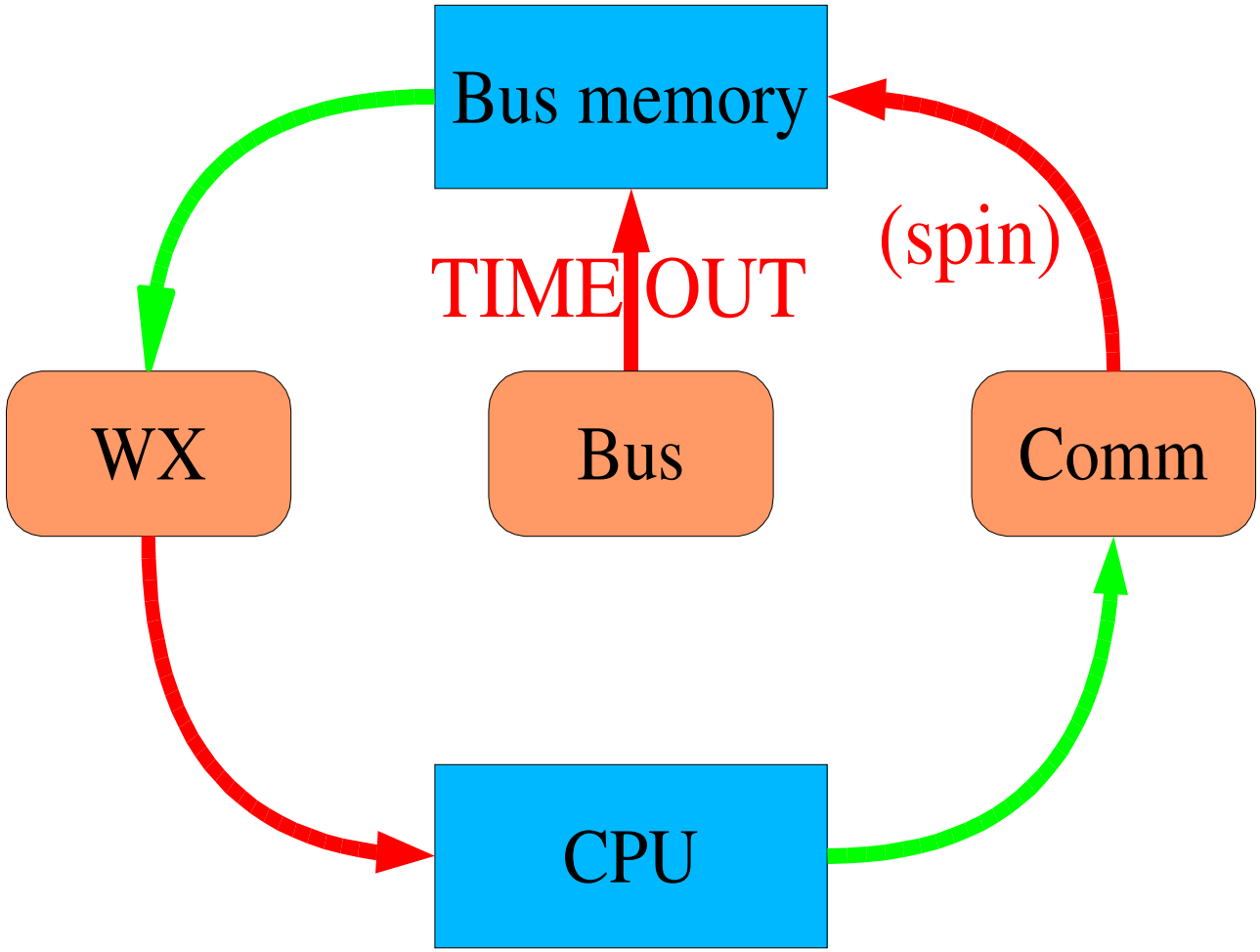

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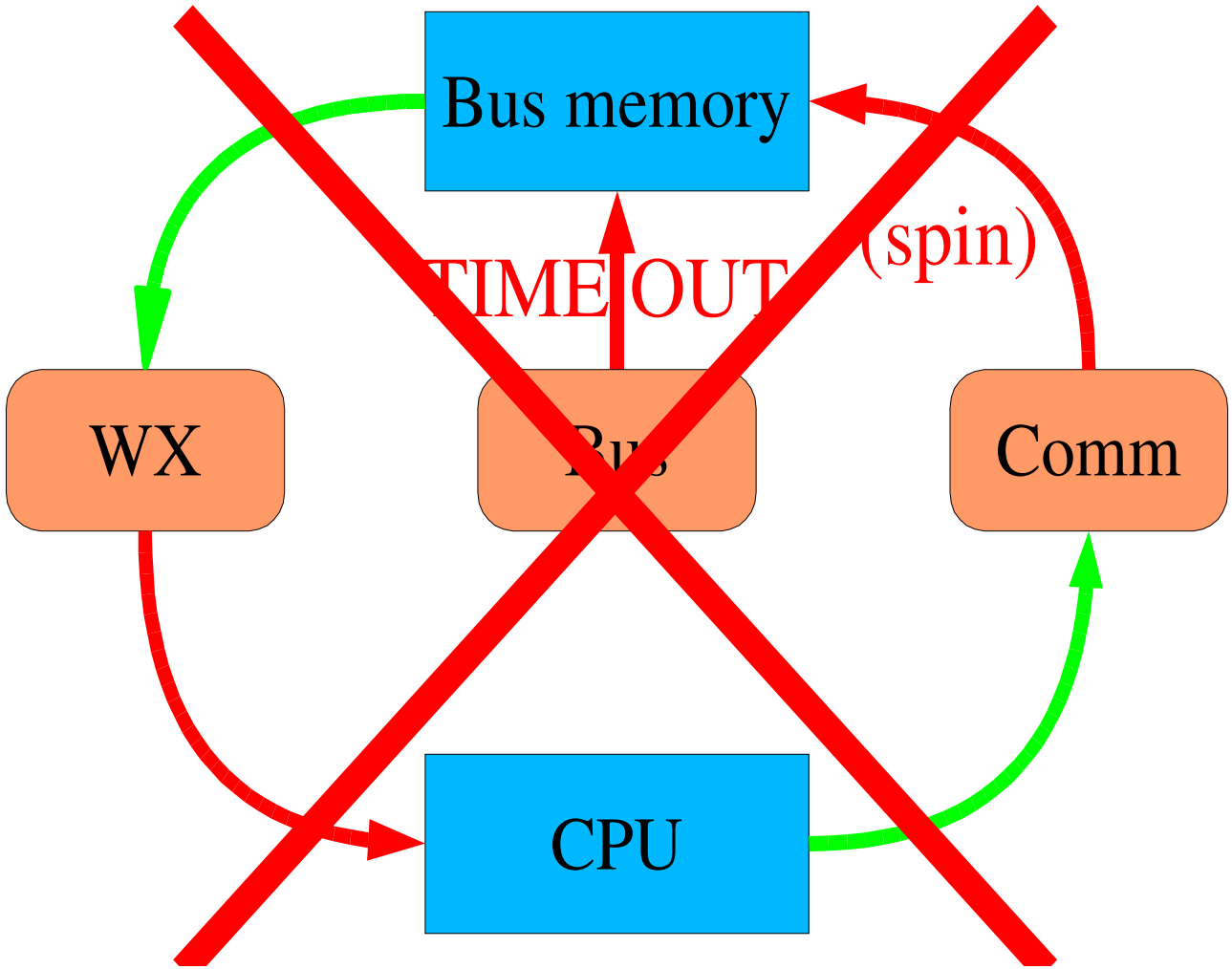
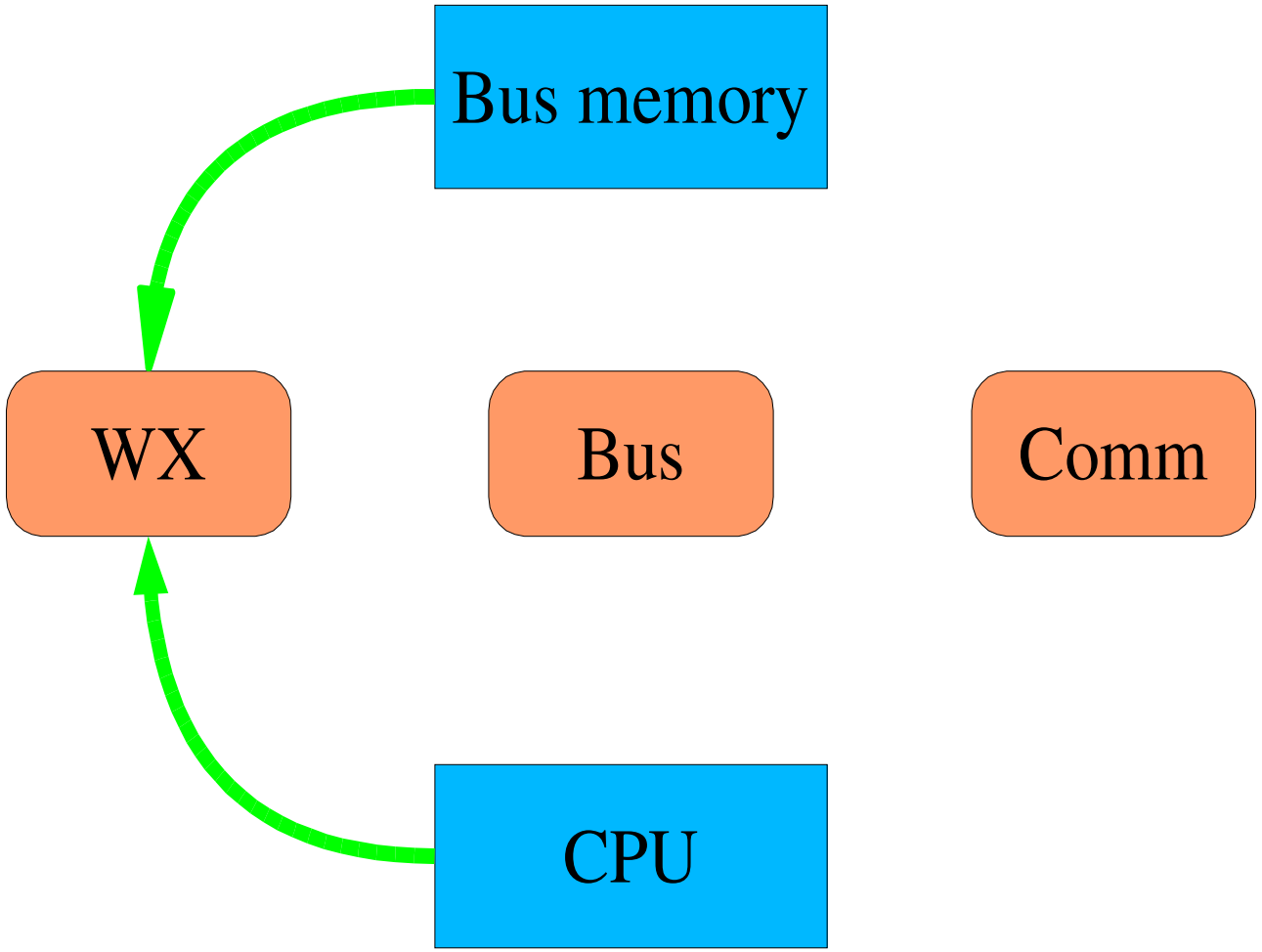


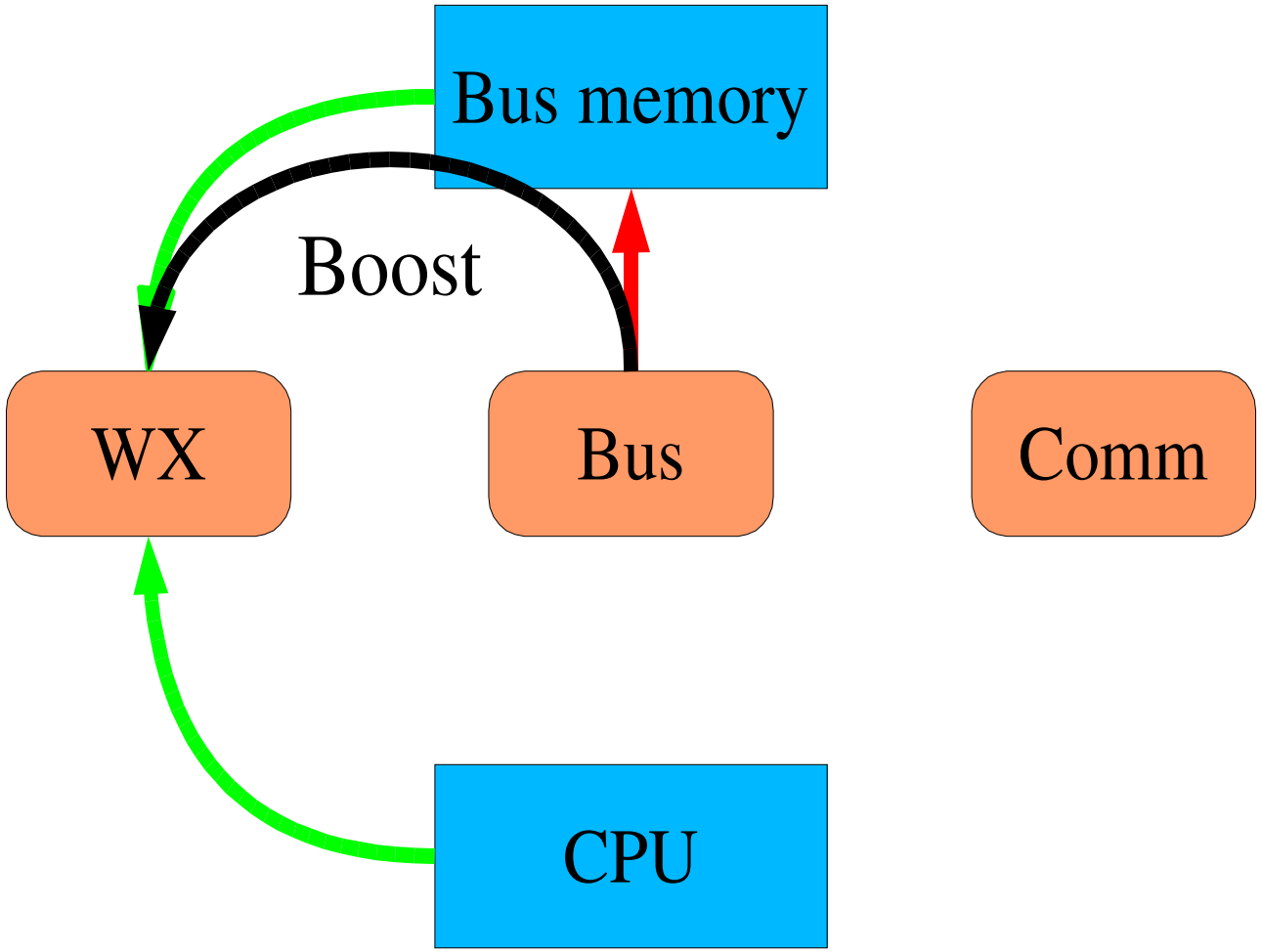
Solution?

- VxWorks has two mutex flavors
  - Normal
  - ***Priority Inheritance***
- Rover code initialized flavor via global variables
- Rover flew with “debug” interpreter enabled
  - Read-eval loop waiting for commands
  - % assign bus_mutex_flavor = MF_P_INHERIT
- All fixed

Weather Thread is Busy



Bus Thread Waits: Priority Inherited!



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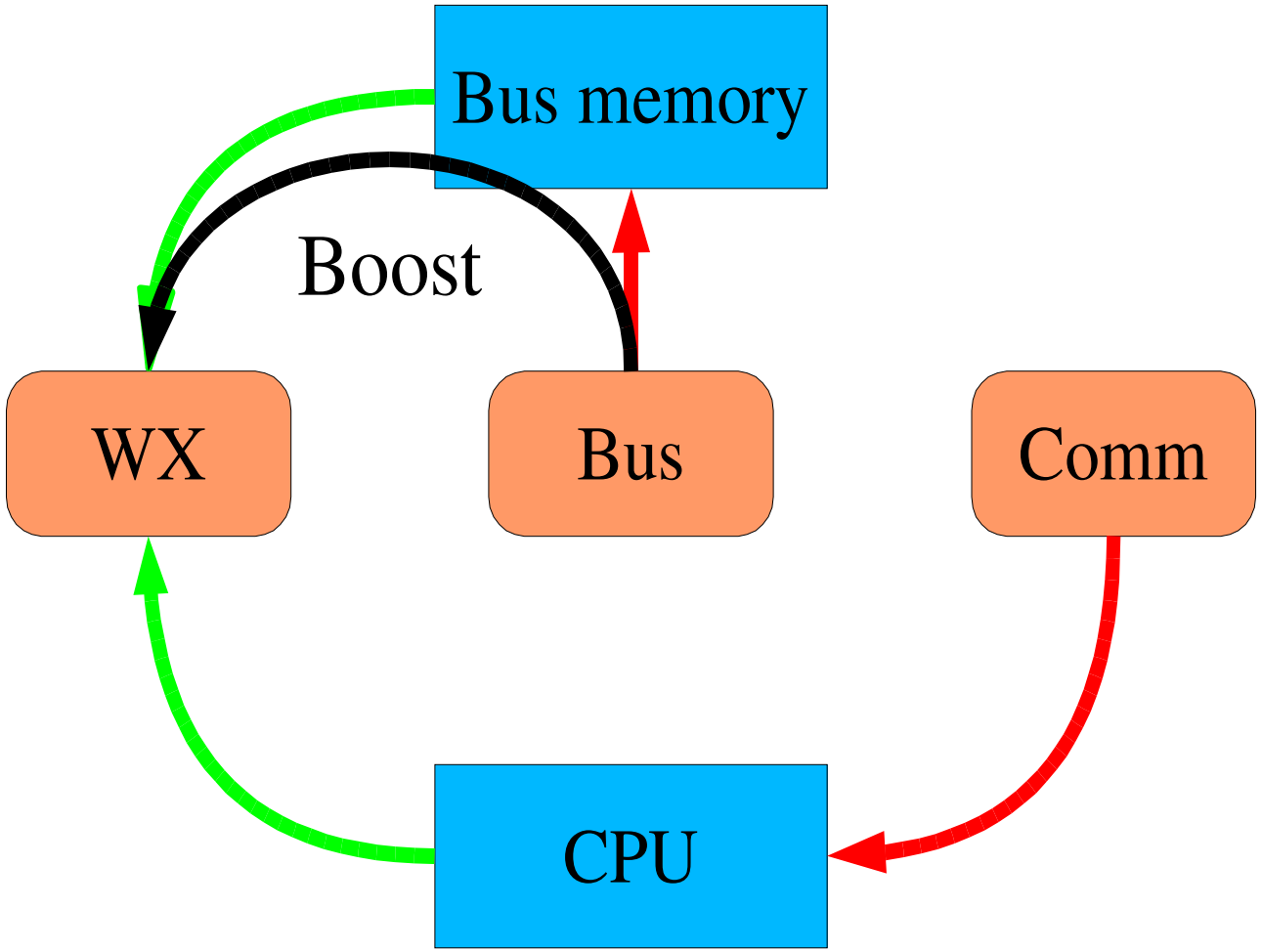
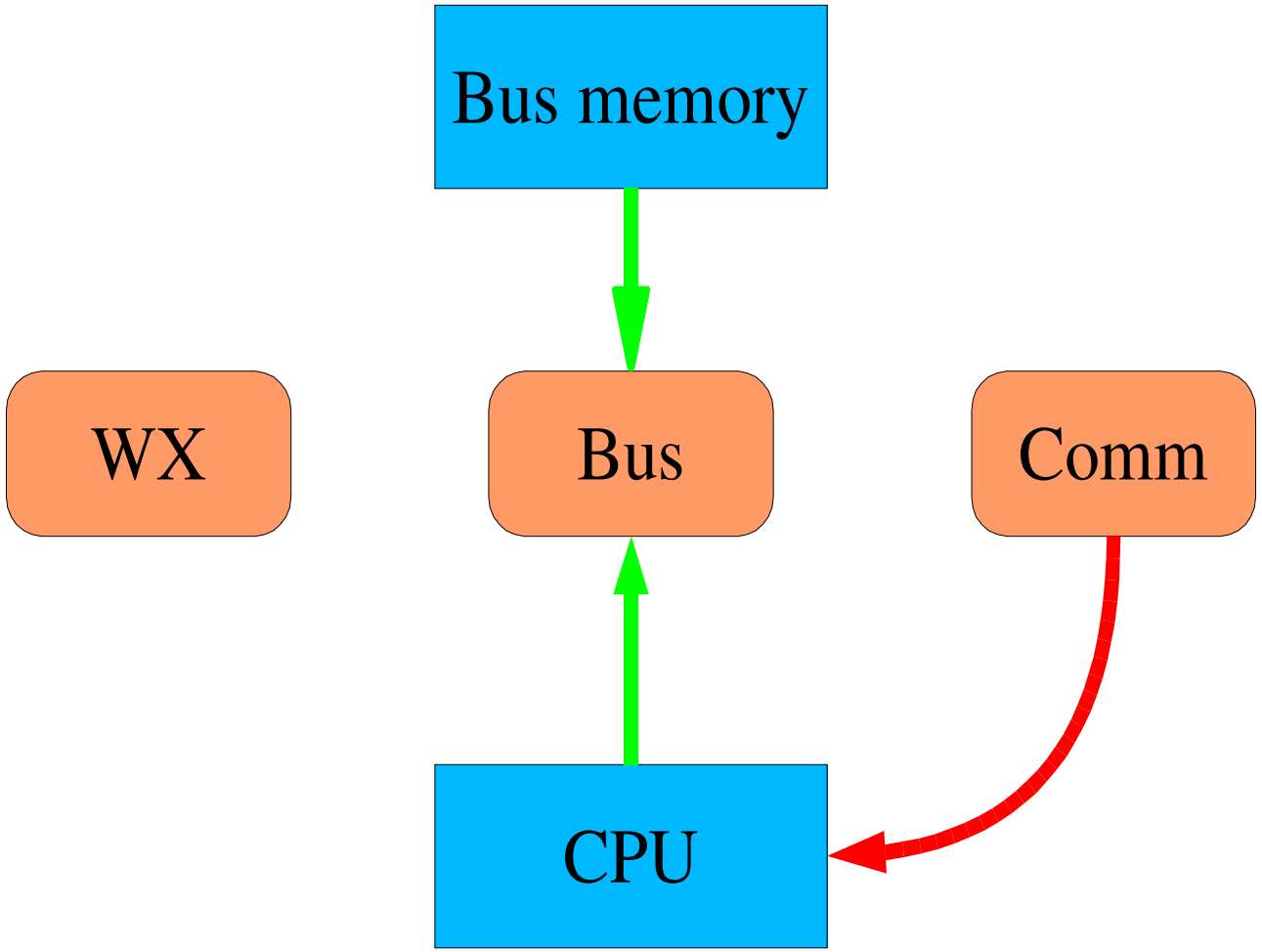


“Low-Priority” Thread Finishes Fast



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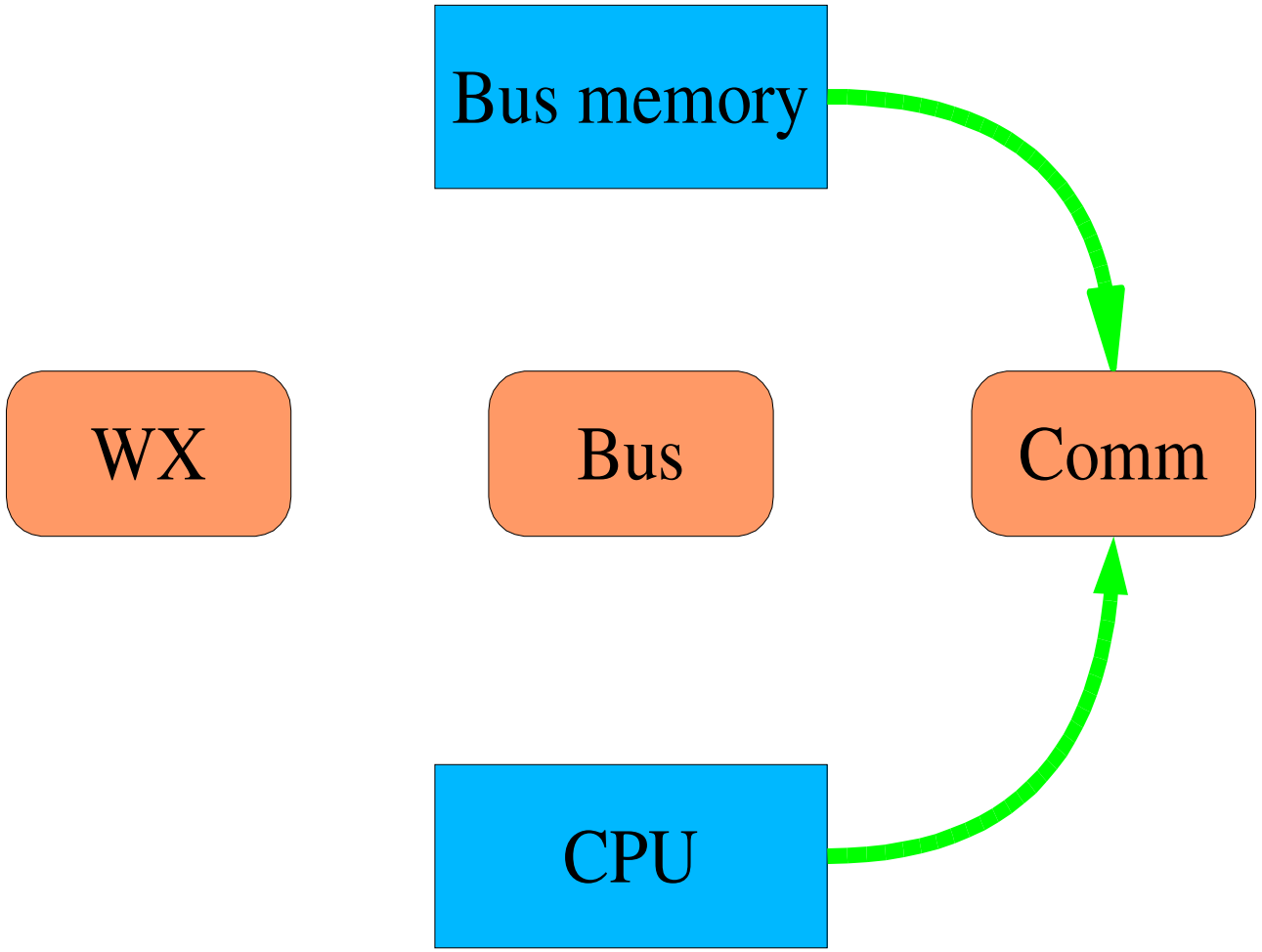

History of an Idea

- Priority Inheritance Protocols: An Approach to Real-Time Synchronization
  - IEEE Transactions on Computers 39:9
    - Lui Sha (CMU SEI)
    - Ragunathan Rajkumar (IBM Research -> CMU ECE)
    - John Lehoczky (CMU Statistics)

History of an Idea

- Events
  - 1987-12 “Manuscript” received
  - 1988-05 Revised
  - 1990-09 Published
  - 1997-07 Rescues Mars Pathfinder
- History courtesy of Mike Jones
  - http://www.cs.cmu.edu/~rajkumar/mars.html