

# 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*

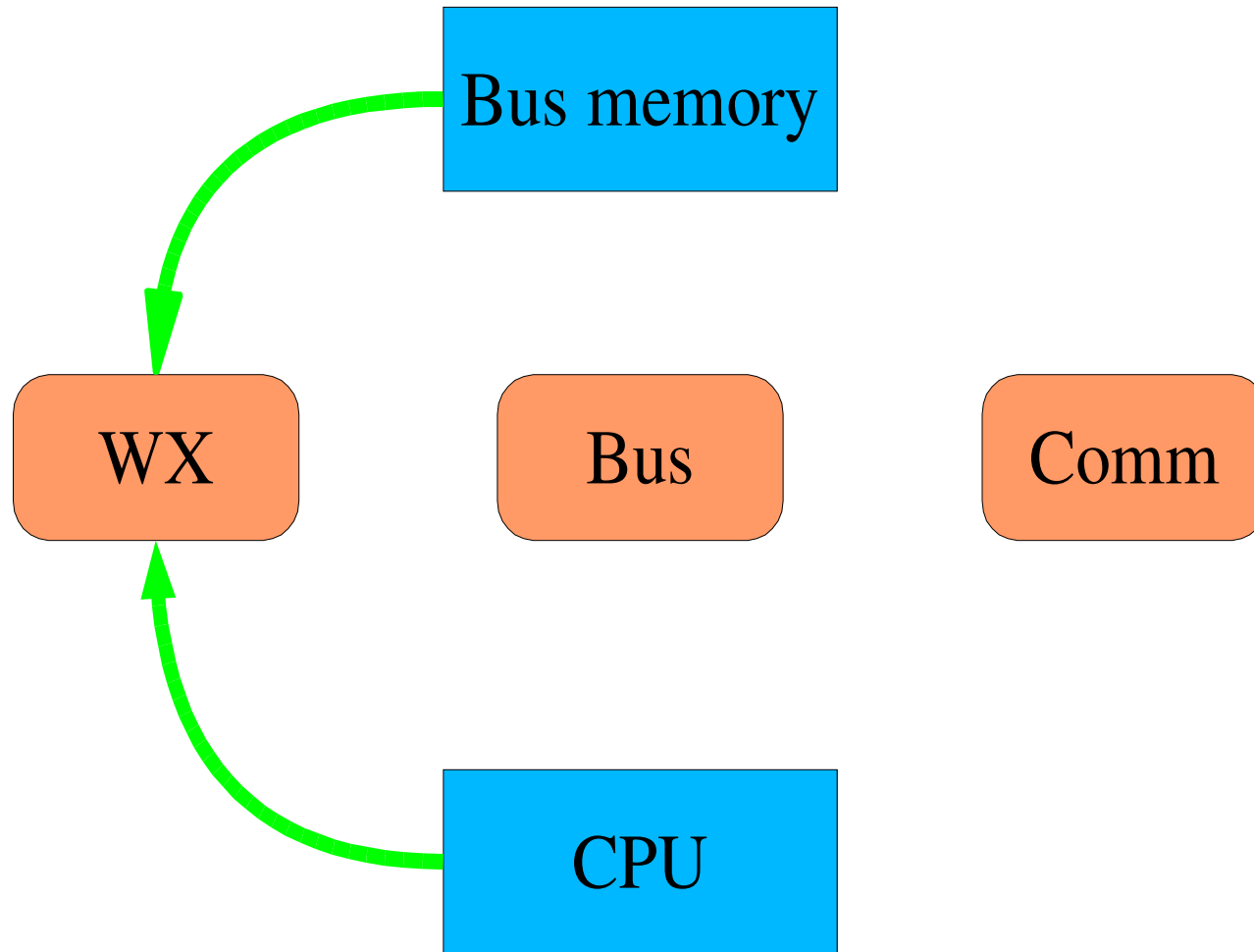
# Internal Architecture

- “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**

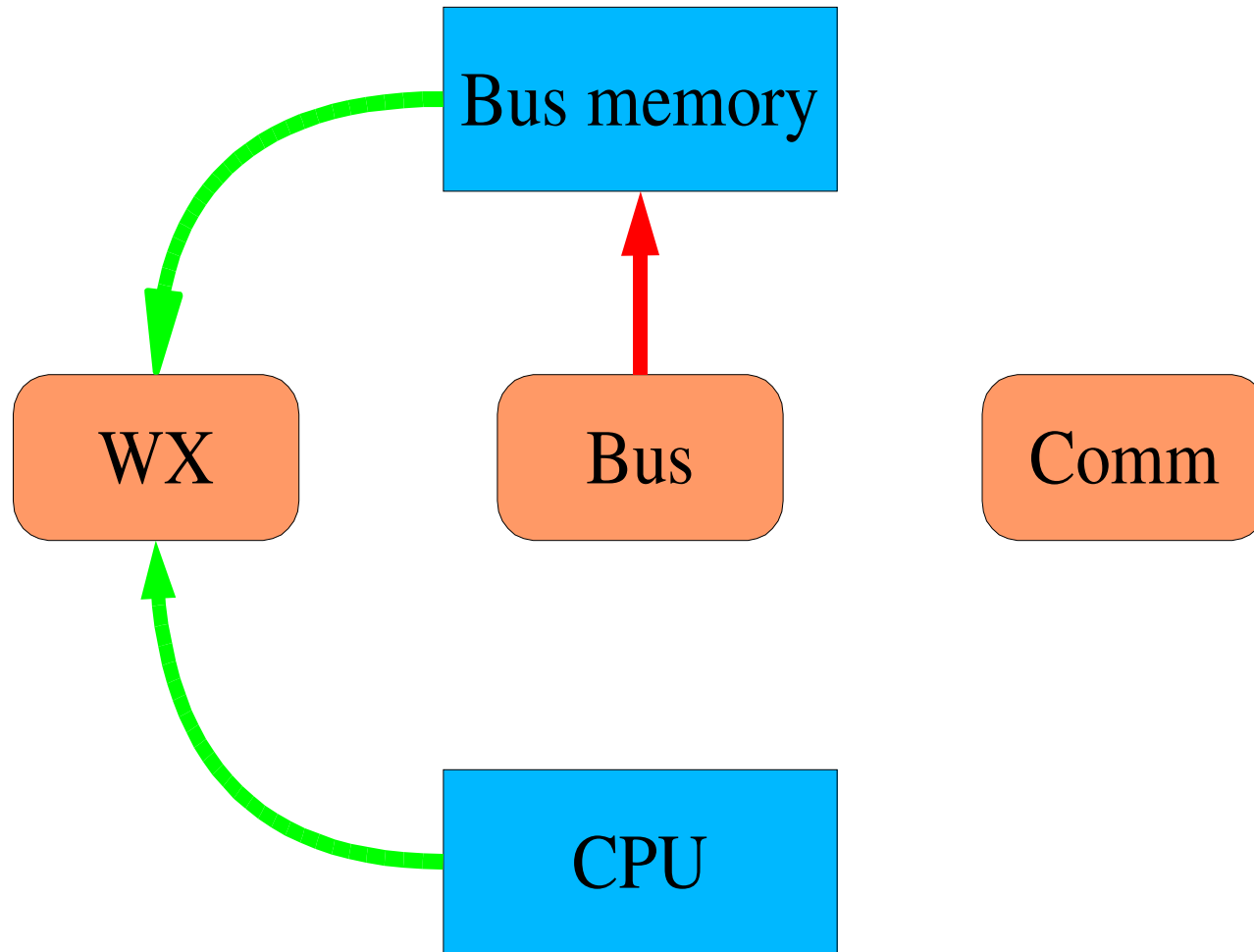
# What could go wrong?

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

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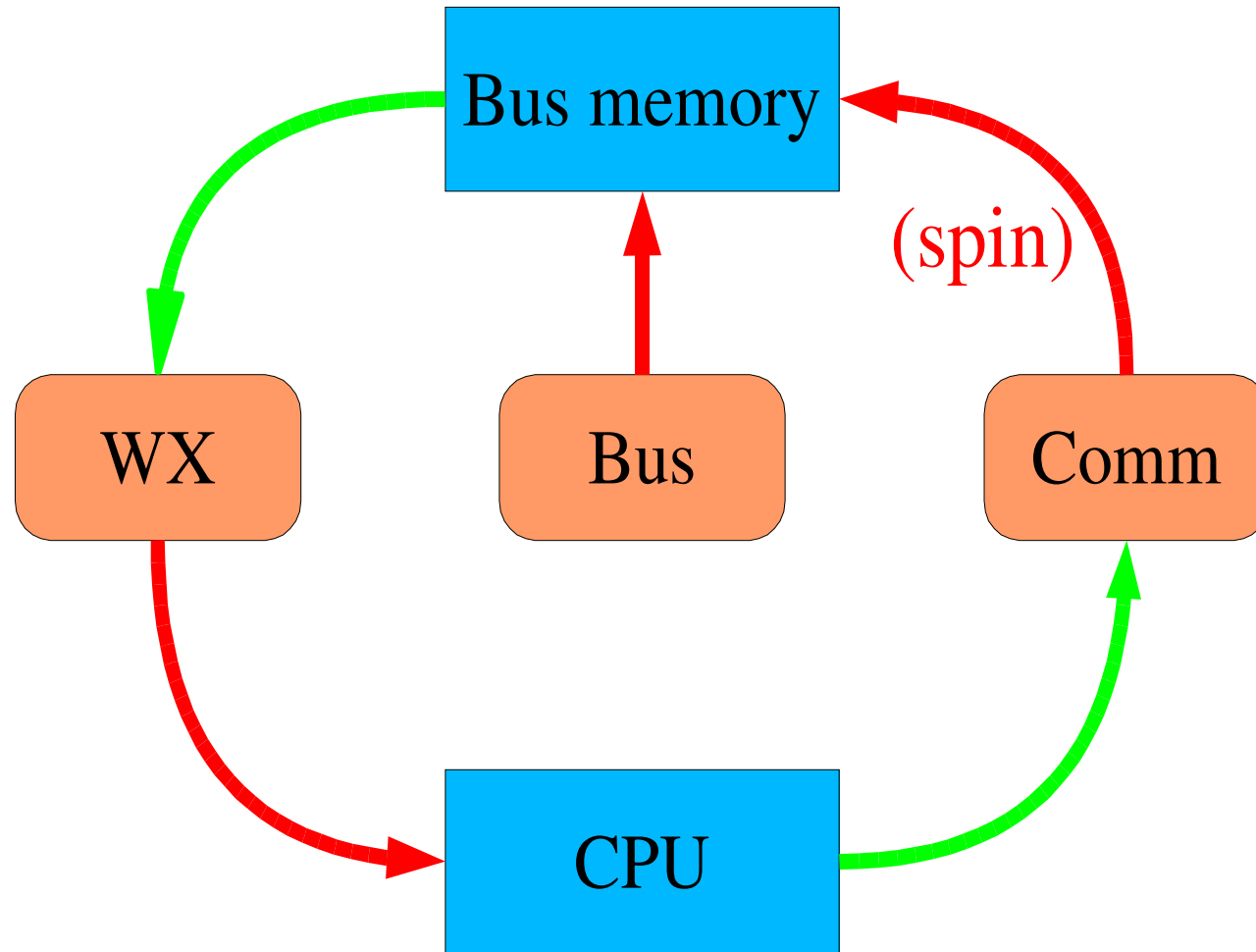
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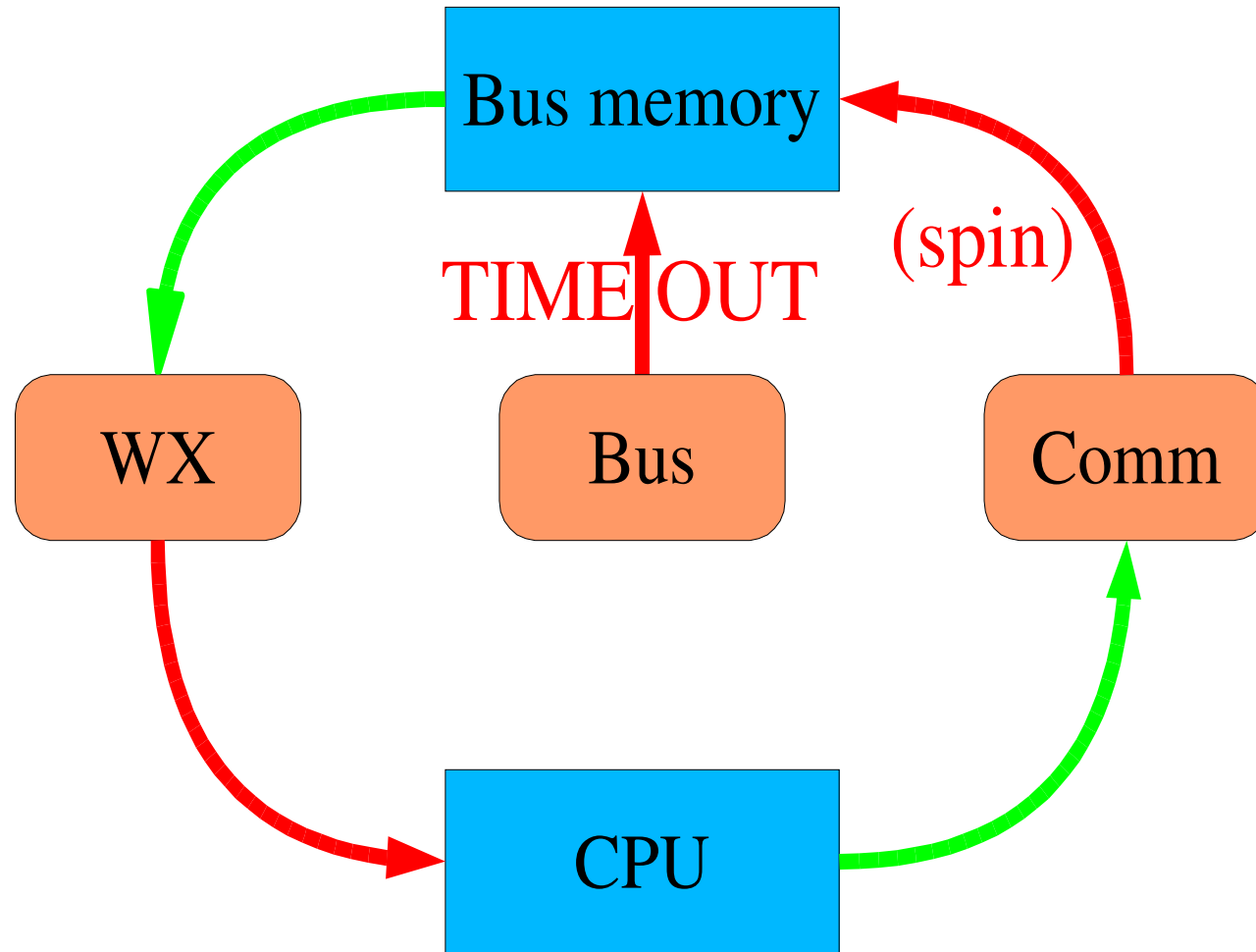
- **Weather data** locks “bus” memory to publish
- High-priority **bus manager** must wait
- ***Interrupt*** makes **communication** runnable
  - “Medium” priority, so preempts **weather data**
  - **communication** then attempts to lock bus
  - Highest-priority runnable task, so it spin-waits

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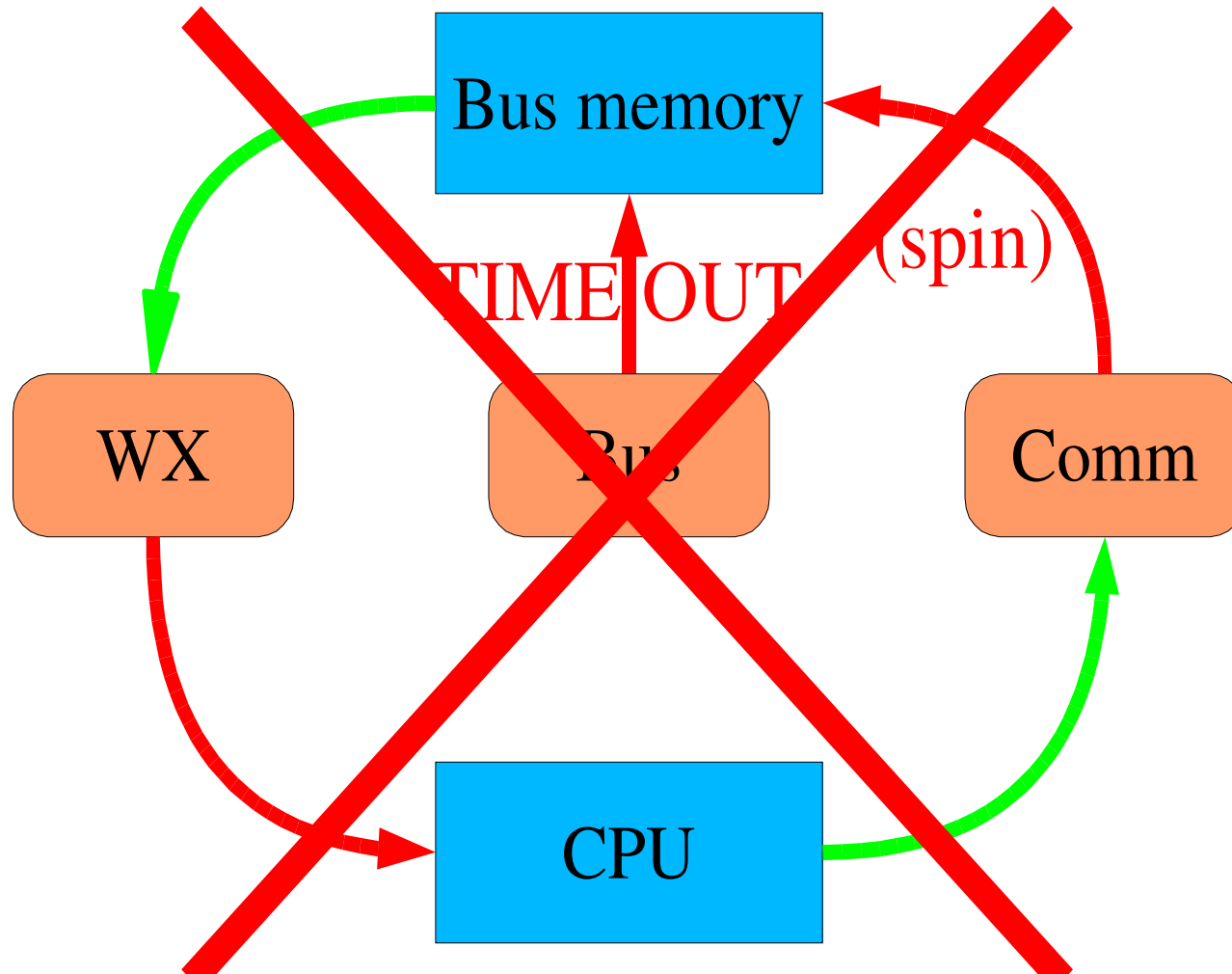




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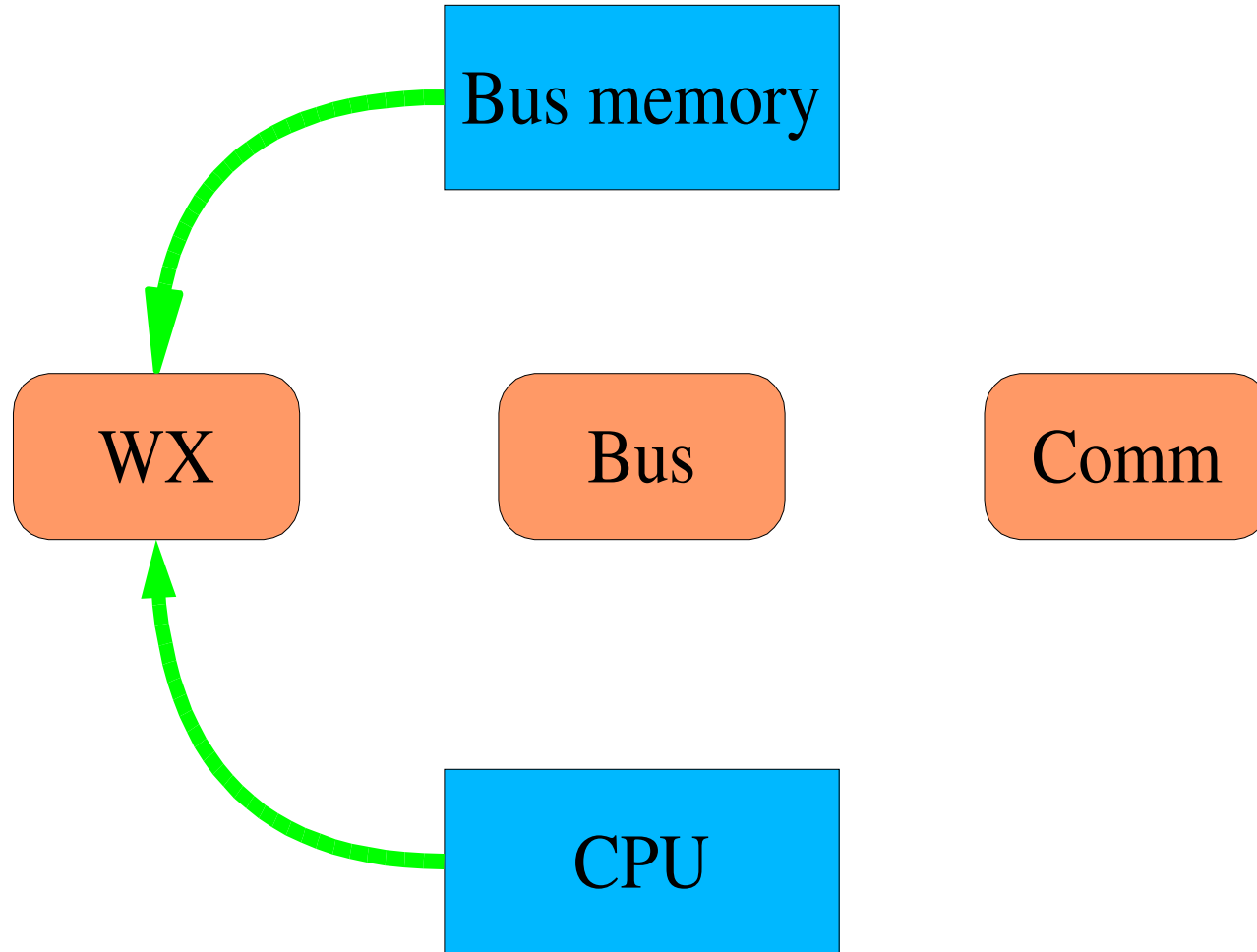
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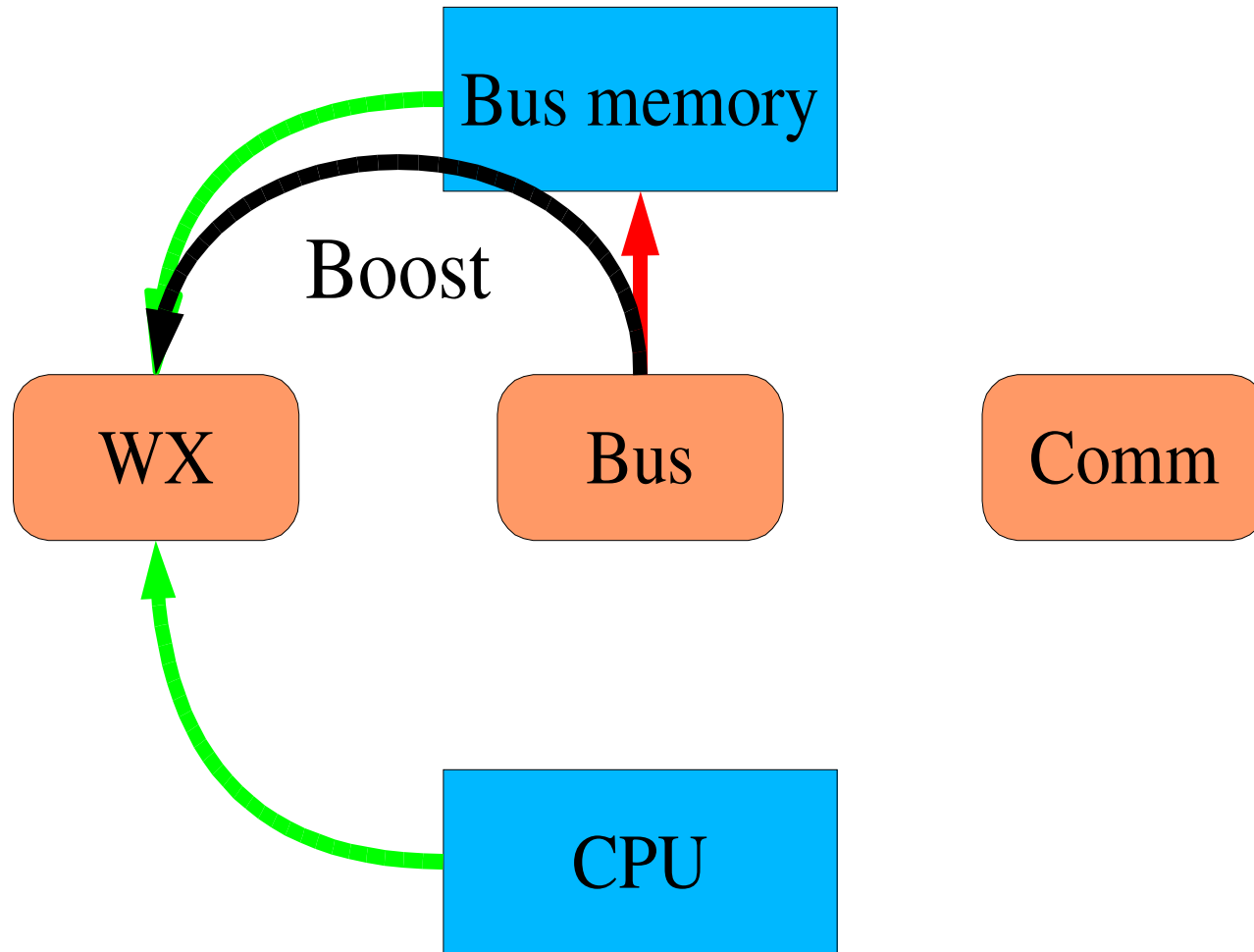
# Solution?

- 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

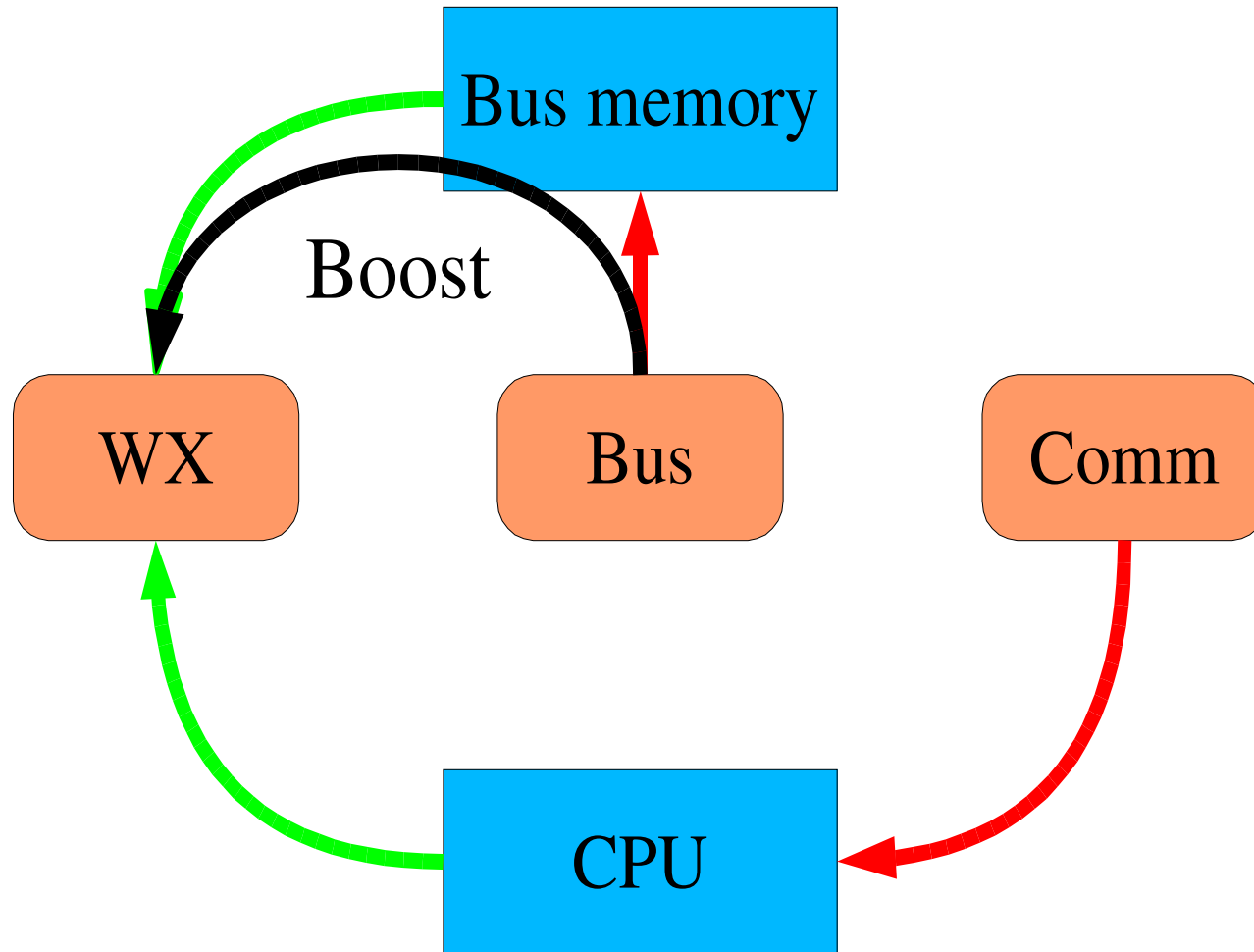
# Weather Thread is Busy



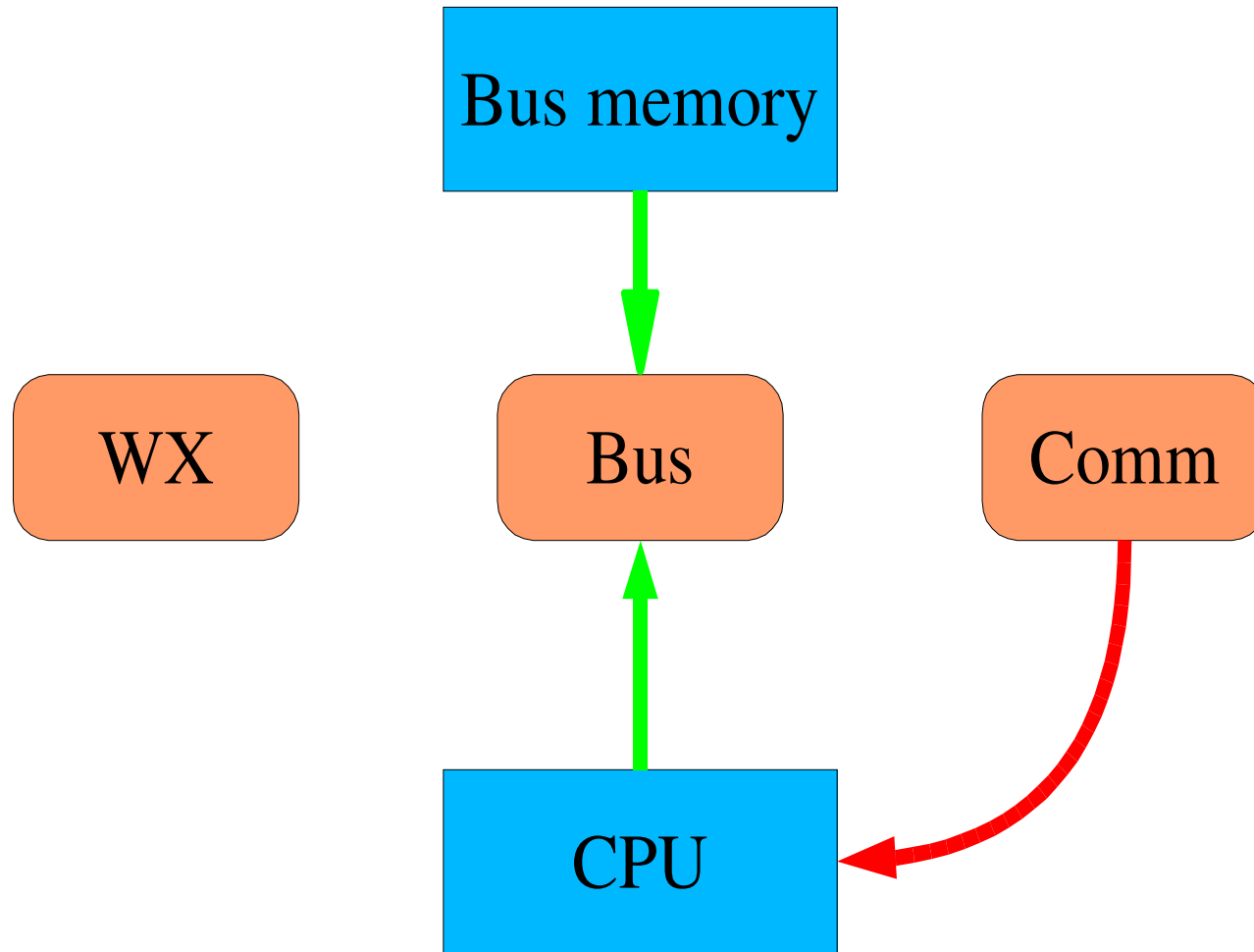
# Bus Thread Waits: Priority Inherited!



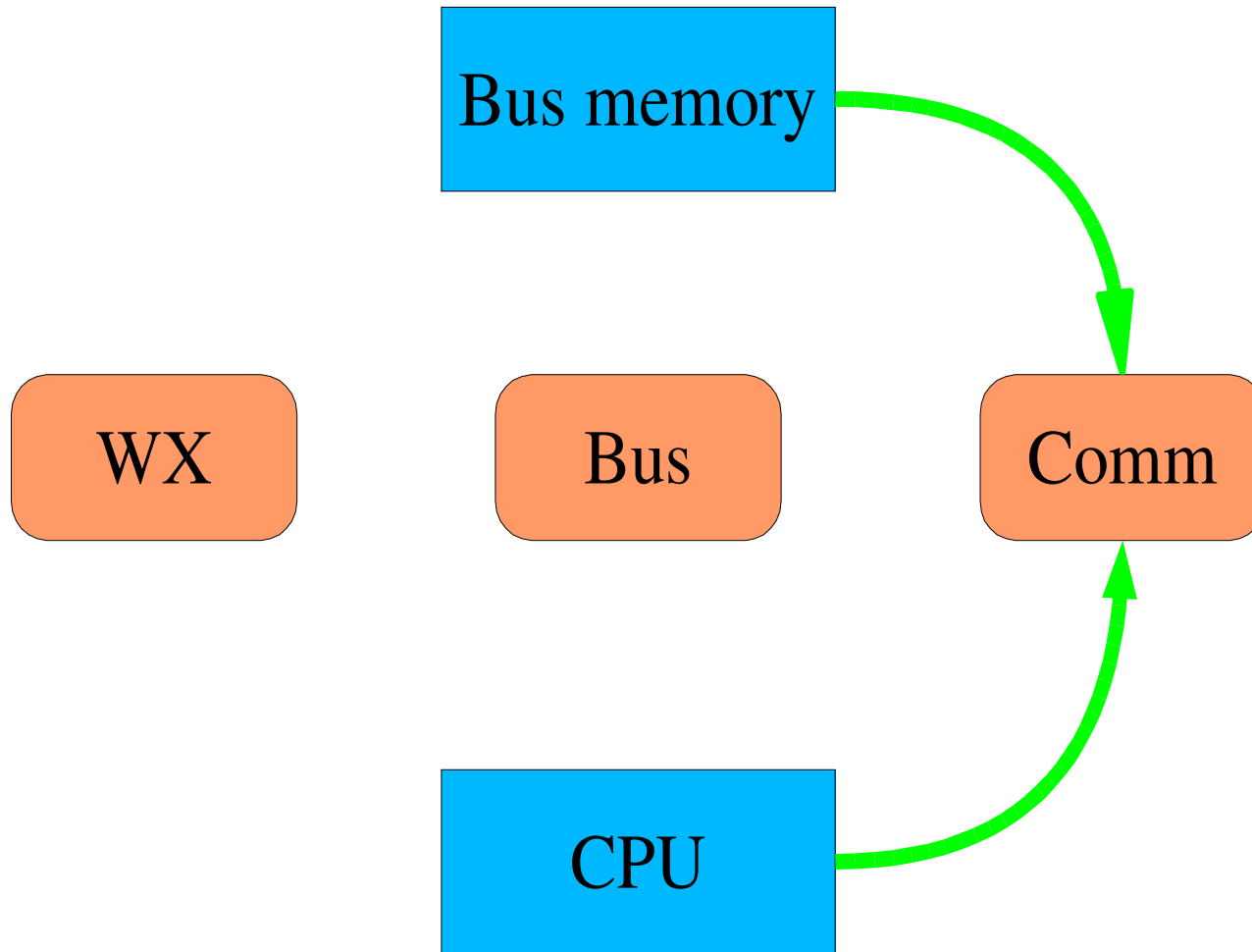
# Bus Thread Waits: Priority Inherited!



# “Low-Priority” Thread Finishes Fast



# “Low-Priority” Thread Finishes Fast





# History of an Idea

- Priority Inheritance Protocols: An Approach to Real-Time Synchronization
  - IEEE Transactions on Computers 39:9
    - Lui Sha (CMU SEI)
    - Ragnathan 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>