15-410
"Delayed Impact"

Scheduling on Mars
Oct. 18, 2006

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Outline

What happened on Mars?

- (1997)

What Happened On Mars?

Mars Pathfinder probe (1997)

Nice launch

Nice transit

Nice de-orbit

Nice thump-down (inflatable air-bag)

Nice rover disembarkation

What Happened On Mars?

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Nice rover disembarkation

Nice rover *spontaneous reboots*

Internal Architecture

"Information bus" (blackboard/whiteboard/...)

- Housekeeping by high-priority bus manager thread

Meteorological data gathering

- Occasional activity
- Low-priority weather data thread

Communication with Earth

- Medium-priority communication thread
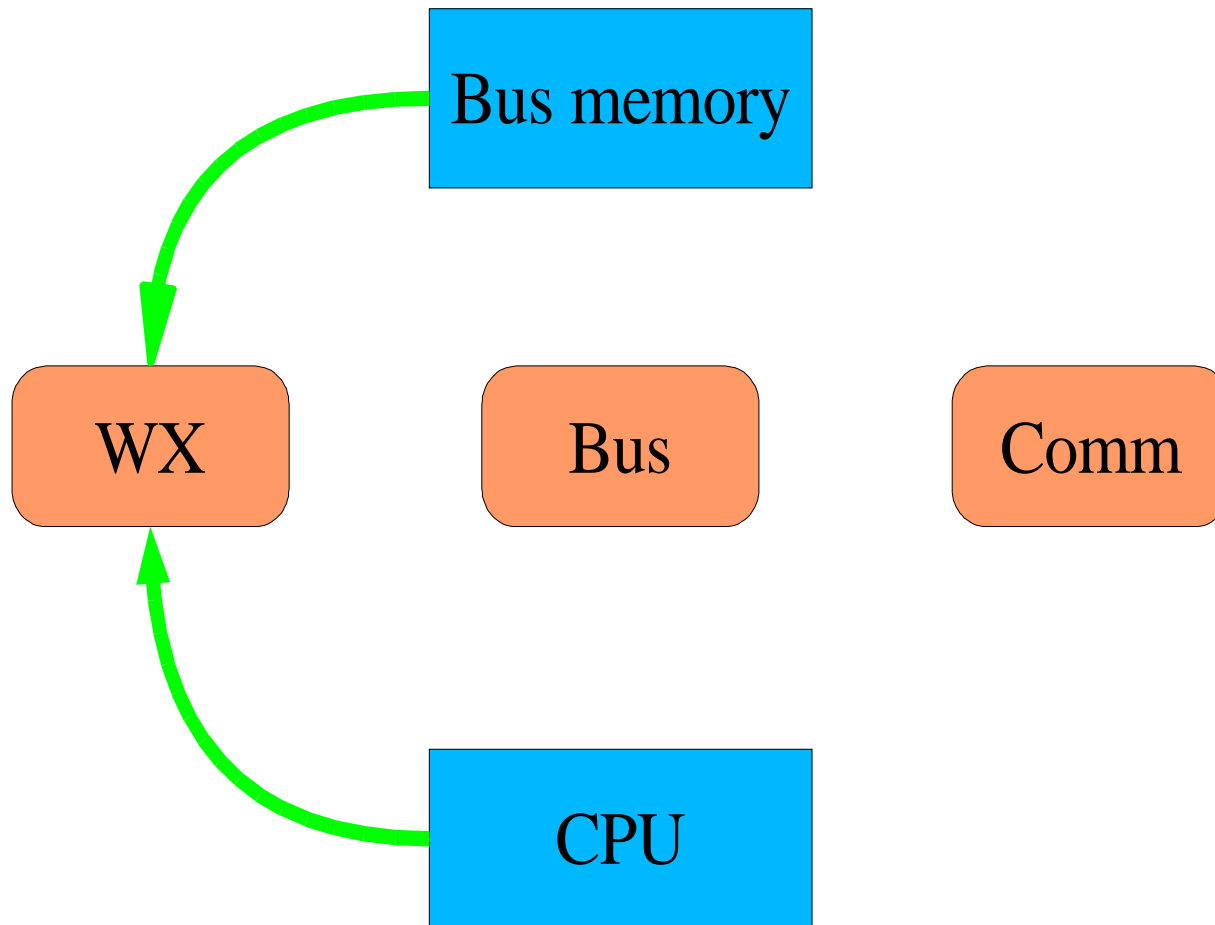
Watchdog "thread" (think: countdown timer)

- "Too quiet"? *Reboot*
- "Shouldn't happen" event was happening repeatedly
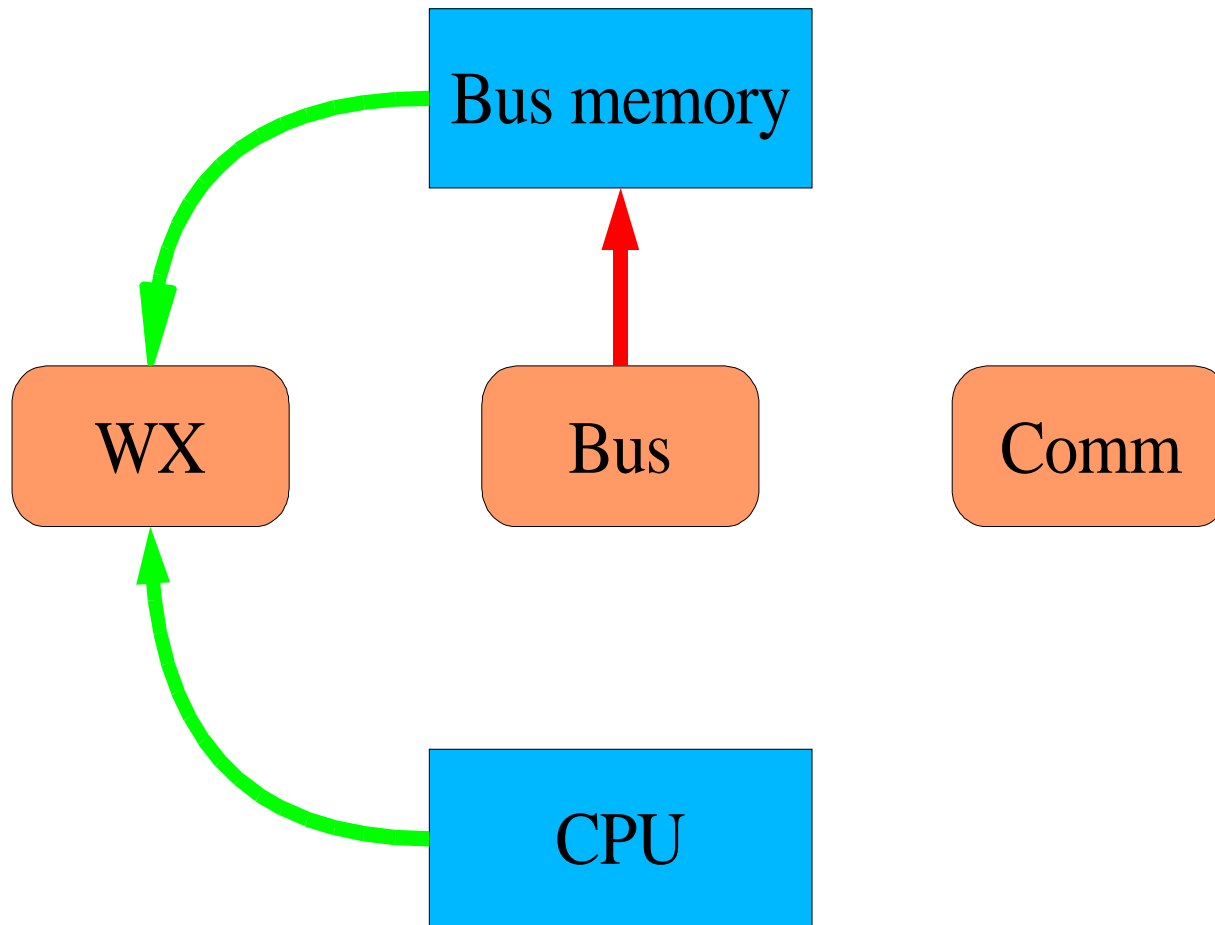
What could go wrong?

Weather data locks "bus" memory to publish reading

High-priority bus manager must wait

What could go wrong?

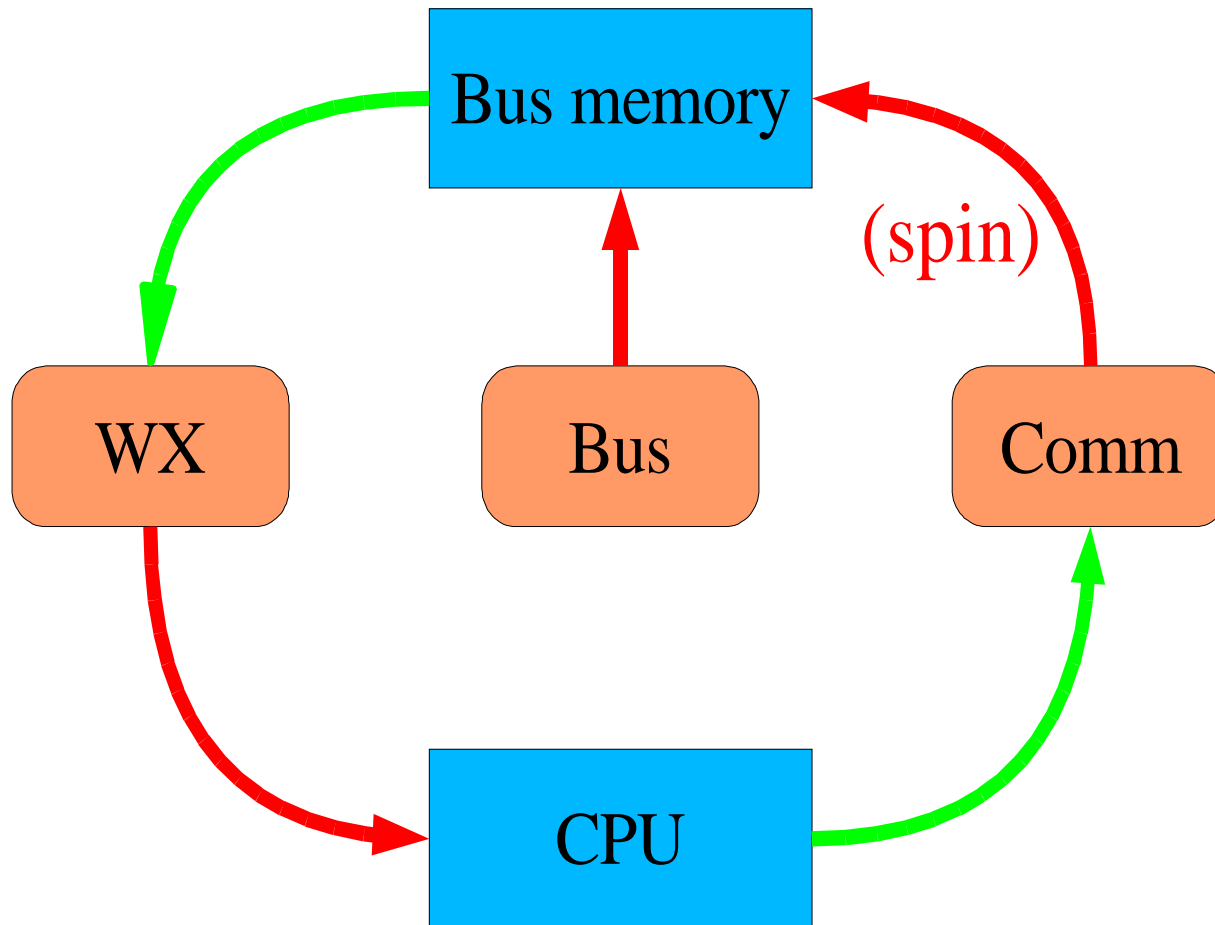# What could go wrong?

What could go wrong?

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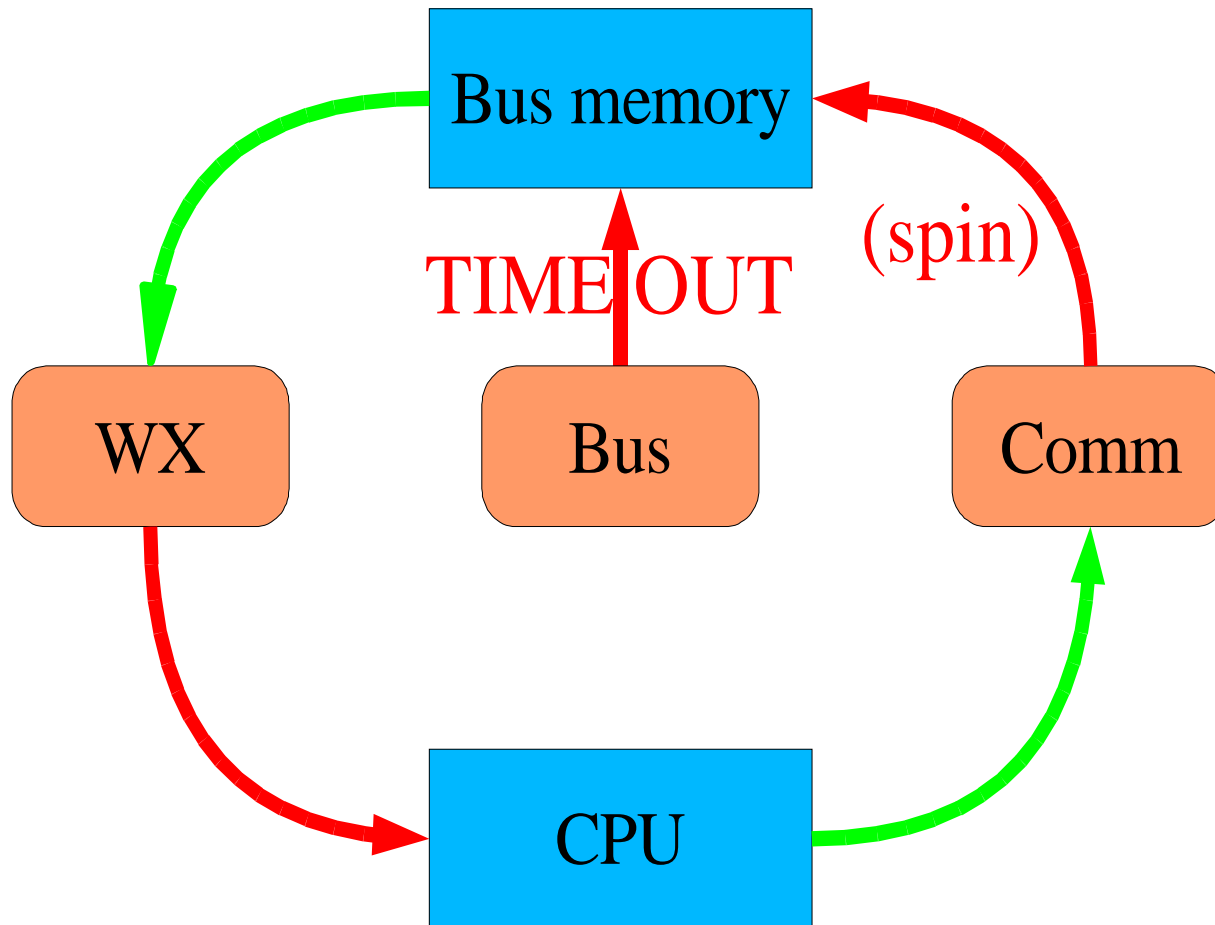
High-priority **bus manager** must wait

Interrupt makes **communication** runnable

- "Medium" priority, so preempts weather data
- Communication then attempts to lock bus
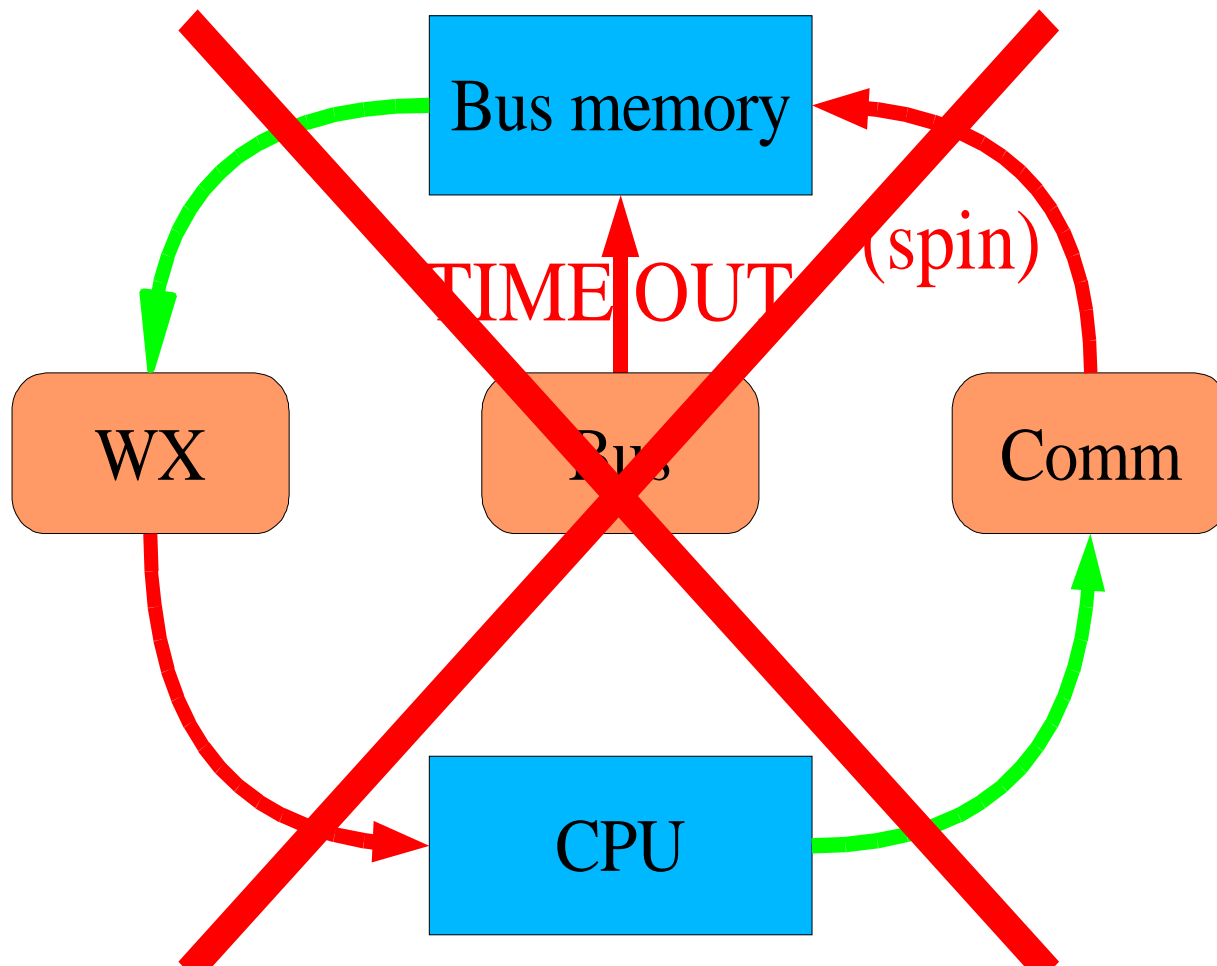- Highest-priority runnable task, so it spin-waits

What could go wrong?

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What could go wrong?

Solution?

VxWorks has two mutex flavors

- Normal
- *Priority Inheritance*

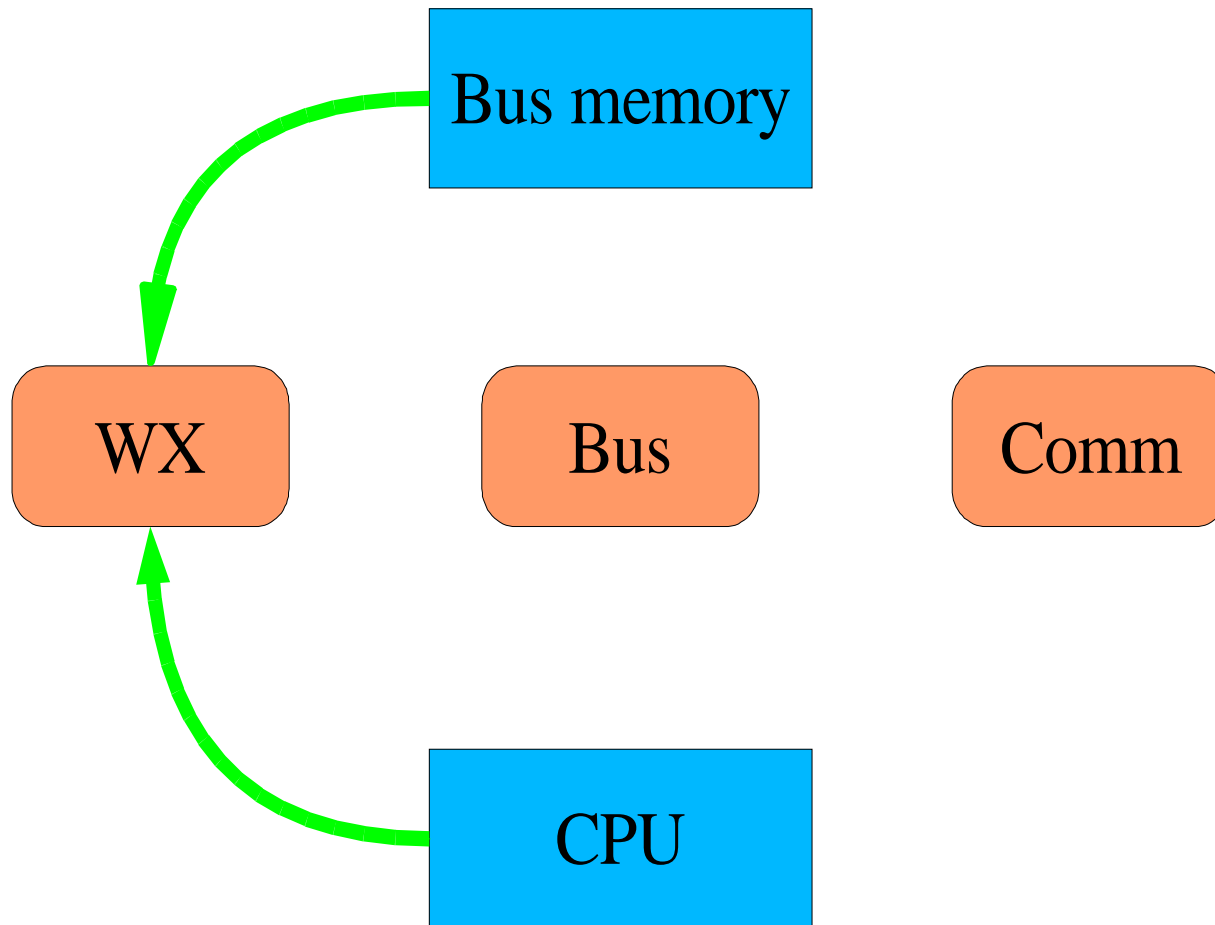**Rover code initialized flavors via global variables**

```
extern int bus_mutex_flavor = MF_DEFAULT;
mutex_init(&bus_mem_mutex, bus_mutex_flavor);
```
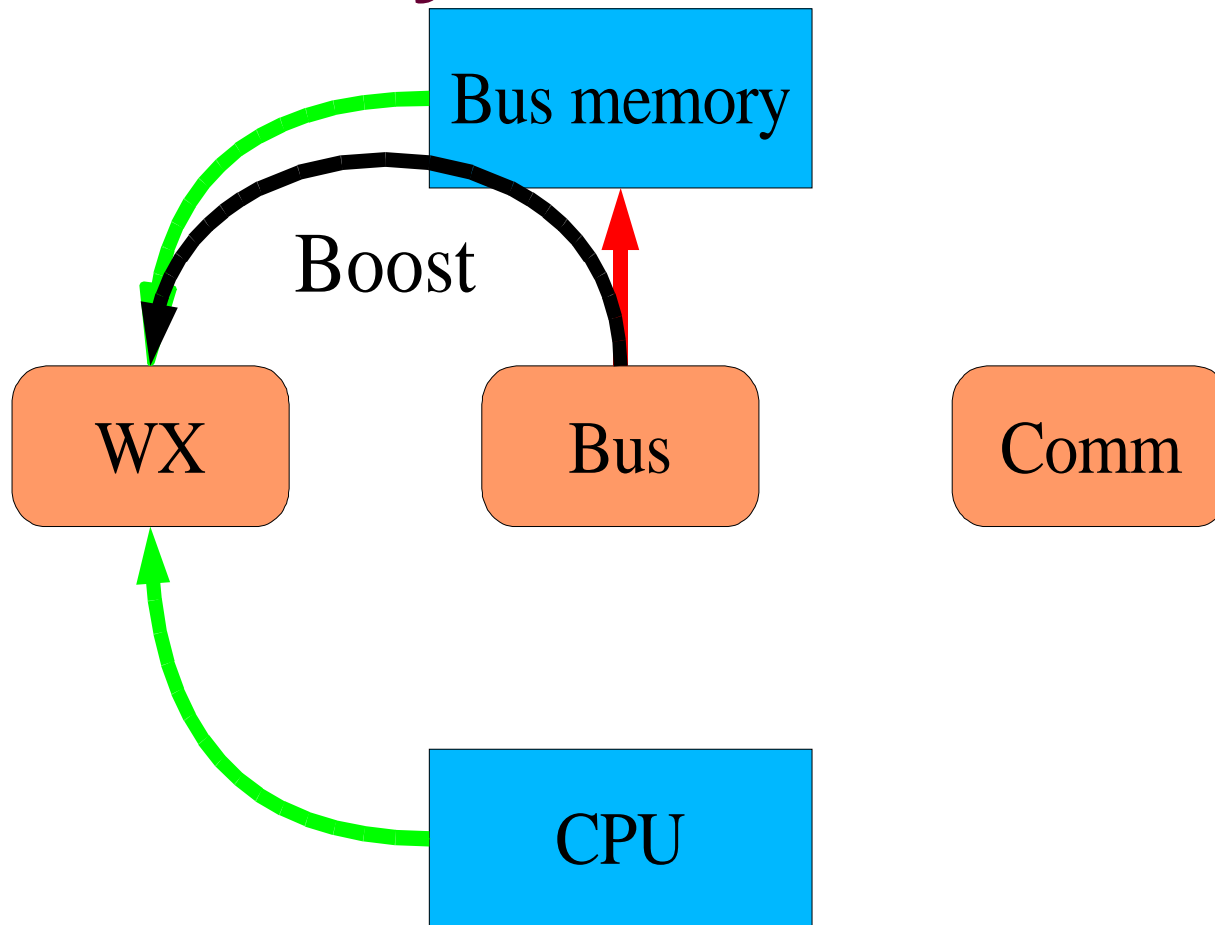
Rover flew with "debug" interpreter enabled

- Read-eval loop waiting for commands

```
% assign bus_mutex_flavor = MF_P_INHERIT
```
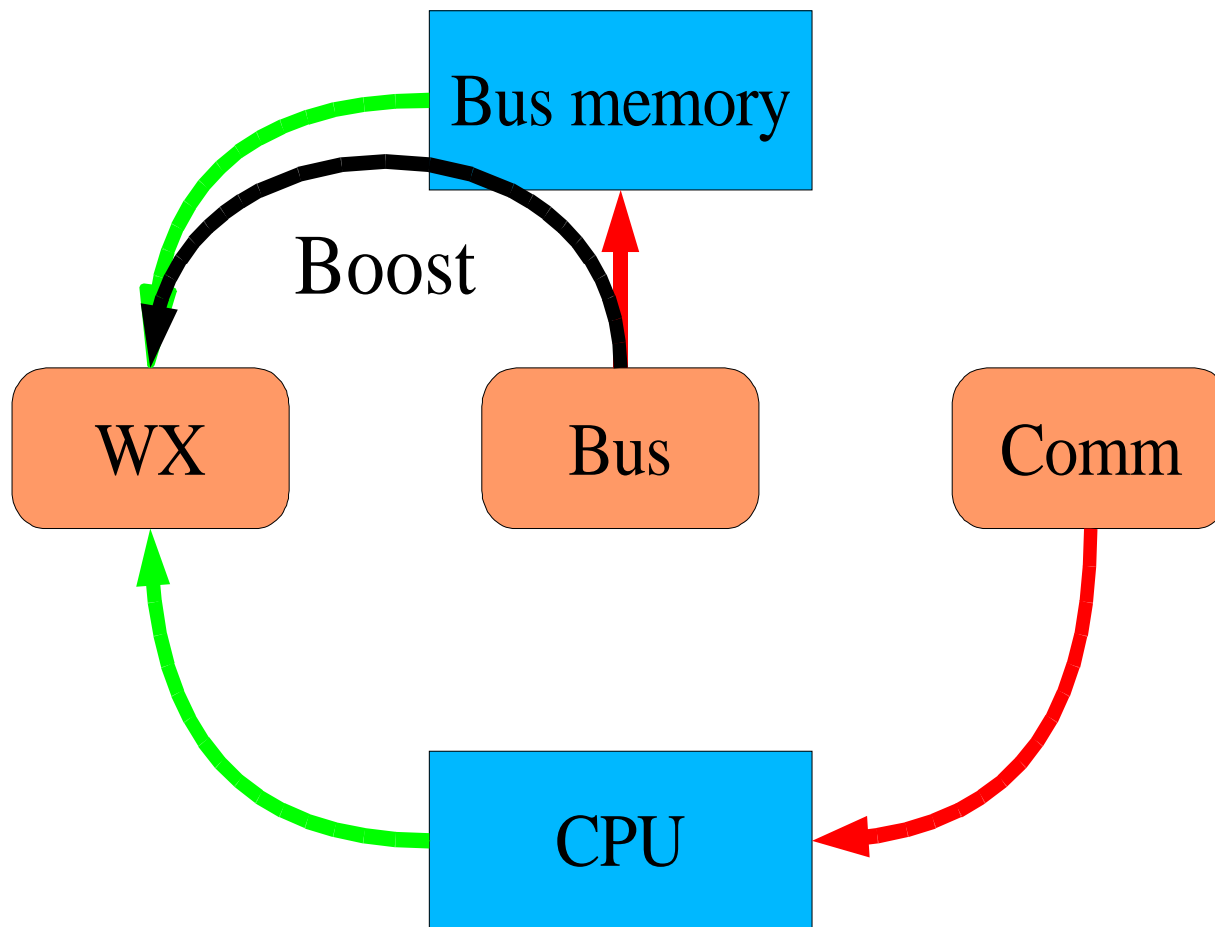
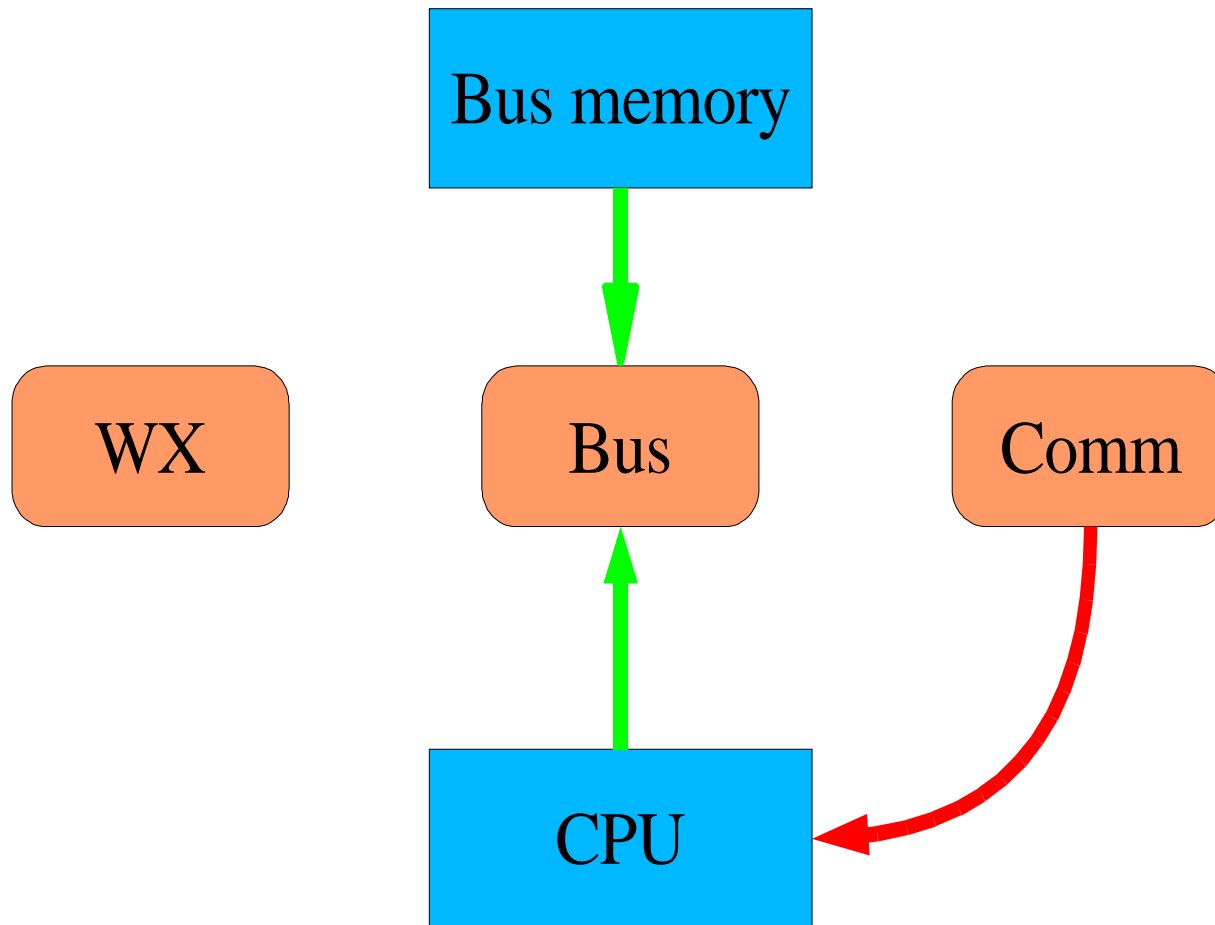**All fixed**

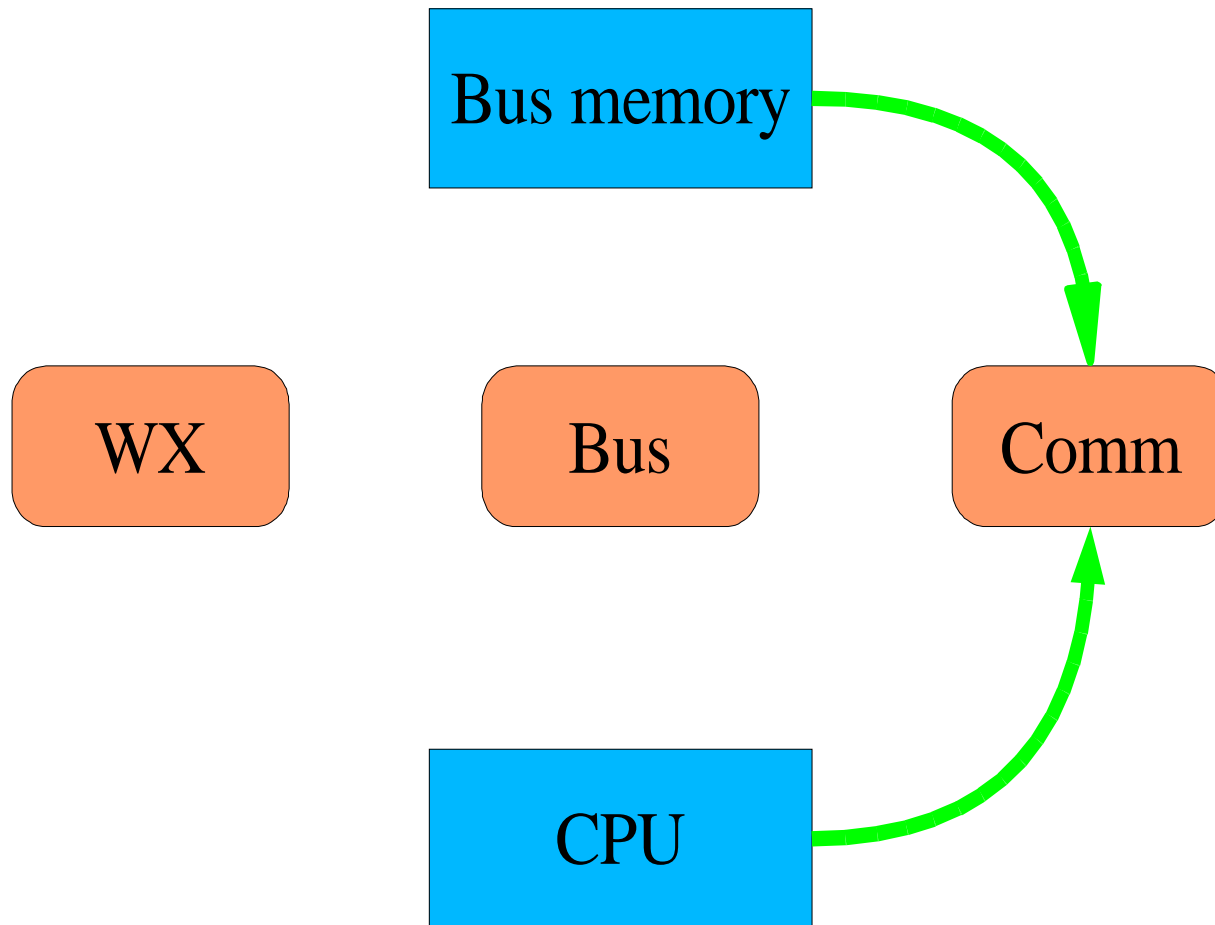# Weather Thread is Busy

Bus Thread Waits: Priority Inherited by WX

Comm Artificially Defers

"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)
  - 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**