Record and replay of ROS nodes with Mozilla rr
Deterministic debugging and reverse execution

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Mozilla rr - record and replay

moz://a

- process execution recording ● REC
  - **lightweight, low performance overhead**
    - only **non-deterministic** inputs are recorded
  - can record entire process trees (e.g. multiple ROS nodes)
- process execution replay ⏯ ⏮ ⏭
  - execution flow is reconstructed
    - using the same binary executable and the recorded non-deterministic inputs
    - **instruction-level** replay accuracy
  - a gdbserver interface is used to debug the replayed process

rr design

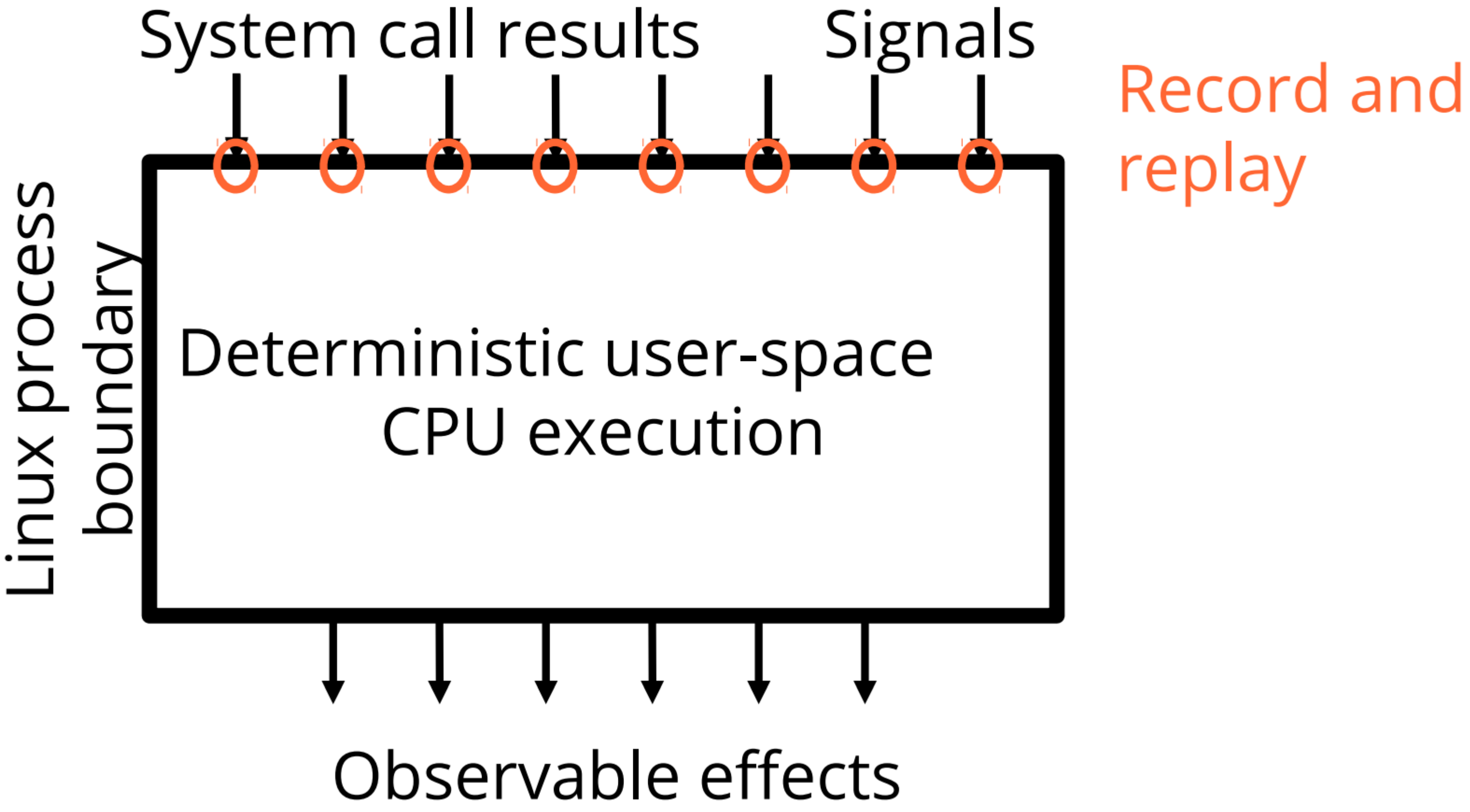
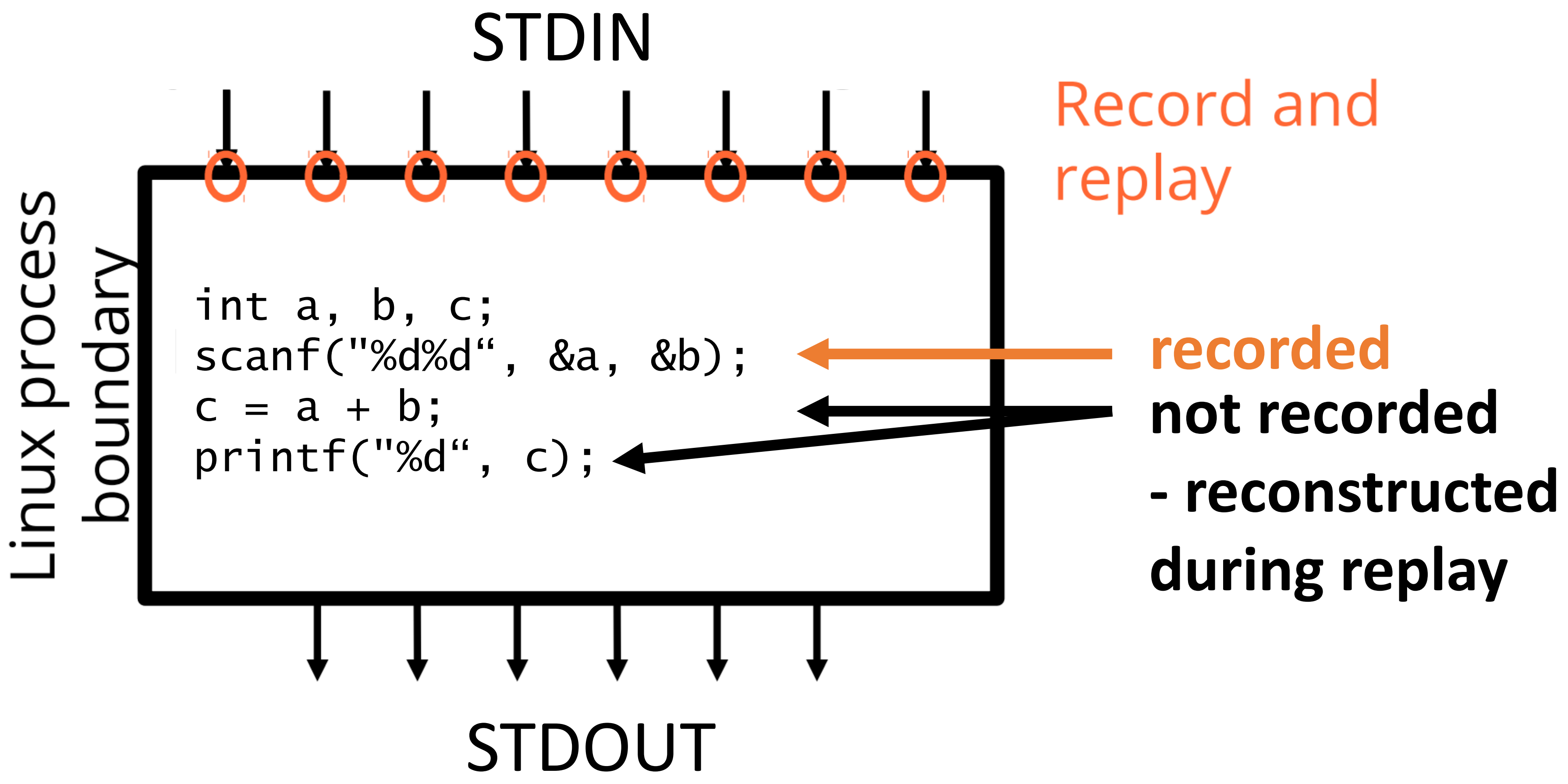


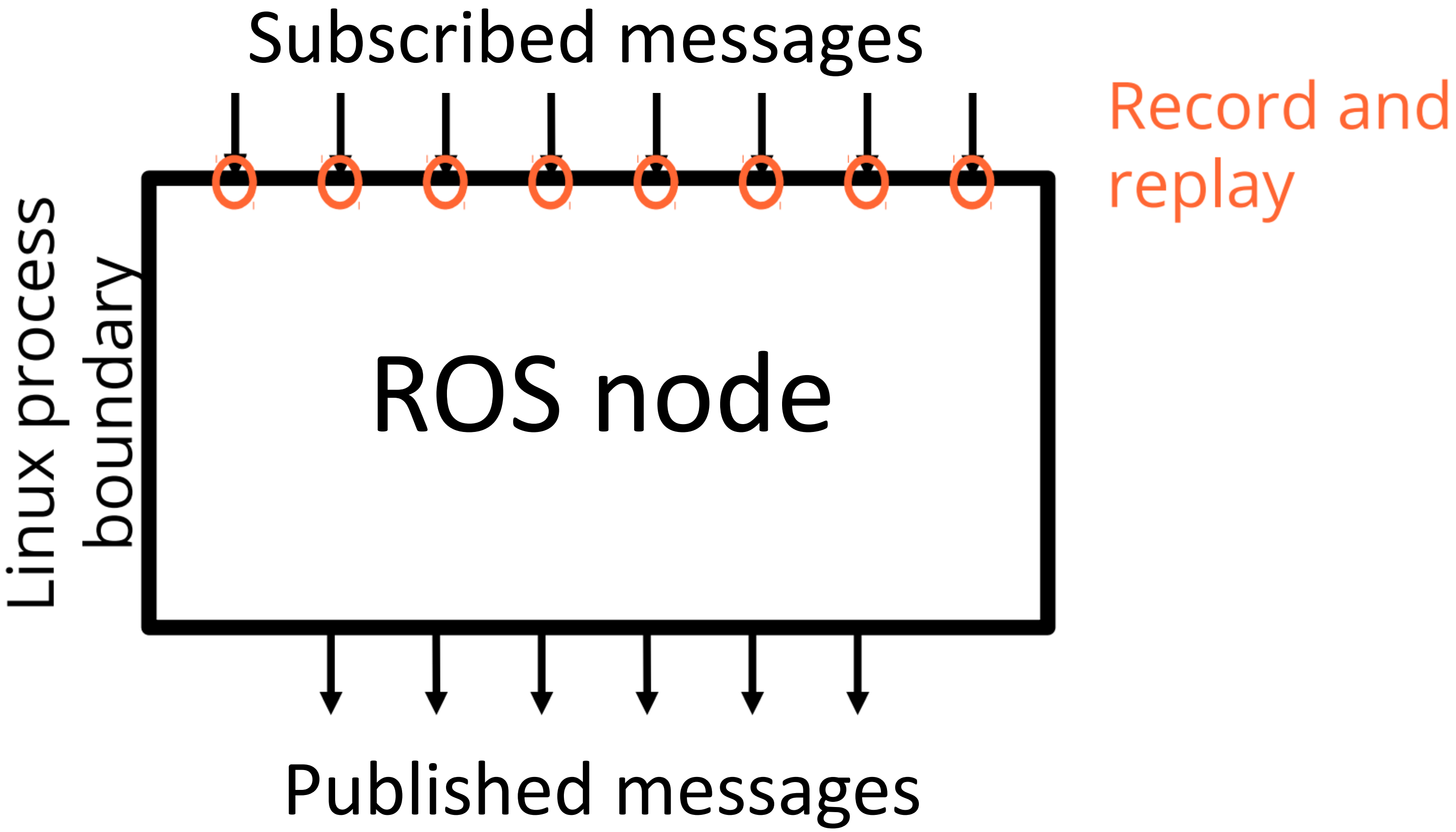
Diagram from Robert O'Callahan, “Practical Record And Replay Debugging With rr”

rr design

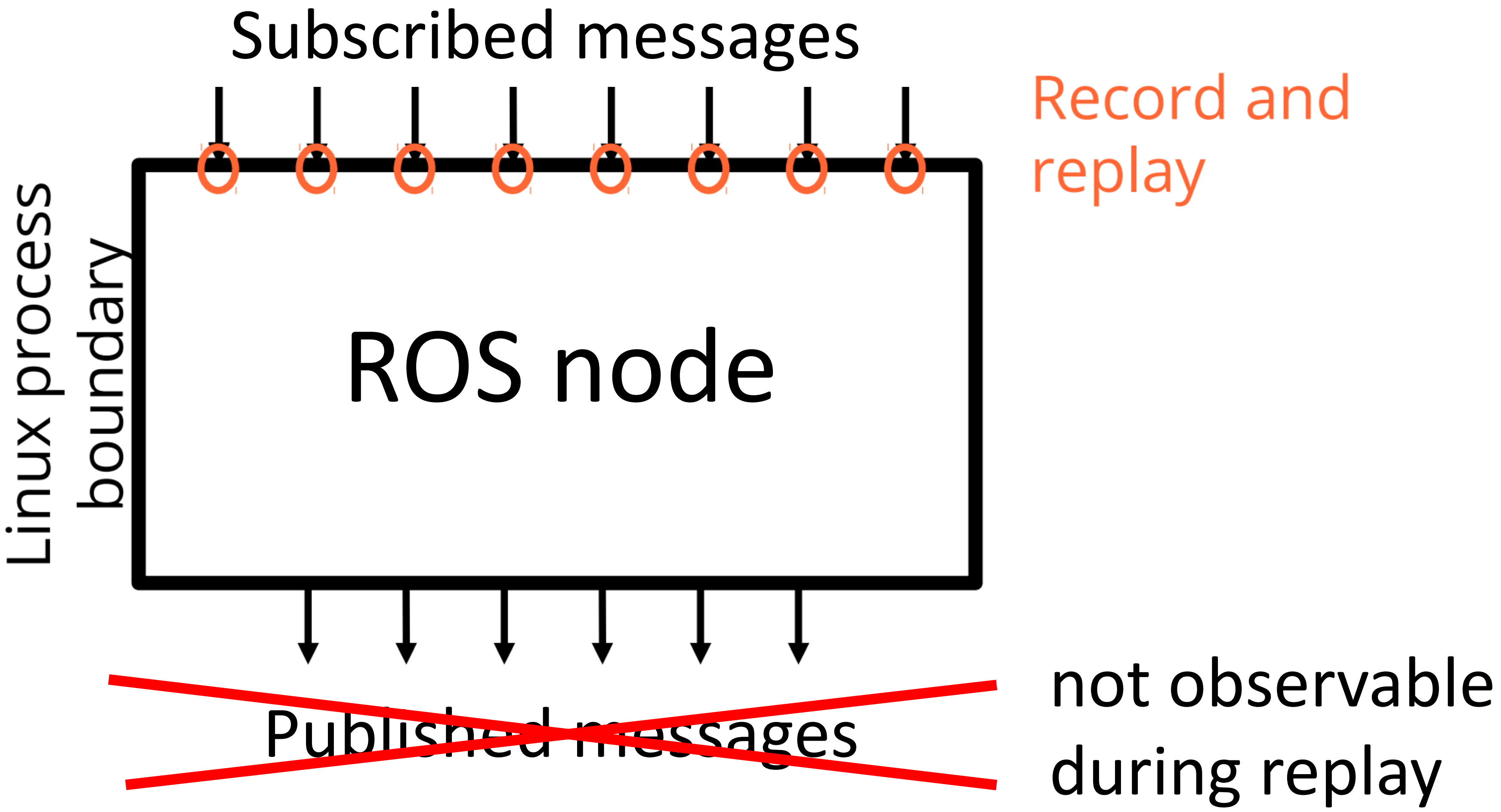


```
int a, b, c;
scanf("%d%d“, &a, &b);
c = a + b;
printf("%d“, c);
```

rr design


Subscribed messages
Record and replay
Linux process boundary
ROS node
Published messages

rr design



Subscribed messages

Record and replay

Linux process boundary

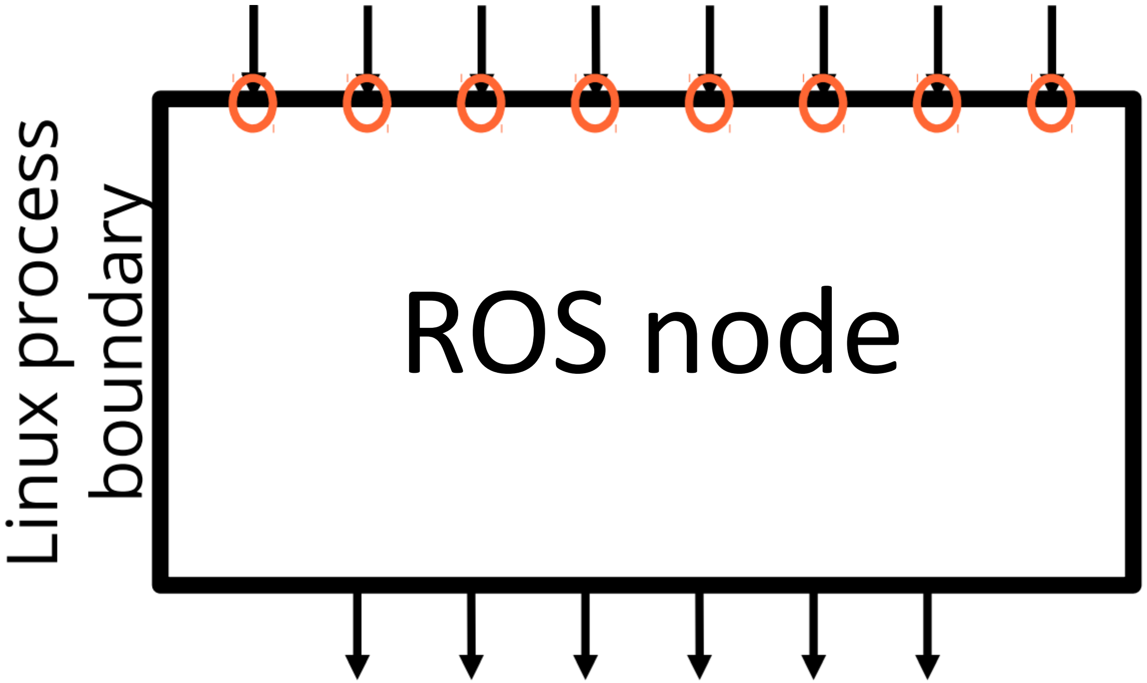
ROS node

~~Published messages~~

not observable during replay

rr design

Subscribed messages



Linux process boundary

ROS node

Record and replay

Published messages

republish with rospy + gdb Python hooks

Caveats

- only for Linux on x86(_64)
  - Intel (>= ~Sandy Bridge)
  - recently merged experimental AMD support

- multithreaded processes are executed sequentially (on a single core) -> slower
  - rr supports a chaotic thread scheduling mode,
    useful for provoking race condition bugs

Ideas for the future (call for action?)

- republishing ROS messages
  - although documented, currently a proof-of-concept hacky script
  - engage with upstream rr for proper integration (a side effect reconstruction plugin?)

- (long-term) recording on robots?

Thank you for your attention!

- `juraj.orsulic@fer.hr`
- `apt install rr` on Ubuntu (git master is better)
- https://rr-project.org/

- https://github.com/larics/gdb_ros_publisher
- http://larics.fer.hr/laricswiki/doku.php?id=software:debugging

- demo video:
  https://youtu.be/tC6ggFehems