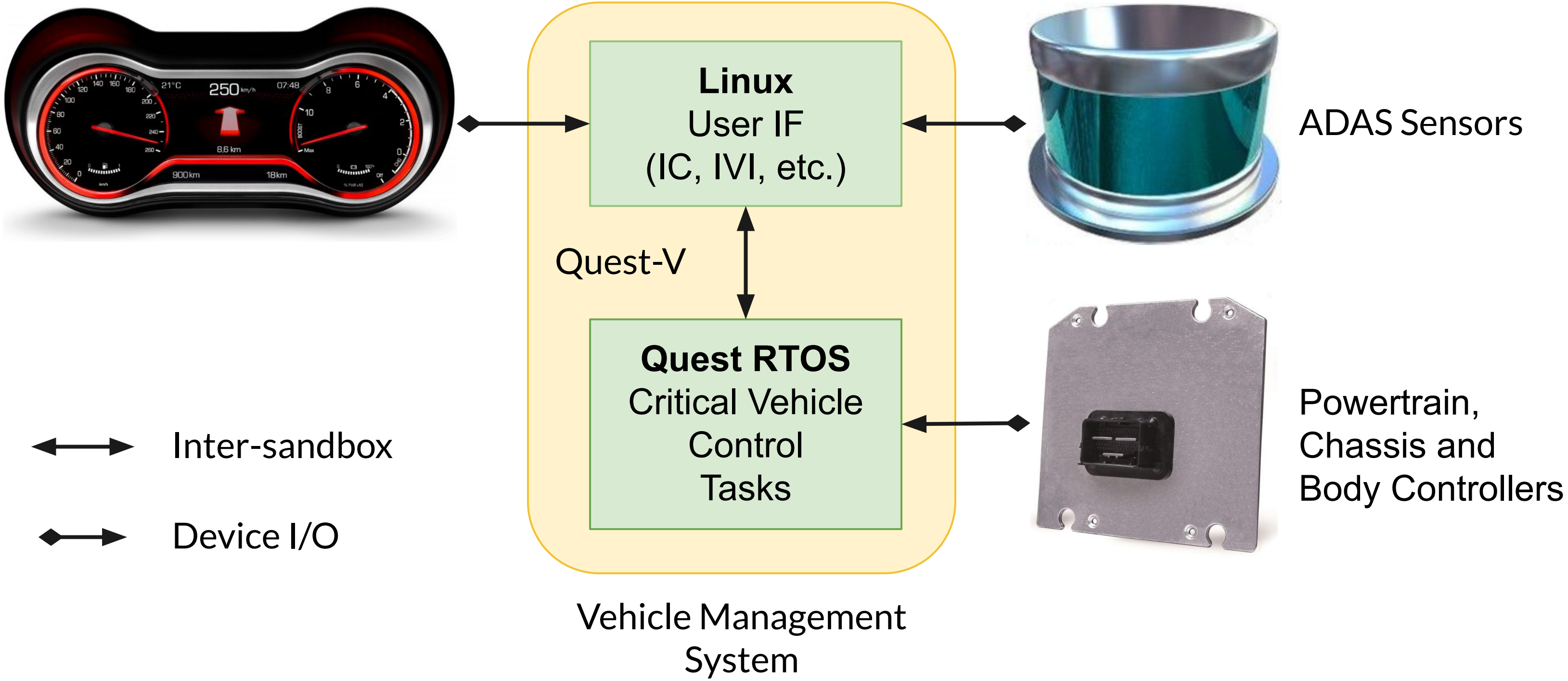
# Jumpstart: Fast Critical Service Resumption for a Partitioning Hypervisor in Embedded Systems

Ahmad Golchin and Richard West

Boston University

# DriveOS



Linux
User IF
(IC, IVI, etc.)
Quest-V
Quest RTOS
Critical Vehicle
Control
Tasks
Vehicle Management
System
ADAS Sensors
Powertrain,
Chassis and
Body Controllers
Inter-sandbox
Device I/O

# Why PC-class Embedded Systems?

**Advantages:**

- Higher Processing Capabilities
- Abundant Resources
- H/W Virtualization Technologies
- Smaller Footprint, Lower Cost, etc.

**Consolidation of 100+ ECUs into 1 Central System**

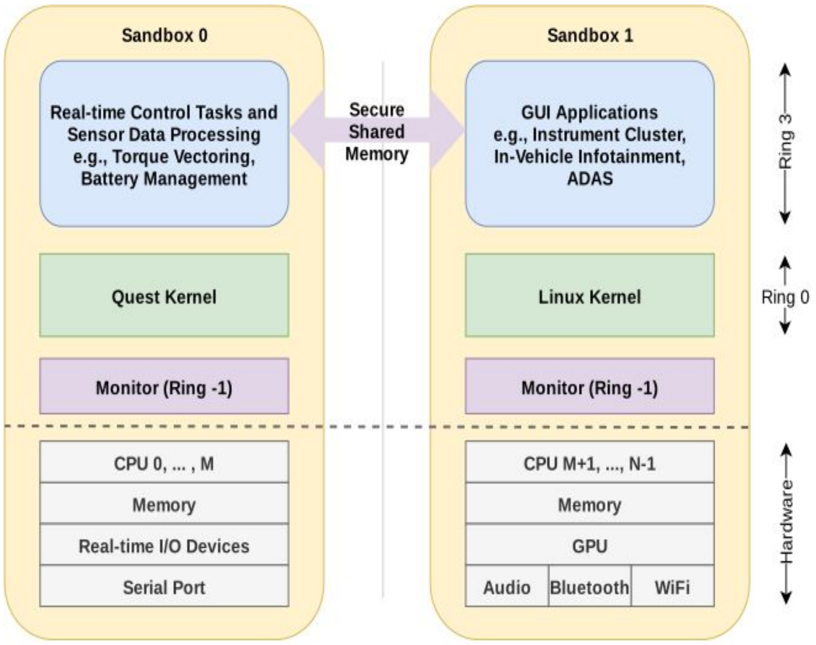
**Disadvantages:**

- Difficult to Provide Spatial/Temporal Isolation, etc.
- **Long Boot Delays**

# Quest RTOS

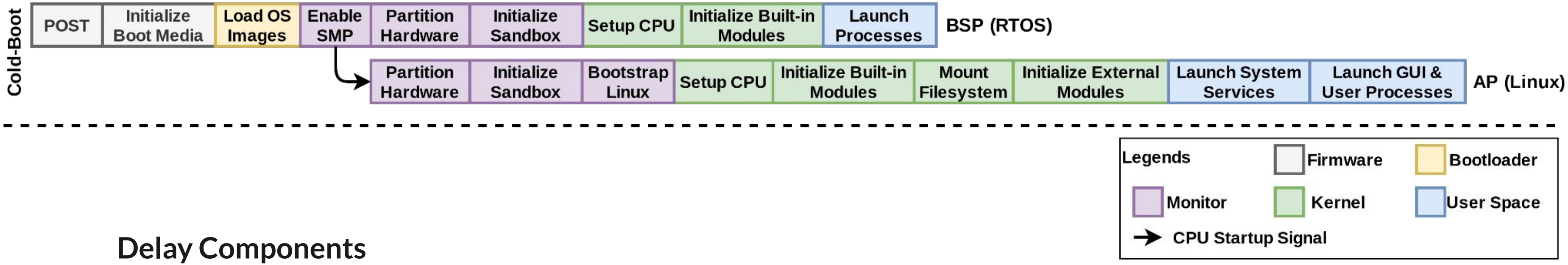
- Real-time OS for multicore x86 platforms
  - UP2, DX1100, Intel Aero, Skull Canyon, etc.
- Dual-mode monolithic kernel
- Unified task and I/O scheduling through time-budgeted virtual CPUs (VCPUs)
  - Main VCPUs for task scheduling
  - I/O VCPUs for interrupt bottom-half scheduling
- More info: www.questos.org

# The Quest-V Partitioning Hypervisor




- RTOS boot-strapped
- Support for Linux SBs
- Static partitioning:
  - CPUs, RAM, I/O
- Shared memory ISBC
- Mixed-criticality
  - Temporal & spatial separation

# Boot Delay of DriveOS




### Delay Components

- Firmware ~ 7 seconds
- Bootloader ~ 1.4 seconds
- Virtualization ~ 4.7 seconds
- RTOS Startup ~ 3.5 seconds
- Linux Startup ~ 11.3 seconds

**~ 24.5 seconds**

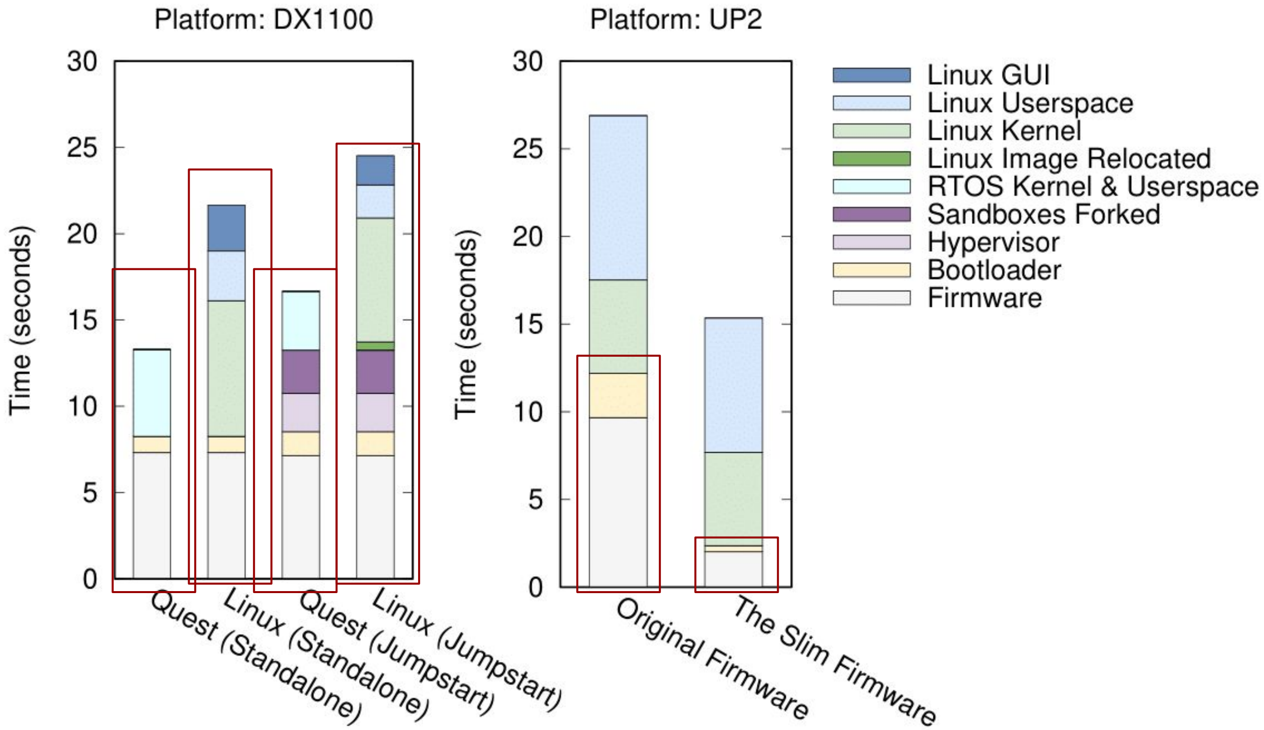
### Objective < 1 second for VMS

# Boot Delay of DriveOS

- **Firmware and Bootloader**
  - At least 2.5 kernels between the Guest and IA-PC H/W (Minich et al)
    - UEFI Firmware
    - Intel Management Engine (IME) running Minix
    - Intel System Management Mode (SMM)
  - **Existing solutions:** NERF, Coreboot, Intel Slim
    - Reduced F/W, ROM-hosted OS images, etc.
- **Hypervisor**
  - Architectural setup, Resource Partitioning, etc.
- **Guest Kernel and Drivers**
- **User-space Services**

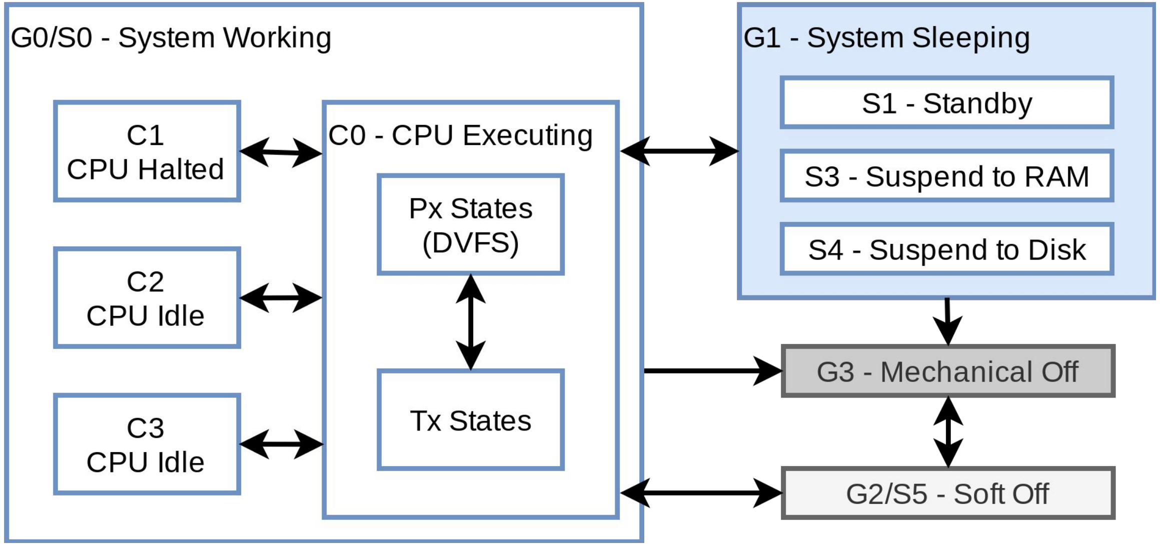
**Issues:**
**Portability**
**Stage Coverage**

# UEFI vs Intel Slim Bootloader

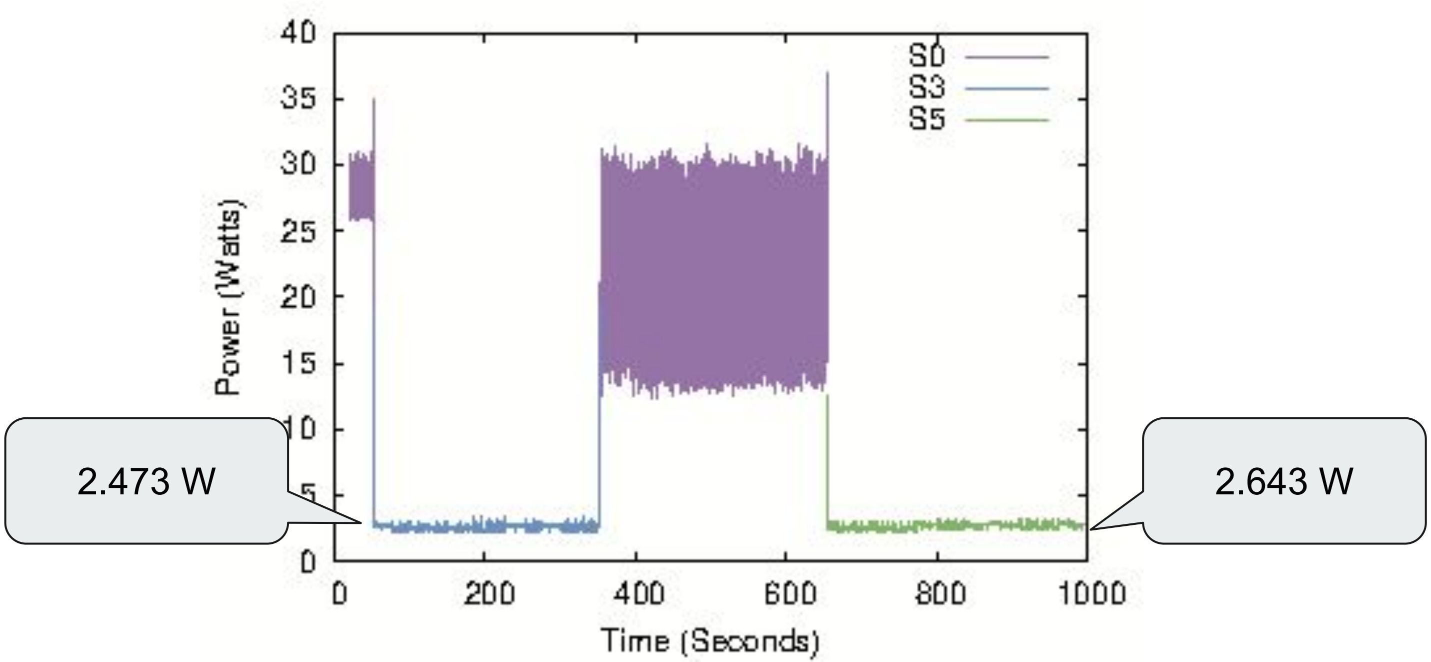


# Power Management

- ACPI(CA)
- PCI-PM
- Dynamic vs Static
- Virtual vs Real



# Feasibility of a PM Solution



# Jumpstart

## Framework

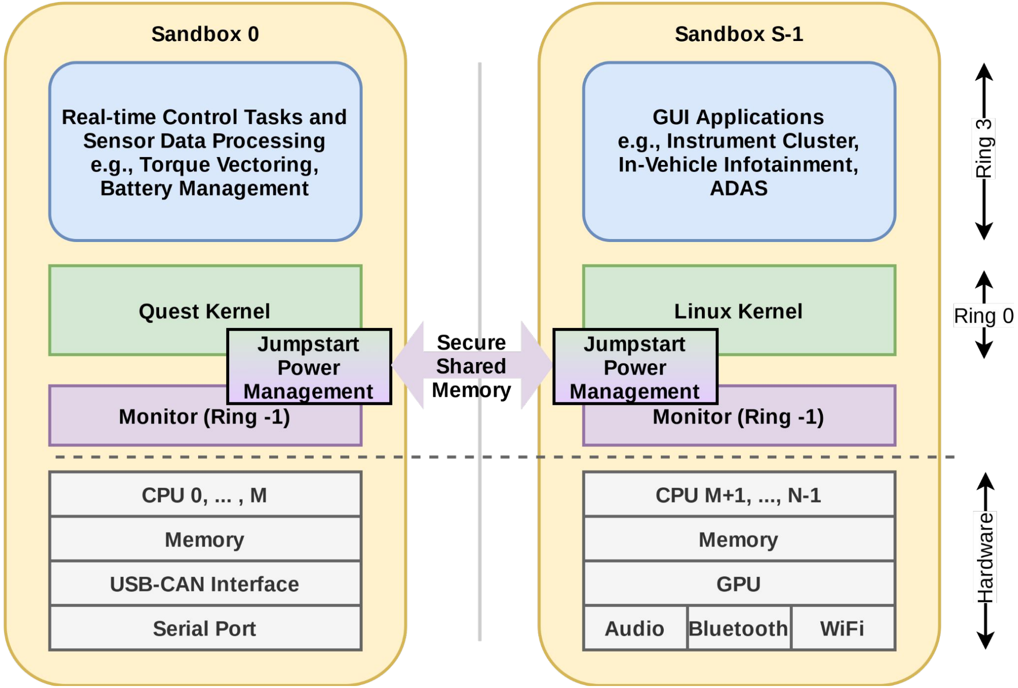
- Quest/Linux Kernel Modules
- Quest-V Monitor Module

## Function

- Turns System-wide Shutdown/Boot into ACPI S3 Suspend/Resume

## Achieves

- ~**600ms** Quest
- ~**1050ms** Linux



# Jumpstart Power Management

**Challenges**

- Unauthorized guest access to the system's Embedded Controller
  - I/O Ports & ACPI memory
- Orchestration of system-wide power transition
  - Power Master & Inter-sandbox IPC
- Resumption of critical real-time tasks
  - Idempotent  vs Resumption
- Resumption of critical real-time sandbox with lower latency
  - Shared boot logic of Quest and Quest-V

**Requirements**

- ACPI-compliance platform
- Support of ACPI S3 natively by the guest

# Control Flow

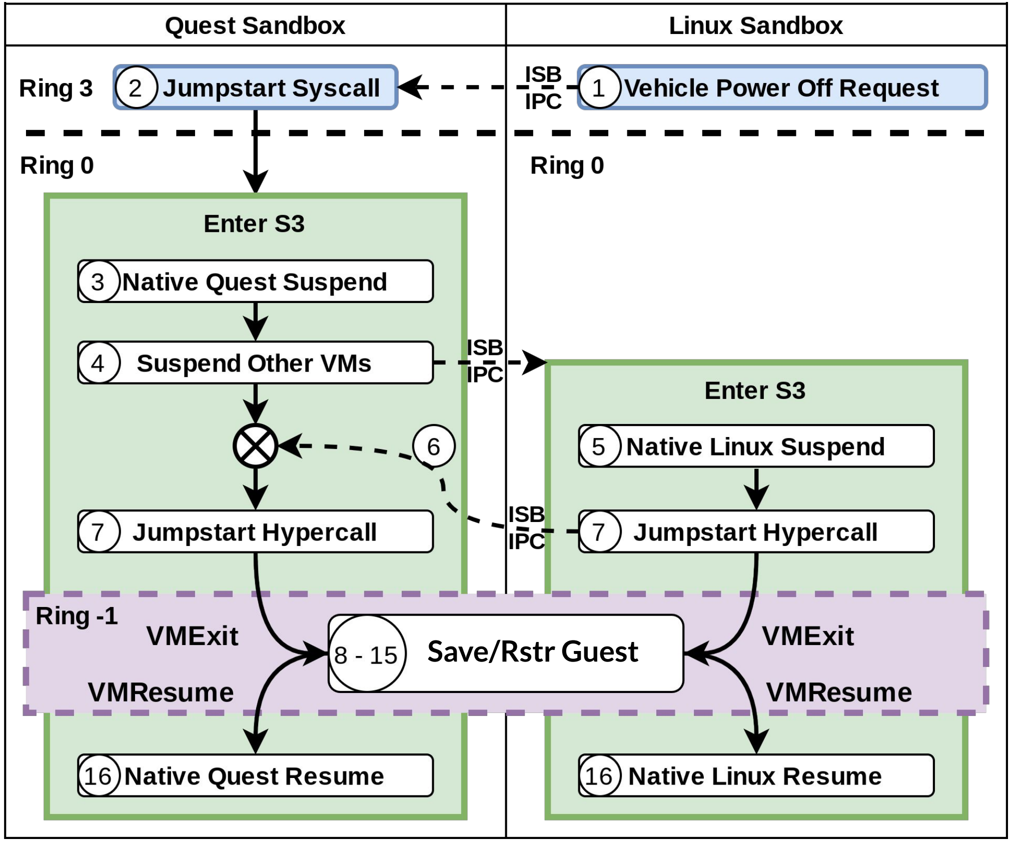
User-space

Kernel

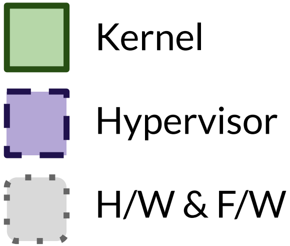
Hypervisor

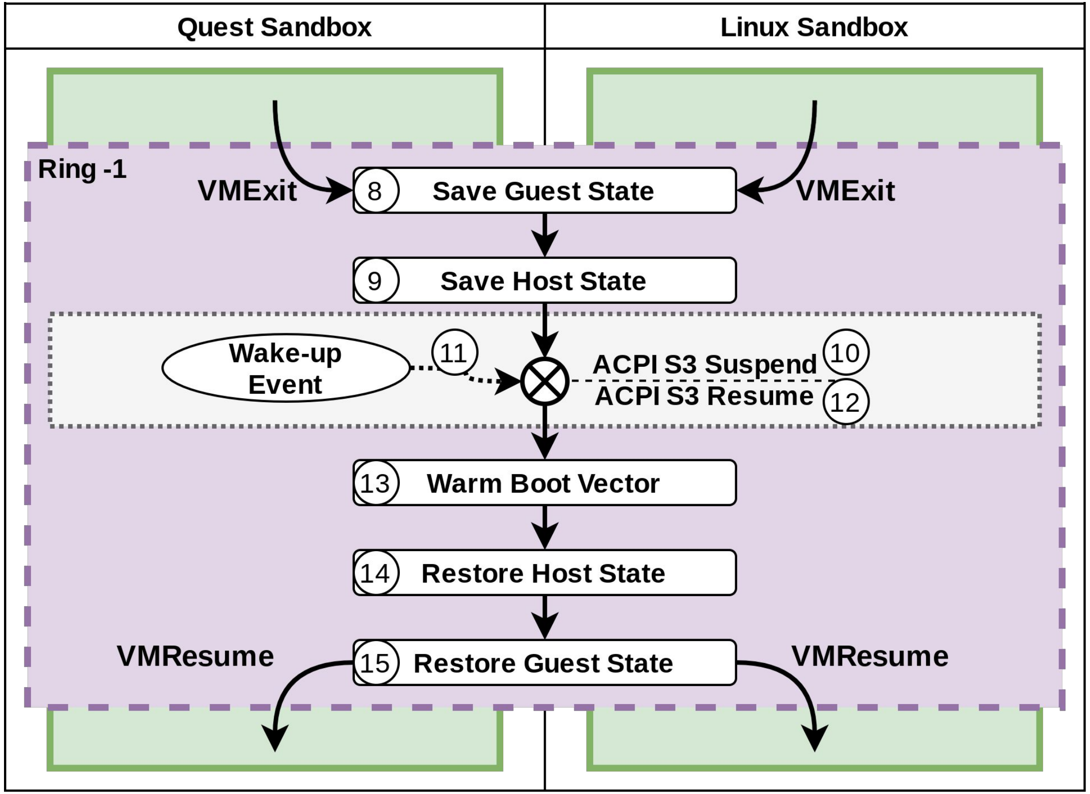
ISB IPC

Synch. Point

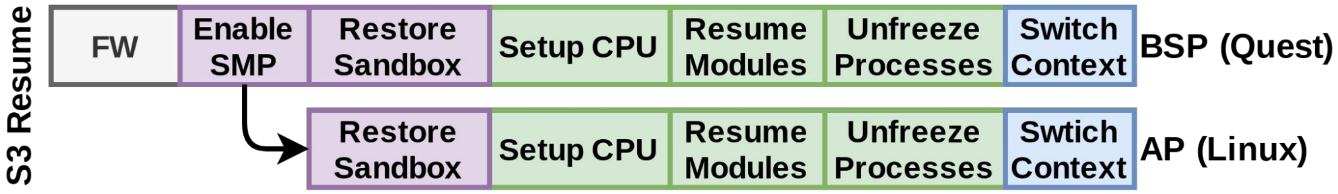


# Control Flow



# Resumption Delay of DriveOS with Jumpstart



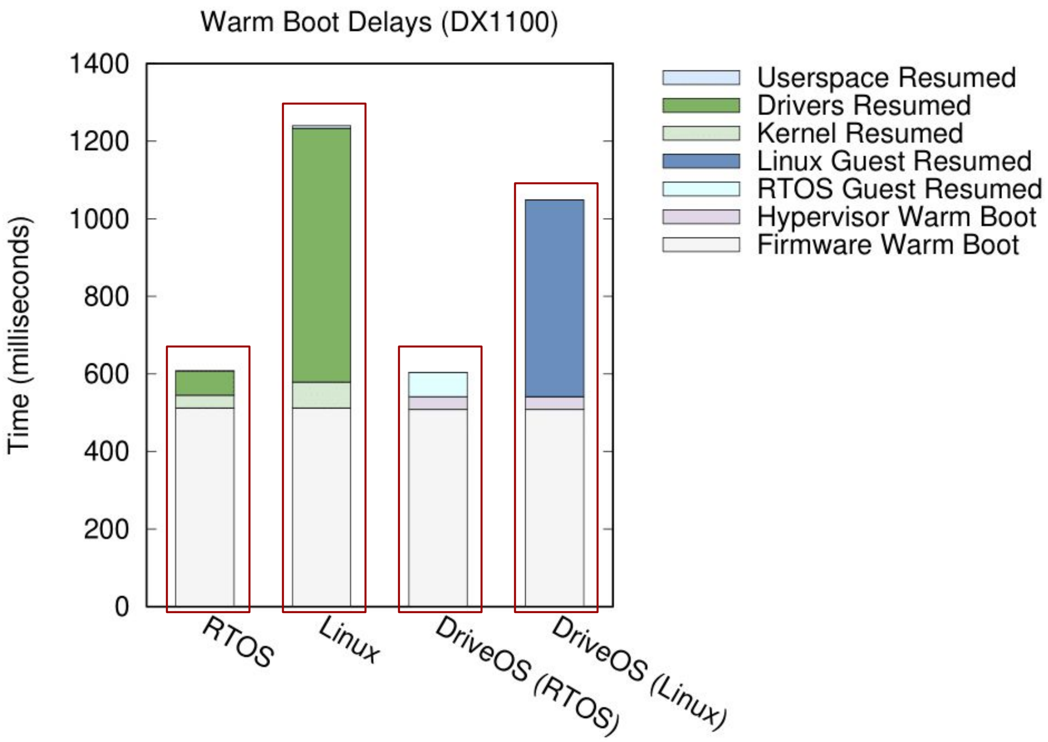

**Delay Components**

- Firmware ~ 500 ms
- Quest-V ~ 30 ms
- Quest Guest ~ 66 ms
- Linux Guest ~ 510 ms

**Quest : 600 ms**

**Linux : 1040 ms**

# Jumpstart vs Standalone Quest/Linux



# Conclusions and Future Work

- Why Jumpstart?
  - Similar power consumption of Suspend-to-RAM and Shutdown
  - Higher degree of portability
  - Faster parallel resumption of partitioned guests w.r.t. Standalone
  - Complementary to firmware optimizations
- Future Direction
  - Fast non-volatile memories and ACPI S4

# Thank you!

Q & A