

Caelaris Linux

Technical Architecture, Subsystem Pipelines, Storage Topology, and Virtualization Integration Architecture

Product Name	Caelaris Linux (x86_64)
Document Type	System Architecture & Technical Design
Distribution Base	Arch Linux Rolling Baseline (Kernel 6.x)
Document Author	Caelaris Core Architecture Team
Display Manager	SDDM with Breeze Theme & Wayland Sessions
Installer Subsystem	Caelaris Native Graphical Installer (PyQt6)
Compression Engine	Zstandard Level 19 (SquashFS)
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1. High-Level Architectural Model

Caelaris Linux is organized into distinct, modular subsystem layers that cleanly isolate the base operating system packages, custom desktop environments, kernel/sysctl performance optimizations, and runtime installer automation:

+-----+ USER EXPERIENCE LAYER +-----+		
KDE Plasma 6 (Wayland) [Default]	GNOME 4x (Wayland) [Alternative]	
Caelaris Welcome Assistant (GTK3)	Desktop Session Hot-Switcher	
+-----+		
DISPLAY & SESSION MANAGEMENT		
Simple Desktop Display Manager (SDDM) with Breeze Theme & Autologin		
AccountsService User Session Tracking & Polkit Privilege Agent		
+-----+		
APPLICATIONS & GAMING INFRASTRUCTURE		
Steam Client (Native / Proton)	MangoHud (32 & 64-bit)	GameMode
VKD3D DirectX 12 Translation	PipeWire Pro-Audio Graph & ALSA/Pulse	
Arch User Repository (yay)	Flatpak / Flathub Application Sandbox	
+-----+		
HARDWARE & HYPERVISOR DRIVERS		
Mesa Gallium / Vulkan (RADV)	NVIDIA Proprietary + DRM Modesetting	
Intel ANV & VA-API Media Driver	VMware open-vm-tools & xf86-video-vm	
VirtualBox Guest Additions	QEMU / SPICE VDAgentd Daemon	
+-----+		
KERNEL & SYSTEM CORE OPTIMIZATIONS		
Linux Kernel 6.x Rolling	mkinitcpio (Default & Fallback)	
sysctl Gaming Performance	ZRAM Compressed Swap Engine (zstd)	
Google BBR TCP Congestion	CAKE Active Queue Management	
+-----+		
BOOTLOADER & STORAGE FOUNDATION		
GRUB 2 (UEFI x86_64 & BIOS MBR)	systemd-boot (Live ISO UEFI)	
Btrfs with Subvolume Layout	Ext4 Standard Filesystem	
SquashFS (Zstandard Level 19)	OverlayFS Copy-on-Write Live Layer	
+-----+		

2. Storage Hierarchy & Live Boot Architecture

2.1 Multi-Tiered Live Layering

Caelaris Linux employs Archiso's standard two-tiered filesystem architecture, enhanced with maximum compression and userspace provisioning:

- **SquashFS Base Layer (`airootfs.sfs`):** The entire root filesystem containing all packages, configuration files, and desktop profiles is compressed using Zstandard level 19 (`-Xcompression-level 19`), delivering rapid decompression with ultra-compact storage (~4.2 GB uncompressed root compressed into ~3.7 GB).
- **OverlayFS Copy-on-Write Layer:** At boot, the Linux kernel mounts `airootfs.sfs` as a read-only lower filesystem and an in-memory `tmpfs` as the upper filesystem, enabling live modifications without disk writes.
- **Copy-to-RAM Mode:** An available bootloader option transfers the entire SquashFS image into RAM during early boot, allowing complete unmounting and physical removal of the installation media.

2.2 Media Layout Topology

```
ISO_ROOT/  
├─ EFI/BOOT/           # BOOTX64.EFI & grubx64.efi executables  
├─ arch/boot/x86_64/    # Kernel (vmlinuz-linux) & initramfs  
├─ arch/boot/intel-ucode.img # Intel CPU microcode updates  
├─ arch/boot/amd-ucode.img  # AMD CPU microcode updates  
├─ arch/x86_64/airootfs.sfs # Compressed OS image (Zstandard-19)  
├─ loader/entries/       # systemd-boot profiles (KDE, GNOME, RAM)  
└─ syslinux/             # BIOS MBR configuration files
```

3. Bootloader & Initramfs Pipeline

3.1 Live Media Boot Sequence

```
[BIOS / UEFI Firmware]
|
v
[Bootloader Menu (systemd-boot / Syslinux)]
- Evaluates boot params: 'desktop=plasma' or 'desktop=gnome'
|
v
[Early Kernel Initialization (vmlinuz-linux)]
- Loads CPU microcode (intel-ucode / amd-ucode)
- Initializes hardware busses (PCIe, ACPI, USB)
|
v
[Early Userspace (initramfs / udev)]
- Mounts squashfs filesystem (airootfs.sfs) via loop device
- Mounts OverlayFS writable ramdisk
|
v
[Systemd Init (PID 1)]
- Provisions liveuser via systemd-sysusers
- Configures SDDM autologin for target desktop environment
|
v
[Simple Desktop Display Manager (SDDM)]
- Launches KWin (KDE) or Mutter (GNOME) Wayland Compositor
```

3.2 Installed System Silent Bootloader Pipeline

To satisfy the requirement for a clean, direct transition into the login screen without console clutter:

- **Suppression Parameters:** `quiet loglevel=3 rd.udev.log_level=3 systemd.show_status=0 vt.global_cursor_default=0 video=1920x1080` suppresses non-critical kernel messages, udev logs, and systemd service startup lines.
- **GRUB Menu Simplification:** Menu entry titles are cleaned of redundant package version strings, reading strictly `Caelaris Linux` (or `Caelaris Linux (Recovery Mode)`).
- **Universal Removable Fallback:** Installs both the standard NVRAM entry and a universal removable fallback at `EFI/BOOT/BOOTX64.EFI`, eliminating UEFI boot loops in VMware Workstation and VirtualBox.

4. Display & User Session Management

4.1 Wayland Display Compositors

Both desktop environments execute natively under Wayland, avoiding X11 tearing and improving input latency:

- **KDE Plasma 6 (Default):** Managed by KWin Wayland compositor, configured with Breeze dark styling.
- **GNOME 4x (Alternative):** Managed by Mutter Wayland compositor.
- **SDDM Integration:** Provides an intuitive session selection dropdown at every login screen post-installation.

4.2 Single User Profile Architecture

Single Profile Guarantee: The live user account is strictly temporary and is permanently removed during installation.

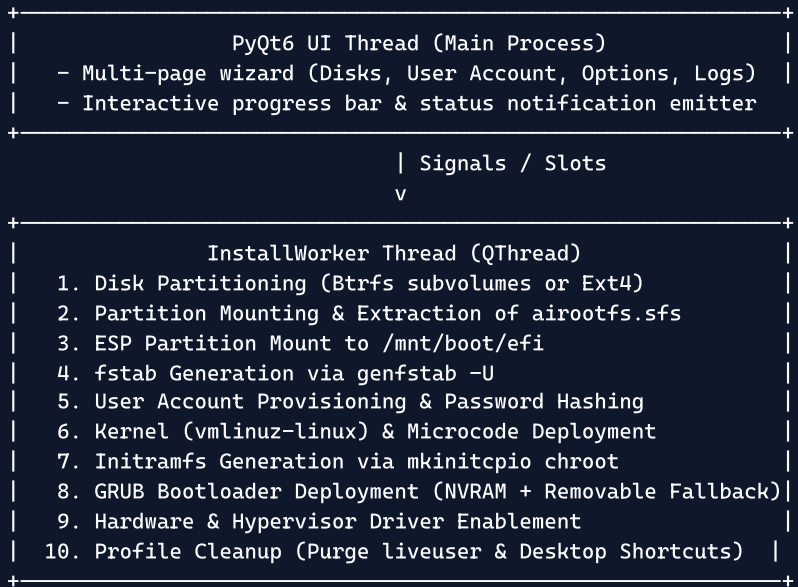
During Step 6 of the installation process:

1. `arch-chroot /mnt userdel -r -f liveuser` deletes the live user and home directory.
2. `/mnt/etc/sysusers.d/caelaris-liveuser.conf` is removed to prevent systemd from regenerating the user.
3. `/mnt/var/lib/AccountsService/users/liveuser` is deleted so only the user-configured account appears in SDDM.
4. The installer desktop shortcut is removed from both `/home/{user}/Desktop/` and `/etc/skel/Desktop/`.

5. Caelaris Native Graphical Installer Architecture

5.1 Process & Thread Model

The installer (`caelaris-installer-gui`) is built on Python 3 and PyQt6, employing a multithreaded architecture that separates GUI interactions from intensive disk I/O operations:



5.2 Btrfs Subvolume Topology

Subvolume	Mount Point	Mount Parameters	Function
@	/	<code>rw,noatime,compress=zstd:1,subvol=@</code>	Operating system root filesystem
@home	/home	<code>rw,noatime,compress=zstd:1,subvol=@home</code>	User files and application dotfiles
@cache	/var/cache	<code>rw,noatime,subvol=@cache</code>	Pacman package downloads and cache
@snapshots	/.snapshots	<code>rw,noatime,subvol=@snapshots</code>	Snapper / system rollback snapshots

6. Hardware & Virtualization Architecture

6.1 Hypervisor Guest Drivers

Hypervisor Platform	Kernel Drivers & Userspace Daemons	Integration Capabilities
VMware Workstation / Fusion	<code>open-vm-tools</code> , <code>vmtoolsd</code> , <code>vmware-vmblock-fuse</code> , <code>vmwgfx</code> DRM	Automatic display resizing, host shared folders, two-way clipboard.
Oracle VirtualBox	<code>virtualbox-guest-utils</code> , <code>vboxservice</code> , <code>vboxvideo</code> DRM	Seamless mouse pointer, dynamic display scaling, bidirectional clipboard.
QEMU / KVM / UTM (macOS)	<code>spice-vdagent</code> , <code>spice-vdagentd</code> , <code>qemu-guest-agent</code> , <code>virtio-gpu</code>	Fast SPICE display synchronization, host clipboard, guest management.

6.2 Dynamic Display Resizing Engine

The userspace daemon `caelaris-autoresize` continuously listens for monitor resolution updates dispatched by hypervisor virtual display adapters, instantly invoking `kscreen-doctor` on Wayland or `xrandr` on XWayland to adapt the guest resolution to the host window.

7. Audio Subsystem Architecture

Caelaris Linux is standard on **PipeWire** with **WirePlumber** session management:

- **Low Latency Audio Graph:** Replaces legacy PulseAudio and JACK with a unified, high-performance graph engine.
- **Compatibility Bridges:** Includes `pipewire-pulse` , `pipewire-alsa` , and `pipewire-jack` , allowing native Linux games, DAW software, and web browsers to route audio simultaneously with zero configuration.