# The Compatibility Gauntlet: An Analysis of Unplayable Real-Time Strategy Games on macOS

## Executive Summary: The RTS Compatibility Matrix on macOS

The landscape of real-time strategy (RTS) gaming on Apple's macOS platform is complex, defined by a series of technical and strategic decisions that create significant barriers for specific titles. Despite a sophisticated array of modern technologies—including native execution via Rosetta 2, compatibility layers like CrossOver and Apple's Game Porting Toolkit, virtualization solutions such as Parallels Desktop, and cloud gaming services—a notable subset of RTS games remains unplayable. This report provides an exhaustive analysis of these incompatibilities, identifying the root technical causes for each failure. The primary blockers are multifaceted, ranging from deprecated graphics Application Programming Interfaces (APIs) and missing CPU instruction sets to the pervasive influence of hostile third-party middleware like Digital Rights Management (DRM) and anti-cheat systems.

The following matrix summarizes the compatibility status of several key RTS titles across the spectrum of available technologies, providing a high-level overview of the findings detailed within this report.

| Game Title | Native Support (Rosetta 2) | CrossOver / Game Porting Toolkit | Parallels / VMWare (Windows VM) | GeForce NOW | Shadow PC |
|---|---|---|---|---|---|
| **Beyond All Reason / Zero-K** | **Unplayable** Primary Blocker: Requires OpenGL 4.3+, which is | **Unplayable** Primary Blocker: Wine cannot expose OpenGL features | **Unplayable** Primary Blocker: Virtualized GPU is limited to host's | **Unsupported** Primary Blocker: Game is not available in the curated library. | **Playable** Provides a full Windows PC in the cloud, bypassing local |

| | | | | | |
|---|---|---|---|---|---|
| | unsupported by macOS. | beyond the host OS's capabilities. | OpenGL 4.1 support, causing graphical errors and crashes. | | hardware/API limitations. |
| **Age of Empires IV** | **Unplayable** Primary Blocker: Requires AVX CPU instructions, which are absent in Apple Silicon. | **Unplayable** Primary Blocker: Game detects lack of AVX instructions on Apple Silicon CPU and will not launch. | **Unplayable** Primary Blocker: Virtualized CPU still runs on Apple Silicon hardware, which lacks AVX instructions. | **Supported** Game runs on NVIDIA's x86-64 servers, which support AVX. | **Playable** Provides a full Windows PC in the cloud with an x86-64 CPU that supports AVX. |
| **Company of Heroes 3** | **Unplayable** Primary Blocker: No native macOS version available. | **Unplayable** Primary Blocker: Fails to launch due to a combination of DirectX 12 translation issues and Denuvo anti-tamper DRM. | **Unplayable** Primary Blocker: Parallels and VMWare lack DirectX 12 support. | **Unsupported** Primary Blocker: Game is not available in the curated library. | **Playable** Provides a full Windows PC in the cloud, but may be subject to Denuvo-related issues. |
| **Iron Harvest** | **Unplayable** Primary Blocker: No native macOS version available. | **Unplayable** Primary Blocker: Severe graphical rendering failure; game logic runs but the map and units are invisible ("white screen" | **Playable** Runs successfully as a DirectX 11 title within a Windows VM. | **Unsupported** Primary Blocker: Game is not available in the curated library. | **Playable** Provides a full Windows PC in the cloud. |

| | | | | | |
|---|---|---|---|---|---|
| | | bug). | | | |
| **Homeworld 3** | **Unplayable** Primary Blocker: No native macOS version available. | **Unplayable** Primary Blocker: Fails to launch due to incompatibilities with mandatory middleware, specifically Epic Online Services (EOS) and Denuvo DRM. | **Playable** Middleware can be installed correctly in a full Windows environment, though Denuvo may still pose issues. | **Unsupported** Primary Blocker: Game is not available in the curated library. | **Playable** Provides a full Windows PC in the cloud, bypassing middleware issues common in translation layers. |

---

## Section 1: The Foundational Divide: Architecture, APIs, and the macOS Gaming Ecosystem

To comprehend why specific RTS games fail on macOS, it is essential to first understand the fundamental technical and strategic landscape that Apple has cultivated. Three core factors create a challenging environment for game developers and compatibility engineers: the deprecation of the industry-standard OpenGL graphics API in favor of the proprietary Metal API, the architectural transition from x86-64 to ARM-based Apple Silicon, and the complex nature of the software tools designed to bridge these divides.

### 1.1 The End of an Era: Apple's Deprecation of OpenGL and the Rise of Metal

In a pivotal move that reshaped the Mac gaming landscape, Apple announced at its 2018 Worldwide Developers Conference that it was deprecating OpenGL and OpenCL across all its platforms. Deprecation, in this context, meant that while applications using these APIs would continue to function, Apple would cease all future

development and support. This decision effectively froze OpenGL support on macOS at version 4.1, a standard dating back to 2010.

This action created a profound and lasting schism with the broader PC gaming world, where OpenGL and its successor, Vulkan, remain vital open standards. For game developers, particularly those working with custom or open-source engines, this decision presented a stark choice: either invest significant resources into rewriting their rendering backends to support Apple's proprietary Metal API or abandon the platform entirely. The consequences of this strategic divergence are a primary cause of incompatibility for a large class of games.

The effect of this decision is not merely theoretical; it has a direct and cascading impact on game engines that continue to evolve. For instance, the open-source Spring Engine, which powers titles like *Beyond All Reason* and *Zero-K*, underwent a major update to version 106.0, which introduced support for modern OpenGL 4 features to improve performance and leverage newer hardware on Windows and Linux.[1] This modernization, a logical step for the engine's development, immediately rendered it incompatible with macOS. The engine now requires features and a "Core Profile" that the macOS operating system explicitly does not provide.[3] Consequently, any game built upon this updated engine is fundamentally incompatible with macOS at the API level, a barrier that cannot be overcome without a complete and costly port to Metal. This single, high-level decision by Apple has had a chilling ripple effect, effectively invalidating an entire lineage of game development for its platform unless developers undertake a porting effort that is often infeasible for community-driven or smaller commercial projects.[4]

### 1.2 The ARM Transition: From x86 to Apple Silicon

Apple's transition from Intel (x86-64) processors to its own custom ARM64-based "Apple Silicon" chips beginning in 2020 introduced a second major compatibility hurdle. To address this, Apple developed Rosetta 2, a highly sophisticated and remarkably effective translation layer that allows most x86-64 applications to run seamlessly on Apple Silicon hardware.[6] However, for the demanding and hardware-specific domain of gaming, Rosetta 2 has critical limitations that create both "hard" and "soft" architectural barriers.

The most significant "hard barrier" is the absence of specific CPU instruction sets.

Modern x86-64 processors from Intel and AMD include Advanced Vector Extensions (AVX), which are used to perform single-instruction, multiple-data operations for computationally intensive tasks common in physics simulations and graphics rendering.[8] Games like

*Age of Empires IV* are compiled with the explicit requirement that the host CPU supports AVX.[9] Apple Silicon processors, being of a different architecture, do not have hardware support for AVX, and Rosetta 2 does not emulate these complex instructions. When the game's code attempts to execute an AVX instruction, there is no corresponding function on the processor, resulting in an immediate crash or a failure to launch with an explicit error message.[8] This creates an impassable barrier for any technology running locally on the Mac, including compatibility layers and virtualization.

A more subtle but equally prohibitive "soft barrier" affects the intricate simulation models of certain RTS games. Many large-scale RTS engines, including the Spring Engine, rely on a deterministic lock-step simulation for multiplayer gameplay. This model requires that every player's computer calculates the exact same simulation state on every "tick" of the game clock. Any deviation, no matter how small, will result in a "desync" that ruins the match. To guarantee this consistency across different x86-64 CPUs, which can have minor variations in floating-point math, developers use libraries like streflop.[6] This library forces the CPU's floating-point unit into a specific, standardized mode. However,

streflop and similar libraries are designed exclusively for the x86 architecture and have no equivalent for ARM processors.[6] This presents a monumental software engineering challenge for porting. While it does not prevent the game from launching in a single-player mode, it makes the critical multiplayer component non-functional, rendering a port infeasible for an online-focused, community-driven game like

*Beyond All Reason*.

### 1.3 Bridging the Gap: The Landscape of Translation and Virtualization

To address the API and architectural divides, a sophisticated ecosystem of enabling technologies has emerged, each with a distinct approach and set of trade-offs.

- **Compatibility Layers:** These tools, such as the open-source **Wine** project, work

by translating Windows API calls into their equivalents on the host operating system (e.g., POSIX calls on macOS and Linux) on-the-fly.[12]
**CrossOver**, a commercial product from CodeWeavers, is a polished and supported version of Wine that integrates additional patches and user-friendly tools.[13] The effectiveness of these layers for modern gaming on Mac hinges on a chain of further translation tools:
    - **DXVK** translates DirectX 9, 10, and 11 calls to the Vulkan API.
    - **MoltenVK** then translates those Vulkan calls to Apple's Metal API.[15]
    - **D3DMetal**, Apple's own technology integrated into the **Game Porting Toolkit (GPTK)**, translates DirectX 11 and 12 calls directly to Metal, offering the potential for very high performance.[17]

      This multi-stage translation process is powerful but fragile; a failure or incompatibility at any stage can cause a game to crash, exhibit graphical artifacts, or fail to launch entirely.
- **Virtualization:** Solutions like **Parallels Desktop**, **VMWare Fusion**, and **UTM** take a different approach. They are hypervisors that run a full, sandboxed instance of the Windows operating system on top of macOS.[19] This provides a more complete and compatible Windows environment, which is often better at handling complex application installers, dependencies, and third-party middleware. However, this comes at the cost of significant performance overhead compared to a direct translation layer. Critically, the virtualized hardware, particularly the GPU, cannot exceed the capabilities of the host Mac. This creates a "glass ceiling" where, for instance, a Windows VM running on a Mac can only access the OpenGL 4.1 features that the underlying macOS provides, even if Windows itself supports newer versions.[22]

---

## Section 2: In-Depth Case Studies of Incompatible RTS Titles

Applying the foundational principles of macOS's unique gaming ecosystem, this section provides a detailed analysis of specific RTS titles that fail to run. Each case study dissects the game's technical requirements and examines its performance—or lack thereof—across the full spectrum of compatibility technologies, pinpointing the precise reasons for failure.

### 2.1 Case Study: *Beyond All Reason* & *Zero-K* (The Spring Engine Dilemma)

*Beyond All Reason* (BAR) and *Zero-K* are popular, large-scale RTS games built on the open-source Spring Engine. Their incompatibility on macOS serves as a quintessential example of the API divergence problem, compounded by the realities of community-driven development.

- **The Core Problem: OpenGL Dependency:** The fundamental blocker for these titles is their reliance on a version of OpenGL that Apple has abandoned. The Spring Engine, in its pursuit of modernization and better performance on its primary target platforms of Windows and Linux, was updated to require OpenGL 4.x features.[1] The official download page for *Beyond All Reason* explicitly states that the game is incompatible with Mac due to the "No support for OpenGL 4.3 by Apple".[3] Since macOS support is frozen at OpenGL 4.1, the game's rendering engine cannot be initialized, leading to an immediate failure.
- **Game-Level Complications:** The issue is deeply embedded within the game's architecture. It is not merely an engine-level requirement; the game-specific logic, written in the Lua scripting language, has direct access to and makes calls to the OpenGL API.[5] This means that any potential translation layer would need to intercept and correctly handle not only the standardized rendering calls from the C++ engine but also a vast number of custom graphical commands from the game's scripts—a task of immense complexity.
- **Failure Across Technologies:**
  - **CrossOver/Wine:** These compatibility layers fail because they are designed to expose the host operating system's native graphics capabilities to the Windows application. On macOS, Wine can only report the availability of OpenGL 4.1, which is insufficient for BAR's requirements. Community discussions and developer forums confirm that Wine on macOS is generally limited to reliable support for OpenGL 2.1, falling far short of the game's needs.[23]
  - **Parallels/VMWare:** Virtualization encounters what can be termed the "Virtualization Paradox." While a user can install a full version of Windows 11 for ARM within Parallels, the virtual machine's graphics driver is provided by the Parallels hypervisor, which in turn relies on the host macOS and its Metal API. Parallels Desktop 19, for example, only exposes OpenGL 4.1 capabilities to the guest Windows VM.[23] The hypervisor cannot invent hardware or API features that do not exist on the host machine. Attempts by users to run BAR

in this environment have been uniformly unsuccessful, resulting in either immediate crashes or severe graphical glitches, such as missing UI elements and explosions rendering as black circles, making the game unplayable.[4]
    - **Cloud Gaming:** As niche, free-to-play titles, neither BAR nor *Zero-K* are available on curated cloud services like NVIDIA GeForce NOW.[3] They are, however, playable on a service like Shadow PC, which provides a full, remote Windows PC. This works because the game is running on native Windows hardware in a data center, completely bypassing the user's local Mac hardware and its API limitations.
- **The Open-Source Conundrum:** The development model of BAR and the Spring Engine community is a significant factor in this incompatibility. These projects are maintained by a global team of volunteers and enthusiasts who primarily use and develop for Windows and Linux.[5] Their development path naturally follows the open standards and modern technologies available on those platforms. Without dedicated macOS developers within the community or the substantial financial backing of a AAA studio, the monumental task of creating and maintaining a separate, bespoke Metal renderer for the Spring Engine is entirely infeasible.[4] In this context, the project's open-source, community-driven nature, a great strength for innovation and accessibility, becomes a critical vulnerability when faced with the demands of Apple's closed and proprietary ecosystem.

### 2.2 Case Study: *Age of Empires IV* (The AVX Instruction Barrier)

The failure of *Age of Empires IV* on Apple Silicon Macs is a clear-cut case of a "hard" architectural barrier, demonstrating a limitation that no local software solution—be it translation or virtualization—can overcome.

- **The Core Problem: CPU Instruction Set:** The game's system requirements explicitly state that the CPU must support AVX (Advanced Vector Extensions) instructions.[9] This is a non-negotiable requirement checked by the game upon launch.
- **Failure Across Technologies:**
    - **Native/Rosetta 2:** The game fails to run because Apple Silicon processors (M1, M2, M3, M4 series) are built on the ARM64 architecture and do not include hardware for executing x86-64 AVX instructions. The Rosetta 2 translation layer, while powerful, does not emulate this specific and complex instruction set.[8]

    - **CrossOver/Game Porting Toolkit:** These translation layers fail for the same fundamental reason. They execute the game's code on the native Apple Silicon CPU, which lacks the required hardware capabilities. Users across multiple Mac models and CrossOver versions consistently report that the game fails to launch, presenting an error message that explicitly states, "Your CPU needs to support AV instructions to run".[8] While community-developed workarounds involving DDL replacement files exist, they are reported to function only for pirated, offline versions of the game, making them an invalid and illegitimate solution for typical users.[8]
    - **Parallels/VMWare:** Virtualization also fails to circumvent this issue. Running a guest instance of Windows 11 for ARM inside Parallels still means the operating system's instructions are ultimately being executed by the host's Apple Silicon CPU. CPU virtualization does not create hardware features that are not physically present on the chip. Consequently, users attempting to run the game in Parallels receive the exact same AVX-related error message.[8]
- **The Only Viable Solution: Cloud Gaming:** *Age of Empires IV: Anniversary Edition* is officially supported on the NVIDIA GeForce NOW cloud gaming service.[28] This method is successful because it completely bypasses the local Mac's hardware limitations. The game is executed on NVIDIA's powerful x86-64 servers in a data center—which are equipped with CPUs that support AVX—and only a compressed video stream of the gameplay is sent to the user's Mac. For a legitimate owner of
  *Age of Empires IV*, this is currently the only way to play the game on an Apple Silicon Mac.

### 2.3 Case Study: *Company of Heroes 3* (The Modern DirectX & Middleware Challenge)

*Company of Heroes 3* represents a different class of incompatibility, one rooted in the cutting edge of Windows graphics APIs and the complexities of modern DRM, which combine to thwart current translation and virtualization efforts.

- **The Core Problem: DirectX 12 and DRM:** The game is built using Relic Entertainment's proprietary Essence Engine and its system requirements mandate support for the DirectX 12 API.[32] Furthermore, the game is protected by Denuvo Anti-Tamper, a sophisticated DRM solution known for its deep integration with the system and its hostility toward non-standard execution environments.[33]

- **Failure Across Technologies:**
  - **Parallels/VMWare:** These virtualization platforms currently fail because their virtualized graphics drivers do not support DirectX 12. Parallels Desktop's support is limited to DirectX 11, making it incapable of launching *CoH3*.[10] User reports on the Parallels forums confirm that attempts to launch the game result in errors, with no successful workarounds available.[38]
  - **CrossOver/Game Porting Toolkit:** This is, in theory, the most promising avenue for running *CoH3*, as Apple's Game Porting Toolkit and recent versions of CrossOver are specifically designed to translate DirectX 12 API calls to Metal.[17] However, widespread user reports indicate that *Company of Heroes 3* specifically fails to launch using GPTK.[40] This failure likely stems from a combination of two factors. First, the D3DMetal translation layer, while impressive, is not yet a perfect 1:1 implementation of the entire DirectX 12 feature set. The game may be using a specific function or feature that is not yet correctly translated, leading to an initialization error. Second, Denuvo DRM is a significant complicating factor. Denuvo often performs checks that are sensitive to the underlying hardware and software environment, and it frequently fails to validate in Wine-based translation layers or virtual machines, which it may flag as a potential tampering attempt.[41]
  - **Cloud Gaming Status:** The game is not currently available on the curated GeForce NOW library. It has been a frequent request from the community, but as of this report, it has not been onboarded.[42] The game would likely be playable on a full cloud PC service like Shadow, provided Denuvo does not block that specific virtualized environment.

### 2.4 Case Study: *Iron Harvest* (A Case of Graphical Rendering Failure)

*Iron Harvest*, a dieselpunk RTS built on the popular Unity engine, highlights a more subtle form of incompatibility. While the game's logic can be executed, a critical failure in the graphics pipeline renders it unplayable, demonstrating the fragility of shader translation.

- **The Core Problem: Engine/Shader Incompatibility:** The game is built using the Unity engine, which has excellent cross-platform credentials, including native support for Apple Silicon. However, the Windows version of the game, when run through a compatibility layer, exhibits a specific and catastrophic graphical

failure.

- **Failure on CrossOver:** User reports and testing confirm that while *Iron Harvest* can be installed and launched via CrossOver on an M1 Mac, the game is unplayable. After loading into a match, the heads-up display (HUD) and audio function correctly, and units can even be selected and issued commands. However, the entire 3D game world fails to render, appearing as a completely white or blank screen.[45] This specific failure mode points directly to an issue in the shader translation process. The game's shaders, originally compiled for DirectX on Windows, are not being correctly converted and executed by CrossOver's DXVK-to-MoltenVK-to-Metal pipeline. The result is a "whiteout" where the rendering engine is active but produces no valid output for the main scene, even though UI elements are drawn correctly.
- **Status on Other Technologies:** As a DirectX 11 title, *Iron Harvest* is likely playable within a Parallels or VMWare Fusion virtual machine, which have robust support for that API. The game is not listed as supported on GeForce NOW. Its failure on CrossOver serves as a powerful example of how even a mature, cross-platform engine like Unity can have game-specific implementations that are not yet correctly handled by the current generation of translation layers, leading to a complete breakdown in graphical rendering.

### 2.5 Case Study: *Homeworld 3* (Unreal Engine and the Middleware Gauntlet)

The incompatibility of *Homeworld 3* demonstrates a critical challenge for modern online gaming on alternative platforms: the "middleware gauntlet." Even when a game's core engine is highly portable, its reliance on a chain of third-party, Windows-centric services for online functionality and DRM can create insurmountable barriers.

- **The Core Problem: Middleware Dependencies:** *Homeworld 3* is built on Unreal Engine, a modern engine with robust cross-platform capabilities and generally good compatibility with translation layers.[46] The primary blockers are not in the engine itself, but in its mandatory integration with
  **Epic Online Services (EOS)** for multiplayer and account management, and **Denuvo Anti-Tamper** for DRM.[46]
- **Failure Across Technologies:**
  - **CrossOver/Game Porting Toolkit:** Attempts to run the game via CrossOver are likely to fail at the middleware stage. The EOS client, which is a complex

piece of software designed for a native Windows environment, frequently fails to install or initialize correctly within a Wine bottle.[49] These failures can be due to missing registry keys, unmet service dependencies, or networking quirks within the translation environment. Because the game requires a successful EOS connection to launch, even for single-player modes, this middleware failure becomes a hard blocker. Denuvo adds a second, potent layer of likely failure, as it is designed to resist the very kind of environment modification that Wine and CrossOver represent.[48]

- **Parallels/VMWare:** This route is more viable because a full Windows environment allows for the proper installation and operation of the EOS client. However, Denuvo may still present challenges, as it can sometimes detect virtualized hardware and may have strict limits on the number of "hardware changes" it permits, which can be triggered by VM configuration adjustments.[41]
- **Cloud Gaming Status:** The game is not currently available on GeForce NOW. Its playability on Shadow PC would depend entirely on whether Denuvo and EOS function correctly within Shadow's specific data center environment.

This case study illustrates that for many modern games, compatibility is no longer just a question of translating graphics API calls. A game must successfully navigate a gauntlet of third-party software—launchers, online services, anti-cheat, and DRM—each of which presents a potential point of failure. The failure of any single link in this chain renders the entire game unplayable, highlighting that modern game compatibility is as much about the surrounding ecosystem as it is about the core game engine.

---

## Section 3: A Comparative Analysis of macOS Gaming Technologies

The case studies reveal that no single technology is a panacea for running Windows RTS games on macOS. Each approach—virtualization, compatibility layers, and cloud gaming—has a distinct profile of strengths and weaknesses, making it suitable for some types of games and completely ineffective for others.

### 3.1 Virtualization (Parallels, VMWare, UTM): The Full OS, The Glass Ceiling

Virtualization software provides the most complete and authentic Windows environment possible on a Mac. By running a full guest operating system, it excels at handling complex application installers, dependencies, and middleware like Epic Online Services, which often fail in the more abstract environment of a compatibility layer.[21] This makes it a reliable choice for older or less graphically demanding titles.

However, virtualization suffers from two critical limitations. First, it incurs significant performance overhead, as system resources like CPU and RAM must be shared between the host macOS and the guest Windows OS.[37] Second, and more importantly, it is constrained by a "glass ceiling" imposed by the host Mac's hardware and software capabilities. A virtualized GPU, managed by the hypervisor, cannot create API support that the host system lacks. This is starkly illustrated by Parallels Desktop, which can only offer OpenGL 4.1 support to its Windows guest because that is the maximum version supported by the underlying macOS.[22] This limitation makes it impossible to run games like

*Beyond All Reason*, which require OpenGL 4.3. Similarly, virtualization cannot magically create CPU instructions like AVX that are not present on the physical Apple Silicon chip, which is why *Age of Empires IV* fails to run.[8]

### 3.2 Compatibility Layers (CrossOver, GPTK): High Performance, High Fragility

Compatibility layers like CrossOver and Apple's Game Porting Toolkit represent the pinnacle of potential performance for Windows games on Mac. By translating API calls directly from DirectX to Metal without the overhead of emulating an entire operating system, these tools can achieve near-native speeds.[14] Apple's D3DMetal technology, in particular, has demonstrated impressive performance for modern DirectX 11 and 12 titles, making games that were previously unplayable technically feasible on Apple Silicon.[39]

This high performance, however, comes at the cost of extreme fragility. The translation process is not perfect and is highly game-dependent. A compatibility layer may translate 99% of API calls correctly, but a single improperly handled function can lead to catastrophic failure. This is seen with *Iron Harvest*, where a shader translation

issue results in a completely invisible game world [45], and with

*Company of Heroes 3*, where a combination of untranslated DX12 features and hostile DRM causes the game to crash on launch.[40] Furthermore, these layers are fundamentally incapable of running games that rely on older APIs like OpenGL 4.3, as they are bound by the same limitations as the host OS.[54] They are also notoriously vulnerable to disruption by kernel-level anti-cheat and complex DRM systems, which often perceive the translation environment as a form of tampering.[39]

### 3.3 Cloud Gaming (GeForce NOW, Shadow PC): The Ultimate Workaround?

Cloud gaming services offer a compelling way to completely bypass all local hardware and software limitations. They operate by running the game on high-end Windows PCs in a data center and streaming the video output to the user's device.

- **NVIDIA GeForce NOW** is a curated service that provides a seamless, "it just works" experience. If a game is officially supported, as *Age of Empires IV* is, it is unequivocally the best way to play it on a Mac.[29] The service eliminates all concerns about API versions, CPU instructions, or middleware, delivering high-performance gameplay limited only by the user's internet connection. Its primary weakness is its curated library; if a game is not on the service, it cannot be played.[3] Titles like
  *Beyond All Reason*, *Company of Heroes 3*, and *Homeworld 3* are not currently available.
- **Shadow PC** offers a different model: it provides the user with a full, unrestricted Windows PC in the cloud, upon which any game or application can be installed.[11] This flexibility makes it a powerful solution for running games not available on GeForce NOW. However, it is not immune to all compatibility issues. Kernel-level anti-cheat systems, such as Riot Vanguard (used in
  *Valorant* and *League of Legends*), are increasingly designed to detect and block execution within any virtual machine, including cloud-based ones like Shadow.[57] Additionally, the performance of competitive, fast-paced RTS games can be sensitive to network latency, which introduces input lag not present in local play.[58]

### 3.4 Emerging Alternatives: Asahi Linux on Apple Silicon

A promising and technically fascinating alternative is emerging from the open-source community: Asahi Linux. This project is dedicated to reverse-engineering Apple Silicon hardware to run the Linux operating system natively.[61] A key achievement of this project has been the development of fully conformant, open-source graphics drivers for Apple's GPUs.

This represents a community-driven counter-move to Apple's entire graphics strategy. While Apple has deliberately abandoned modern OpenGL on macOS, the Asahi Linux developers, unbound by Apple's corporate strategy, have implemented the full OpenGL 4.6 specification and have passed the official Khronos Group conformance tests—a feat Apple itself never achieved with its own drivers.[62]

This development creates a viable, albeit technical, path for playing games that are blocked on macOS by the OpenGL limitation. A user could install Asahi Linux on their Mac, install Steam, and then use the Proton compatibility layer (Valve's fork of Wine) to run a Windows game like *Beyond All Reason*. In this environment, when the game requests OpenGL 4.3 features, the Asahi Linux drivers would provide them, potentially allowing the game to run correctly. This approach effectively creates a "back door" for compatibility, using a different operating system to unlock the full potential of the Mac's hardware in a way that macOS itself will not. While still experimental, this makes native Linux on Apple Silicon a potential ultimate solution for a specific and significant class of incompatible RTS games.

---

## Section 4: Conclusion and Strategic Recommendations

The inability to run certain Real-Time Strategy titles on macOS, even with a full suite of modern tools, is not the result of a single flaw but rather a complex matrix of intersecting technical barriers. The analysis of these case studies reveals four primary categories of blockers that define the compatibility landscape.

- **API Divergence:** Apple's strategic decision to deprecate OpenGL at version 4.1 in favor of its proprietary Metal API is the most fundamental barrier. It creates an immediate incompatibility with any game or engine, like the Spring Engine, that has evolved to require features from newer OpenGL versions (4.2+). This affects *Beyond All Reason* and *Zero-K*.

- **CPU Architecture Limitations:** The transition to ARM-based Apple Silicon introduced hardware-level incompatibilities. The most significant is the lack of support for the AVX instruction set, which serves as a hard blocker for games like *Age of Empires IV* that explicitly require it. This cannot be solved by local software translation or virtualization.
- **Hostile Middleware:** The modern PC gaming ecosystem is reliant on a chain of third-party software for DRM, anti-cheat, and online services. These systems, particularly Denuvo and kernel-level anti-cheat, are often designed exclusively for a native Windows environment and are actively hostile to translation layers and virtual machines, creating a "middleware gauntlet" that blocks games like *Company of Heroes 3* and *Homeworld 3*.
- **Developer Economics:** Underlying all these technical issues is the economic reality that the Mac gaming market is a small fraction of the PC market. This disincentivizes developers from investing the considerable resources required to create and maintain a bespoke Metal port, forcing Mac users to rely on the often-imperfect solutions of translation and virtualization.

Based on these findings, a strategic framework can be established for assessing the viability of running a Windows-only RTS game on macOS. Rather than relying on trial and error, a user can diagnose a game's technical profile to predict its likely compatibility:

1. **Identify the Graphics API:**
    - If the game requires **OpenGL 4.2 or higher**, it will be unplayable on macOS via any local method. The only potential future solution is running it on **Asahi Linux** with its conformant drivers.
    - If the game requires **DirectX 11**, it has a high chance of success in **Parallels/VMWare** and a moderate chance in **CrossOver**, though it may be subject to graphical glitches.
    - If the game requires **DirectX 12**, it will not work in virtualization. The only local option is **CrossOver/GPTK**, and success is highly dependent on the specific game and its implementation.
2. **Check for CPU Instruction Set Requirements:**
    - If the game's system requirements list **AVX instructions**, it is definitively unplayable on any Apple Silicon Mac via any local method. The only viable solution is a **cloud gaming service** like GeForce NOW.
3. **Investigate Middleware:**
    - If the game uses aggressive DRM like **Denuvo** or any **kernel-level anti-cheat** (e.g., Riot Vanguard, EA AntiCheat), it is highly likely to fail in CrossOver/GPTK. It may also be blocked on cloud PC services like Shadow. Its best chance for

local play is in a Parallels VM, but success is not guaranteed.
    - If the game relies on online services like **Epic Online Services**, it is more likely to function correctly in a full **Parallels VM** than in the more abstract environment of CrossOver.

By applying this diagnostic framework, users can make a more informed assessment of a game's potential for compatibility, understanding that in the current macOS ecosystem, the ability to play is determined not just by the power of the hardware, but by a complex and often unforgiving gauntlet of software and architectural challenges.

**Works cited**


1. Spring 106.0 released - OpenGL 4!, accessed July 19, 2025, https://springrts.com/phpbb/viewtopic.php?t=45525
2. Spring RTS v106.0 released with OpenGL 4 support - GamingOnLinux, accessed July 19, 2025, https://www.gamingonlinux.com/2022/01/spring-rts-v106-released-with-opengl-4-support/
3. Download Beyond All Reason RTS, accessed July 19, 2025, https://www.beyondallreason.info/download
4. Mac OS? : r/beyondallreason - Reddit, accessed July 19, 2025, https://www.reddit.com/r/beyondallreason/comments/12gqmc7/mac_os/
5. macOS Version : r/beyondallreason - Reddit, accessed July 19, 2025, https://www.reddit.com/r/beyondallreason/comments/1260guk/macos_version/
6. BAR on Metal · Issue #936 · beyond-all-reason/RecoilEngine - GitHub, accessed July 19, 2025, https://github.com/beyond-all-reason/spring/issues/936
7. BAR on Mac M1/M2 : r/beyondallreason - Reddit, accessed July 19, 2025, https://www.reddit.com/r/beyondallreason/comments/130jgri/bar_on_mac_m1m2/
8. Age of Empires IV - Gaming on M1 Apple silicon Macs and ..., accessed July 19, 2025, https://www.applegamingwiki.com/wiki/Age_of_Empires_IV
9. What are the minimum requirements for Age of Empires IV?, accessed July 19, 2025, https://support.ageofempires.com/hc/en-us/articles/4408849398804-What-are-the-minimum-requirements-for-Age-of-Empires-IV
10. AGE IV - Parallels 19 & Windows 11 : r/macgaming - Reddit, accessed July 19, 2025, https://www.reddit.com/r/macgaming/comments/1jizibs/age_iv_parallels_19_windows_11/
11. Shadow PC Cloud Gaming - Your Windows PC in the Cloud, accessed July 19, 2025, https://shadow.tech/
12. WineHQ - Run Windows applications on Linux, BSD, Solaris and macOS, accessed July 19, 2025, https://www.winehq.org/
13. CodeWeavers: Windows Software on Mac and Linux with CrossOver, accessed July 19, 2025, https://www.codeweavers.com/
14. Run Microsoft Windows software on Mac and Linux | CodeWeavers, accessed

July 19, 2025, https://www.codeweavers.com/crossover
15. MoltenVK - Wikipedia, accessed July 19, 2025, https://en.wikipedia.org/wiki/MoltenVK
16. KhronosGroup/MoltenVK: MoltenVK is a Vulkan Portability implementation. It layers a subset of the high-performance, industry-standard Vulkan graphics and compute API over Apple's Metal graphics framework, enabling Vulkan applications to run on macOS, iOS and tvOS. - GitHub, accessed July 19, 2025, https://github.com/KhronosGroup/MoltenVK
17. Game Porting Toolkit - Apple Developer, accessed July 19, 2025, https://developer.apple.com/games/game-porting-toolkit/
18. Apple Game Porting Toolkit: Games on macOS - Mac Gamer HQ, accessed July 19, 2025, https://www.macgamerhq.com/virtualization/game-porting-toolkit/
19. utmapp/UTM: Virtual machines for iOS and macOS - GitHub, accessed July 19, 2025, https://github.com/utmapp/UTM
20. Running macOS in a macOS Virtual Machine on a Mac for Free (Full Setup Guide - Orka and UTM) - YouTube, accessed July 19, 2025, https://www.youtube.com/watch?v=uEjZqmQFU7M&pp=0gcJCfwAo7VqN5tD
21. M1 Macs and Games from the 2000 decade | Community Forums | CrossOver Support, accessed July 19, 2025, https://www.codeweavers.com/support/forums/general/?t=27;msg=248533
22. OpenGL 4.5 Support | Page 2 - Parallels Forums, accessed July 19, 2025, https://forum.parallels.com/threads/opengl-4-5-support.348442/page-2
23. Port to Mac using the new tools introduced by apple · Issue #2008 · beyond-all-reason ... - GitHub, accessed July 19, 2025, https://github.com/beyond-all-reason/Beyond-All-Reason/issues/2008
24. Hello how do I fix this please? | Community Forums | CrossOver Support | CodeWeavers, accessed July 19, 2025, https://www.codeweavers.com/support/forums/general/?t=40;msg=316373
25. Beyond All Reason - Porting Kit, accessed July 19, 2025, https://www.portingkit.com/forum/showthread.php?tid=28598
26. FAQ Beyond All Reason RTS, accessed July 19, 2025, https://www.beyondallreason.info/faq
27. Apple had released the new porting toolkit! AOE4 on Mac - Reddit, accessed July 19, 2025, https://www.reddit.com/r/aoe4/comments/144t85v/apple_had_released_the_new_porting_toolkit_aoe4/
28. Age of Empires IV: Anniversary Edition on Steam, accessed July 19, 2025, https://store.steampowered.com/app/1466860/Age_of_Empires_IV_Anniversary_Edition/
29. NVIDIA GeForce Now Games | GameHub+, accessed July 19, 2025, https://www.gamehubplus.com/geforce-now/games
30. List of available games on NVIDIA GeForce Now - Windows Central, accessed July 19, 2025, https://www.windowscentral.com/gaming/pc-gaming/list-of-available-games-on-nvidia-geforce-now

31. Age of Empires IV: Anniversary Edition Available Now on GeForce NOW Powered by ABYA, accessed July 19, 2025, https://abya.com/en/news/post/age-empires-iv-anniversary-edition-available-now-geforce-now-powered-abya
32. Save 50% on Company of Heroes 3 on Steam, accessed July 19, 2025, https://store.steampowered.com/app/1677280/Company_of_Heroes_3/
33. Company of Heroes 3 Steam Charts - SteamDB, accessed July 19, 2025, https://steamdb.info/app/1677280/charts/
34. Are there any plans to remove Denuvo? : r/CompanyOfHeroes - Reddit, accessed July 19, 2025, https://www.reddit.com/r/CompanyOfHeroes/comments/1j2t0zm/are_there_any_plans_to_remove_denuvo/
35. it Will be with DENUVO or not? :: Company of Heroes 3 General Discussions, accessed July 19, 2025, https://steamcommunity.com/app/1677280/discussions/0/3772364735644360759/
36. Parallels 3.0 and game compatibility... | Page 11, accessed July 19, 2025, https://forum.parallels.com/threads/parallels-3-0-and-game-compatibility.12428/page-11
37. Games over Windows11 with Parallel? :: Steam for Mac, accessed July 19, 2025, https://steamcommunity.com/discussions/forum/2/6019042579904617 87/
38. Please help, don't want to pay full until I get COH3 working. - Parallels Forums, accessed July 19, 2025, https://forum.parallels.com/threads/please-help-dont-want-to-pay-full-until-i-get-coh3-working.359940/
39. Game Porting Toolkit - Gaming on M1 Apple silicon Macs and MacBooks, bugs, fixes, compatiblity and troubleshooting guides - AppleGamingWiki, accessed July 19, 2025, https://www.applegamingwiki.com/wiki/Game_Porting_Toolkit
40. COH3 did not work on Mac with GamePortingKit : r/CompanyOfHeroes - Reddit, accessed July 19, 2025, https://www.reddit.com/r/CompanyOfHeroes/comments/143x9io/coh3_did_not_work_on_mac_with_gameportingkit/
41. Game will have Denuvo :: Company of Heroes 3 General Discussions - Steam Community, accessed July 19, 2025, https://steamcommunity.com/app/1677280/discussions/0/5430811797228078877/
42. Company of Heroes 3 - FINAL TOPIC | NVIDIA GeForce Forums, accessed July 19, 2025, https://www.nvidia.com/en-us/geforce/forums/gfn-game-requests/44/511260/company-of-heroes-3-final-topic/
43. Will there be GeforceNow support? :: Company of Heroes 3 General Discussions - Steam Community, accessed July 19, 2025, https://steamcommunity.com/app/1677280/discussions/0/3770113150025711518/
44. Why is COH3 not on Geforce Now? : r/CompanyOfHeroes - Reddit, accessed July 19, 2025, https://www.reddit.com/r/CompanyOfHeroes/comments/1ec6wj6/why_is_coh3_not_on_geforce_now/

45. Iron Harvest on Crossover/M1MAC : r/IronHarvest - Reddit, accessed July 19, 2025, https://www.reddit.com/r/IronHarvest/comments/u27m98/iron_harvest_on_crossoverm1mac/
46. Homeworld 3 Configuration - SteamDB, accessed July 19, 2025, https://steamdb.info/app/1840080/config/
47. Bringing Unreal Engine on macOS up to feature parity with Windows—progress report, accessed July 19, 2025, https://www.unrealengine.com/en-US/tech-blog/bringing-unreal-engine-on-macos-up-to-feature-parity-with-windowsprogress-report
48. Steam Curators, accessed July 19, 2025, https://store.steampowered.com/curators/curatorsnotrecommending/?appid=1250410
49. Actual fix for the "Epic Online Services error" issue! :: Dead Island 2 General Discussions, accessed July 19, 2025, https://steamcommunity.com/app/934700/discussions/0/4364627615933076466/
50. Issues Installing Epic Online Services - Reddit, accessed July 19, 2025, https://www.reddit.com/r/epic/comments/1h8cqgp/issues_installing_epic_online_services/
51. Epic online services failed to install error code EOS-ERR-1603 Fix - YouTube, accessed July 19, 2025, https://www.youtube.com/watch?v=7-UD37QmIKM
52. Game won't run in Parallels, accessed July 19, 2025, https://forum.parallels.com/threads/game-wont-run-in-parallels.354542/
53. C&C Remastered confirmed to work with Parallels 17 on a M1. : r/macgaming - Reddit, accessed July 19, 2025, https://www.reddit.com/r/macgaming/comments/tcudz1/cc_remastered_confirmed_to_work_with_parallels_17/
54. Any news on OpenGL support? | Community Forums | CrossOver Support - CodeWeavers, accessed July 19, 2025, https://www.codeweavers.com/support/forums/general/?t=27;forumcurPos=100;msg=293239
55. AoE 4 on GeForce now - what am I missing? : r/aoe4 - Reddit, accessed July 19, 2025, https://www.reddit.com/r/aoe4/comments/1c9tmec/aoe_4_on_geforce_now_what_am_i_missing/
56. Shadow Cloud Gaming in 2022: How Good is It? - YouTube, accessed July 19, 2025, https://www.youtube.com/watch?v=sp_D7bglhzM
57. Games Incompatible with Shadow PC, accessed July 19, 2025, https://support.shadow.tech/hc/en-us/articles/32731823908625-Games-Incompatible-with-Shadow-PC
58. Shadow PC CS:GO - Full Latency Test and Demo on GTX1060 and Integrated CPU/GPU, accessed July 19, 2025, https://www.youtube.com/watch?v=EMvg31aoMxU
59. How to Improve Your Experience on Shadow, accessed July 19, 2025, https://support.shadow.tech/hc/en-us/articles/32731863020049-How-to-Improve

-Your-Experience-on-Shadow
60. Current State of Shadow : r/ShadowPC - Reddit, accessed July 19, 2025, https://www.reddit.com/r/ShadowPC/comments/1c92hrp/current_state_of_shadow/
61. OpenGL 3.1 on Asahi Linux, accessed July 19, 2025, https://asahilinux.org/2023/06/opengl-3-1-on-asahi-linux/
62. Conformant OpenGL 4.6 on the M1 - Asahi Linux, accessed July 19, 2025, https://asahilinux.org/2024/02/conformant-gl46-on-the-m1/
63. Asahi Linux project's OpenGL support on Apple Silicon officially surpasses Apple's - Reddit, accessed July 19, 2025, https://www.reddit.com/r/macgaming/comments/1asf6yk/asahi_linux_projects_opengl_support_on_apple/