

## **GADS7322 POE: Part 1 Process Document**

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## Table of Contents

GADS7322 POE: Part 1 Process Document.....	1
1. Research and Future Scenarios .....	3
2. Ideation and Exploration .....	8
3. Selected Concept Development .....	15
4. Visual Exploration .....	17
5. Concept Art.....	20
6. Platform and Technologies.....	24
7. UI Guide .....	25
8. Creative rationale .....	28
URL Link To game on Itch.io .....	32
7. References .....	33

## 1. Research and Future Scenarios

### The Future of Nuclear Energy: Navigating Shifting Trends and Envisioning Scenarios

In an era marked by accelerating climate change, rising global energy demands, and the rapid evolution of advanced technologies, nuclear energy is re-emerging as a pivotal element in the pursuit of sustainable energy solutions. Often misunderstood or politically contentious, nuclear power is undergoing a significant transformation driven by the intersecting pressures of decarbonization, digitization, and workforce disruption. This essay investigates the mega, macro, and micro trends shaping the future of nuclear energy, particularly with regard to the evolving relationship between human expertise and automation. It culminates in four richly detailed future scenarios and the conceptualization of a serious game, designed to help players engage with and reflect on these complex futures in an educational and interactive way.

#### 1.1 Mega Trends

##### 1. Climate Change and the Energy Transition

The global effort to combat climate change has redefined energy policy priorities worldwide. As countries set increasingly ambitious targets for carbon neutrality, nuclear energy is gaining renewed attention due to its capacity to generate large-scale electricity with minimal greenhouse gas emissions. Unlike solar and wind energy, nuclear provides a stable and continuous power supply, unaffected by weather or seasonal variation. According to the International Atomic Energy Agency (IAEA, 2023), nuclear energy could account for up to 25% of global electricity production by 2050 a sharp increase from today's levels. This transition is not just a technical shift but a societal one, requiring public trust, regulatory innovation, and cross-sector collaboration.

##### 2. Technological Automation

Advancements in artificial intelligence (AI), robotics, and machine learning are transforming every layer of industrial operations, and nuclear energy is no exception. AI-enabled systems can optimize reactor performance, forecast maintenance needs, detect anomalies, and reduce human error. Smith and Johnson (2023) report that predictive analytics powered by AI can identify system malfunctions as much as 72 hours before traditional diagnostics would. As operational efficiency and safety standards continue to improve, the role of human operators is shifting from hands-on control to strategic oversight and ethical governance.

### 3. Workforce Evolution

The nuclear sector is facing an acute generational shift. A significant portion of the current workforce is approaching retirement age, while the industry struggles to attract younger talent. The Institute of Nuclear Power Operations (INPO, 2023) notes that approximately 45% of the current workforce will retire within the next decade. At the same time, the skills required for future nuclear operations are evolving: digital literacy, software fluency, systems thinking, and ethical awareness are now seen as essential competencies. The talent pipeline must adjust accordingly, incorporating new modes of education and training that align with the realities of a digitized energy sector.

## 1.2 Macro Trends

### 1. Small Modular Reactors (SMRs) and Generation IV Technologies

A new generation of nuclear reactors is emerging, including Small Modular Reactors (SMRs) and Generation IV designs, offering flexibility, safety, and economic benefits over traditional models. These reactors are factory-fabricated, scalable, and require less time and capital investment to construct. The Electric Power Research Institute (EPRI, 2023) indicates that SMRs can reduce construction costs by up to 40% while still meeting high safety standards. Furthermore, SMRs can be deployed in regions that are unsuitable for larger power plants, including remote or disaster-prone areas. This decentralization aligns with broader energy access and equity goals.

### 2. Evolution of Safety and Regulatory Frameworks

As AI and automation assume greater roles in plant operations, safety and regulatory practices must evolve in tandem. The U.S. Nuclear Regulatory Commission (NRC, 2023) and other international bodies are adapting their safety frameworks to address algorithmic governance, transparency, and accountability. AI systems are now integrated into decision-making processes, but human oversight remains a regulatory necessity. These hybrid models have reduced average incident response times by 35%, illustrating how well-designed automation can enhance, rather than replace, human vigilance.

### 3. Digital Twin Technology

Digital twins virtual models that replicate the behavior of real-world systems are increasingly used in nuclear energy to simulate operational scenarios, test emergency responses, and support training. These technologies enable "what-if" simulations without physical risk, improving preparedness and decision-making. According to EPRI (2023), the use of digital twins in nuclear facilities has reduced real-world operational errors by 25% and boosted the effectiveness of technical training programs by over 40%.

### 1.3 Micro Trends

#### 1. Gamified Training Systems

To address the engagement gap with younger professionals, the nuclear industry is turning to gamified training environments. These systems use interactive simulations, real-time feedback, and role-based learning to enhance the retention and application of complex knowledge. The *2023 Training Innovation Report* shows that gamified modules can improve knowledge retention rates by up to 40%. Additionally, the immersive nature of serious games helps learners practice decision-making under pressure, an essential skill in nuclear operations.

#### 2. Remote Monitoring and Operations

Advances in encryption, communication, and cybersecurity now allow for more reliable and secure remote operations. Over 65% of global nuclear facilities have integrated remote monitoring systems (Nuclear Operations Report, 2023), allowing off-site experts to oversee reactor performance, perform diagnostics, and even participate in crisis response. This trend supports decentralized workforce models and could play a significant role in expanding nuclear power to areas with limited technical labor availability.

#### 3. Cross-Disciplinary Skill Demands

Modern nuclear facilities operate at the intersection of engineering, computer science, and systems design. As such, the ideal nuclear operator must possess hybrid expertise. INPO (2023) reports that 80% of facilities now require employees to have competencies in both a technical field (such as mechanical or nuclear engineering) and a digital discipline (such as software development or cybersecurity). This trend demands a significant overhaul in education pipelines and corporate training models.

### 1.4 Four Future Scenarios

Based on the interplay of mega, macro, and micro trends, four detailed future scenarios were developed. Each explores a different pathway for the nuclear industry possible, plausible, probable, and preferred.

#### Possible Scenario (2030): The Hybrid Facility

By 2030, most nuclear facilities operate under a dual-management model, where advanced AI systems perform constant real-time monitoring and diagnostics, while human experts are responsible for oversight and emergency decisions. This model reduces operator fatigue and enhances safety outcomes but presents challenges in transparency and public accountability. The combination of human and machine decision-making improves performance by 30%, yet

cybersecurity remains a significant risk due to the complexity of digital interconnectivity and the potential for AI misinterpretation of real-world conditions.

#### Plausible Scenario (2035): The Connected Control Room

By 2035, global nuclear operations are linked through a secure, multilingual AI-driven network. Operators from different countries collaborate in real time, sharing operational insights, incident responses, and training protocols. AI translators bridge language and cultural barriers, enabling rapid international knowledge transfer. While operational response times improve by 40%, the system also introduces dependencies on digital infrastructure, creating new vulnerabilities such as cyberattacks, deepfakes, and misinformation. AI biases in translation and decision support may also affect the accuracy of collaboration.

#### Probable Scenario (2040): AI-Enhanced Operations

In this scenario, AI systems govern nearly all routine nuclear plant functions. From temperature regulation to predictive maintenance and emergency management, these systems operate autonomously, validated through digital twins before real-world implementation. Human roles are limited to supervision and strategic ethical decisions. While safety metrics and operational efficiency improve, there is widespread concern about the “black box” nature of AI. Operators often do not fully understand how the systems reach their conclusions, potentially undermining accountability and long-term trust.

#### Preferred Scenario (2045): The Competitive Excellence Center

In the preferred future, nuclear facilities operate as centers of excellence, combining automation with gamified continuous learning environments. Operators engage in real-time simulations, scenario planning, and competitions in immersive virtual spaces. These gamified systems boost engagement by 75% and reduce operator error by 60%. The nuclear profession becomes prestigious and attractive to a new generation of interdisciplinary experts. Public opinion shifts dramatically in favor of nuclear energy, which is now viewed as safe, innovative, and essential for environmental sustainability. Global trust is fostered by transparent practices, citizen oversight, and open data access.

### 1.5 Game Concept: *Core Clash: Reactor Run*

To explore and communicate the Preferred Scenario interactively, a serious game titled *Core Clash: Reactor Run* has been developed. Set in the year 2045, the game simulates the daily operations of a futuristic nuclear facility where players take on the role of high-performance operators balancing AI assistance with human judgment. It uses real-time strategy and puzzle mechanics to engage players in system diagnostics, resource allocation, crisis response, and ethical dilemmas.

#### Gameplay and Mechanics

Players must quickly interpret data from AI systems, validate it through simulations, and implement decisions within a limited time window. They collaborate or compete with virtual co-operators, train in digital twin environments, and face sabotage scenarios that test system resilience. Scoring is based on safety, efficiency, and ethical decision-making, encouraging players to consider both technological and human factors.

#### Learning Objectives and Educational Impact

The game is designed to:

- Promote awareness of the nuanced balance between automation and human responsibility in high-risk industries.
- Encourage ethical reasoning in the face of AI-driven recommendations.
- Support STEM education by demonstrating how complex systems function.
- Introduce gamified training as a viable solution for workforce development in future industries.

The immersive nature of *Core Clash* makes it suitable not only for students and educators, but also for corporate training programs and public awareness campaigns. By confronting players with real-world challenges in a simulated environment, the game offers a safe yet meaningful exploration of the energy systems of the future.

## 2. Ideation and Exploration

The selected scenario for game development is the Preferred Scenario: The Competitive Excellence Center (2045). This futuristic vision highlights the importance of human AI collaboration, gamified training, and continuous skill development in the context of nuclear operations. To generate viable game concepts that align with this scenario, a structured ideation process was followed using a variety of tools including mind mapping, word clouds, and AI-assisted brainstorming.

### 2.1 Mind Map

A mind map was developed to unpack and explore the scenario's key components. Central thematic pillars included:

Competition: High-performance benchmarking among participants.

Collaboration: Human-AI teamwork and peer cooperation.

Gamified Training: Simulation-based learning modules.

AI Integration: Real-time decision-making with machine assistance.

Emergency Response: Managing crises under time pressure.

These nodes were expanded into actionable clusters such as *Performance Metrics*, *Predictive Safety Systems*, *Digital Sabotage*, and *Real-time Training Feedback*. The mind map provided a clear visual breakdown of gameplay potential and helped scaffold three unique game ideas.





Figure 1: Cursor. [USA]. *Competition: High-performance benchmarking among participants. Collaboration: Human-AI teamwork and peer cooperation. Gamified Training: Simulation-based learning modules. AI Integration: Real-time decision-making with machine assistance. Emergency Response: Managing crises under time pressure. These nodes were expanded into actionable clusters such as Performance Metrics, Predictive Safety Systems, Digital Sabotage, and Real-time Training Feedback. (Cursor, 2025)*

## 2.2 Word Cloud

To surface relevant keywords and mechanics, a word cloud was generated based on scenario themes and nuclear training terminology. Prominent words included:

Competition, Automation, Human Factor, Simulation,

Sabotage, Emergency, Collaboration, Safety, AI, Training.

These terms were used to guide mechanic and narrative brainstorming, with particular attention to how human-AI interaction and performance pressure could be expressed through gameplay.

# Competition Human Factor Simulation Sabotage Emergency Collaboration Safety Training

Figure2: ChatGPT5. [SA]. *Competition, Automation, Human Factor, Simulation, Sabotage, Emergency, Collaboration, Safety, AI, Training.* (ChatGPT5, 2025)

## 2.3 Game Concept Ideas

From the ideation process, three distinct game concepts were developed. Each explores different aspects of the scenario while targeting engagement and skill-building.

### Concept 1: Core Clash – Reactor Run (Selected Concept)

Genre: 2D Puzzle-Platformer (Split-Screen Competitive)

Two players race to stabilize a simulated nuclear reactor by solving complex logic puzzles, avoiding hazards, and outmanoeuvring each other. Each facility challenge mimics a real-world operational problem, with opportunities to collaborate temporarily or sabotage rival progress. AI assistants offer strategic guidance, and each decision impacts overall safety scores and personal rankings.

Learning Outcomes:

Systems thinking

Ethical decision-making under pressure

Peer benchmarking in performance-based tasks

## Concept 2: Nuclear Network

Genre: Online Strategy / Simulation (Co-op & Competitive Modes)

Players manage a network of nuclear facilities in a shared simulation. They must allocate resources, develop AI protocols, and respond to emergencies, all while choosing when to compete or collaborate. Randomized crises simulate unpredictable conditions, and long-term decisions affect future simulation rounds.

Learning Outcomes:

Strategic planning under uncertainty

Interoperability of human and AI systems

Cooperative emergency management

## Concept 3: Meltdown Masters

Genre: Local Multiplayer Party Game (2–4 Players)

Fast-paced mini-games simulate various nuclear facility tasks: AI overrides, maintenance drills, evacuation races, and more. Each mini-game tests a different skill like reaction speed, team coordination, or safety decision-making. Designed to be accessible yet educational.

Learning Outcomes:

Safety protocol retention

Team-based coordination

Adaptive problem-solving

## 2.4 Use of AI in Ideation

Generative AI (ChatGPT) was used to assist with early ideation. Prompts focused on simulating nuclear facility systems and safety challenges. Examples of prompts used include:

*“Design puzzles based on nuclear facility systems and control logic.”*

*“Create sabotage mechanics that simulate digital interference and misinformation.”*

*“Suggest co-op game mechanics for managing simulated emergencies.”*

The AI responses produced high-level ideas that were critically filtered, adapted, and aligned with realistic training environments. Rather than using suggestions verbatim, the outputs were iteratively refined through a human design lens to ensure educational and gameplay relevance.

Design puzzles based on nuclear facility systems and control logic

Alright — I’ll design you a **set of puzzle mechanics** themed around nuclear facility systems and control logic, so they fit perfectly with *Core Clash: Reactor Run*.

These puzzles are structured to work in **Unity** or any 2D/3D engine, and they’re based on real-world nuclear plant procedures but simplified for gameplay.

### Puzzle Concepts for Nuclear Facility Systems

#### 1. Reactor Cooling Loop Balance

**Theme:** Manage heat output by regulating coolant flow.

**Mechanic:**

- The puzzle is a **fluid-routing grid** where players must connect intake and outflow pipes.
- Each valve changes pressure and flow direction.
- Players must balance **temperature gauge** and **coolant gauge** to stay within a safe range before time runs out.
- Failure overheats the reactor, triggering alarms.

**Twist:**



Figure 3: ChatGPT. [SA]. *Design puzzles based on nuclear facility systems and control logic.* (ChatGPT, 2025)

Create sabotage mechanics that simulate digital interference and misinformation

Here's a sabotage mechanic set tailored for *Core Clash: Reactor Run*, specifically simulating **digital interference and misinformation** inside a nuclear facility setting.

They're designed to integrate with your **puzzle systems** so sabotage isn't just a nuisance — it actively alters puzzle states, injects false data, and forces players to question what they see.

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## Digital Interference & Misinformation Sabotage Mechanics

### 1. Ghost Data Injection

#### Effect:

- Displays **fake readings** on control panels (e.g., coolant temp appears safe but is rising rapidly).
- Creates **phantom hazards** in the HUD that don't exist in the environment.

#### Player Counterplay:

- Cross-check data between multiple terminals or with AI logs.
- Requires "Data Purge" mini-puzzle — matching checksum codes to remove fake entries.

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### 2. Display Lag & Desync



Figure 4: ChatGPT. [SA]. *Create sabotage mechanics that simulate digital interference and misinformation.* (ChatGPT, 2025)

Suggest co-op game mechanics for managing simulated emergencies.

Here's a set of **co-op game mechanics** for *Core Clash: Reactor Run* that focus on **managing simulated emergencies** in a nuclear facility environment.

These are built to keep both players **engaged, interdependent, and under pressure**, so teamwork is necessary for survival.

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## 🔥 Co-op Emergency Management Mechanics

### 1. Split Responsibilities – Linked Systems

#### Concept:

- Each player controls **different but interdependent systems** (e.g., Player A manages coolant loops, Player B handles reactor output).
- Actions in one system affect the other's puzzles (e.g., coolant flow changes reactor pressure).

#### Why It Works:

- Forces communication and coordination.
- No single player can solve the crisis alone — they must exchange status updates.



Figure 5: ChatGPT. [SA]. *Suggest co-op game mechanics for managing simulated emergencies.* (ChatGPT, 2025)

### 3. Selected Concept Development

Core Clash: Reactor Run was selected as the final concept due to its strong alignment with the "Competitive Excellence Center" scenario and its ability to gamify real-world safety and efficiency procedures in a high-stakes environment. The concept offers an engaging, fast-paced competitive experience while subtly reinforcing the importance of protocols, teamwork, and critical thinking in technical or high-pressure settings. Among the initial ideas explored, this concept stood out for balancing entertainment with educational value and for providing meaningful replayability through procedural variation and player-versus-player dynamics.

The core design centers on a competitive split-screen format, where two players either human or AI attempt to stabilize their assigned malfunctioning reactor core before their opponent. This setup was chosen over cooperative multiplayer or solo puzzle-solving because it introduces urgency, encourages strategic sabotage, and mirrors real-world scenarios where multiple operators or teams may work independently while being evaluated on performance. This competitive framing naturally motivates players to act quickly but safely, directly reinforcing the game's learning objective: excellence under pressure.

To support this core idea, several gameplay mechanics were considered. The selected mechanics include physics-based puzzles (example, circuit relays, pressure plates), dynamic hazards (such as blackouts, electric arcs, and mobile patrol drones), and a set of limited sabotage tools (like EMP bursts, gravity flips, or decoy objects). These mechanics were retained because they all contribute to the game's core learning outcome recognizing and responding to changing variables in a system while also promoting engagement through challenge and variation.

The sabotage tools were particularly critical in adding tension and interactivity between players. After prototyping several forms of sabotage, the design team decided to keep sabotage temporary and non-lethal to avoid frustrating gameplay loops or unfair penalties. For example, the EMP burst may temporarily disable a door mechanism or puzzle component but cannot permanently lock players out. This decision was grounded in pedagogical principles: mistakes should create setbacks, not punishments, and learning should arise from recovery and adaptation rather than failure. More destructive or long-term sabotage options were discarded because they risked creating negative feedback loops and disrupting the game's pacing and fairness.

Another discarded mechanic was thermal load balancing, a system where players would have to redistribute energy levels across multiple sectors of the facility. While realistic and thematically consistent, the mechanic introduced too much complexity for a fast-paced match format and detracted from the clarity of goals. Instead, the focus remained on accessible, tactile puzzles that have clear cause-and-effect feedback, allowing players to feel the impact of their decisions immediately.

Game controls were designed with accessibility and clarity in mind. Each action interact, sabotage, sprint, map view is tied to a minimal control scheme to reduce cognitive load. Symmetry in puzzle layout and hazard placement ensures that both sides of the reactor facility present equivalent challenges, maintaining fairness regardless of which side the player is assigned to. Environmental feedback such as warning sirens, flickering lights, and drone audio cues was prioritized over on-screen UI to create a more immersive, reactive experience that trains situational awareness.

The end condition of the game, successfully rebooting the reactor core under time pressure, serves both as a victory metric and a narrative resolution. It emphasizes not just speed, but efficiency and safety players must complete all safety steps (e.g., activate cooling systems, secure circuits) before they are allowed to execute the final restart protocol. This mechanic encourages adherence to procedure even under time constraints and mirrors real-world industrial and safety-critical environments where skipping steps can lead to disaster.



## 4. Visual Exploration

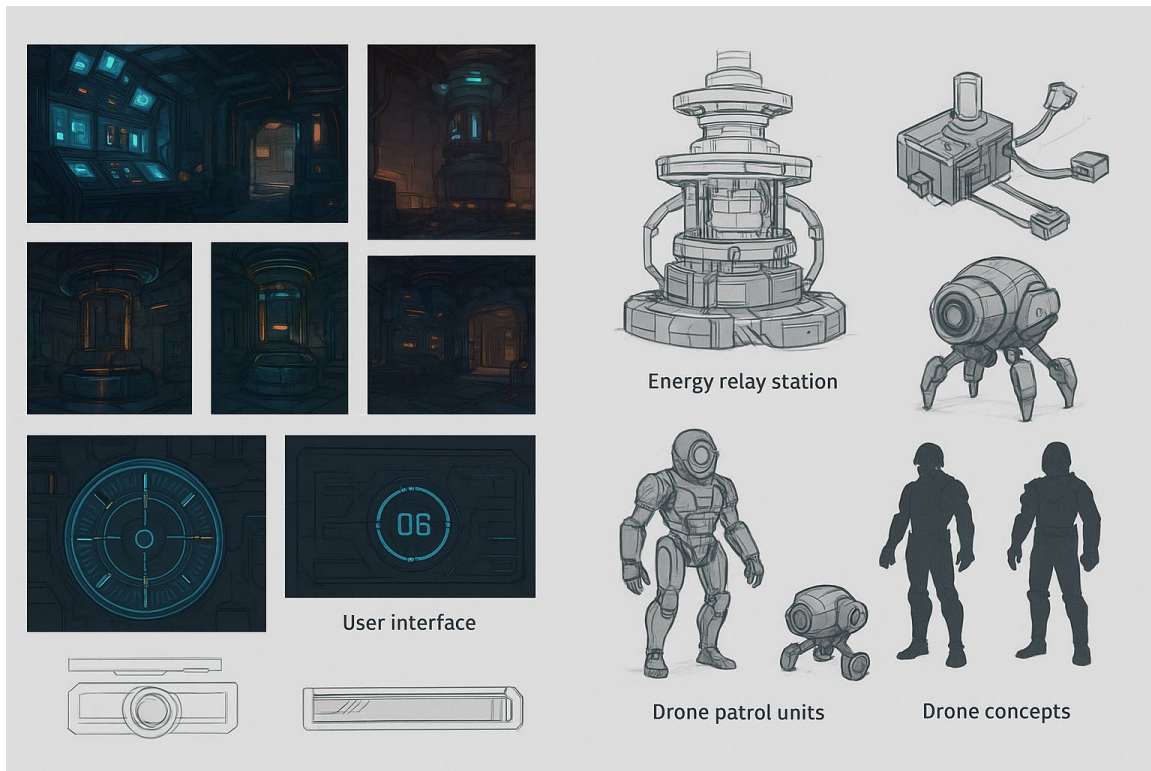


Figure 6: ChatGPT. [SA]. *explore visual themes relevant to the game's setting a high-stakes reactor facility. These boards drew from a range of sources, including: Retro-futuristic industrial design: blending clean, sleek lines with worn mechanical elements and neon-glow interfaces, evoking a sense of advanced but aging technology.* (ChatGPT, 2025)

To establish the aesthetic and thematic direction of *Core Clash: Reactor Run*, extensive visual exploration was conducted. This included the creation of mood boards and exploratory sketches to shape the look and feel of the game world and its key characters.

### Mood Boards & Inspiration Boards

Multiple mood boards were assembled to explore visual themes relevant to the game's setting a high-stakes reactor facility. These boards drew from a range of sources, including:

Retro-futuristic industrial design: blending clean, sleek lines with worn mechanical elements and neon-glow interfaces, evoking a sense of advanced but aging technology.

Control room interfaces: showcasing layered HUDs, schematics, and energy meters that inspired the UI layout and interaction design.

Modular energy systems and puzzle architecture: referencing nuclear energy facilities, sci-fi server rooms, and drone maintenance bays to inform level design and environmental storytelling.



Figure 7: ChatGPT. [SA]. *explore visual themes relevant to the game's setting a high-stakes reactor facility. These boards drew from a range of sources, including: Retro-futuristic industrial design: blending clean, sleek lines with worn mechanical elements and neon-glow interfaces, evoking a sense of advanced but aging technology.* (ChatGPT, 2025)

### Sketches and Scamps

Initial sketches were developed to prototype:

The Reactor Core: a towering, multi-tiered energy hub at the center of gameplay. Designs included rotating rings, containment arms, and cooling conduits.

Energy Relay Stations: modular puzzle nodes with wiring interfaces, fuse locks, and rotating connectors that players must interact with.

Drone Patrol Units: humanoid and wheeled variations of autonomous security units with exaggerated sensors and motion patterns to emphasize threat visibility.

Player Character Silhouettes: agile, masked technicians in radiation suits with swappable toolkits and UI-linked armbands.

User Interface Elements: sketches of circular HUDs, interactive overlays, and countdown indicators to emphasize urgency and control.

These explorations informed a cohesive art direction that balances functionality and style, delivering a clean, gamified industrial aesthetic that reinforces the reactor theme while enhancing gameplay clarity.

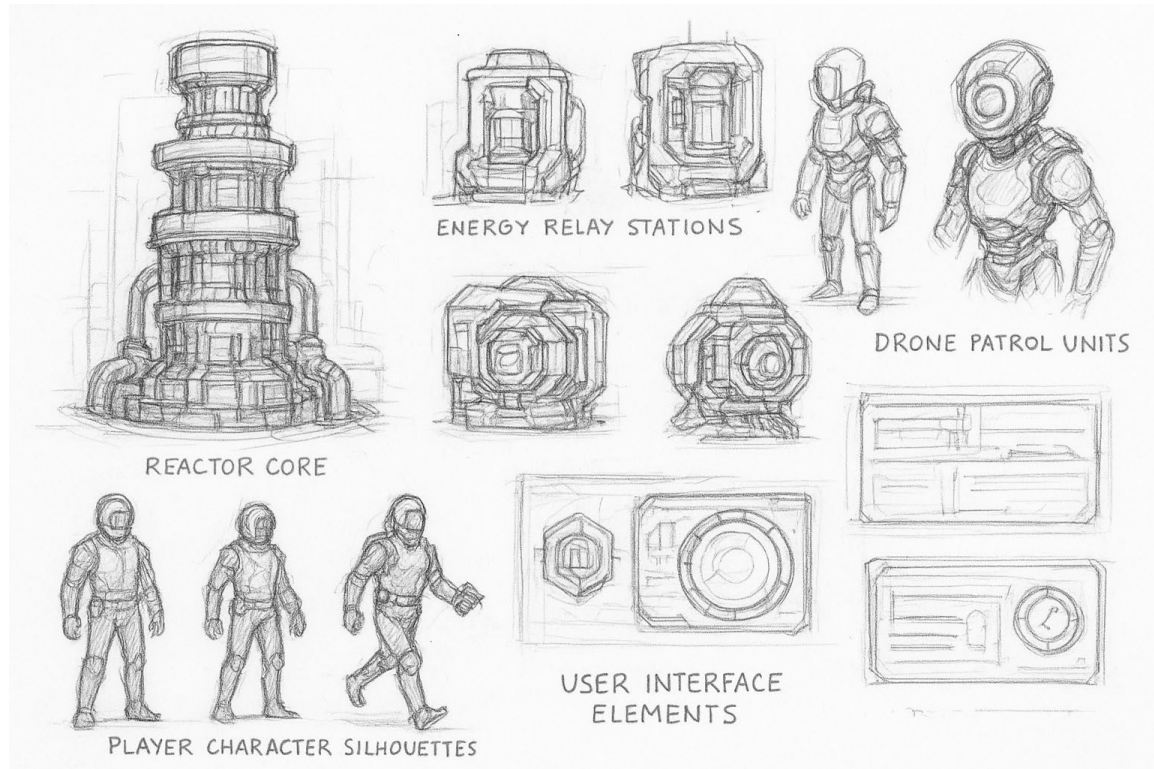


Figure 8: ChatGPT. [SA]. *The Reactor Core: a towering, multi-tiered energy hub at the center of gameplay. Designs included rotating rings, containment arms, and cooling conduits. Energy Relay Stations: modular puzzle nodes with wiring interfaces, fuse locks, and rotating connectors that players must interact with. Drone Patrol Units: humanoid and wheeled variations of autonomous security units with exaggerated sensors and motion patterns to emphasize threat visibility. Player Character Silhouettes: agile, masked technicians in radiation suits with swappable toolkits and UI-linked armbands. User Interface Elements: sketches of circular HUDs, interactive overlays, and countdown indicators to emphasize urgency and control. These explorations informed a cohesive art direction that balances functionality and style, delivering a clean, gamified industrial aesthetic that reinforces the reactor theme while enhancing gameplay clarity.* (ChatGPT, 2025)

## 5. Concept Art

High-quality concept art was produced to visually define the key characters and environments in the game world. Two main player characters were designed with distinct silhouettes and gear to reflect their unique gameplay roles and personalities. Key environmental structures such as the central reactor core, energy relays, and hazard walls were illustrated to establish the industrial, sci-fi aesthetic of the facility. The user interface was also visualized, focusing on clarity, minimalism, and intuitive layout for efficient in-game navigation. The overall art style maintains a balance between clean, professional lines and a subtle retro-futuristic influence to reinforce the game's tone and setting.



Figure 9: ChatGPT.[SA]. 2D pixel art game character, futuristic engineer wearing a protective jumpsuit, helmet with clear visor, gloves, and utility belt, Player 1 in neon cyan and silver, Player 2 in bright orange and steel gray, side view idle pose, clean 2–3 pixel outlines, 48–64px height, industrial sci-fi reactor style, high contrast top-left lighting, sprite sheet with walking, jumping, interacting, and sabotage animations, PNG transparent background. (ChatGPT, 2025)



Figure 10: ChatGPT.[SA]. 2D pixel art game character, futuristic engineer wearing a protective jumpsuit, helmet with clear visor, gloves, and utility belt, Player 1 in neon cyan and silver, Player 2 in bright orange and steel gray, side view idle pose, clean 2–3 pixel outlines, 48–64px height, industrial sci-fi reactor style, high contrast top-left lighting, sprite sheet with walking, jumping, interacting, and sabotage animations, PNG transparent background sprite sheet. (ChatGPT, 2025)

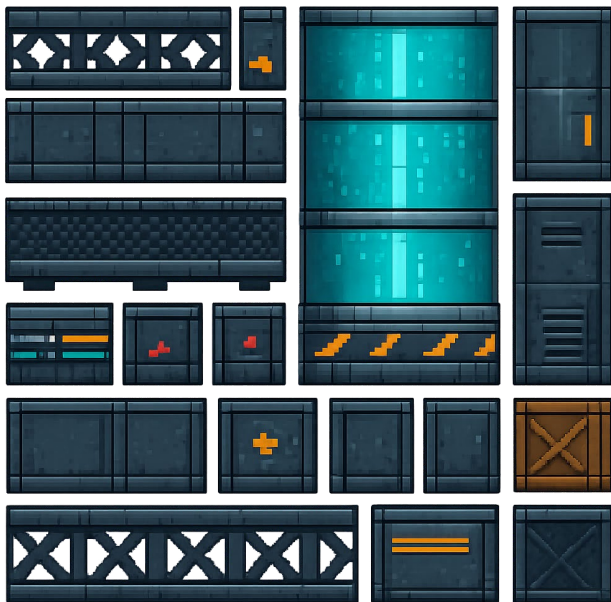


Figure 11: ChatGPT.[SA]. 2D pixel art industrial reactor facility tileset, modular 32×32 tiles, includes grated steel walkways, glowing reactor walls, pipes, switches, crates, color-coded wires, reinforced metal barriers, clean 2–3 pixel outlines, consistent lighting from top-left, seamless tiling, dark metallic base tones with neon cyan and hazard yellow highlights, PNG transparent background. (ChatGPT, 2025)



Figure 12: ChatGPT.[SA]. *Hazards Security Drone 2D pixel art hovering security drone, metallic steel body with hazard stripes, glowing red sensor eye, small side thrusters with blue glow, animated idle hover in 4 frames, side view, clean outlines, consistent scale and palette, industrial sci-fi style, PNG transparent background.* (ChatGPT, 2025)



Figure 13: ChatGPT.[SA]. *Particle Effects EMP Pulse: 2D pixel art EMP pulse, concentric glowing cyan energy rings expanding outward, electric sparks, smooth 6-frame loop, clean outlines, consistent lighting, PNG transparent background Explosion: 2D pixel art explosion, bright orange and yellow fireball with shockwave ring, debris particles in gray and hazard yellow, smoke fade-out in 6 frames, cartoon-realistic style, PNG transparent background Energy Flow: 2D pixel art energy beam, glowing neon blue and cyan streaks moving inside a transparent pipe, animated 6-frame loop, clean outlines, industrial sci-fi theme, PNG transparent background.* (ChatGPT, 2025)





Figure 14: ChatGPT.[SA]. *UI Elements 2D pixel art sci-fi user interface pack, includes split-screen overlay borders, circular timers, sabotage cooldown meters, score display, win/lose banners, uses neon cyan and hazard yellow accents over dark gray base, clean pixel edges, tech-inspired shapes, industrial sci-fi style, PNG transparent background. (ChatGPT, 2025)*

# CORE CLASH REACTOR RUN



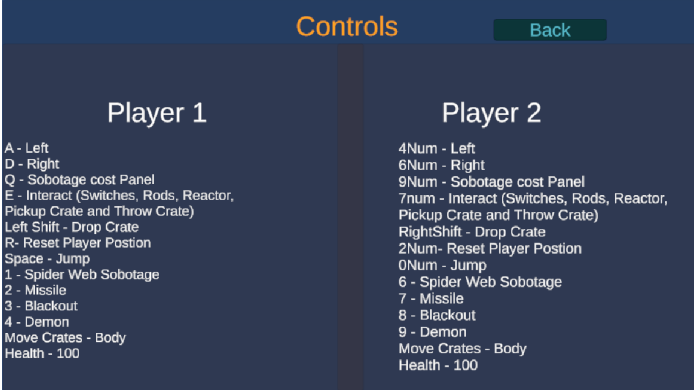
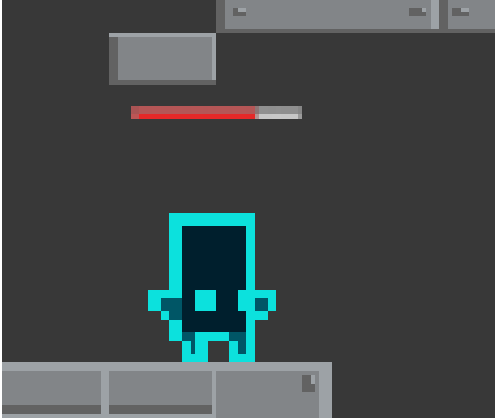
Figure 15: ChatGPT.[SA]. *Fonts / Title Art 2D pixel art title text for “Core Clash: Reactor Run”, bold uppercase letters, retro arcade style with futuristic twist, neon cyan glow and bright orange secondary highlight, clean pixel edges, consistent with industrial sci-fi theme, PNG transparent background. (ChatGPT, 2025)*

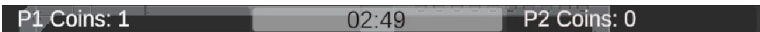
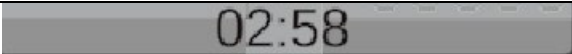


## 6. Platform and Technologies





The game will be developed using Unity 2D and initially deployed on Windows PC. Unity is a versatile and widely supported engine that excels in both 2D and 3D game development, offering a robust physics engine ideal for the game's puzzle-based mechanics and environmental interactions. Its integrated UI Toolkit also makes it possible to build an intuitive and polished interface for players navigating complex systems and split-screen gameplay. The choice of Windows PC as the primary platform is motivated by several key factors: the larger screen real estate allows players to better observe environmental details and UI elements, while mouse and keyboard input enables precision for puzzle-solving and system navigation. Furthermore, PC platforms are highly suitable for local multiplayer configurations, making them ideal for split-screen co-op modes where players must communicate and collaborate. To enhance the gameplay experience and provide technical flexibility, several supporting technologies have been selected. The Unity Input System will be used to accommodate diverse input methods, including keyboard, mouse, and game controllers, ensuring the game is accessible across a variety of setups. Unity Netcode is also under consideration for future-proofing the game with potential online multiplayer support, which could allow players to engage in remote co-op puzzle scenarios. Additionally, Unity Analytics will be integrated to gather data on how players interact with puzzles and systems, providing valuable feedback for balancing difficulty and improving educational outcomes, especially in training-focused versions of the game. To expand on immersive learning and simulation potential, a virtual reality (VR) mode is planned for future development. This optional feature would allow users particularly those in professional or educational contexts to engage with the game's environment in a more embodied and spatially rich manner. Using platforms like Meta Quest or PC-based VR headsets, players could perform safety protocols or system manipulations as part of a training simulation, enhancing realism and retention. In summary, the chosen platform and technologies were selected not only for their compatibility with the game's technical and design needs, but also for their ability to scale across future features like remote access, immersive training, and analytics-driven iteration.



## 7. UI Guide

UI Element	Image	How It Supports Player Experience
Main Menu (Start / Exit)		Provides clear entry point to the game. Minimal options reduce cognitive load → good learnability and efficiency. Large readable buttons ensure accessibility.
Objective Panel		Helps players quickly understand goals before playing. Supports memorability by reminding them what to do. Can reduce errors by clarifying tasks.
Player Controls Panel		Ensures players know the key bindings. Improves learnability for new players and accessibility (clear layout helps differently-abled players using assistive tools).
HUD – Health Bar		Non-diegetic world-space slider above character gives constant feedback about health. Improves situational awareness and error forgiveness (players can react before death).

HUD – Sabotage Points Counter		Tracks sabotage currency in real-time. Clear numeric display = efficiency. Easy to learn and remember. Supports fairness in multiplayer.
HUD – Timer		Keeps urgency high while ensuring players know how much time is left. Good for orientation, pacing, and engagement.
Sabotage Item Panel		Clear costs help prevent mistakes (error prevention). Toggle system (open/close with Q / Numpad 9) = efficiency.
Blackout Panel Overlay		Meta UI that simulates loss of vision. Adds tension and immersion. Balanced duration prevents frustration, maintaining fun.

Game Over Screen	 The Game Over screen features a dark, industrial background with a large, glowing orange sun in the center. Two silhouetted figures are running towards the sun. On the left, there is a yellow radiation symbol. On the right, there are three buttons: 'Retry', 'Main Menu', and 'Exit'. The text 'Game Over Both Players Lost' is displayed in orange at the top.	Provides closure and feedback. High memorability (clear “You Lost” state). Encourages replay without confusion.
Win Screen (P1 / P2)	 The Win Screen features a dark, industrial background with a large, glowing orange sun in the center. Two silhouetted figures are running towards the sun. On the left, there is a yellow radiation symbol. On the right, there are three buttons: 'Retry', 'Main Menu', and 'Exit'. The text 'Player 2 Wins!' is displayed in orange at the top.	Gives direct recognition of the winner. Clear differentiation (P1 vs P2) ensures ease of orientation and fairness. Builds satisfaction and a pleasurable experience.
Pause Panel	 The Pause Panel features a dark background with a yellow radiation symbol at the top. Below it, the text 'Sabotage Points: 0' is displayed on the left and right. In the center, there is a timer showing '02:40'. Below the timer, the word 'Pause' is displayed in orange. At the bottom, there are four buttons: 'Retry', 'Main Menu', 'Exit', and 'Player Controls'.	Allows players to pause gameplay anytime to take a break, retry, or look at player controls again. Provides error forgiveness by letting players stop before failing. Improves ease of orientation with clear labeled buttons.
NodeImagePanelP1	 The NodeImagePanelP1 features a dark background with a yellow radiation symbol at the top. Below it, there is a blue and yellow container with a yellow radiation symbol.	This gives feedback to the user when they collect nuclear reactor rods, so if they pick one up, it will show an image of the one they picked up.

## 8. Creative rationale

### Introduction

Core Clash: Reactor Run is a competitive 2D puzzle-platformer designed to critically engage players with the challenges of managing unstable nuclear reactors in a speculative, energy-scarce future. The game combines puzzle solving, sabotage, and time-limited reactor repair into an experience that is both entertaining and metaphorically reflective of real-world debates about nuclear energy management. This rationale critically examines how the design objectives were achieved, focusing on the future scenar...

### 1. Critical Engagement with the Topic

The future scenario of Core Clash situates players in an underground nuclear facility where two rival engineers race to stabilize malfunctioning reactors. This framing is not purely fictional; it metaphorically represents real-world challenges of nuclear energy oversight, including equipment failure, human error, and the pressure of emergency response (IAEA, 2023). By requiring players to solve logic-based puzzles under time pressure, the game simulates the precision and coordination demanded in nuclear ...

The sabotage system adds a critical dimension. Players can disrupt opponents with tools such as EMPs, blackouts, missiles, and spider webs. This mechanic underscores the vulnerability of critical infrastructure to deliberate interference and cyberattacks (NRC, 2021). In doing so, the game invites reflection on the precarious balance between technological innovation and systemic fragility. Core Clash is not simply entertainment: it frames nuclear oversight as a sociotechnical problem that combines technic...

### 2. Application of Game Design Principles

#### Gameplay and Mechanics

The game applies Schell's (2008) lenses of challenge and competition to sustain engagement. Players must juggle puzzle solving with resource management and tactical sabotage. The introduction of Sabotage Coins as a limited resource forces meaningful decision-making, aligning with Salen and Zimmerman's (2004) emphasis on games as systems of choice.

Mechanics were designed with learnability in mind. Movement and jumping follow established platformer conventions, reducing the barrier to entry. Sabotage actions are mapped to single keys (Q/1–5 for Player 1, Numpad 9/6–0 for Player 2), minimizing cognitive load and improving efficiency. The global time limit introduces urgency and mirrors the pressures of real-world emergency response, while maintaining fairness by equally constraining both players.

### **Level Design**

The split-screen mirrored arena ensures fairness and ease of orientation. Each player faces identical puzzle challenges—switches, crates, and pressure plates—so victory derives from skill rather than environmental imbalance. Hazards such as drones and electric arcs add dynamic difficulty but maintain clarity of goals: collect nodes, stabilize the core, and outlast sabotage.

Progression is structured around three puzzle nodes that must be collected before victory is possible. This prevents premature wins, sustains tension, and ensures pacing. Sabotage costs were calibrated against coin distribution to avoid imbalance. Players cannot spam abilities; they must invest in resource collection, reinforcing the importance of planning and economy.

## **3. Aesthetics, Narrative, and Immersion**

### **Visual Aesthetic**

The game adopts a retro-futuristic pixel art style, drawing from accessible asset libraries such as Kenney.nl and OpenGameArt. This choice promotes clarity: characters, hazards, and UI elements remain easily distinguishable even in chaotic sabotage sequences. Pixel art also evokes arcade traditions, aligning with the competitive ethos of the design.

Industrial tilesets, glowing reactors, and animated sabotage effects reinforce the nuclear facility setting. These are not merely decorative—they act as spatial UI cues, guiding player navigation while embedding feedback in the environment.

### **Narrative and World-Building**

While the game lacks a linear story, it tells an emergent narrative through play: human struggle against unstable systems. The duality of cooperation (stabilizing the reactor) and competition (sabotage) reflects real debates around nuclear energy—its promise of clean power versus its catastrophic risks. Players, cast as engineers, embody this tension by oscillating between problem-solving and disruption.

### **Immersion**

Immersion is enhanced through layered UI integration:

- Diegetic elements: Reactor glow, alarms, and blackout overlays increase urgency inside the world.
- Non-diegetic elements: Health bars, sabotage counters, and timers provide structured feedback, supporting Csikszentmihalyi's (1990) concept of flow.

#### **4. Fun and Player Experience**

The fun of Core Clash lies in its balance of mastery and disruption. Puzzle-platforming satisfies players motivated by achievement, while sabotage introduces unpredictability and tension. This duality aligns with Bartle's taxonomy (1996): achievers pursue progress, while killers thrive on opponent disruption.

#### **UX principles underpin the pleasurable experience:**

- Learnability: Conventional controls and mirrored arenas lower the learning curve.
- Memorability: Consistent sabotage iconography aids recall across sessions.
- Efficiency: Critical information—timer, sabotage points, health—is positioned for rapid recognition.
- Error forgiveness: Sabotage effects (e.g., blackout or slowdown) are temporary, allowing recovery rather than permanent punishment.
- Accessibility: Text and icon redundancy supports color-blind players; large hitboxes ease interaction for varying skill levels.

Replayability emerges from uncertainty. Every match creates new tension: Will I stabilize the reactor, or will sabotage decide my fate? This unpredictability ensures long-term engagement.

#### **5. Awareness Contribution**

Beyond play, Core Clash functions as an interactive metaphor for nuclear risk. By embodying the role of reactor engineers, players confront the stakes of energy systems under duress. Unlike static education, the game transforms abstract issues into embodied experiences—players feel the urgency of oversight and the vulnerability of sabotage.

Sabotage mechanics in particular highlight the reality of infrastructure risks, echoing contemporary concerns around cyberattacks and systemic fragility. As Gee (2003) argues, games promote critical learning by embedding knowledge in meaningful contexts. Core Clash situates players in a scenario where energy debates are lived through play, fostering reflection long after the session ends.

## **Conclusion**

Core Clash: Reactor Run demonstrates how game design principles, aesthetics, and UX/UI integration can be used to craft a polished and meaningful experience. Its speculative future scenario promotes reflection on nuclear energy risks, while its mechanics balance fairness, mastery, and competitive sabotage. The retro-futuristic visuals and layered audio design immerse players in a tense industrial atmosphere, and the accessible UI ensures usability for diverse audiences.

Ultimately, the game achieves more than entertainment: it raises awareness of the fragile balance between technological progress and human responsibility in shaping sustainable energy futures. By transforming abstract nuclear debates into embodied play, Core Clash delivers both pleasure and critical engagement a fusion that reflects the potential of games as tools for learning and reflection.

### URL Link To game on Itch.io

<https://kinglilmeowing.itch.io/core-clash-reactor-run>



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## List of Figures:

Figure 1: Cursor. [SA]. *Competition: High-performance benchmarking among participants. Collaboration: Human-AI teamwork and peer cooperation. Gamified Training: Simulation-based learning modules. AI Integration: Real-time decision-making with machine assistance. Emergency Response: Managing crises under time pressure. These nodes were expanded into actionable clusters such as Performance Metrics, Predictive Safety Systems, Digital Sabotage, and Real-time Training Feedback.*

Figure2: ChatGPT5. [SA]. *Competition, Automation, Human Factor, Simulation, Sabotage, Emergency, Collaboration, Safety, AI, Training*

Figure 3: ChatGPT. [SA]. *Design puzzles based on nuclear facility systems and control logic.*

Figure 4: ChatGPT. [SA]. *Create sabotage mechanics that simulate digital interference and misinformation.*

Figure 5: ChatGPT. [SA]. *Suggest co-op game mechanics for managing simulated emergencies.*

Figure 6: ChatGPT. [SA]. *explore visual themes relevant to the game's setting a high-stakes reactor facility. These boards drew from a range of sources, including: Retro-futuristic industrial design: blending clean, sleek lines with worn mechanical elements and neon-glow interfaces, evoking a sense of advanced but aging technology.*

Figure 7: ChatGPT. [SA]. *explore visual themes relevant to the game's setting a high-stakes reactor facility. These boards drew from a range of sources, including: Retro-futuristic industrial design: blending clean, sleek lines with worn mechanical elements and neon-glow interfaces, evoking a sense of advanced but aging technology.*

Figure 8: ChatGPT. [SA]. *The Reactor Core: a towering, multi-tiered energy hub at the center of gameplay. Designs included rotating rings, containment arms, and cooling conduits. Energy Relay Stations: modular puzzle nodes with wiring interfaces, fuse locks, and rotating connectors that players must interact with. Drone Patrol Units: humanoid and wheeled variations of autonomous security units with exaggerated sensors and motion patterns to emphasize threat visibility. Player Character Silhouettes: agile, masked technicians in radiation suits with swappable toolkits and UI-linked armbands. User Interface Elements: sketches of circular HUDs, interactive overlays, and countdown indicators to emphasize urgency and control. These explorations informed a cohesive art direction that balances functionality and style, delivering a clean, gamified industrial aesthetic that reinforces the reactor theme while enhancing gameplay clarity.*

Figure 9: ChatGPT.[SA]. 2D pixel art game character, futuristic engineer wearing a protective jumpsuit, helmet with clear visor, gloves, and utility belt, Player 1 in neon cyan and silver, Player 2 in bright orange and steel gray, side view idle pose, clean 2–3 pixel outlines, 48–64px height, industrial sci-fi reactor style, high contrast top-left lighting, sprite sheet with walking, jumping, interacting, and sabotage animations, PNG transparent background.

Figure 10: ChatGPT.[SA]. 2D pixel art game character, futuristic engineer wearing a protective jumpsuit, helmet with clear visor, gloves, and utility belt, Player 1 in neon cyan and silver, Player 2 in bright orange and steel gray, side view idle pose, clean 2–3 pixel outlines, 48–64px height, industrial sci-fi reactor style, high contrast top-left lighting, sprite sheet with walking, jumping, interacting, and sabotage animations, PNG transparent background sprite sheet.

Figure 11: ChatGPT.[SA]. 2D pixel art industrial reactor facility tileset, modular 32×32 tiles, includes grated steel walkways, glowing reactor walls, pipes, switches, crates, color-coded wires, reinforced metal barriers, clean 2–3 pixel outlines, consistent lighting from top-left, seamless tiling, dark metallic base tones with neon cyan and hazard yellow highlights, PNG transparent background.

Figure 12: ChatGPT.[SA]. Hazards Security Drone 2D pixel art hovering security drone, metallic steel body with hazard stripes, glowing red sensor eye, small side thrusters with blue glow, animated idle hover in 4 frames, side view, clean outlines, consistent scale and palette, industrial sci-fi style, PNG transparent background.

Figure 13: ChatGPT.[SA]. Particle Effects EMP Pulse: 2D pixel art EMP pulse, concentric glowing cyan energy rings expanding outward, electric sparks, smooth 6-frame loop, clean outlines, consistent lighting, PNG transparent background Explosion: 2D pixel art explosion, bright orange and yellow fireball with shockwave ring, debris particles in gray and hazard yellow, smoke fade-out in 6 frames, cartoon-realistic style, PNG transparent background Energy Flow: 2D pixel art energy beam, glowing neon blue and cyan streaks moving inside a transparent pipe, animated 6-frame loop, clean outlines, industrial sci-fi theme, PNG transparent background.

Figure 14: ChatGPT.[SA]. UI Elements 2D pixel art sci-fi user interface pack, includes split-screen overlay borders, circular timers, sabotage cooldown meters, score display, win/lose banners, uses neon cyan and hazard yellow accents over dark gray base, clean pixel edges, tech-inspired shapes, industrial sci-fi style, PNG transparent background.

Figure 15: ChatGPT.[SA]. Fonts / Title Art 2D pixel art title text for “Core Clash: Reactor Run”, bold uppercase letters, retro arcade style with futuristic twist, neon cyan glow and bright orange secondary highlight, clean pixel edges, consistent with industrial sci-fi theme, PNG transparent background.