# Autonomous Economic Governance: Architectural Frameworks for Terminal Logistics and Industrial Manufacturing in High-GCL Screeps Empires

The architectural evolution of a Screeps empire from a collection of isolated colonies to a unified, multi-room economic powerhouse necessitates the implementation of highly sophisticated autonomous processes. As an empire scales beyond the threshold of twenty rooms, the manual or semi-automated management of resources becomes a primary bottleneck for both credit accumulation and defensive stability. This transition requires the deployment of a centralized 'Terminal Overlord' for inter-room logistics and a data-driven 'Economic Analyst' for market-facing operations. These systems must collectively manage the complexities of 14-day statistical market filtering, imperial resource balancing via quota-delta modeling, the prevention of terminal deadlocks through algorithmic resource ordering, and the strategic transition to Tier-5 commodity manufacturing for NPC-based credit injection.

## The Economic Analyst: Statistical Market Filtering and Threshold Determination

The foundational component of any endgame economic strategy is the ability to interpret market data with high precision while remaining resilient against price manipulation. In Screeps, the global market is the primary mechanism for credit generation, yet it is frequently subjected to "whaling"—the practice of placing high-volume, distorted-price orders to manipulate automated scripts.[1] The Economic Analyst process mitigates this risk by applying technical analysis indicators, primarily the 14-day Exponential Moving Average (EMA), to the data retrieved from the Game.market.getHistory API.

### Mathematical Implementation of the 14-day Exponential Moving Average

Unlike a Simple Moving Average (SMA), which weights all days equally, the Exponential Moving Average applies a weighting factor that decreases exponentially for older data points. This provides a "faster" response to genuine market shifts while maintaining enough historical context to ignore transient spikes.[3] For a 14-day window, the smoothing constant $k$ is defined as follows:

$$k = \frac{2}{N+1} = \frac{2}{14+1} \approx 0.1333$$

The recursive formula for calculating the EMA on any given day $t$ is expressed as:

$$EMA_t = (Price_t - EMA_{t-1}) \times k + EMA_{t-1}$$

The Economic Analyst must process the historical array returned by Game.market.getHistory(resourceType) to derive this value.[2] Because the Screeps API returns up to 14 days of history, the system must handle cases where the history is incomplete. In such scenarios, the analyst initializes the process by calculating an SMA for the first available $N$ days to serve as the initial $EMA_{t-1}$.[3] This initialization ensures that the starting point of the exponential curve is structurally sound.

## Filtering Manipulation via Volume-Weighted Indicators and Outlier Detection

Price manipulation in the Screeps market often occurs through low-volume transactions designed to shift the avgPrice reported in the history.[1] To neutralize these signals, the Economic Analyst integrates volume-weighting and standard deviation filters. The Game.market.getHistory object provides not only the average price but also the stddevPrice and volume for each 24-hour period.[2] A robust filtering algorithm identifies outliers by calculating a Z-score for the daily price relative to the existing EMA. Any daily data point where the price deviates by more than $2\sigma$ without a corresponding surge in volume (Relative Volume or RelVol) is flagged as suspicious and either discarded or heavily penalized in the weighting calculation.[5]

| Data Field | Utility in Market Analysis | Filtering Application |
|---|---|---|
| avgPrice | Base unit for EMA calculation. | Normalized to detect percentage changes.[3] |
| stddevPrice | Measure of price volatility within a day. | High standard deviation signals a "flash crash" or manipulation.[5] |
| volume | Total units traded. | Used to differentiate "muscle" moves from fake |

| | | |
|---|---|---|
| | | signals.[8] |
| RelVol | Current volume compared to historical average. | Identifies periods of abnormal market participation.[7] |

By implementing a "Rolling Midpoint" of price that incorporates both structural range and volume flow, the Analyst establishes a "Hybrid Equilibrium".[5] This equilibrium acts as the fair-market value baseline for all buy and sell thresholds. A buy order is only executed if the current market price is significantly below the $EMA - (x \times ATR)$, where ATR represents the Average True Range, a measure of historical volatility.[5]

# The Terminal Overlord: Quota and Delta Logistics Architecture

Managing a 20-room empire requires a shift from local room storage logic to a globalized "Quota and Delta" architecture. The Terminal Overlord is a high-level process that treats the collective storage and terminal capacity of all rooms as a single, distributed inventory. This architecture is built upon the definition of strict target amounts—Quotas—for every resource in every room, and the calculation of the deviation from those targets—the Delta.

## Quota Definitions and Resource Zoning

In an advanced empire, rooms are rarely identical; they serve specialized roles such as Military Hubs, Industrial Refineries, or Market Export Centers. The Quota for a specific resource is therefore a function of the room's current role and Room Control Level (RCL).[10] For instance, a room performing high-tier lab reactions requires a significant Quota of base minerals (H, O, U, L, Z, K, X) and catalysts, whereas a room focused on upgrading the controller may only require a Quota for energy and Ghodium.[1]

$$\Delta_{room,resource} = CurrentAmount - Quota_{room,resource}$$

Rooms with a positive Delta ($\Delta > 0$) are categorized as Suppliers, while those with a negative Delta ($\Delta < 0$) are Consumers. The Terminal Overlord maintains a global priority queue of these Deltas, matching the greatest needs with the largest surpluses.

## The Delta Dispatching Engine

The dispatching engine iterates through the imperial resource map to identify optimal transfer pairs. This process incorporates the energy cost of the transfer, which is non-linear and based on the distance between terminals.[1] The energy cost of moving resources between room $A$

and room $B$ is calculated using the formula provided by Game.market.calcTransactionCost:

$$Cost = \lceil Amount \times (1 - e^{-\frac{distance}{30}}) \rceil$$

To minimize the empire's total energy footprint, the Terminal Overlord employs a greedy matching algorithm that prioritizes the closest Supplier-Consumer pairs.[2] In a 20-room setup, this often leads to the emergence of "Logistics Hubs"—centrally located rooms that act as intermediaries to reduce the average distance of transfers.[12] These hubs maintain high energy reserves to facilitate the rapid movement of minerals across sectors.

| Resource Category | Quota Priority | Delivery Urgency |
|---|---|---|
| Energy | Critical | Immediate (Tier 0) |
| Base Minerals | High | Sustained (Tier 1) |
| Commodities | Medium | Just-in-Time (Tier 2) |
| Market Surpluses | Low | Opportunistic (Tier 3) |

The priority system ensures that survival-level resources, such as energy for tower defense and terminal fees, are never delayed by lower-priority industrial transfers.[13]

# Preventing Terminal Deadlocks: Algorithmic Safeguards and Stability

A significant risk in highly automated logistics systems is the Terminal Deadlock—a condition where a terminal possesses resources to send but lacks the energy required to pay the transfer fee, and it cannot receive energy because its incoming transaction queue is full or it cannot execute a trade deal.[1] In an empire of 20+ rooms, a single deadlocked terminal can cause a cascading failure across the industrial chain.

## The Four Conditions of Deadlock in Screeps Logistics

Drawing from traditional operating system theory, terminal deadlocks occur when four conditions are met: Mutual Exclusion (only one sender per tick), Hold and Wait (holding minerals while waiting for energy), No Preemption (cannot forcibly take energy from another terminal), and Circular Wait (Room A needs energy from Room B, which needs energy from Room A).[13] The Terminal Overlord prevents these by strictly enforcing an acyclic resource request graph.

### Implementation of the Reserved Energy Buffer

The most effective practical defense against deadlocks is the implementation of a "Reserved Energy Buffer." Every terminal is programmed to maintain a minimum amount of energy (e.g., 50,000 units) that is excluded from all industrial and market calculations. This buffer is used exclusively for paying transfer fees.[12] If a terminal's energy drops below this threshold, the Overlord halts all outgoing non-energy transfers and initiates an emergency energy "Push" from the nearest logistics hub.

Furthermore, the Overlord utilizes "Push-Only" logic for energy balancing. Unlike minerals, which are "Pulled" by the consumer, energy is "Pushed" by the supplier. This ensures that a room with zero energy is never required to initiate a transaction (and thus pay a fee) to receive the energy it needs to resume operations.[1]

### Leveraging Power Creeps for System Stability

At RCL 8, the use of Power Creeps (specifically Operators) is essential for terminal stability. The OPERATE_TERMINAL power can be applied to a terminal to reduce its transfer energy cost and cooldown by up to 50%.[15] The Terminal Overlord monitors the imperial power fleet and prioritizes the activation of OPERATE_TERMINAL in logistics hubs and high-volume industrial rooms. This not only increases the throughput of the network but also significantly widens the safety margin for energy reserves, as each unit of energy can now transport twice as many resources.[15]

## The Industrial Transition: From Raw Minerals to Tier-5 Commodities

The progression to a mature Screeps economy involves moving away from the sale of raw minerals toward the manufacturing of Tier-5 (T5) commodities. While raw minerals (H, O, U, L, Z, K, X) are essential for lab-based boosts, their market value is relatively low and subject to high volatility.[4] In contrast, high-level commodities are designed specifically as a sink for NPC traders, serving as the primary mechanism for injecting new credits into the game world.[4]

### Factory Scaling and Level Matching

The manufacturing of T5 commodities is a vertically integrated process that spans five levels of factory production. A factory structure, available at RCL 7, can be permanently assigned a level from 1 to 5 through the application of the OPERATE_FACTORY power by a Power Creep of the corresponding level.[4] Once set, this level is permanent; a Level 5 factory cannot produce Level 1 commodities, and vice versa. Consequently, a full T5 production line requires at least five separate rooms, each dedicated to a specific tier in the chain.[16]

## Regional Resource Dependency and the Quad-Map Strategy

Commodity production relies on "Regional Resources"—Metal, Silicon, Biomass, and Mist—which are found exclusively in highway rooms and are distributed by map quadrant.[4]

- **Mechanical Chain (Metal)**: Dominant in the North-West quadrant.
- **Electronic Chain (Silicon)**: Dominant in the North-East quadrant.
- **Biological Chain (Biomass)**: Dominant in the South-West quadrant.
- **Mysterious Chain (Mist)**: Dominant in the South-East quadrant.

For an empire of 20+ rooms, achieving full vertical integration often requires either controlling rooms across quadrant boundaries or establishing a robust long-distance logistics network to transport these raw materials to the refinery hubs.[4]

## The Common Component Bottleneck

Regardless of the specialized chain being pursued (Mechanical, Electronic, Biological, or Mysterious), all Tier-5 products require "Common Components" produced at Tiers 1 through 3.[11] These common items act as the primary industrial bottleneck and must be produced in high volumes to sustain the T5 factories.

| Common Commodity | Factory Level | Components Required | Cooldown |
|---|---|---|---|
| COMPOSITE | Level 1 | Utrium Bar, Zynthium Bar, Energy.[4] | 50 Ticks |
| CRYSTAL | Level 2 | Lemergium Bar, Keanium Bar, Purifier, Energy.[4] | 21 Ticks |
| LIQUID | Level 3 | Oxidant, Reductant, Ghodium Melt, Energy.[4] | 60 Ticks |

The Economic Analyst must coordinate with the Terminal Overlord to ensure that the factories producing these common components are never starved of base minerals. This requires a "Just-In-Time" (JIT) delivery model where minerals are moved to Level 1-3 factories only when the factory cooldown is low and the store is below the production threshold.[16]

# Manufacturing the Tier-5 Apex: Specialized

# Production Chains

The ultimate goal of the industrial empire is the consistent output of Tier-5 commodities. Each chain culminates in a high-value item that NPCs are programmed to purchase at substantial prices, providing the credits needed for empire expansion, subscription tokens, and account-bound resources.[4]

## The Electronic Chain (Silicon)

The Electronic chain focuses on advanced logic and circuitry. It is often considered the most accessible chain for players with high Silicon access.

1. **Level 1 - SWITCH**: Requires Wire, Oxidant, and Utrium Bar.[11]
2. **Level 2 - TRANSISTOR**: Requires Switch, Wire, and Reductant.[11]
3. **Level 3 - MICROCHIP**: Requires Transistor, Composite, Wire, and Purifier.[11]
4. **Level 4 - CIRCUIT**: Requires Microchip, Transistor, Switch, and Oxidant.[11]
5. **Level 5 - DEVICE**: The final product, requiring Circuit, Microchip, Crystal, and Ghodium Melt.[11]

## The Mechanical Chain (Metal)

The Mechanical chain represents heavy industrial engineering. It consumes vast quantities of Alloy and Zynthium.

1. **Level 1 - TUBE**: Requires Alloy, Zynthium Bar, and Energy.[11]
2. **Level 2 - FIXTURES**: Requires Composite, Alloy, and Oxidant.[11]
3. **Level 3 - FRAME**: Requires Fixtures, Tube, Reductant, and Zynthium Bar.[11]
4. **Level 4 - HYDRAULICS**: Requires Liquid, Fixtures, Tube, and Purifier.[11]
5. **Level 5 - MACHINE**: The final product, requiring Hydraulics, Frame, Fixtures, and Tube.[11]

## The Biological Chain (Biomass)

The Biological chain utilizes organic cellular structures to build synthetic organisms.

1. **Level 1 - PHLEGM**: Requires Cell, Oxidant, and Lemergium Bar.[11]
2. **Level 2 - TISSUE**: Requires Phlegm, Cell, and Reductant.[11]
3. **Level 3 - MUSCLE**: Requires Tissue, Phlegm, Zynthium Bar, and Reductant.[11]
4. **Level 4 - ORGANOID**: Requires Muscle, Tissue, Purifier, and Oxidant.[11]
5. **Level 5 - ORGANISM**: The final product, requiring Organoid, Liquid, Tissue, and Cell.[11]

## The Mysterious Chain (Mist)

The Mysterious chain involves high-energy "Emanations" and "Essences" derived from condensed mist.

1. **Level 1 - CONCENTRATE**: Requires Condensate, Keanium Bar, and Reductant.[11]
2. **Level 2 - EXTRACT**: Requires Concentrate, Condensate, and Oxidant.[11]
3. **Level 3 - SPIRIT**: Requires Extract, Concentrate, Reductant, and Purifier.[11]
4. **Level 4 - EMANATION**: Requires Spirit, Extract, Concentrate, and Keanium Bar.[11]
5. **Level 5 - ESSENCE**: The final product, requiring Emanation, Spirit, Crystal, and Ghodium Melt.[11]

The Terminal Overlord must manage the recursive nature of these chains. For instance, a RESOURCE_DEVICE (T5) cannot be produced unless the RESOURCE_CIRCUIT (T4) is available. The Overlord monitors the production status of every factory in the chain and proactively moves intermediate goods to the next room in the sequence.

# NPC Trading Mechanics and Credit Inflow

NPC traders are the primary sink for all produced commodities. Unlike player-to-player trades, NPC orders replenish according to a set of rules and are specifically programmed to provide a reliable floor for commodity prices.[1] While NPC prices may not be the most competitive during periods of high player demand, they are the only reliable way to convert massive industrial output into credits without saturating the player market.[17]

## Price Volatility and Supply Adaptation

NPC traders constantly adjust their buy prices based on the supply provided by players. If the empire floods the market with RESOURCE_DEVICE, the NPC buy price will gradually decrease until the supply slows.[4] The Economic Analyst tracks these price shifts using the same 14-day EMA logic applied to the player market. This allows the empire to pivot between production chains—for example, switching from Mechanical to Biological production when RESOURCE_MACHINE prices are depressed.[4]

## Strongholds and Alternative Acquisition

While manufacturing is the primary source of commodities, the empire can also supplement its inventory by raiding NPC Strongholds.[4] Strongholds contain significant quantities of high-tier commodities as loot. The Terminal Overlord must be prepared to handle these sudden influxes of resources, routing them either to market hubs for immediate sale or to the appropriate tier of the industrial chain for further processing into T5 apex products.[4]

# Performance Engineering: Scaling the Overlord Process

In an empire of 20+ rooms, the computational cost of running complex logistics and market analysis can become significant. The architecture must be optimized to minimize CPU

overhead while maintaining responsive logistics.

### Staggered Heartbeats and Execution Tiers

The Terminal Overlord does not need to balance every resource in every room on every tick. Instead, it employs a "Staggered Heartbeat" model.

- **Tick 1: Critical (Energy)**: Every room checks its energy buffer and initiates emergency pushes if needed.[12]
- **Ticks 2-10: Industrial (Minerals)**: The system balances one or two base minerals per tick across the empire.
- **Tick 20: Market (Arbitrage)**: The Economic Analyst updates market thresholds and checks for profitable trade deals.[2]
- **Tick 100: Global Strategy**: The system re-evaluates room quotas and industrial targets based on total empire reserves.

This staggering ensures that the logistics CPU cost remains relatively flat, regardless of the number of rooms, while still providing rapid response times for critical resources like energy.[18]

### Minimizing Intent Overhead

The most expensive operations in Screeps are successful intents, which cost a flat 0.2 CPU each.[18] The Terminal Overlord minimizes these costs by "Batching" transfers. Instead of sending 1,000 units every few ticks, the Overlord waits until it can send a full terminal batch (e.g., 25,000 to 50,000 units), maximizing the resource-per-intent efficiency. This also reduces the frequency of terminal cooldowns, allowing the terminal to remain available for emergency energy imports.[1]

## Conclusion: The Integrated Autonomous Economy

The construction of a Terminal Overlord and an Economic Analyst represents the pinnacle of Screeps systems architecture. By grounding the empire's economic decisions in the statistical reality of 14-day EMAs and volume-weighted filtering, the architect ensures that market operations are both profitable and resilient to manipulation. The Quota and Delta logistics framework, fortified by deadlock-prevention algorithms and the strategic use of Power Creeps, transforms a collection of rooms into a unified industrial entity.

The transition to Tier-5 commodity production is not merely a change in resource focus but a structural evolution. It requires the precise synchronization of multilevel factories, the management of regional resource flows, and a deep understanding of NPC market mechanics. For a 20-room empire, this architecture is the difference between a struggling colony and a global superpower, providing the financial and logistical foundation necessary to dominate the Screeps world. Through continuous optimization of CPU heartbeats and JIT delivery models, the systems architect creates an economy that is not only autonomous but truly self-scaling,

capable of sustaining the empire's growth indefinitely in the face of both player and NPC competition.

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