# AiSTRAEUS: Adaptive Integrated Space Trajectory Resource Allocation & Economic Utility System


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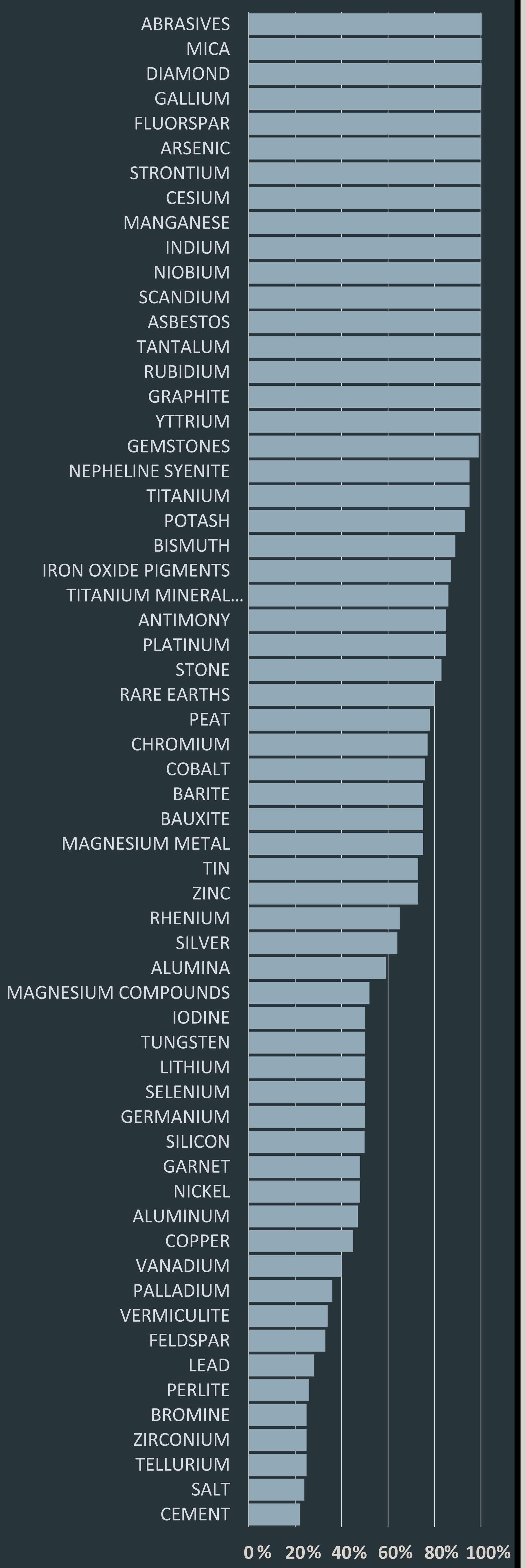
## 2024 U.S. Net Import Reliance[1]




[1]Rare Earths includes lanthanides cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, samarium, terbium, thulium, and ytterbium.

**Figure 1.** U.S. Net Import Reliance for Selected Nonfuel Mineral Commodities (2024) *[5]*. *Source: U.S. Geological Survey, Mineral Commodity Summaries 2025.*

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## Introduction

Space resource exploration is rapidly emerging as a viable industry due to dramatic shifts in launch economics and growing demand for critical minerals. As heavy-launch costs to LEO have fallen by over 95% and commercial spaceflight expands, the prospect of extraterrestrial mining becomes increasingly feasible [2].

**Launch Costs:**
Costs have fallen over 95%, making missions economically viable [2].

**Mineral Market:**
Energy-transition mineral market doubled to $320 B in five years [4].

**Supply Vulnerability:**
The U.S. is 100% import-reliant for 12 critical minerals and over 50% for 28 more [5].

**In-Space Demand:**
Space operations need in-space materials to lower costs and enable growth [6].

These drivers underscore the need for a platform that merges real-time resource pricing, trajectory modeling, and economic analysis. AiSTRAEUS (Adaptive Integrated Space Trajectory Resource Allocation & Economic Utility System) addresses this gap [7].

## Methodology

**Leverage and Extend Existing Tools:** Begins by combining existing techniques in asteroid composition, economic analysis, & mission planning [9].

- Later phases will shift to custom tools.

**Dynamic NPV Modeling for Profit Optimization:** A dynamic Net Present Value model, based on Hein's framework planning [9], drives profitability analysis using adjustable parameters like:

- Fleet scalability
- Throughput optimization
- Mission phasing
- Spacecraft reuse
- Additional cost-reduction strategies

**Real-Time Market and Resource Integration:** The model incorporates real-time commodity pricing, depletion forecasts, and game theory to anticipate the economic impact of space-sourced materials planning [9].

## Concept of Operations

The system will be comprised of three major components:

**Data Acquisition:**

- *Live Economic and Mineral Data:* Collect global and national reserve data alongside dynamic mineral market prices.
- *Celestial Body Repository:* Aggregate data on mineral composition and orbital parameters.
- *Launch Vehicles:* Incorporate detailed information on vehicle capabilities and cost structures.

**Data Processing:**

- *Resource Valuation Analysis:* Continuously evaluate the value of celestial bodies.
- *Economic Modeling:* Perform on-demand projections of mineral market fluctuations using techniques such as Monte Carlo simulations and game theory [9].
- *Mission Modeling:* Provide a breakdown of mission options, cost structures, and comparative analyses [9].
- *Net Present Value Calculation:* Quantify economic feasibility with an integrated Net Present Value (NPV) model [9].

**User Interface:**

- *Data Visualization:* Present insights via interactive charts and 3D models.
- *Comparative Tools:* Allow users to contrast different mission options and cost scenarios.

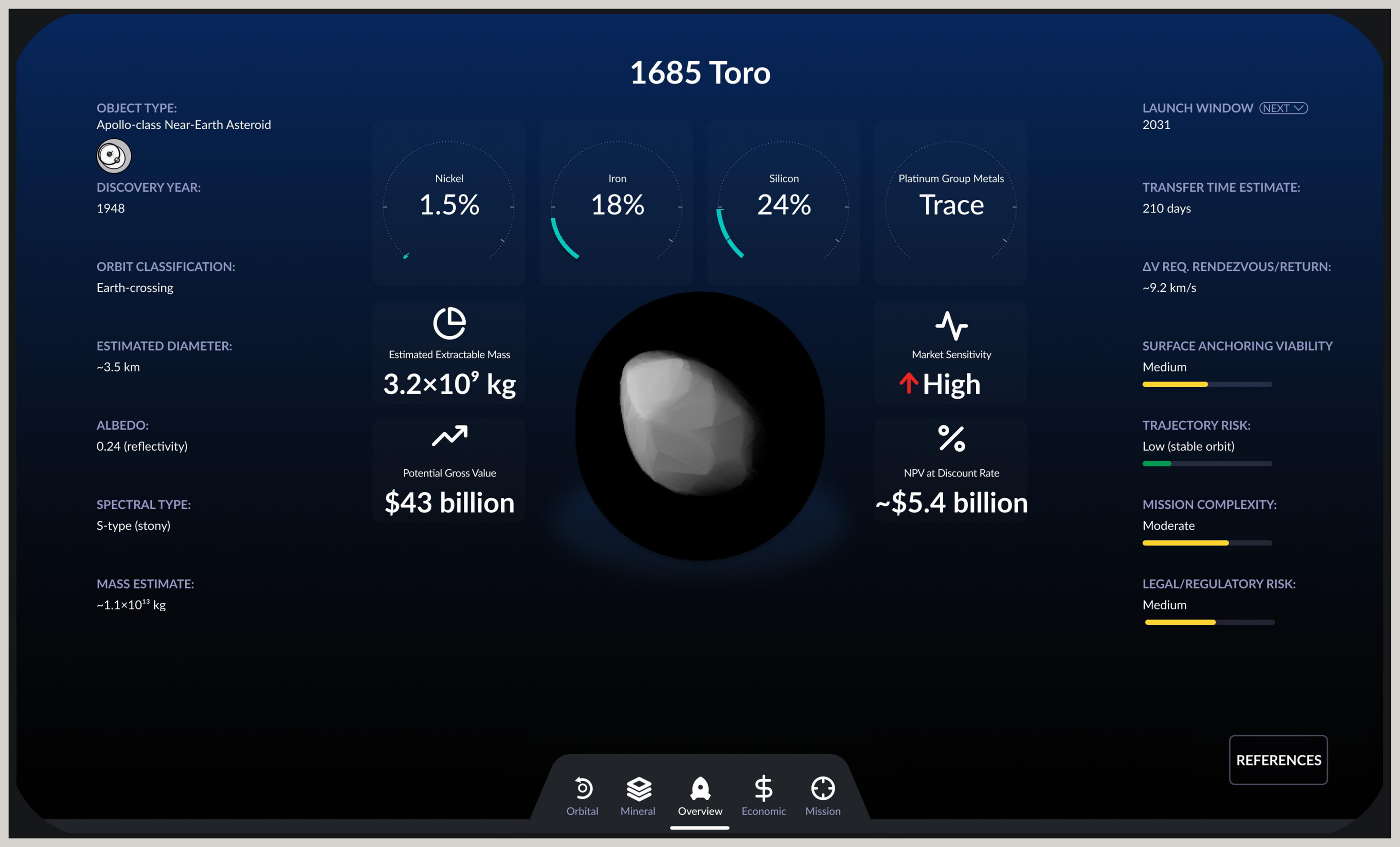


**Figure 2.** Extraterrestrial Resource Valuation Platform Wireframe

## References


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## Challenges

Integrating multiple, disparate data sources proved to be a core challenge.

- **Data Integration:** Varying source formats and update cadences necessitate extensive preprocessing, and ensuring clear metadata across providers adds coordination overhead.
- **Valuation Uncertainty:** Inconsistent mineral surveys and volatile market prices lead to fluctuating economic estimates for candidate targets.
- **System Performance & Scalability:** As more sources are added, keeping ETL pipelines efficient and under strict response-time requirements becomes harder.

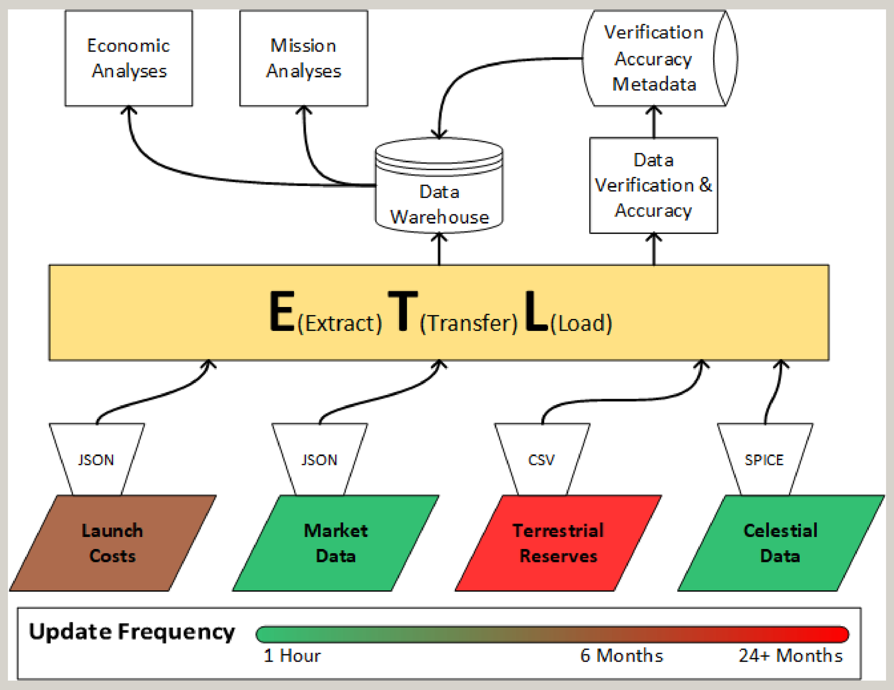


**Figure 3.** Data Acquisition & Data Processing Flow: Extract, Transfer, Load and Metadata Annotations.

## Conclusion

AiSTRAEUS will deliver a transformative framework for evaluating the economic feasibility and operational potential of extraterrestrial mining.

By integrating diverse data streams with advanced modeling techniques, the platform will provide robust, real-time insights for mission planning and serve as a vital decision-support tool.

As a pioneering solution, AiSTRAEUS will aim to catalyze innovative strategies in space resource exploration and foster collaborative progress, thereby paving the way for sustainable growth in this industry.

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