

CASDE: Computational Astronomical Simulation and Dynamics Engine

Abstract

Space data is spread across many databases, and telescope measurements carry errors, which makes predicting orbits difficult. Researchers often have to scratch several websites and tools just to follow one object. To address this, we developed CASDE (Computational Astronomical Simulation and Dynamics Engine), a unified system that brings space data, physics calculations, and error checking into one place.

CASDE runs in the browser using HTML, CSS, and JavaScript, users do not need to install anything. It uses Three.js to render a 3D sky map and CesiumJS to display 3D views of the Earth and the Moon. The sky map lets users search for a star or planet and see where it sits from a chosen location. Orbit calculations are handled by Astronomy Engine for natural celestial objects and Satellite.js for artificial satellites. The prototype retrieves live data from trusted sources, including CelesTrak (satellite orbital elements), NASA/JPL Horizons (planetary positions), the NASA Image and Video Library, LROC (lunar maps), and Open-Meteo (weather). The backend uses Node.js for development, and the prototype is deployed on Vercel for demonstration at <https://casde.vercel.app/>.

To predict how objects may change position over time, CASDE plans to compare two numerical integration methods, Leapfrog and fourth-order Runge-Kutta (RK4). The comparison will examine how both methods handle energy error during long-term orbital simulations, with Leapfrog expected to provide better long-term stability due to its symplectic nature. This can help select a suitable method for long-term orbit prediction.

Finally, CASDE addresses measurement uncertainties through Monte Carlo simulations. Instead of calculating a single deterministic path, the engine generates a probability distribution cloud of future positions. The number of simulation runs will be optimized during the implementation and testing phase. This approach allows users to better understand and quantify observational uncertainty.