ODYSSEIA

Orbital DYnamics Spaceflight Simulator Environment Including Astrophysics

Abstract

We propose a space exploration scenario, based on the Jenet Physics Engine V2.0 and Creighton World Generator, for teaching and exploring concepts in space travel. While inspired by games such as Kerbal Space Program and Orbiter, ODYSSEIA expands the scientific and educational content to inclde a relativistically accurate physics engine, realistic astrophysics, planetology, and plausible advanced spaceflight technologies.

Setting

The technological and scientific setting for a game must typically make compromises between playability, technological plausibility, and scientific realism. Kerbal Space Program uses rocket technologies similar to actual current and historical systems, but uses unrealistic astrophysics to make orbital and interplanetary spaceflight easier to achieve. Orbiter, by contrast, is based on real-world technology and setting; this makes spaceflight (realistically) challenging and limits its use for play and exploration. Other space exploration games typically take artistic license with both technology and physics to produce an entertaining scenario. ODYSSEIA aims for a high degree of scientific accuracy and playability.

The base setting for ODYSSEIA is a far-future terraformed Mars, known as *Erith* to its inhabitants (the *Erithlings*). Erith has been engineered to have an Earthlike atmosphere and biosphere. Ancient disasters have destroyed Terrestrial civilization, while the Erithlings underwent a period of technological regression, and are now rediscovering spaceflight technology.

The following considerations inform this choice of scenario:

- Mars has about 40% the surface gravity and escape velocity of Earth, which makes it substantially easier to achieve orbit with realistic starting technologies (1950s equivalent). Having low gravity and an Earthlike atmosphere also makes spaceplanes and similar alternative flight technologies more achievable.
- Mars has two moons in close proximity: Phobos and Deimos. These provide useful targets for "early-game" exploration after achieving spaceflight but before undertaking interplanetary missions.
- From Mars, the asteroids and giant planets are well within reach using modern-day-equivalent technology, making them appealing "mid-game" targets. Travel to Earth is substantially more challenging, but opens up potential dramatic arcs in the mid to late game.
- The post-collapse scenario creates substantial incentives for exploration, beyond simple curiosity or resource exploitation. Uncovering centuries-old ruins on the Martian moons or asteroids would be the basis for rapid scientific and technological development. A sample return or manned mission to Earth's surface, while technologically challenging, would result in a trove of new discoveries.
- If ancient technological achievements include stellation of Jupiter, then Jovian moons might also have been terraformed into habitable environments. Similarly, if these achievements include creation of stargates (see p. 4), then this opens up interstellar travel to other – possibly habitable – starsystems.

Gameplay and Goals

ODYSSEIA is intended as a "toy" rather than a "game", in that the players are largely free to set their own goal and objectives. However, ODYSSEIA can offer three different modes of gameplay, which impose different criteria on the player and create different dramatic storylines. These are conceptually similar to the "sandbox", "science", and "career" modes of Kerbal Space Program, though they are quite different in implementation.

- A *creative* game allows players to build and test spacecraft according to their own goals and self-imposed restrictions. The level of technology is set by the player, and can be adjusted at will. There are no economic restrictions for craft launched from Erith (though access to resources and construction "in the field" would follow normal resource extraction rules). "Teleportation" and "telekinesis" tools allow vessels and other structures to be placed directly in desired locations or orbits.
- In an *exploration* game, players start with only early space age technology. Technology level increases as time passes or as the player achieves certain in-game objectives (testing experimental systems, performing research missions, or discovering ancient records or artifacts). In addition to any objectives that the player chooses to pursue, this mode imposes a general story arc of exploring new worlds, making scientific discoveries, and achieving technological breakthroughs.
- In a *colonization* game, the player must pursue economic objectives alongside scientific or other goals. Construction and research on the homeworld, as well as maintaining staff and morale, would cost money; while discoveries and resources extracted "in the field" would provide a source of income. Late-game missions would include setting up outposts with refineries, factories, and other industrial capacity; and performing supply and trade missions. After these initial "milk run" missions, outposts would autonomously generate wealth and resources, and serve as points of departure for launching later missions.

Technology

One of the goals of ODYSSEIA is to explore the possbilities of future technologies on space exploration. It would offer a somewhat simplified menu of past and current spaceflight systems, but an extensive set of plausible future extrapolations.

The following is summary of some of the spaceflight technologies that might be offered, based on historical equivalents or postulated future developments:

1. **Early Space Age:** Basic solid and liquid fuel rockets, jet engines.
   (a) **Alternative Paths:** Basic nuclear-thermal rockets, basic nuclear pulse propulsion (Orion), fission ramjets.
2. **Modern Age:** Advanced liquid fuel rockets (SSME), scramjets, ion drives, early solar sails, mature nuclear-thermal rockets.
3. **Near-Future:** Advanced electric rockets (VASIMR), mass drivers, hybrid ramjet-rockets, high-termperature nuclear thermal rockets, mature solar sails, magnetic sails.
   (a) **Optimisitic Near-Future:** Fusion pulse propulsion (Daedelus), basic fusion rockets, metal oxide rockets.
4. **Intermediate Future:** Improved fusion rockets, Bussard fusion ramjets.
5. **Far future:** Optimized Bussard scramjets, antimatter rockets, contragravity drives, stargates.

Rather than using "tech trees" popular among many games, technology in ODYSSEIA would progress along "tech tracks" in major fields of science and technology: basic science, materials, power systems, propulsion, instrumentation/electronics, chemistry, and biosystems. Players can choose to prioritize development along some of these tracks, but there would be a limit to how far any track could advance beyond the others, and specific systems would require a certain level of development in multiple fields. This emphasises the interdependence of technology much better than tech trees.

In exploration gameplay mode, a certain amount of steady technological advancement would occur due to research on the homeworld; in colonization mode, such research would require monetary investment as well as time. Certain in-game activities would also push technology forward, adding "tech points" to some or all technology tracks, including: testing new or experimental components in flight; performing observations or collecting data in new environments; or discovering records or artifacts from ancient facilities.

Supplies

ODYSSEIA's level of realism demands a more involved accounting of consumable resources than is found in many space exploration games. These are key constraints on the duration of missions and the establishment of self-sustaining outposts. While certain abstractions are still maintained for playability, the general goal is to enumerate resources in a concrete and realistic manner. The following summarizes the consumable resources that play a role in space mission design:

Raw Material	**Description**
Interplanetary medium	Tenuous hydrogen gas & plasma
Atmosphere	Various gaseous elements and compounds depending on body
Sea & Ice	Various liquid & solid H, C, N, O, S compounds depending on body
Rock	Various solid metal oxides, silicates, and sulphides
Ore	Rocks especially enriched in metals, or raw metals

Refined Resource	**Obtained from**	**Major uses**
Hydrogen	Atmosphere, sea, ice	Chemical fuel, fusion fuel, reaction mass
Oxygen	Atmosphere, sea, ice, rock	Chemical fuel, reaction mass, life support
Storable hydrocarbons	Atmosphere, sea, ice	Chemical fuel, reaction mass, synthetics
Storable oxidizer	Atmosphere, sea, ice	Chemical fuel (mono- and bi-propellant)
Water	Atmosphere, sea, ice	Reaction mass, life support
Noble gas	Atmosphere	Ionizable reaction mass
Light metals	Rock	Chemical fuel, reaction mass, construction
Heavy metals	Ore	Industrial processes, nuclear fuel, money

Manufactured Product	**Obtained from**	**Major uses**
Food	Hydrocarbons & water	Life support
Fission bomblets	Heavy metals	Nuclear pulse propulsion
Fusion pellets	Hydrogen	Fusion pulse propulsion
Antimatter	Power/Electricity	Antimatter rocket fuel

Immaterial Resource	**Obtained from**	**Major uses**
Power/Electricity	Sunlight, fuels	Powering systems
Money	Other resources	Abstracted resource allocation

Various ship systems are required for collection or conversion of resources: e.g. magnetic scoops to collect interplanetary medium; pumps to collect gases and liquids; mining equipment to acquire solid materials; refineries to produce refined resources; factories to produce manufactured supplies; power plants and solar collectors to produce electricity; etc. Factories and industrial systems can also convert resources into finished products such as spacecraft components, or entire spaceships. Initially, systems must be specialized to the particular resource they collect or produce, while at higher tech levels reconfigurable or multipurpose systems appear. High-tech systems will also be more efficient in resource usage.

In a pure creative or exploration game, the only requirements are that the vessel carries or obtains sufficient resources to maintain operation (including life support) throughout its mission. In a colonization/commerce game, resources may be traded for money or vice-versa. Initially this will only be possible on the homeworld Erith; however, a sufficiently developed outpost or network of outposts could switch from a "subsistence" to "consumer" economy. The game will take over and abstractify the acquisition and distribution of resources within a sustainable economic unit, and the player will interact with this economy using money. Normally this will occur after the player has walked through some set of resource supply missions to establish the outpost's viability.

Ultimately, ODYSSEIA aims to represent interplanetary economic activities, particularly the construction of spacecraft and other facilities, in a reasonable but coarse-grained manner. If an in-game goal is to develop self-sufficient outposts and colonies, then there should be no game-mechanical difference between a mission built and launched from the homeworld or from a shipyard at one of those colonies. This may prove to be a long-term project by the game development team: it is much easier to simulate realistic physics than a realistic economy!

Interstellar Travel

ODYSSEIA aims to include realistic planetology and plausible interstellar travel, to increase the entertainment and educational value of the game. There are two ways to incorporate interstellar travel into the game:

- In a "hard" science scenario, advanced spaceflight technologies, such as fusion rockets or Bussard ramjets, would permit vessels capable of interstellar flight. Even at lower technologies, an Orion-drive vessel could plausibly mount an interstellar mission. Given the timescales required for realistic interstellar travel, such missions would essentially spawn a new subgame in the new system. Possible vessels include self-contained generation ships, hibernation ships, or AI robot probes. Their objectives might be exploration, establishing a colony, or, in the case of a robot mission, creating an industrial base for launching follow-on missions (von Neumann probes).
- In a "firm" science scenario, a wormhole or stargate network, possibly a relic of the pre-collapse civilization, would offer a shortcut to many different starsystems even with early- to mid-game technological capabilities. This simply expands the base game to include any number of mundane or exotic planetary systems – once the player has achieved the requisite milestones (gaining access to the interstellar network).

All planetary systems beyond the Solar system are generated procedurally, using a simulation engine that abstractly represents our currently understanding of planetary formation and evolution. One of the pedagogical goals of ODYSSEIA is to allow players to explore planetary systems and learn about comparative planetology as they pursue in-game missions.

Stargate Network

In the default "firm" science scenario, a preestablished wormhole network exists to facilitate travel to other starsystems. It is possible for players to discover an existing stargate once they begin interplanetary travel. Plausible locations for a stargate are stable orbits with minimal debris, such as the L4 or L5 Lagrange points of Earth, Luna, or Saturn. The entire Solar system may only contain one such stargate, or possibly multiple gates.

The standard interstellar stargate is a ring of ultradense matter about 5 metres across — making it quite a challenge to discover! Through the ring is a portal to some other region of space. There is no obvious "surface" or tunnel: looking through the ring, one sees whatever is on the other side of the portal. The ring itself behaves like an ordinary (but massive) object, with a mass of about 400 tons.

Passing through the ring, one emerges at a "transfer station" deep in interstellar space, indeed well outside the plane of the Galaxy. The transfer station consists of millions of portals in a planar triangular grid with a roughly 40-metre spacing. If one flies away from the grid, one finds that the "station" is a rough hexagon some 800 km across, thus containing about 400 million gateways, each leading to a different starsystem. The array is not a perfect hexagon, indicating that it may be incomplete. However, no activity or sign of technological civilization is to be seen on this side of the portals, other than the network itself.

The stargates are visually identical. While the builders may well have assigned them labels, these are not readily apparent, so explorers would be wise to place their own beacons or markers to avoid getting lost. The gates are held in position by a rigid framework of ultradense matter, which resists any attempt at bending or breaking; ramming the lattice at any significant velocity will destroy the vessel with no effect on the stargates. (It is worth noting that simply holding open a wormhole requires material with a tensile strength exceeding theoretical limits for normal matter, so the stargate structure must necessarily incorporate exotic energy-canceling contramatter.)

Occupational Specializations

In exploration and colonization gameplay modes, a ship's complement may require certain specialists in order to operate efficiently, necessitating multiple crew positions. Personnel can be cross-trained: that is, a single crewmember might have skill in multiple categories. However, serving in multiple specialist roles may impose skill penalties for multitasking. At higher technology levels, automated systems can fulfill some or all of these positions.

The coarse-grained list of occupations and associated crew tasks are as follows:

Pilot: Covers shiphandling, navigation, and command duties. In gameplay terms, piloting skill adds negative feedback to the player's control inputs, improving handling. At higher skill levels, it allows the game to automate certain shiphandling and navigation tasks (e.g. docking).

Technician: Covers operation, maintenance, and repair of the ship's mechanical and electronic systems. This includes "engineers" in the vehicle operation sense. Technician skill can improve the efficiency of certain ships systems (such as life support, refineries, factories, etc.), and mitigates wear-and-tear.

Scientist: Covers operating information-gathering instruments, performing scientific research, and technology development. This includes "engineers" in the science & technology sense. Science skill improves the scientific return of data collection tasks, and is required to operate R&D facilities.

Medic: Maintains the health of crew and passengers. This position is required for long missions. Similar to Service personnel (below), except that lack of a medic may result in incapacitation or even death of personnel, rather than reduction in efficiency or happiness.

Service: A catchall category for occupations that support the *social* needs of personnel. This includes administration, education, entertainment, hospitality, etc. Without service personnel, other crew lose efficiency (effective skill) over long missions, and paying passengers become unhappy. In a generation ship or colony, service occupations also cover caregiving and teaching of younger generations.

Passenger: Covers personnel with no assigned duties or skill requirements. Passengers are commonly a source of income; they may also train into other occupations.

Ship Design

Details of the ship design system (and specific ship systems) have yet to be determined.

The Solar System

The ODYSSEIA storyline begins in our own Solar system, and will be recognizable as such under any careful examination, but tens of thousands of years of terraforming and other changes mean that it might superficially appear to be an alien star system. The names of the major bodies in the ODYSSEIA setting, and their general properties, are as follows.

0. **Eli:** Also known as the Sun, a G2 main sequence star. Tens of thousands of years have not significantly changed its properties. Unlike the present-day Sol, Eli is considered to be one star in a binary system, due to the stellarforming of Esti (Jupiter).

1. **Taki:** The in-game name for Mercury. It is quite difficult to reach, but has substantial metalic ore deposits and an abundance of solar energy.

2. **Therm:** The planet we know as Venus. Therm is a "dry greenhouse" world with a crushing atmosphere of carbon dioxide and sulfuric acid, and surface temperatures that can melt lead. Beyond intellectual interest or a desire for completeness, there is little reason to go here.

3. **Bary:** This is Earth as it is known to the civilization of ODYSSEIA. It is much heavier than Erith and correspondingly challenging for Erith-adapted people and technologies to operate in. Its climate is a "wet greenhouse", with an opaque smoggy atmosphere, rich in carbon dioxide and depleted in oxygen compared to contemporary Earth, and with somewhat smaller and more acidic oceans. Despite its hostile environment, there are extensive relics of past civilization that would make a visit worthwhile.

    (a) **Lept:** Bary's natural satellite; i.e. Luna. With its lower gravity and benign, sterile environment, it is a science-rich target more accessible than Bary.

4. **Erith:** The homeworld of the ODYSSEIA civilization. Erith is a future terraformed Mars, with a breathable near-Earth-standard atmosphere, small but substantial oceans, extensive grasslands, and even a few forests (with amazingly tall low-gravity trees). Its appearance from space is quite striking, with red deserts, green vegetation, blue oceans, and white clouds and ice caps: it may not be immediately recognizable as Mars, though the underlying topography is the same.

   (a) **Pete:** The larger of Erith's two natural satellites (i.e. Phobos). Pete is in a relatively low orbit (below Erithostationary orbit), and has nearly negligible surface gravity, making it a useful milestone and waypoint in players' exploration program. In addition to subsurface ices and other hydrated compounds, Pete has extensive surface ice deposits from volatile ejecta during the terraforming of Erith. These can be mined for fuel.

   (b) **Koko:** The smaller of Erith's natural satellites (i.e. Deimos), similar to Pete but half the size. It is just outside Erithostationary orbit, making it another handy stepping-stone.

5. **Chalik:** This refers to the asteroids in the belt between Erith (Mars) and Esti (Jupiter). Chalik-1 (Ceres) through Chalik-25 (Aurora) correspond to actual asteroids with radii greater than 100 km; additional asteroids will be procedurally generated in the game.

6. **Esti:** Formerly the planet Jupiter, Esti has been stellarformed into a brown dwarf star through a variation on the Thorne-Żytkow process. It has a radiant flux (luminosity) of about $2 \times 10^{-5}\, L_\odot$ and a surface temperature of 1200 K, meaning that the Sun (Eli) remains the dominant source of *visible* light within the Esti system, even as Esti provides enough infrared heating to melt the ice on its inner moons.

   (a) **Piro:** The innermost of Esti's four major satellites. Formerly known as Io, this world has become even more hellish with the stellating of Esti: combining Io's tidally-driven vulcanism with Venus-like levels of heating. Piro's atmosphere is a thick toxic brew of hydrogen sulfide and hydrocarbons, blanketing a surface dominated by seas of boiling sulfur.

   (b) **Cleo:** The stellation of Esti has transformed icy Europa into the pleasantly tropical ocean world of Cleo. Ancient terraforming projects have also introduced specially-engineered algae into Cleo's oceans, giving it a breathable oxygen atmosphere. However, unlike the real Earth or terraformed Erith, Cleo's ocean is world-spanning and over a hundred kilometres deep. Its only solid surface structures are floating mats of biogenic matter: these shifting "archipelagos" support diverse island ecosystems.

   (c) **Ermo:** The largest of Esti's satellites. Within the Esti system, Ermo/Ganymede and Cleo/Europa have a similar orbital ratio as Erith/Mars and Bary/Earth. Ermo has been slightly terraformed to give it a cold but liveable temperature: mostly frozen but with a large lake of liquid water at its Esti-facing pole. However it has only microbial life and a thin unbreathable atmosphere.

   (d) **Krio:** The most distant of Esti's major satellites, Krio remains largely unchanged from its days as Jupiter's moon Callisto. It has an icy surface pocked with craters, and no significant atmosphere.

7. **Kirk:** This is Saturn, and still has its distinctive rings thousands of years into the future. Perhaps more than any other world, Kirk's distinctive appearance marks the Eli system as our own Solar system. Kirk has numerous moons, including 7 major moons, one of which bears special mention.

   (a) **Thol:** The largest of Kirk's moons, indeed the largest moon in the entire system (now that Ermo/Ganymede is technically a planet of the "star" Esti). Thol has a thick atmosphere of nitrogen organic particles, and lakes of cryogenic hydrocarbons. In the ODYSSEIA setting, Thol also has an extensive biosphere of complex but slow-moving organisms, based on a hydrogen metabolism.

8. **Hal:** The gas giant formerly known as Uranus. Its most significant feature is its high axial tilt, which can lead to interesting transfer orbits to and from its satellite system. It has faint but notable rings, and five major moons, all of which are fairly ordinary iceballs with no atmosphere.

9. **Kian:** The outermost gas giant, known today as Neptune. Kian's rings are even fainter than Hal's, but are still significant. It has one major iceball moon.

10. **Chione:** This refers to Eli's Kuiper belt and other bodies outside of Kian's orbit, including several planetary-mass objects. Chione-1 through Chione-25 correspond to contemporarily known trans-Neptunian objects with radii larger than 300 km, while other bodies, inluding comets on eccentric orbits, will be procedurally generated.

Name origins

Astronomical names in ODYSSEIA are based on mutated abbreviated Ancient Greek, because why not? This allows the names to have a whimsical familiarity, without implying that human civilizations millennia from now will still be speaking English or any other contemporary language.

Specifically, the names have the following linguistic roots:

- **Eli** derives from ‘ήλιος (*hēlios*, "sun").
- **Taki** derives from ταχύς (*takhys*, "swift"), since it's the fastest-orbiting planet.
- **Therm** derives from θέρμη (*thermē*, "heat"), due to its high surface temperature.
- **Bary** derives from βαρύς (*barys*, "heavy"), since it's the most massive Terrestrial world.
- **Lept** derives from λεπτός (*leptos*, "small"), since it's much lighter than Bary.
- **Erith** derives from ερυθρός (*erythros*, "red"), from its original colour.
- **Pete** derives from πέτρα (*petrā*, "rock"), since it's a big rock.
- **Koko** derives from κόκκος (*kokkos*, "granule"), since it's smaller than Pete.
- **Chalik** derives from χάλιξ (*khalix*, "gravel"), since it's a group of small rocky bodies.
- **Esti** derives from ‘εστία (*hestiā*, "hearth"), since it warms its nearby worlds.
- **Piro** derives from πῦρ (*pŷr*, "fire"), due to its hellish surface.
- **Cleo** derives from χλιαρός (*khliaros*, "lukewarm"), due to its mild temperature.
- **Ermo** derives from έρῆμος (*erêmos*, "wasteland"), becuase it is barely habitable.
- **Krio** derives from κρύος (*kryos*, "cold"), since it is a frozen iceball.
- **Kirk** derives from κίρκος (*kirkos*, "ring"), because of its distinctive ring system.
- **Thol** derives from θολός (*tholos*, "sepia"), due to tholins (carbon-nitrogen polymers) on its surface.
- **Hal** derives from ‘άλς (*hals*, "sea"), due to its sea-green colour.
- **Kian** derives from κυάνεος (*kyaneos*, "blue"), due to its darker aquamarine colour.
- **Chione** derives from χιών (*chiōn*, "snow"), since it's a group of small icy bodies.

Players might infer other connections (Erith with Earth; Kirk, Cleo, and Hal with certain SF characters), but the names just come from Ancient Greek. Really.