

Space Simulator

1.0.8

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Contents

Chapter 1

Main Page

Here you can find the latests guides and documentation the project. Given the constant improvements and increase of scope , some parts would be temporarily un-documented. We are periodically updating this documentation - and from version 1.0.9 - the documentation will be updated on your device in an automated way. If you can't find a topic of your interest, please dont hesitate to contact us at info at brixtondynamics.co.uk

- [Introduction](#) Introduction of the project, change history, etc.
- [Controls](#) Introduction of the main controls
- [Spacecrafts](#) Identification of the different spacecrafts available in Space Simulator.
- [Astronautics](#) Learn the foundations of space travel
- [Mission Guides](#) Mission guides for most scenarios
- [Orbit Planner Introduction](#) Learn to use the Orbit planner

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Chapter 2

Astronautics

Astronautics

Astronautics (or cosmonautics) is the theory and practice of navigation beyond Earth's atmosphere.

- [History](#) History
- [RocketDesign](#) Principles of Rocket Design
- [Orbital Dynamics](#) Orbital Dynamics
- [Orbital Attitude](#) Spacecraft Attitude
- [Spacecraft Propulsion](#) SpaceCraft Propulsion
- [Terms and Definitions](#) Terms and Definitions

2.1 History

* **A bit of History wont' hurt.**

Astronautics is the theory and science of navigation beyond's earth's atmosphere. As with its related science aeronautics, the restrictions of mass, temperatures, forces, etc.. require of complex analysis to solve the practicalities of space-travel.

The early astronautics was purely theoretical. Although its principles were laid by Isaac Newton in the 17th century, it wasn't until the beginning of 20th century when Konstantin Tsiolkovsky derived his most famous equation, the principle of a mass-expelling (rocket) based propulsion. With his formula, it was possible to link the rocket's mass, its total propellant, its non-propellant mass, and both the exhaust and final rocket's velocity.

But it wasn't until 1920s when American Robert Goddard first developed a serious -viable way to generate the rocket exhaust velocities required to at least consider astronautics.

At the end of WWII, American's Goddard's design were a foundation basis for the first practical rocket: The German A-4 (V2).

Until then, liquid fuel rockets were more of a scientific curiosity, or some way to test exotic experiments on combustion. The German Rocket A-4 changed all that, becoming the first man-made object to exit to Space.

With a monstrous (at the time) 25 tons of thrust, it was able to generate enough lift to lift off the ground a Panzer II, or to send an American Willys Jeep to space and back 300 kms away. This engineering wonder was mostly useless to alter the outcome of the war, but its performance and capabilities were well noted for both American and USSR's engineers.

With the American success of the Manhattan project in building the first atomic bombs, it was suddenly clear that the combination of the -relative- huge destructive power of the weapon plus the ability of a A-4 (V2) to launch that device well beyond enemy lines, that would be a war-winning weapon. A race in both hands ensued to solve the tremendous difficulties of fitting nuclear weapons small enough to fit in the limited cargo available of the era's ballistic missiles.

In the 50s, most of those ballistic missiles were merely more or less copies of the original V-2 team design. A game changer happened with the discovery by USA (and later copied in USSR) of an even new larger and more destructive weapon (the Teller-Ulam's Hydrogen Bomb). The new device didn't weigh hundreds of kilos, but tons. The first design were as heavy as buildings topping 10-20 metric tons. As with the A-Bomb both countries raced again to solve the problems of fitting the hugely heavy H-Bomb in an intercontinental ballistic missile.

A curious event happened then: Due to the inability of Soviet designers to reduce the weight of their hydrogen bomb, the department of Soviet defense, drafted a requirement for a rocket -so huge- that it could lift 5 metric tons (the lighter Soviet H-bomb at the time) on to US. The requirements were so ambitious that only one rocket bureau's proposal was submitted (and approved): Sergei Korolev's huge Semiorka R-7 ICBM. On the other side of the world, miniaturizing efforts of the bomb designer's paid off into making way smaller hydrogen bombs, so the request for the rocketeer's designs were substantially smaller. It was obvious that with such a large rocket as Korolev R7 it was possible to send artificial objects into quasi-permanent orbits. Even more, it was possible to send a -rather limited- "spacecraft" into orbit with some lone cosmonaut inside. And so it happened, in 1956, The Socialist Union of Soviet Republics succeeded to be the first nation to send a man into space, -not really completing an entire orbit, and not even landing with its own spacecraft-.

Due to the limited cargo of the American rocket designs, USA tried to save face by sending an Astronaut's into an even smaller capsule, for a ballistic 20 minutes 'jump', not unlike the flights that Virgin Galactic flight is proposing.

Having been matched into putting humans in space both the USA and USSR were racing against each other into another series of "First". Some meaningful as first two-people crew, first entire day in orbit, first three people crew, etc..

By then the cargo capacities of the rockets of both countries have increased hugely, They were powerful enough to break of Earth gravitational well and send objects to their part of the Solar System. The 60s was the decade of big space exploration projects, first by LUNA series, (first man-made object to escape Earth's gravity), the MARS, VENERA series, PIONEER, and later VOYAGER.

Human exploration was also in both's countries top priorities. The obvious new goal of landing men on the moon was first studied in the late 50s' and later made official in the early 60s' with Kennedy historical speech. A race to the moon ensued. While the Russians never publicly admitted attempting to beat the Americans into landing a man on the moon, they put a proportionally larger percentage of GNP onto the -then- secret project.

Both countries quickly realizing that any lunar landing attempt would involve spacecraft-to-spacecraft docking (Rendezvous) the engineering teams raced to research, develop, and test in-orbit dual spacecraft rendezvous.

For that series, the Americans designed an interim program (Program Gemini), using the new series of Atlas ICBM boosters. The Gemini Spacecraft was America's first 'real' spacecraft, with orientation and translation thrusters, and some crude form of docking. It had a cramped room for two (preferably small) astronauts. Russia, on the other hand, stuck loyal to its trusted R7 booster, by then obsolete as a weapon but a very reliable space booster). A new spacecraft was designed -the Soyuz- with docking capabilities, space for 2-3 astronauts, and rotation/translation thrust.

Finally, at the end of the decade, another real engineering wonder: The Saturn V with its associated hardware Gruman's Moon Lander and Boeing Command and Service module, performed flawlessly into the goal of landing a man on the moon, and bringing them safely back to Earth. At the very same time, Russians were experiencing all sorts of -almost comical- troubles, explosions, and disaster with their boosters, rockets, and spacecraft.

Ironically , the Russian decision of sticking to one rocket (R7) and one spacecraft (Soyuz) have eventually paid off. By far the most successful of the rockets, and reliable of spacecrafts, Soyuz capsules are even today routinely launched of modern versions of R7 on the way to the ISS. America's decision to focus on a new -unnecessarily reusable- Space Shuttle , were finally grounded when Columbia Shuttle desintegrated upon reentry , showing a major -not really fixable - design flaw.

Today's , with the view more focused on profitability and reliability , a new breed or rockets are being designed. Some even by private companies (SpaceX) , other by Europe (Ariane) , and recently by the Chinese Space Agency .

2.2 RocketDesign

Principles of Rocket Design

Leaving aside digital electronics, and exotic composite materials, current rockets are dissapointly similar to Von Braun's A-4 (V2). All current rockets compose a number of stages, each holding two very large (and very light!) tanks of Fuel and Oxidizer. A set of Turbopumps (not unlike the turbocharger on diesel engines), force the fuel and oxidizer into the combustion chamber , achieving this by burning a small fraction of fuel/oxidizer generally in a smaller combustion chamber. The bell shaped (de Lavall nozzle) is sh] 888aped in a way that the maximum pressure happens at the narrowest point , and hence , pushes the exhaust gases to tremendous velocities. The mass of those gasses (both are termed propellants) at those speeds, create a reaction force (thrust)that pushes the rocket forward.

Ideally an ideal rocket would have very little mass and hold huge values of propellant . However this is not possible. The engines, the tanks ,the structures, are basically dead-weight. As the rockets burns its propellants, it obviously decreases significantly its weight , and so need less thrust to keep on accelerating . The engines are big enough (huge!) to lift a 2000 Tons rocket off the ground .But one couple of minutes later , the same rocket weights only 1000Tons. It could do with smaller rocket engines, smaller tanks, etc.. In other words, the huge rocket engines, turbo pumps, etc.. are oversized by the rocket in mid-flight. Here is when it comes the concept of Staging. It can be derived that it is more efficient to split the rocket in incresigly smaller detachabnle ,parts, to be shred as the velocities increase and the need for thrust is required. Soon it was realized that the optimum number for earth orbit is somewhere beetween 2 and 3 (the tradeoff beetween carrying larger rocket engines and heavier emtier tanks , versus , carrying a set of non-pushing (smaller) rocket engines in upper stages.

Outside the Earth's atmosphere ,a rocket will keep oits velocity , affected only by gravitational forces. Most space-crafts , the ISS, space Shuttle in orbit, Apollo spacecraft on its way to the moon , etc , are NOT using fuel. They are simply coasting .Trust -and hence fuel -is only needed to change the spacecraft's velocity. That brings up to a point :A rocket can only accelerate forward. As rockets have no way of braking , the only way a rocket can slow down ,is rotating the rocket/spacecraft engine side front (as in pointing backwards) and using the engine to accelerate backwards :i.e. recuding the speed.

Fuel in rockets is in extremely limited quantities. The science and art of astronautics and orbital maneuvers consist on finding the more efficient ways to achieve the required mission. In Space-Simulator (the app)you can practice and simulate the outcome of different orbital maneuvers.

2.3 Orbital Dynamics

Orbital Dynamics

Orbital dynamics -also refered as orbital mechanics- refers to the application of newtonian physics (forces, move-ments) to bodies with mass in a gravitatorial environment. It can refer both to spacecraft or to celestial bodies. The

basic element of orbital dynamics is the concept of orbit, that is the path that -given an object with mass- will follow based purely on momentum and gravitational forces. In most (but not all !) of the cases, orbits are closed, that is : given a certain amount of time -called orbital period-, the orbiting body will return to the same point, bearing the same velocity. Of course, this is an abstraction -every body is attracted to the mass of every single moving atom in the universe-, so orbits are not perfectly periodical, not fixed. Most importantly, the "bigger" object, either the Sun or the Earth, also is affected by the mass of the orbiting body, and indeed are following another orbit of its own.

If we can assume the orbiting body (satellite) has a very small mass, we can consider the main object (Earth) fixed in space.

It is important to remember that an orbiting body/satellite does not need any more energy to be orbiting. As the satellite follows its orbital path, it may trade some kinetic energy -velocity- for potential energy -altitude-, but this is later converted back to kinetic. So the total orbital energy (being kinetic + potential) is always the same.

Sometimes happens that the orbital energy is too large for the gravitational field, so the body gets too far, so far that the gravitational forces are so small that the object is no longer bound to a cyclical orbit. This way, the object will follow a hyperbolic (i.e. "open") orbit forever, and will never come back to the starting point.

Basic concepts of orbits applied to astronautics:

- Without any external force, the shape and period of the orbit will not change.
- The smaller (lower) the orbit, the faster the satellite needs to orbit.
- If any kind of force/thrust is applied at any point in the orbit, the rest of the orbit will change, but the satellite will return to the same point at the same velocity.
- Positive thrust (accelerating) will increase the orbital altitude at the opposite end of the orbit
- Negative thrust (reducing orbital velocity) will decrease the altitude at the opposite end of the orbit

[Orbits](#) Orbits

[Orbital Elements](#) Orbital Elements

[Orbital Maneuver](#) Orbital Maneuver

[Hohmann Transfer Orbits](#) Hohmann Transfer Orbits

[Common Orbits](#) Common Orbits

[Orbital Points](#) Special points on orbits.

2.3.1 Orbits

In space where there is no friction, air resistance or other forces to change the movement of an object, objects are affected only by gravity. In particular, bodies with mass follow paths which are only affected by the bodies' mass.

If the velocity of the moving body around a celestial body is inside a certain range, the object will be moving around that celestial body perpetually, without ever falling into it or escaping from it.

Orbits are usually *but not necessarily* closed.

If the eccentricity of an orbit is greater than 1, the orbit is an open hyperbolic orbit. If the eccentricity of an orbit is 0, the orbit is perfectly circular. A spacecraft can escape the sphere of influence of a planet if it has large enough orbital velocity.

2.3.2 Orbital Elements

Orbits and the position of spacecraft in those , can be defined on different ways, depending of the physical/matematical approach we are taking

- We could define an orbit around a large body simply by specifying the relative position (x, y, z) of the Spacecraft respect the body, the velocity (dx, dy, dz) relative to the body , and the mass of the body. This is the way orbits are internally computed on this simulation, and the preferred way for computers to simulate, analyze, predict, render orbits. This is commonly referred as Cartesian definition of orbital elements.
- however, we can also define the same orbit ,and position - using the Keplerian orbital elements (from Johannes Kepler). They are a set of 6 ANGULAR values, that determine the characteristics of the orbit
- *
- ***Semi-major axis**: half of the longest diameter of an ellipse.
- ***Eccentricity**: how much the orbit deviates from a circle.
- ***Inclination**: the tilt of the orbital plane in relation to the reference plane.
- ***Mean Anomaly**: where the satellite is in relation to the perigee.
- ***Argument of Perigee**: where the perigee in relation to the Earth's surface.
- ***Longitude of Ascending Node**: defines the position of the ascending orbit in relation to the reference plane.

2.3.3 Orbital Maneuver

Orbital Maneuvers

In spaceflight , an orbital maneuver is the use of propulsion systems to change the orbit of a spacecraft.

Orbital Changes

- [Hohmann Transfer Orbits](#) Hohmann Transfer Orbit
- [BiEllipticTransfer](#) Bi-Elliptic Orbital Transfer*
- [GravityAssist](#) Gravity Assist
- [OberthEffect](#) OberthEffectManeuver

Rendezvous and Docking Maneuvers

- [Coelliptic Chase Rendezvous](#)
- [Co-Planar Rendezvous](#)

Trans-Lunar Injection

Trans-Martian Injection

2.3.3.1 Hohmann Transfer Orbits

One of the most common procedures you need to carry out in any space mission is to move from one orbit to another. The Hohmann Transfer is the most useful bit of orbital mechanics you'll need to know for this game. Designed by German engineer Walter Hohmann in 1925, the Hohmann Transfer is the most fuel efficient maneuver to move between two co-planer orbits.

See the below diagram:

To move from the initial lower orbit to the higher orbit, we need to increase thrust at points A and B parallel to the direction of travel.

STEP 1: At point A we throttle up to increase the velocity, taking the spacecraft out of the initial orbit into an elliptical transfer orbit. If we take no further action, the spacecraft will remain in the transfer ellipse, returning to point A on the other side. STEP 2: To complete the transfer, upon reaching the apogee at point B, we throttle up again to increase the velocity to put the spacecraft into the trajectory of the final circular orbit.

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The orbital maneuver to perform the Hohmann transfer uses two engine impulses, one to move a spacecraft onto the transfer orbit, and a second impulse to move off it -usually by circularizing the orbit to the same degree as the orbital target.

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Please note that due to the reversibility of orbits, Hohmann transfer orbits also work to bring a spacecraft from a higher orbit into a lower one. In this case, the spacecraft's engine is fired in the opposite direction to its current path (retrograde) slowing the spacecraft and causing it to drop into the lower energy elliptical transfer orbit. The engine is then fired -again- at the lower distance to slow down the spacecraft into a circular lower orbit.

2.3.3.2 BiEllipticTransfer

Bi-Elliptic Transfer

A Molniya orbit is a type of highly elliptical orbit with an inclination of around 63.4 deg. and an argument of perigee of -90 degrees and one and a half days of orbital period.

Molniya orbits are named after a series of Soviet communications satellites which have been used this orbit since the 60s'

2.3.3.3 GravityAssist

Gravity Assist

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2.3.3.4 OberthEffect

Oberth Effect

In astronautics, a powered flyby or Oberth Maneuver is an orbital maneuver in which a spacecraft falls into a gravitational well, and then accelerates when it reaches maximum relative speed. The resulting maneuver is a more efficient way to attain kinetic energy, than applying the same impulse outside the gravitational well.

This is explained by the Oberth Effect, in which the use of a thrusting engine at higher speeds generates greater mechanical energy than when used at lower speeds. In brief, this means that more kinetic energy can be obtained for the same amount of propellant expended.

The Oberth effect is the strongest at the periapse, which is the point of minimum altitude (potential energy, and such is the point of maximum speed), as thrusting engines (all rocket and jet engines) generate constant thrust, regardless of the distance during the thrust, the faster the spacecraft, the more work (as in force $\times$ space) is created for the same amount of propellant.

2.3.3.5 Coelliptic Chase Rendezvous

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2.3.5 CommonOrbits

Common Orbits

[GeoStationaryOrbit](#) Geostationary Orbit

[MolniyaOrbit](#) Molniya Orbit

2.3.5.1 GeoStationaryOrbit

GeoStationary Orbits

A geostationary orbit, is a circular orbit, around 35780Km above the Earth's surface and following the direction of the Earth's rotation.

When a spacecraft is in that orbit, it has its orbital period similar to the length of the Earth's day, as both spins with the same angular velocity. Thus, the spacecraft appears still -as observed from the Earth-, and so the Earth will show always the same view to the spacecraft.

Another related concept is a geosynchronous orbit. Which is every orbit with the same orbital period as the Earth's rotation. On a geosynchronous orbit the spacecraft is in the same position at the same local time -every day- but its apparent position changes over time. Any orbit -even with the same period as the earth's rotation - BUT NOT OVER THE ECQUATOR will be a geosynchronous orbit.

2.3.5.2 MolniyaOrbit

Molniya Orbits

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Molniya orbits are named after a series of Soviet communications satellites which have been used this orbit since the 60s'

2.3.6 OrbitalPoints

Orbital Points of Interest

An orbit is defined by their keplerian parameters .However, some points arise from the equations , of certain relevance to astronautics.

- * [Perigee & Apogee](#)
- [Lagrangian Points](#)
- [Orbital Focus](#)

2.3.6.1 * Perigee & Apogee

An APSIS is an extreme point in a objects's orbit. For elliptic(planeatry) orbit , there are two apsides , named with the prefixes PERI and AP.

PERI denotes the lowest point in the orbit (maximum velocity) APO denotes the highest point in the orbit -and hence- the minimum orbital velocity.

Typical examples would be

- PERI-GEO and AP(o)GEO -> GEO = EARTH
- PERI-LUNE and APO-LUNE -> LUNE = MOON
- PERI-CYNTION and APOCYNTION ->CYNTION = MOON
- PERI-HELION and APHELION ->HELIOs = SUN

etc..

2.3.6.2 Lagrangian Points

In orbital dynamics we refer to *Lagrangian points* to positions relative to two large bodies (planets/sun), in which the gravitational pull of both large bodies cancel each other , creating a equilibrium . They are relevant to astronautics, as they allow for a spacecraft to stay still , free of forces (as they cancel each other) in points that they don't belong to any possible orbit. This way , a spacecraft can *hover* in Lagrangian point 2 in a perpetual night as the earth blocks the sun , without needing to rotate around earth.

- [Lagrange1](#)
- [Lagrange2](#)
- [Lagrange3](#)
- [Lagrange4](#)

2.3.6.2.1 Lagrange1

Lagrange Point 1

If a spacecraft is placed between the Sun and the Earth, the Earth's gravity pulls it in the opposite direction and cancels some of the pull of the sun. With a weaker pull towards the sun, the spacecraft then needs less speed to maintain its orbit.

If the distance is just right, about 4 times the distance to the Moon, or 1/100 of the distance to the sun, the spacecraft too will need just one year to go around the sun and will keep its position between the Sun and the Earth.

This precise position is the Lagrangian Point L1, so called after the Italian-French mathematician who discovered it - Joseph Louis Lagrange.

The L1 point is a very good position for monitoring the solar wind, which reaches it about one hour before hitting us in the Earth. In 1978 the International Sun-Earth Explorer (ISEE-3) was launched towards Lagrangian point L1. Once there, it conducted such observations for several years. Equipped with an on-board rocket and plenty of fuel.

2.3.6.2.2 Lagrange2

Lagrange Point 2

lagrange point2 definition here

2.3.6.2.3 Lagrange3

Lagrange Point 3

lagrange point3 definition here

2.3.6.2.4 Lagrange4

Lagrange Point 4

lagrange point4 definition here

2.3.6.3 Orbital Focus

The focus is the idealized point around the orbit of an orbit revolves, having constant orbital momentum. All orbits around a big enough celestial body can be simplified as ellipses of varying eccentricity. The big object (Sun, in the case for planets) can be thought as the geometrical focus of that ellipse.

Hence, an orbital focus is one of two points on the major axis (from Apogee to Perigee) of an elliptical orbit, whose separation from the other focus determines the shape of the elliptical orbit. At one of the foci is the body being orbited, for example the Sun. The other focus is unoccupied.

2.4 Orbital Attitude

In Space, the standard concepts of orientation (North , Up , down,etc) are meaningless. The only absolute reference is the spacecraft's current orbit. So , when defining the orientation of a spacecraft , we refer it as its attitude respect its current orbit OR Orbital Attitude.

A spacecraft can orient towards some special axis.

- **Prograde** : The spacecraft is oriented "nose" first , and the engine pointing "backwards" relative to its orbit.
- **Retrograde** : The spacecraft travels 'engine first'. It is the opposite to prograde.
- **Normal Plus** : (or normal +) , The spacecraft points perpendicular 'up' to the plane that lies in the orbit
- **Normal Minus** : (also normal -) the spacecraft points opposite Normal+ , that is perpendicular 'down' to the plane of the orbit
- **Radial Plus** : (Or Radial+) the Spacecraft lies perpendicular to the velocityVector and in the same plane as the orbit.
- **Radial Minus** : (Or Radial-) the Spacecraft lies perpendicular to the velocityVector and in the same plane as the orbit (opposite)

Each of those orbital attitudes are relevant for certain orbital maneuvers. For example:

- Using the propulsion engine when the spacecraft is Prograded or retrograded, increases or decreases its orbital velocity , without altering the orbital plane. These are the only practical orientations, in which all the energy used in the engine, is transformed to an increase/decrease of orbital velocity. UNLESS there is a good reason for not doing so , the engine should only be fired in the Prograded (or retrograded) orientation.
- Alternatively , firing the engine when the spacecraft is in its normal_plus or normal_minus orientations, will change its orbital inclination. the orbital plane will rotate -very slowly- but the final orbital velocity will be identical. We have used fuel , but the final kinetic (orbital) energy of the spacecraft is still the same (although at a different orbital angle). This maneuver is intrinscely wasteful , and so its -most of the time- avoided , other than a very fine correction of orbital plane when performing orbital rendezvous.

SpaceCraft Attitude Control

Spacecrafts in orbit arent affected by anything else than the gravity of the object they are orbiting around. In the vacuum of space , the spacecraft will keep its rotational velocity (whatever it is) for ever, only affected by its own momentum. In other words, a steady spacecraft will keep its orientation until a rotation force is applied. A rotating/ tumbling spacecraft will keep its rotation or tumbling until a new rotational force is exerted. As the spacecrafts are in the vacuum of space, normal aeronautic attitude controls (ailerons, elevators, rudders) wouldnt work in space. To solve this problem , there exist just two ways to apply rotational forces to an spacecraft:

A rotational force ,is a force that doesnt cross the center of gravity , and as such ,makes the object change its rotational speed. In more precise terms is named TORQUE. From now onwards, we will refer to TORQUE as the forces that make a spacecraft accelerate its rotation . Please note that -unlike aircrafts - spacecrafts will keep their rotation for ever, so in order to -say, a change in roll- we need to accelerate the roll velocity , and -once nearing the desired roll- decelerate the roll velocity to an standstill.

- **Reaction Control System (RCS)** . A set of -usually paired- small rockets, that fire in pairs, to apply some Torque.
- **Reaction Wheels**. A set of 3 or more heavy electrically controlled flywheels that -by spinning them up - increase the rotation around the desired axis.

Which way is Up, anyway?

Well, in absence of fixed coordinates, we can only refer to rotations as viewed from within the rocket.

- Roll is the angle that varies when the rocket rotates along its longer (UP) axis. For a forward(up) facing observer, a roll will be seen as a rotation of the whole view. This could be similar to the movement side-to-side of an aircraft aileron control.
- Pitch is the angle that varies when the rocket rotates around its side. For a forward(up) facing observer, a pitch movement will make its horizon move up/down. This could be similar to moving an aircraft's yoke forward or pulling backwards.
- Yaw is the angle that varies when the rocket rotates around its up/down side. Think of this as an aircraft rudder (foot-rudder).

Some spacecrafts (notably the Grumman LM Moon Lander) have the main windows not facing UP, but forward. But the main engine still fires traditionally "up". The controls in the forward facing landers, are modified accordingly (roll is pitch, yaw is roll, etc) for simplicity.

Little rocket engines ?

Well, it sounds simple but is not that simple at all. RCS is one of the most prone to malfunction elements in story of spaceflight. The dangers of a non functional RCS are dwarfed by the dangers of a non-stoppable RCS (as it happened to N. Armstrong in Gemini X mission). They need to work, and most importantly they need to stop when commanded so. Given the non-zero chance of a valve sticking open (RCS could not stop, waste of fuel), or sticking closed, most critical RCS fuel valves are designed on 'Valve Quads'. A valve Quad is a combination in parallel of two combination of valves in series. It can be seen that not a single valve malfunction would prevent normal operation. The rockets themselves tend to be simple. Normal RCS are monopropellant, just a highly active (and toxic!) fluid that -in contact with some exotic catalysts on the rocket's bell surface- will ignite spontaneously. Basically as simple as a rocket engine could be. For the Apollo program, a different kind of RCS were used, mainly for the Moon lander. As the final lunar orbit rendezvous maneuvers would take an unknown amount of fuel for final corrections, and given the extremely serious consequences of running out of RCS fuel, the moon lander's RCS used the same fuel as the Ascent Stage main engine. This way, the (hopefully lots of) unused fuel and oxidizer from the main ascent engine could be used to trim the final docking velocities via RCS. Also, in case of a non catastrophic Ascent Engine malfunction, the fuel could be used by the four RCS in translation mode to -with a bit of luck- limp into orbit.

2.4.1 Prograde

Prograde orientation is such that the spacecraft is pointing 'head-first', that is pointing in its own direction of movement. That will *generally* make the astronauts look forward. This is the orientation/attitude that -when firing the engine- will result in an increase of orbital Velocity.

Prograde orientation is such that the spacecraft is pointing 'engine-first', that is pointing backwards to the direction of movement. That will *generally* make the astronauts look backwards. This is the orientation/attitude that -when firing the engine- will result in a decrease of orbital Velocity.

2.4.2 Normal Plus

In Space, the standard concepts of orientation (North, Up, down, etc) are meaningless. The only absolute reference is the spacecraft's current orbit. So, when defining the orientation of a spacecraft, we refer it as its attitude respect its current orbit OR Orbital Attitude.

A spacecraft can orient towards some special axis.

2.4.3 Normal Minus

In Space, the standard concepts of orientation (North , Up , down,etc) are meaningless. The only absolute reference is the spacecraft's current orbit. So , when defining the orientation of a spacecraft , we refer it as its attitude respect its current orbit OR Orbital Attitude.

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2.4.4 Radial Plus

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In Space, the standard concepts of orientation (North , Up , down,etc) are meaningless. The only absolute reference is the spacecraft's current orbit. So , when defining the orientation of a spacecraft , we refer it as its attitude respect its current orbit OR Orbital Attitude.

A spacecraft can orient towards some special axis.

2.5 Spacecraft Propulsion

Spacecraft Propulsion

Spacecraft , -except the most basic satellies- have at least one way to change its velocity. Ignoring new exotic way of propulsion , most known spacecrafts achieve propulsion by the use of a rocket engine. The basics of the rocket engine are very simple -known since the antiquity- . Any mass expelled from an object at a certain speed ,generates an opposite force to the object called "reaction force" . It is importantn to understand that the force arises from the fact of expelling mass at a speed ,and has nothing to do with the medium (air,water, space) onto this mass is expelled to. That is, a reactive rocket engine is the only way to accelerate an object in the vacuum of space.

A rocket engine can not generally use the oxygen in the atmosephe for combustion , hence it needs to carry its own oxygen , usually liquified and very cold -to minimize tankage requirements -

Essentially , a typical rocket engine burns oxidizer (generally oxygen) and fuel (generally Kerosene) into a closed combustion chamber with just one exit , the pressure of the aforementioned combustion expells all exhaust gases outside at tremendous pressure that due to the gremetrical design of the nozzle, it is transformed into brutal velocities of several times the speed of sound. The masss expelled -the mass of the exhaust- a those velocities , generates the opposite force (reaction force) that pushes the rocket forward.

This ,however simple , requires the highest grade of engineering and materials to achieve, due to some reasons

- For efficiency , the hotter the combustion is , the faster the exhaust velocioty is and hence the better the efficiency
- The pressures generated inside the combustion chamber (can be considered a pressure vessel) requires the ultimate stregnth of materials, all of this at a very high temperatures. Correct design of the combustion chamber is paramount
- Fuel and oxidizer need to be pumped into the already highly pressurized combustion chamber , requiring turbopumps running at fantastic speeds.
- For obvious reasons , the rocket, the chamber , turbopumps, and nozzle should be designed to be as light as possible

On the other hand, rocket engines are merely designed to last for a few minutes (hours at most) , and so they dont have any long-term engineering challenges (rust , treatments, oil quality, etc) .

(Thrust vs Power) and Why Rocket engines arent measured on Din HP/Kw

Rocket engines (and airplane turbojet engines for that matter) dont' produce work , in the traditional way. They just generate a reactive FORCE .In contraposition , a Otto/Diesel engine generate WORK (that is force over distance). Power ,normally measured on HP is the ability to create work (force ALONG distance) over time. For example an engine of 1 Kilowatt , can Lift 1 Kilo one meter up , in one second. If it were to lift 1Kilo over to meters, it would require demultiplication/gearing , so it takes 2 seconds. This is the reason cars have gearboxes. The further along they need to 'spread' the power , minimizes the possible force applied. But the ammount of work-per-hour a standard car can create is the same (a lot of force , over very small distance -when in first gear- , or the opposite , very little force over a large distance ,in top-gear).

On the other hand ,a rocket engine doesnt generate force based on distance. It generates just force. Always the same force for as long as there is oxidizer and fuel left. The same force , is also generated regardless the rocket is inching up in the first second after launch ,or blasting at 10km/s at the end of a Lunar Injection. The force is the same, no matter how fast or slow the rocket is moving.

So... then what is the power generated? Depends on how fast is moving. Consider this respect to a motor vehicle, in which generates *at most* same power at any range of speed. Indeed, at rocket launches, with all the drama , concert of light , smoke, fire, and shakes, all these.. and the rocket is generating ZERO work.Total output: ZERO Horsepower.But it generates forces. Forces that will keep accelerating the rocket constantly -as opposed as the car, that needs to spread the power into increasingly larger distances, and hence needs to reduce power -

So the rocket (assuming the fuel is constant) will accelerate constantly , 1m/s ->2 m/s , 1000m/s -> 1001 m/s , 10000 m/s ->10001 m/s . Suddenly this apparent drawback of rockets vs motorcars converts into a huge advantage.

This effect also applies to jet engines, and is the reason behind jet engines -while monstruous inefficient- become even more economically than propeller planes at certain speeds. Take the mythical Aeroespiale Concorde. With all the huge four turbofan spitting fire and fuel , it was most economically to fly at its unrivalled speed of Mach 2.1.It is said that the Concorde spent more than 1/5th of its total fuel taxing , due to the gross inefficiencies of a reaction engine running at low speeds.

2.6 Terms and Definitions

Apsis point on an orbit farthest away from the focus.

Apogee point on an orbit of the Moon or a satellite of the Earth farthest away from the Earth.

Attitude Orbital attitude refers to the orientation of an object in space.

Eccentricity the eccentricity of an orbit measures how much it deviates from a perfect circle. A circular orbit has eccentricity 0. An elliptical orbit has eccentricity between 0 and 1. Eccentricity greater than 1 indicates a hyperbolic orbit.

Periapsis point on an orbit closest to the focus.

Perigee point on an orbit of the Moon or a satellite closest to the Earth.

Stage one section of a rocket that is meant to separate from other parts of the rocket once its fuel is empty

Thrust the force exerted by the engines of a rocket

Chapter 3

Controls

Before controlling Space Simulator there are a few important concepts to master

- [Control Windows](#)
- [Autopilots](#)

3.1 Control Windows

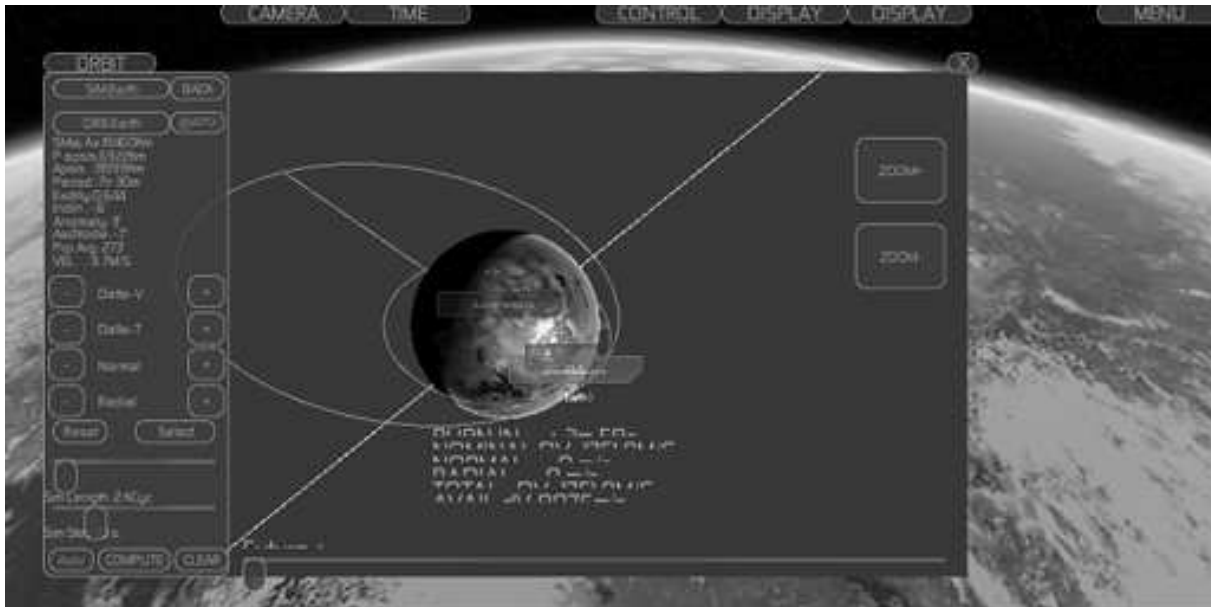
All controls in Space Simulator are inside one of the eight windows. Open any of these windows by tapping on the buttons along the top of the screen. Every window contains a group of relevant controls corresponding to the name of the window.



To open a window just click the top tabs. You can move the window around by dragging and dropping the window tab situated at the top left of the actual window frame.

If your device has a small screen, you can force the ORBIT window and/or the BROWSER Window to be fullscreen by turning on the Menu/Config/Graphics/ "Full Screen Mode" option.

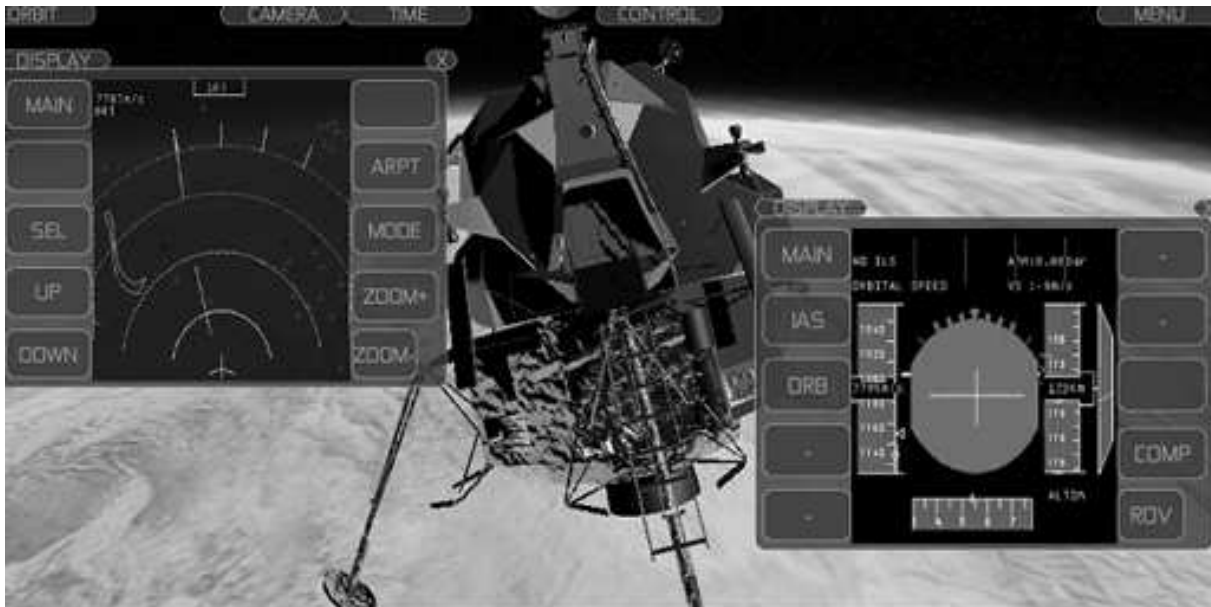
- In the [Orbit Window](#) Orbit window you can visualize, analyze, modify and predict your orbit



- In the [Camera Window](#) Camera window you can select from internal, cockpit or external cameras and -if on a mobile device- to send a screenshot to facebook
- In the [Time Window](#) Time Window you can modify the time advance/compression to accelerate the game
- In the [Rudder Window](#) Rudder Window you can control the yaw of your spacecraft



- In the [Control window](#) Controls Window you can control your spacecraft's engine, orientation and other actu-ations.



- In the [Window MFD \(Multi-Function Displays\)](#) Display/MFD window you can use a MFD (Multi Function Display) to gain a vast array of information and data about your current position, status, orbit, etc.

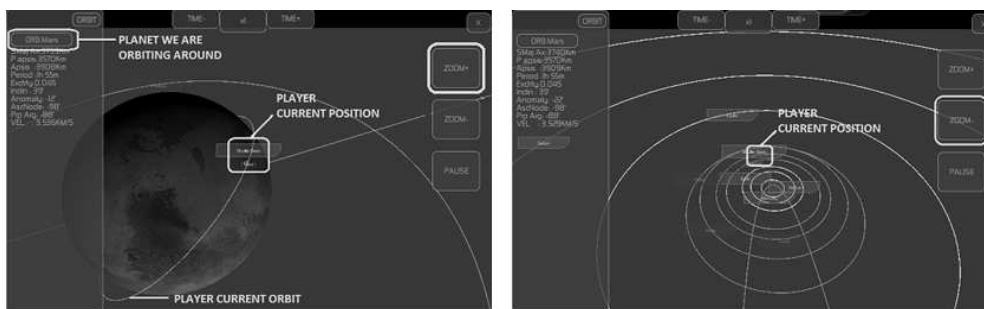


- In the [Window Menu](#) Window Menu (Browser) you can navigate through all the game options and settings such as selecting a mission, create custom scenarios, configuring Space Simulator, etc.
- Apollo Guidance Computer (AGC) [ApolloGuidanceComputer](#) AGC
- In the [ApolloDisplayConsole](#) there is an overview of the flight control panel switches

3.1.1 Orbit Window

The Orbit window is an extremely powerful tool designed to help players visualize their position within the Solar System. In the Orbit mode you will see schematic view of the orbits of every orbiting body in the game. These lines draw the paths of the orbits each body is following. In the Orbit mode the camera is always centered on your spacecraft.

Below is an example scene of the Shuttle Orion orbiting Mars. Zooming in and out will help you situate and orientate yourself, giving you a clear idea of how your spacecraft is orbiting around the planet and how you are situated in the bigger picture of things.



You can modify the orbit in any of the three planes:



APO

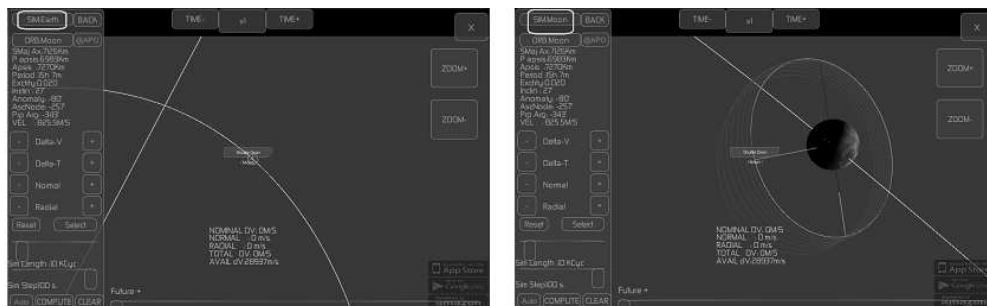
APO shows with red labels where the planets will be when you are on the other side of your orbit.

This is very useful for seeing whether your spacecraft will intersect another planet at a future point in time.



Auto The AUTO button refreshes calculations as you drag the sliders. With the AUTO button on you don't have to CALCULATE each time.

Predicted Orbit Reference You can also change the reference of the orbit you are predicting. The below example shows the same orbit as seen from the perspective of the Earth and the Moon.



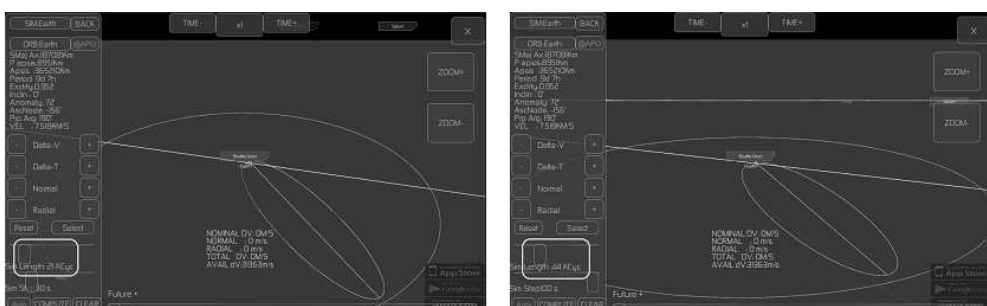
[v1.0.7]

Scale In v1.0.7 we simplified the orbit window parameters to include scale and sim steps. Scale adjusts the resolution of the +/- Delta-V, Delta-T, Normal and Radial. The larger the scale the greater the change. Increase scale when adjusting for interplanetary paths. Decrease scale when finetuning paths.

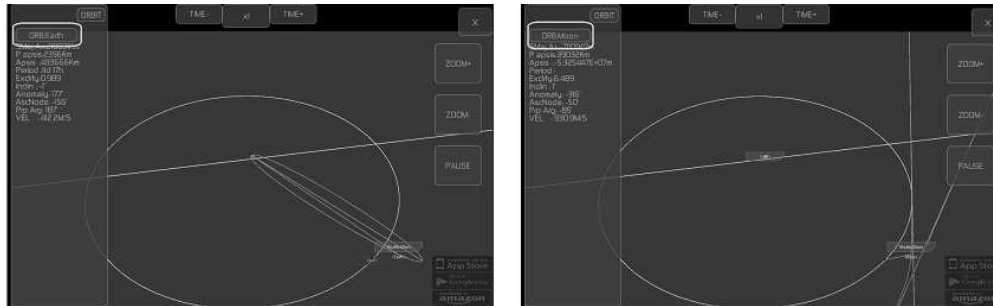
Sim Step In v1.0.7 Sim Step replaces the previous Orbit Sim Length. The greater the number of steps, the farther in time the orbit path is calculated.

GO Replaces the APPLY button in previous versions.

[v1.0.6] **Orbit Sim Length** Adjust the sim length slider to adjust how much into the future the orbit is calculated. Select **COMPUTE** to recalculate with the new sim length parameter.



Orbit Reference You can change the reference of your current orbit. In the below TLI example you can see the orbit as an elliptical Earth orbit or hyperbolic lunar orbit.

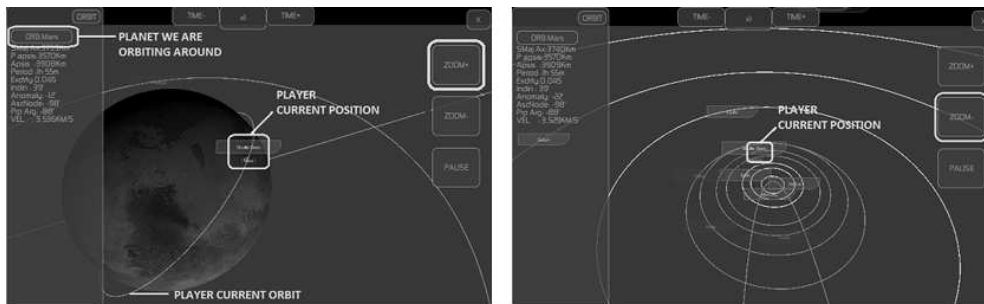


TIPS:

- double click on any planet to center on it
- planets are red pink when representing a future state

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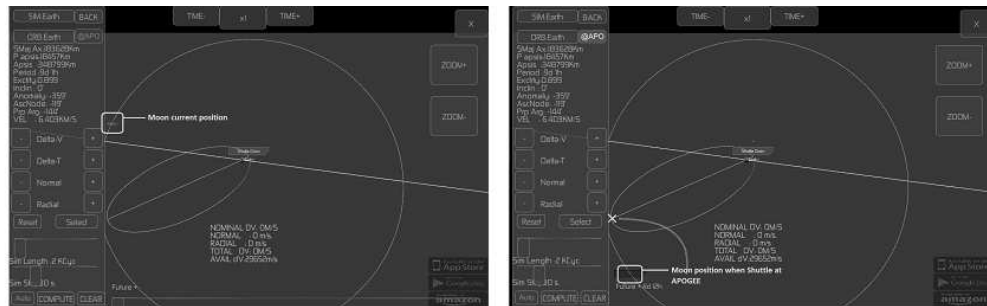
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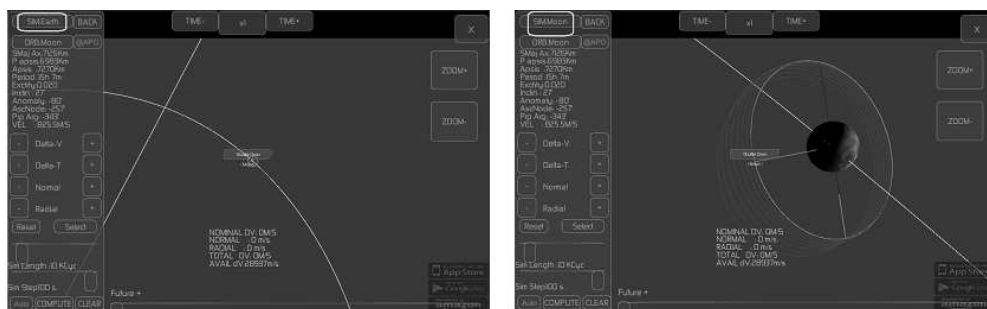


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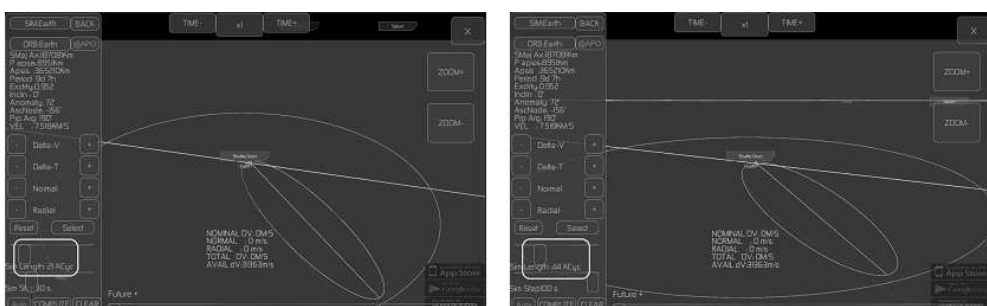
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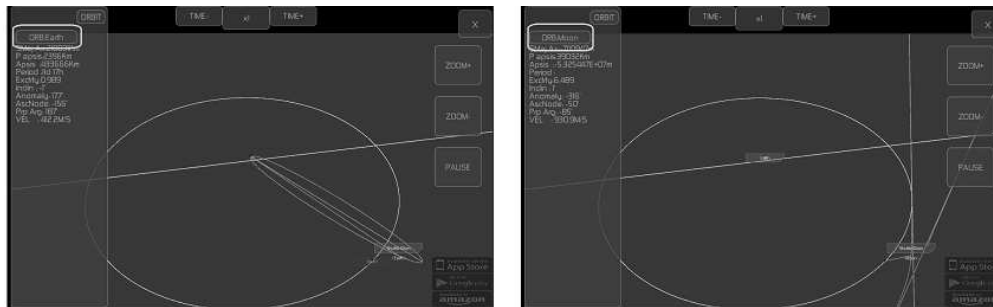
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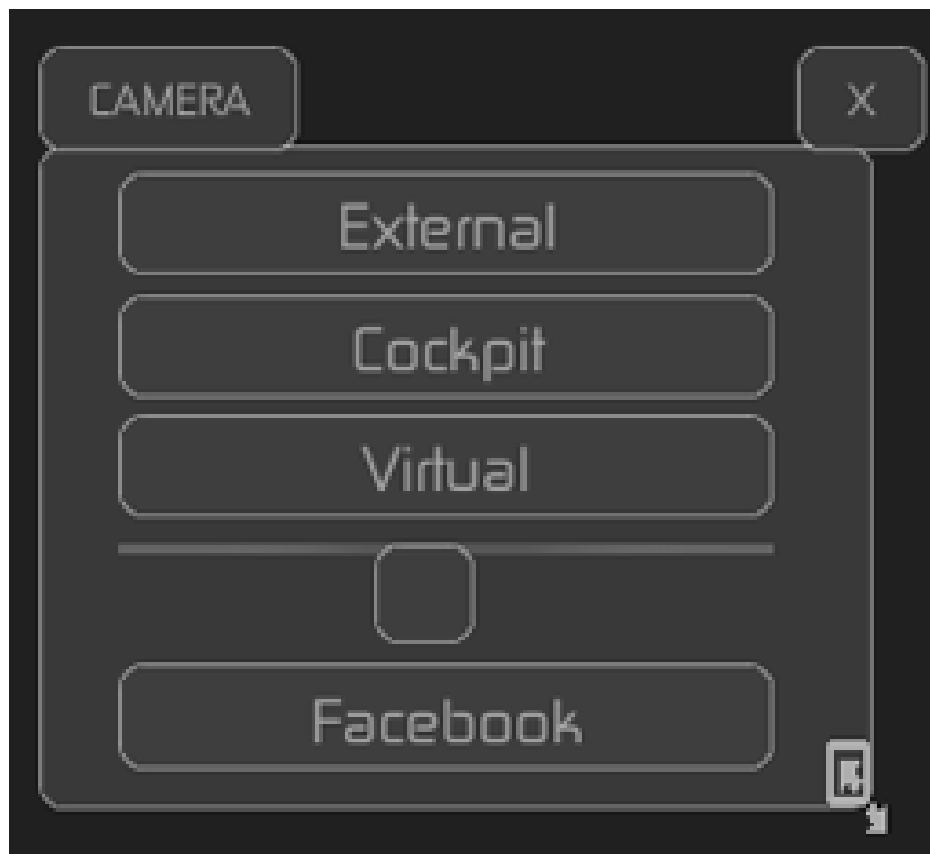
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TIPS:

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- planets are red pink when representing a future state

3.1.2 Camera Window



External is the default 3rd person view centering on the spacecraft or stage of the spacecraft you are controlling.

Cockpit takes you inside the spacecraft putting you in the pilot seat for an immersive experience

Virtual shows a magnificent unobstructed 1st person view from the nose of the spacecraft

Don't forget to post a screenshot of your favorite scene to **Facebook** with the Facebook button!

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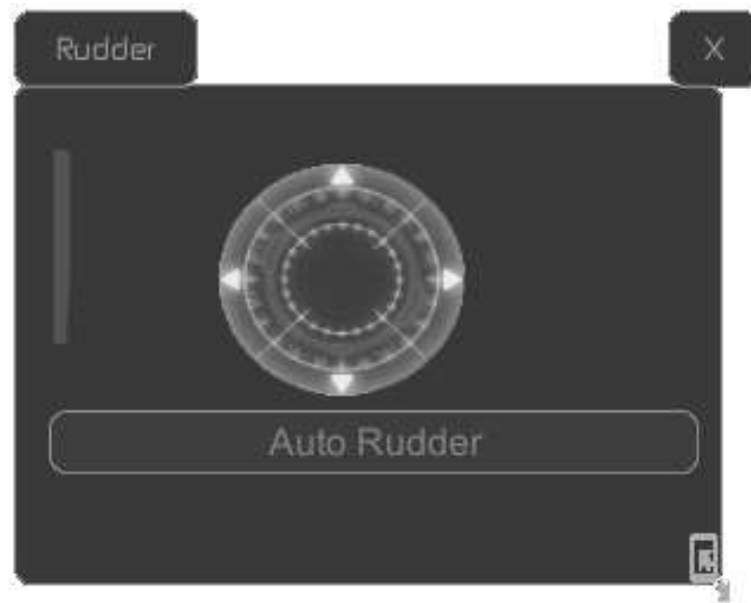
3.1.3 Time Window



Time compression buttons to speed up the simulation for longer flights. Time compression will only work when you are outside the atmosphere.

3.1.4 Rudder Window

This is the yaw control window for v106. In previous versions the yaw was controlled by the main throttle.



This is the yaw control window for v106. In previous versions the yaw was controlled by the main throttle.

3.1.5 Control window

Control Window

This window contains most of the traditional arcade style controls to control your spacecraft, namely, throttle and joystick. The sub-tabs opens different sets of controls (manual controls, automatic orientation, spacecraft systems, computer. As any other window, you can drag and resize it to suit your preferences according to your device screen size.



In the control window there are four different tabs:

- [Control SHIP](#) SHIP tab opens ship-related command modes, eg, to operate the landing gears, dock/undock, stage, ejections, etc.
- [Control ATTD](#) ATTD (Attitude) tab opens automatic orbital attitude programs, eg, to prograde/retrograde your spacecraft. See orbital attitudes for more in-depth reference of orbital attitudes.
- [Manual Control](#) MAN (Manual) mode allows you to operate your spacecraft fully manually with the aid of a virtual joystick and a main engine throttle slider.
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3.1.5.1 Control SHIP

CONTROL SHIP



In this control page , you can perform certain ship-related events.

- CHUTE will open the reentry parachute(If equipped)
- GEAR will extend-retract the landing gear/struts (If equipped)
- CARGO will open/close the cargo fairing (Space Shuttle)
- STAGE will eject the current Stage (if applicable)
- ABORT will trigger the abort Sequence (if applicable)
- UNDOCK will undock current spacecraft from its docking target
- TXFER will change the users' control from the current spacecraft to the one is docked to.
- RNDV To be implemented
- ENGSTOP Stops the engines
- BRAKES Applies the brakes to the landing gears' wheels. (If equipped)

3.1.5.2 Control ATTD

Orientation / Attitude CONTROL



This control panel allows you to select the desired orbital orientation of your spacecraft.

- PROGR will make your spacecraft orient towards Prograde , that is towards its velocity vector. Usefull if you want to increase your orbital velocity
- RETRO will meke your spacecraft orient towards Retrograde ,pointing the spacecraft against its velocity vector , usefull if you want to decrease your orbital velocity.
- NORM+ will point your spacecraft towards the positive normal (as in perpendicular) plane of the orbit. Usefull to change orbital inclinations
- NORM- will point your spacecraft against the positive normal (as in perpendicular) plane of the orbit. Again ,usefull to change orbital inclinations
- HOVER will point your spacecraft away from the center of the orbital reference(i.e "Standing up") .Usefull for landing.
- HLEVEL will level your spacecraft/spaceplane/plane horizontally.

Remember that those orbital attitudes deppend on the orbital reference. Thus what it may be a prograd-ing attitude with the Earth as the orbital reference , can be a different attitude if in the same situation we are using the Sun as our orbital reference.

3.1.5.3 Manual Control

MANUAL CONTROL



The spacecraft controls have two main modes

- Rotation Mode. In this mode you can control the attitude (Orientation) of the spacecraft. This way , moving the joystick sideways will make your spacecraft roll, etc..
- Translation Mode. In this mode, you can control the translation (Movement) of the spacecraft linearly . This way moving the joystick sideways will make your spacecraft accelerate slowly sideways. You can toggle between both modes by pressing the button "RCS LIN " or "RCSROT"

In ROTATION mode the control's color will be overall blue. In TRANSLATION mode the controls color will be RED

Rotation Mode

In the Manual Control window in Rotation Mode (default), you can control your spacecraft with a joystick , the same way you would do in a plane. The left vertical slider , controls the engine's throttle. If your spacecraft is equipped with hover thrusters , a second slider will show.

The button "HOLD" will engage the autopilot in a mode that will stop your rotation .This is usefull when we want to keep a desired attitude.

Translation Mode

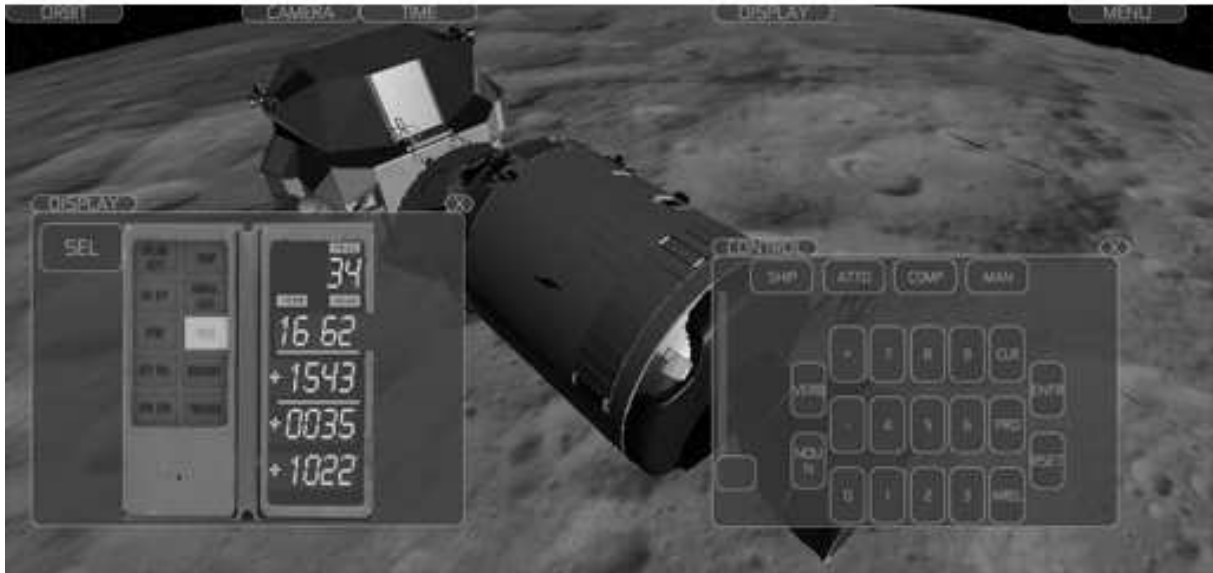
In the Manual Control window in Translation Mode (default), you can move your spacecraft , accelerating on the direction of the joystick

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Throttle Lever

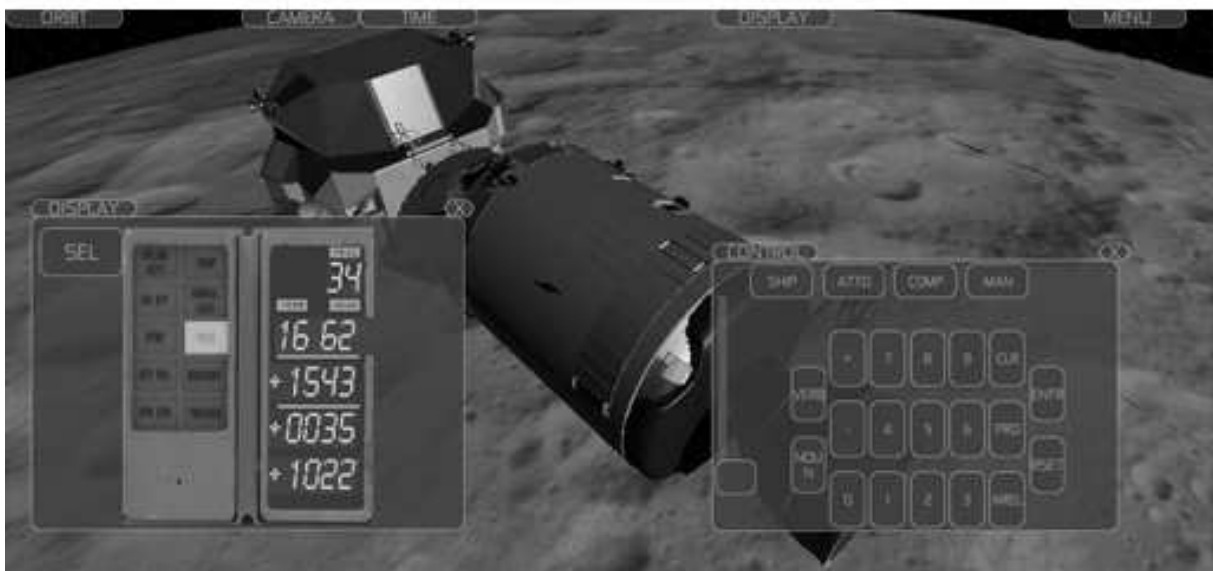
The throttle lever is a virtual lever/joystick on the left of the control panel. It activates the spacecraft's main engines. On those spacecrafts equipped with hover engines (Shuttle Orion), the hover engines are controlled by the vertical slider next to the joystick on the right side.

3.1.5.4 Computer control



Computer Control

This control panel allows you to enter verb/nouns instructions directly in the Apollo Guidance Computer (AGC) . The layout is reminiscent of the DataEntryKeyboardSystem DSKY of the apollo era. To see the display , select any MFD window and click in the "COMP" mode.



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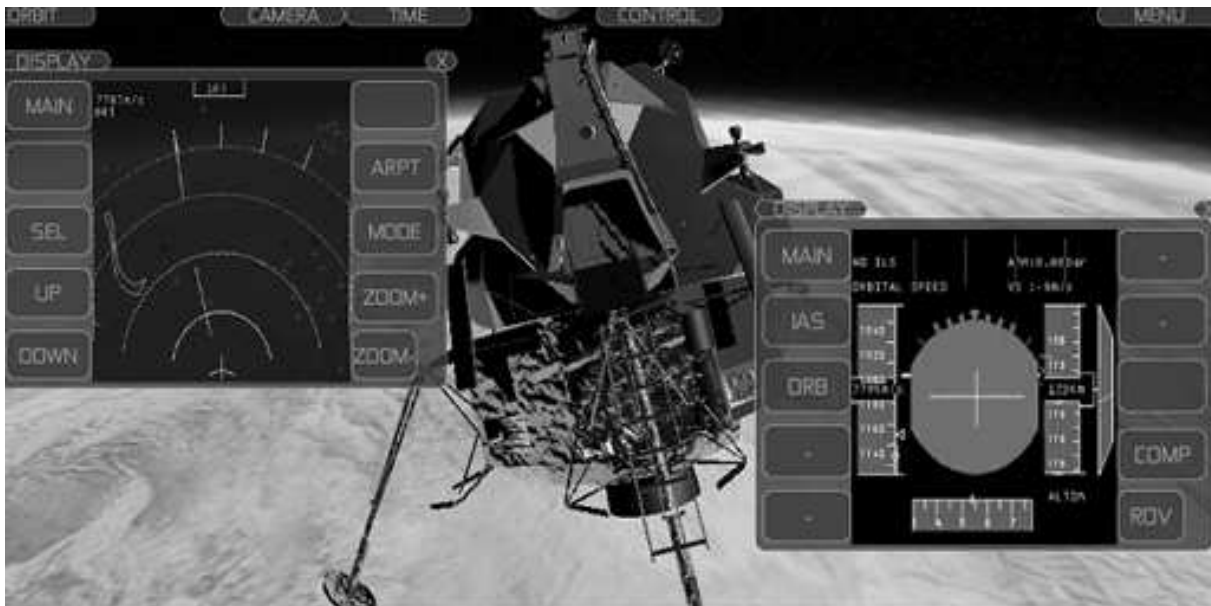
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The COMPUTER control panel allows you to enter verb/nouns instructions directly in the Apollo Guidance Computer (AGC). The layout is reminiscent of the Data Entry Keyboard System DSKY of the Apollo era. To see the display, select the COMP mode in any MFD.

3.1.6 Window MFD (Multi-Function Displays)

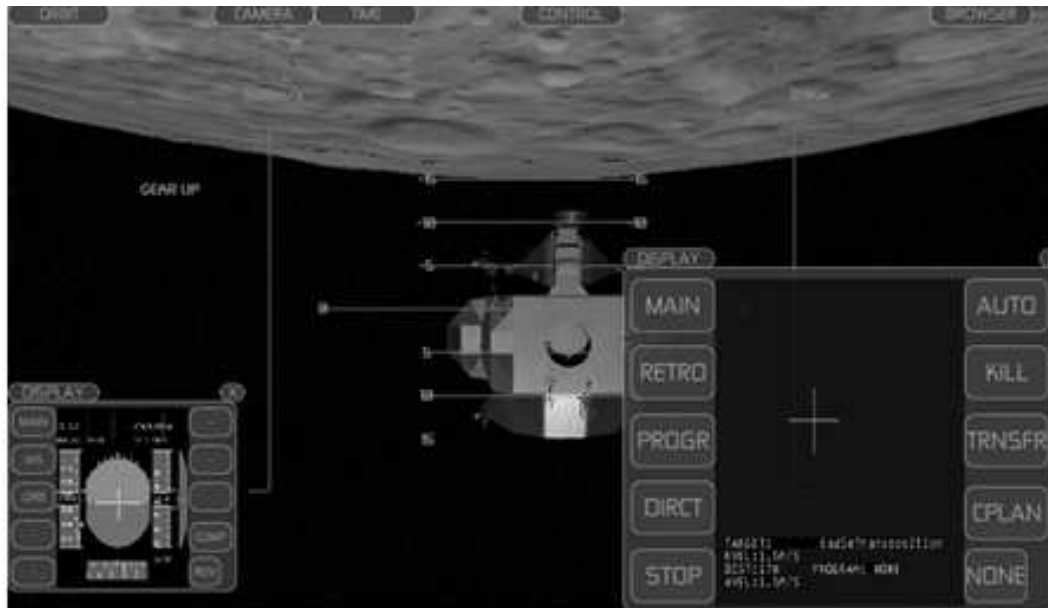
Multi Function Displays (MFDs)



- [MFD Docking](#) MFD Docking
- [MFD Flight](#) MFD Flight
- [MFD Orbit](#) MFD Orbit
- [MFD HSI](#) MFD HSI
- [Map MDF](#) MFD Map

3.1.6.1 MFD Docking

MFD Docking



The Docking mode on the MFD allows you to control and orient your spacecraft in very specific ways to perform a orbital rendezvous and docking . Docking is usually performed in 3 steps

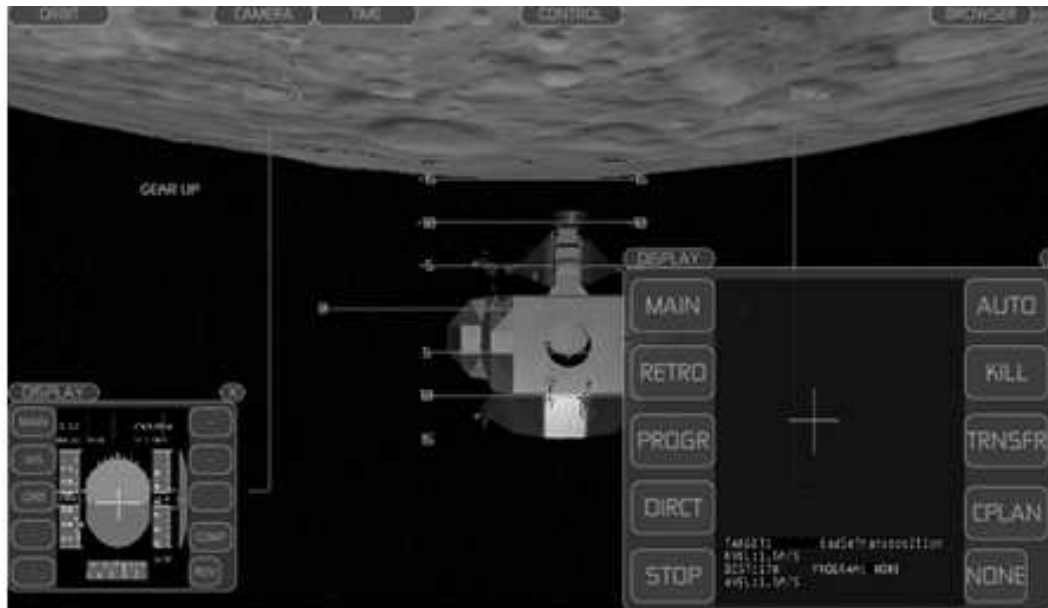
- *Orbital Rendezvous* , consisting on getting both spacecrafts within 200 km of distance
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The MFD Docking mode allows you to perform the approach phase. Basically , for spacecrafts closer than approx 250km you can perform a trivial trial-and-correct docking .

RETRO will orient your spacecraft against the *RELATIVE* velocity between them. *PROG* will orient your spacecraft towards the *RELATIVE* velocity between them. *DIRCT* Will point your spacecraft towards your docking target *STOP* will reduce the relative velocity between your spacecraft and the docking target *AUTO* perform automated dock *(In Apollo11 mode) *KILL* will stop the relative velocity AND the rotational velocity between spacecraft and docking target *TRANSFER* will move your crew (i.e. you) from your spacecraft to the one you are docked to *CPLAN* orient your spacecraft aligned to the docking target

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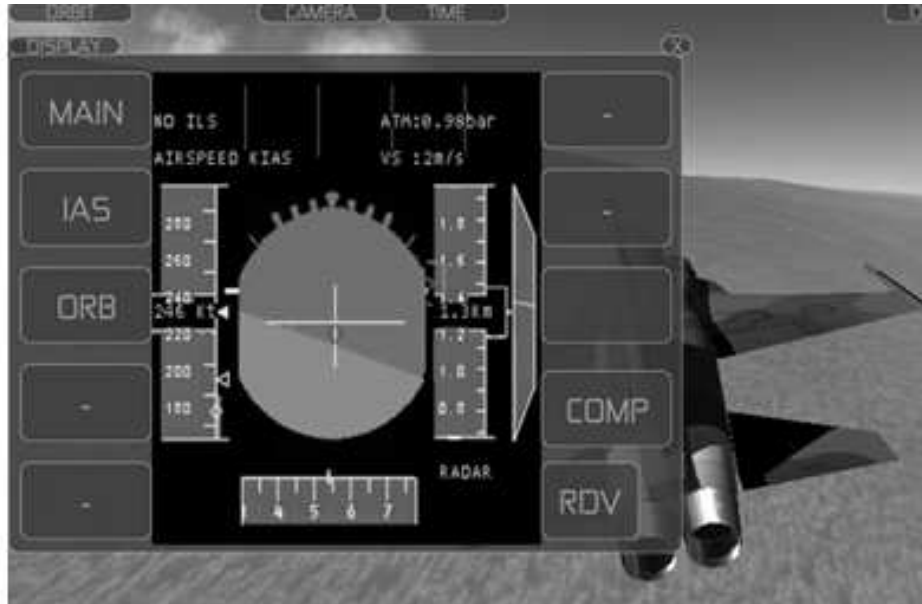
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The Yellow Cross indicates the position of your target as seen from your docking port. The GREEN Cross indicates your position , as seen from your target's docking port.

A centered Yellow Cross indicates your target is exactly on front of you . while a Centered Green Cross indicates that you are exactly in front of your target.

3.1.6.2 MFD Flight

MFD Flight



The Flight MFD replicates the de-facto standard Flight Director in modern aircrafts . It offers a combined view of Artificial Horizon (representing the terrain by a orange/brown), an airspeed indicator , altitude indicator , and vertical velocity indicator.

Speed in aircrafts is usually referred to *airspeed*. This is the relative pressure of the air against the sensors in a plane. As the plane gains altitude -and hence the air pressure is lower - , the indicated airspeed will be smaller, even that the plane is flying at higher speeds. Eventually , when our spaceplane exits the atmosphere

the airspeed will bring down to zero.

You can select two ways of indicating speed :

- Orbital (ORB) . Indicates speed in meters/second of the current orbit around the current orbital reference
- AirSpeed (IAS) . Indicates airspeed in Knots , thus depending on the altitude/pressure.

3.1.6.3 MFD Orbit



MFD Orbit

The Orbit mode of the MFD panel is perhaps the most useful of all the modes. It draws a representation of the current orbit, relative to our orbital reference body.

The circle in grey represents the orbital reference (in this case the moon) . the blue represents the theoretical path of the spacecrafts as it follows the orbit. Please do note that the orbit may intersect the planet.

The orbit mfd main buttons are :

- ORB Sets the panel to orbital mode
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Orbital Projection

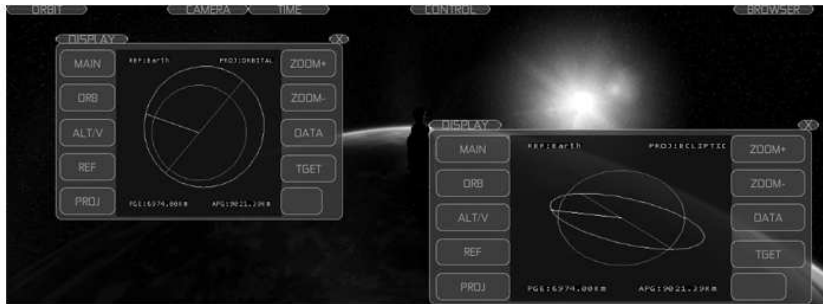


Figure 3.1 Same orbit view with different projections

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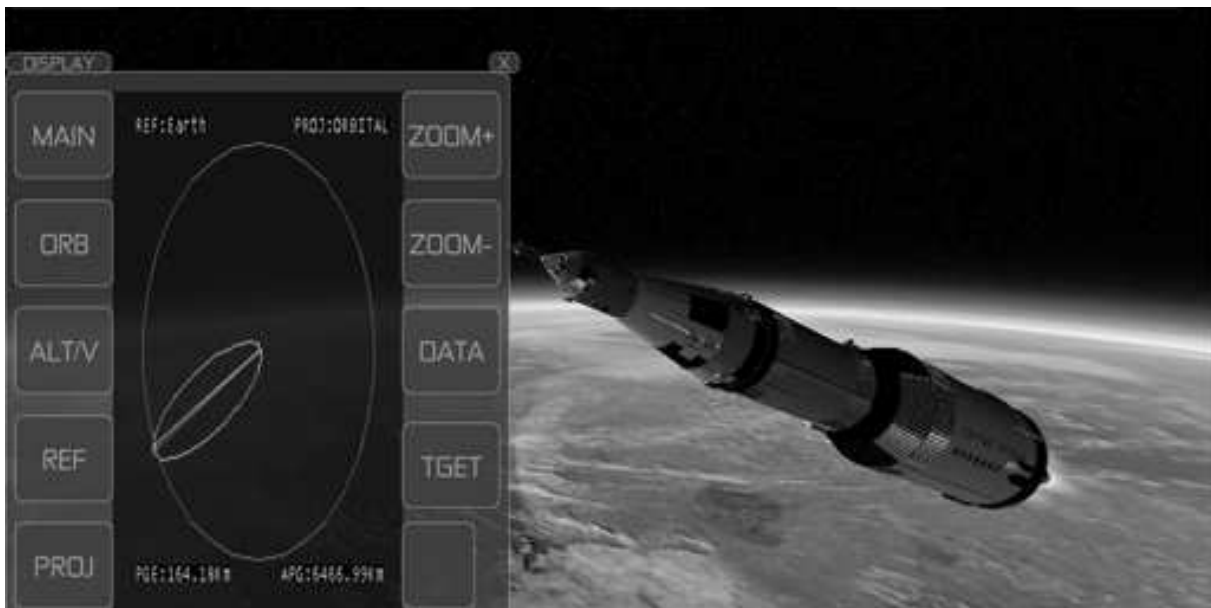


Figure 3.2 Orbit intersecting the planet.

In theory , every object around a planet will follow an orbit , *if it weren't colliding with the planet's surface*. As such , some orbits can be seen to intersect the planet's circumference . In theory , the spacecraft would follow that orbit around the planet's center. In practice ,will crash against the surface/atmosphere . Here we can see the orbital MFD of a spacecraft not yet in a circular orbit around the earth

In order to determine the viability (as in the orbit not intersecting the planet's surface) we need to use the "Orbital" orbit projection.

Orbital Excentricity

Orbital excentricity is a numeric value , from zero to infinity , that determines how "out of round" is an orbit . Hence :

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MFD Orbit

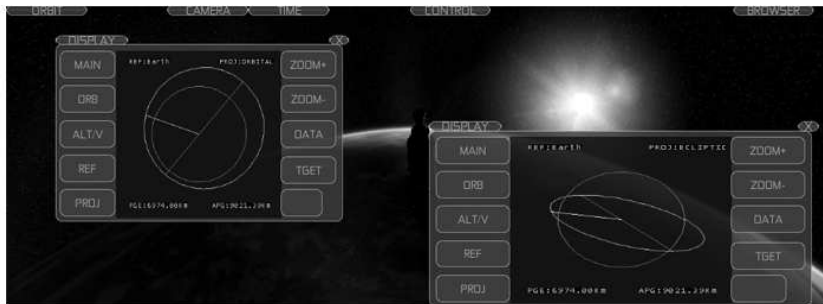
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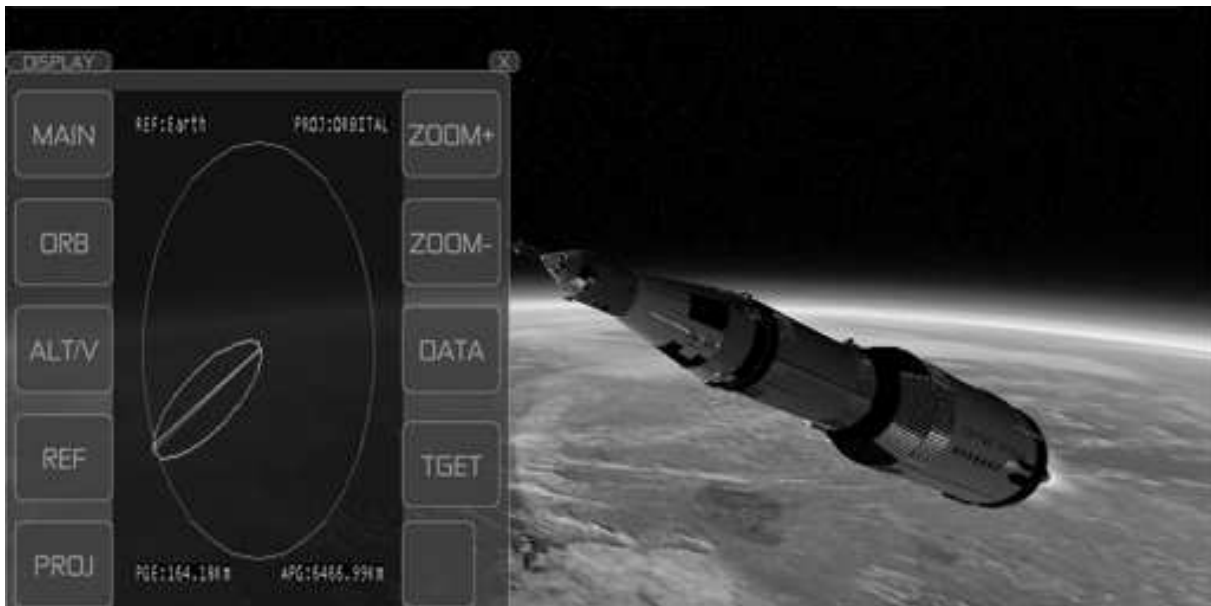


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The Map MFD shows your orbit trajectory projected on a flat map in a standard cartographic projection view. The Map MFD is a great aid to help visualize a circular orbit on a 2D map. Unless the orbit circles exactly at the equator, in which case the projected path will be a horizontal straight line across the center of the map, the projected path is usually in the shape of a sine wave due to the inclination of the orbit.

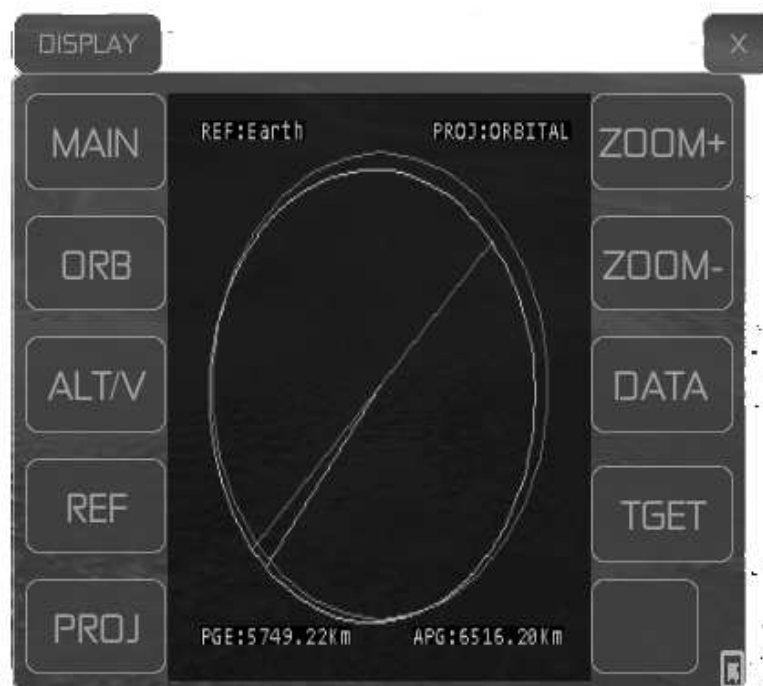
How to read the Map MFD

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If no more force is applied, your spacecraft will stay in orbit and above ground for the remaining yellow portion of the projected path. You will have reached orbit when the entire projected path is yellow.

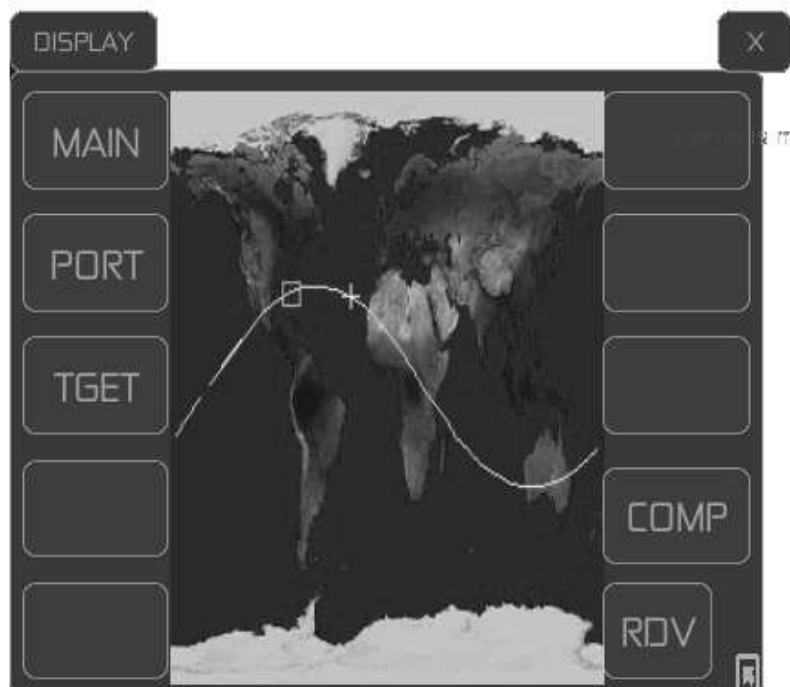
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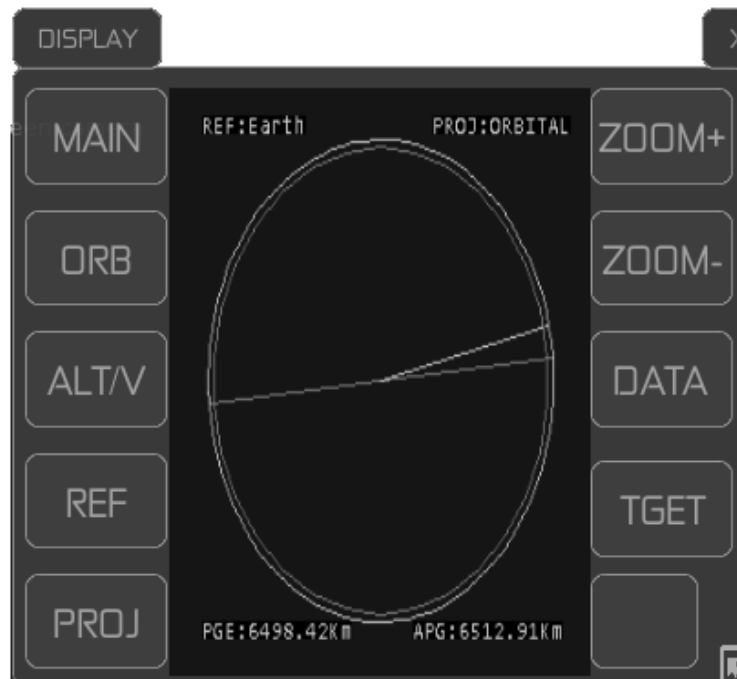




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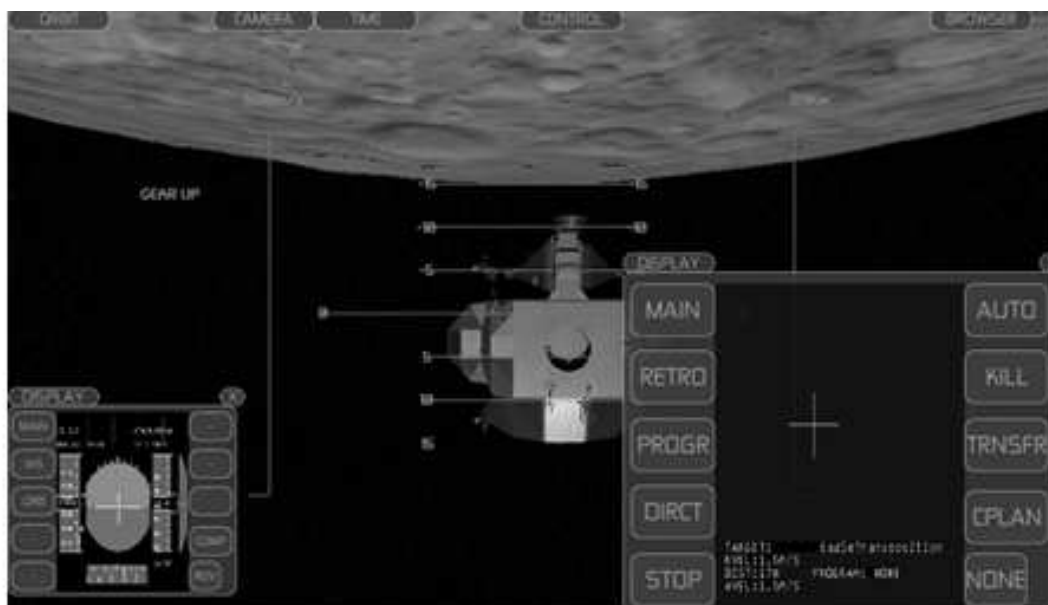




When the entire projected path of the Map MFD is yellow we know we have reached full orbit. You can confirm this with the Orbit MFD which should show that all parts of the orbit are now above ground.

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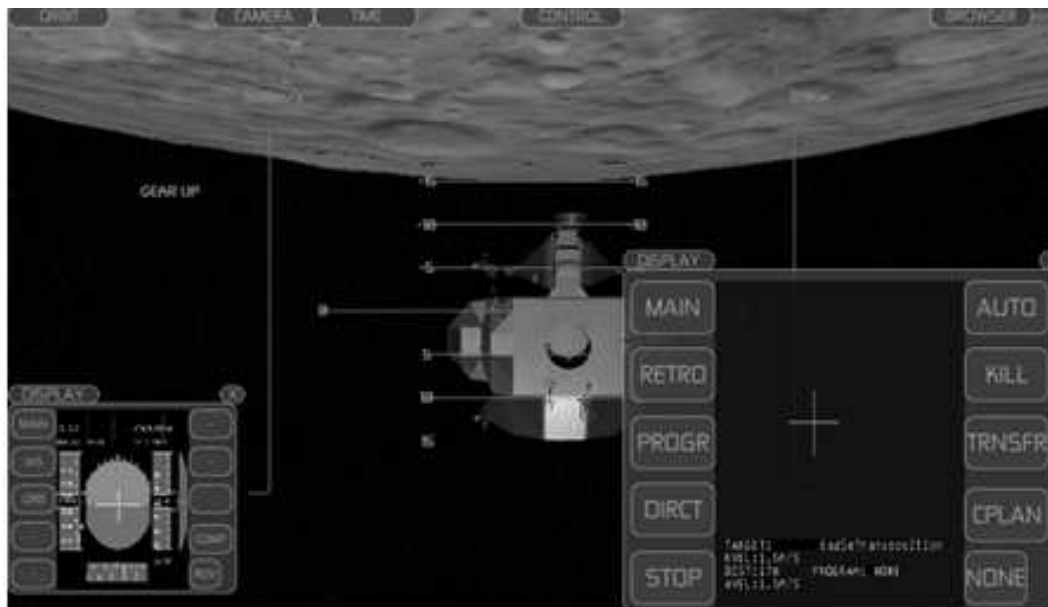
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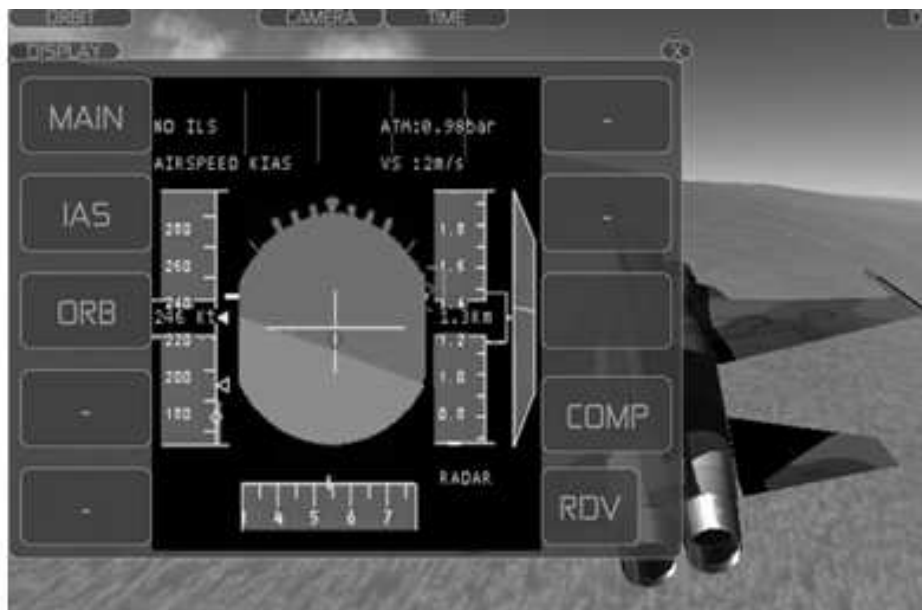
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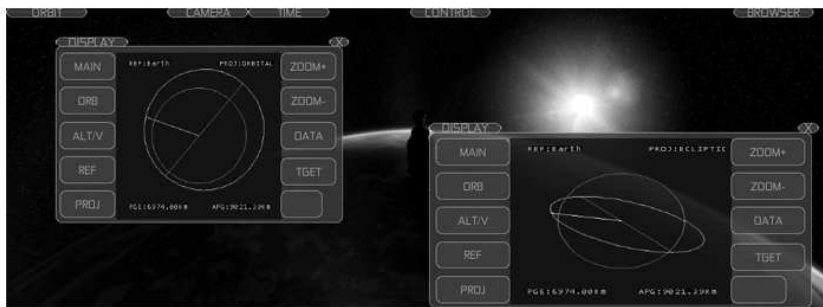


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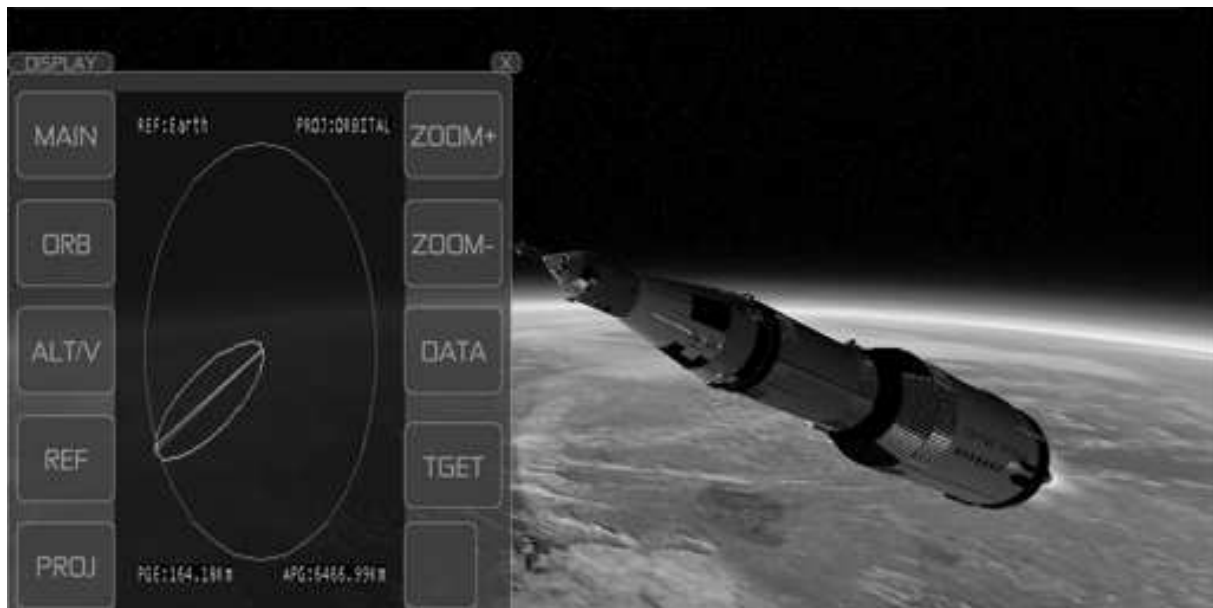


Figure 3.5 Orbit intersecting the planet.

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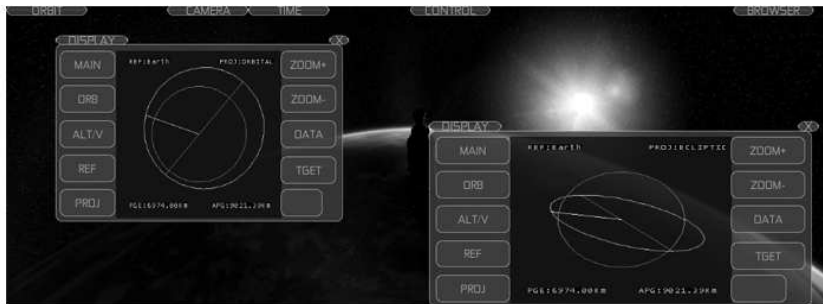
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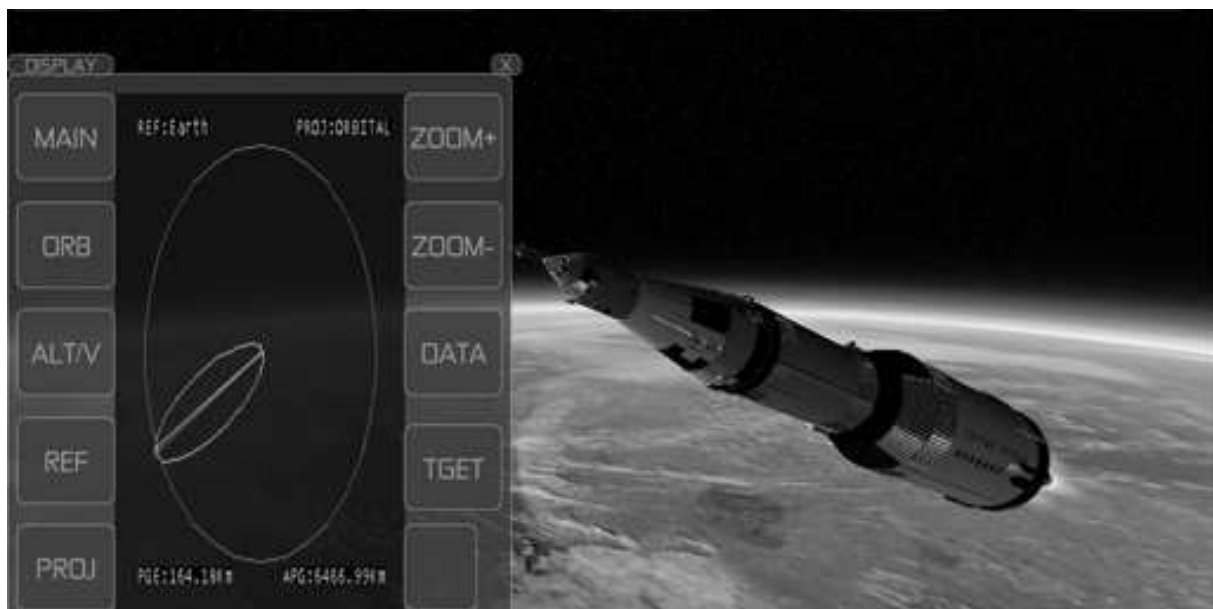


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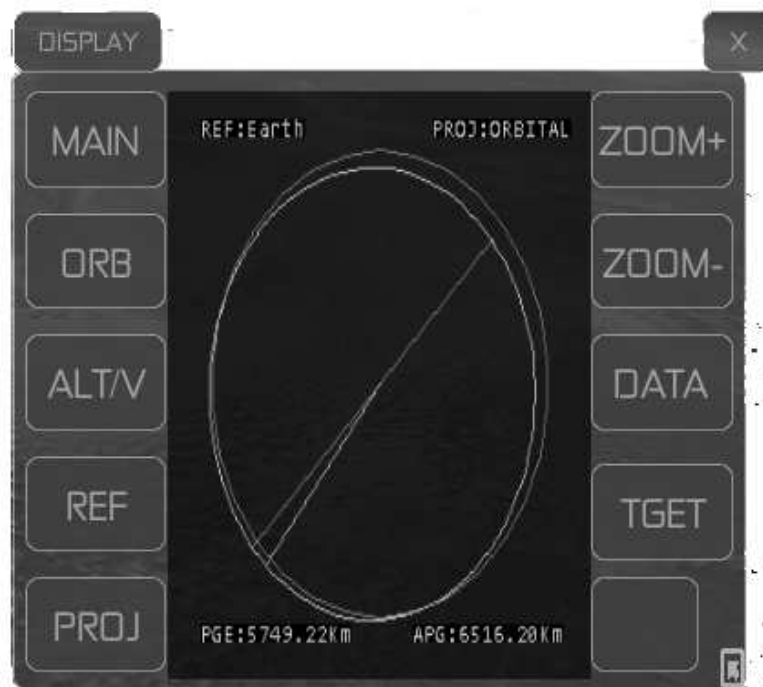
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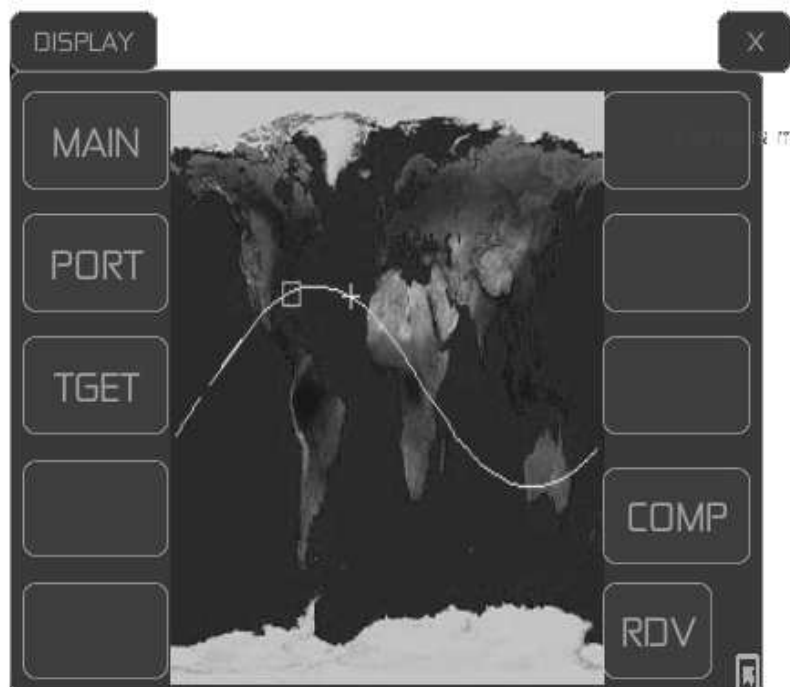
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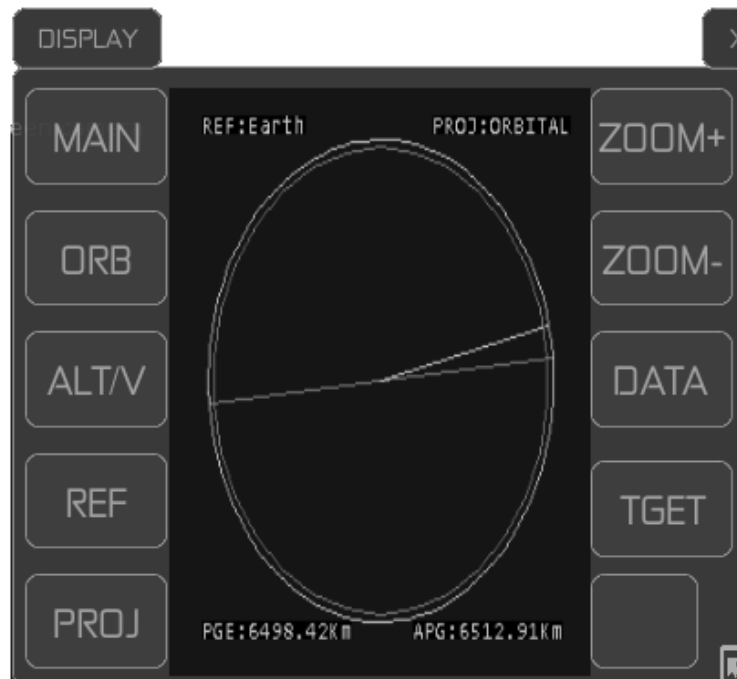




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When the entire projected path of the Map MFD is yellow we know we have reached full orbit. You can confirm this with the Orbit MFD which should show that all parts of the orbit are now above ground.

3.1.7 Window Menu

The Menu window takes you to the main menu where you can access the missions and config menu.

3.1.8 ApolloGuidanceComputer

Apollo Guidance Computer

The Apollo Guidance Computer (AGC) was a small programmable computer that was carried inside the Apollo spacecrafts. It was one of the first digital computers to make use of -rudimentary- integrated circuits, which were just being developed around the 60s.

The AGC's primary and critical function was to provide navigation references at times when telemetry could not be sent from Earth. Both Trans-Lunar Insertion and Trans-Earth Injection burn maneuvers need to be performed at the far side of the Moon without relying on any telemetry signals sent from home.

Besides keeping track of position and orientation, the AGC also performed a number of more specialized tasks. Special maneuvers such as Moon descent and landing, coplanar orbit adjustments, Trans-Lunar Injections, etc. were also controlled via the AGC.

AGC PROGRAMS

PHASE	PROGRAM NUMBER	PROGRAM TITLE
PRE-LAUNCH AND SERVICE	00	CMC IDLING
	01	PRELAUNCH OR SERVICE-INITIALIZATION
	02	PRELAUNCH OR SERVICE-GYRO COMPASSING
	03	PRELAUNCH OR SERVICE-OPTICAL VERIFICATION OF GYRO COMPASSING
BOOST	04	GNC'S POWER DOWN
	07	SYSTEMS TEST
	11	EARTH ORBIT INSERTION MONITOR (EOI)
	15	TLI INITIATE/CUTOFF
COAST	20	UNIVERSAL TRACKING
	21	GROUND TRACK DETERMINATION
	22	ORBITAL NAVIGATION
	23	CIBLUNAR MIDCOURSE NAVIGATION
PRE-THRUST TARGETING	24	RATE-AIDED OPTICS (LANDMARK TRACKING)
	27	CMC UPDATE
	29	TIME-TO-LONGITUDE
	30	EXTERNAL DELTA V
THRUSTING	31	HEIGHT ADJUSTMENT MANEUVER (HAM)
	32	CO-ELLIPTIC SEQUENCE INITIATION (CSI)
	33	CONSTANT DELTA ALTITUDE (CDH)
	34	TRANSFER PHASE INITIATION (TPI)
ALIGNMENT	35	TRANSFER PHASE (TPF)
	36	PLANGE CHANGE (PCM)
	37	RETURN TO EARTH (RTE)
	40	SPS
ENTRY	41	RCS
	47	THRUST MONITOR
	51	IMU ORIENTATION DETERMINATION
	52	IMU REALIGN
PRE-THRUSTING OTHER VEHICLE	53	BACK-UP IMU ORIENTATION DETERMINATION
	54	BACK-UP IMU REALIGN
	61	ENTRY - PREPARATION
	62	ENTRY-CM/SM SEPARATION AND PRE-ENTRY MANEUVER
	63	ENTRY INITIALIZATION
	64	ENTRY-POST 0.05G
	65	ENTRY-UP CONTROL
	66	ENTRY-BALLISTIC
	67	ENTRY-FINAL PHASE
	72	LM CO-ELLIPTIC SEQUENCE INITIATION (CSI) TARGET
	73	LM CONSTANT DELTA ALTITUDE (CDH) TARGETING
	74	LM TRANSFER PHASE INITIATION (TPI) TARGETING
	75	LM TRANSFER PHASE (MIDCOURSE) TARGETING
	76	LM TARGET DELTA V
	77	CSM TARGET DELTA V
	79	RENDEZVOUS FINAL PHASE

Apollo Guidance Computer

The Apollo Guidance Computer (AGC) was a small programmable computer that was carried inside the Apollo spacecrafts. It was one of the first digital computers to make use of -rudimentary- integrated circuits, which were just being developed around the 60s.

The AGC's primary and critical function was to provide navigation references at times when telemetry could not be sent from Earth. Both Trans-Lunar Insertion and Trans-Earth Injection burn maneuvers need to be performed at the far side of the Moon without relying on any telemetry signals sent from home.

Besides keeping track of position and orientation, the AGC also performed a number of more specialized tasks. Special maneuvers such as Moon descent and landing, coplanar orbit adjustments, Trans-Lunar Injections, etc. were also controlled via the AGC.

AGC PROGRAMS

In the [Apollo Guidance Computer Programs](#) you can see a detailed list of AGC Sub programs.

3.1.8.1 Apollo Guidance Computer Programs

Those are the main programs , originally intended for every phase of the Apollo 11 moonshot. To run any of those programs, you need to call the [Verb 37] [Noun20] [ENTER] on the DSKY

- [Program 11 Launch Monitor](#) Program 11 Launch Monitor
- [Program 12 Launch to Lunar Orbit](#) Program 12 Launch To Lunar Orbit (Lunar Excursion Module)
- [Program 15](#) Program 15 Trans Lunar Injection
- [Program 17 Descent Orbit Insertion](#) Program 17 Descent Orbit Initiation
- [Program 20](#) Program 20 Prograde
- [Program 21 Retrograde](#) Program 21 Retrograde
- P22 Program 22 Orient Normal +
- [Program 23 Cislunar Correction Burn](#) . Program 23 Cislunar Correction (CSM)
- P24 Program 24 Attitude Hold (Kill ROT)
- P25 Program 25 Hover
- P26 Program 26 Level Flight
- P27 Program 27 Radial +
- P28 Program 28 Radial -
- P33 Program 33 Docking (Automated Transposition Rotation & Docking)
- P39 Program 39 Kill Relative Docking Vel
- P42 Program 42 Auto-Hover
- P52 Program 52 Parking Orbit Alignment
- P58 Program 58 Normal
- [Program 63 Powered Descent Initiation](#) Program 63 Powered descent Initiation (LM)
- [Program 64 Final Moon Landing](#) Program 64 Final Descent Entry Gate Go/NoGo(LM)
- [Program 66 Rate of Descent](#) Program 66 Vertical velocity hold .
- [Program 72](#) Program 72 Co-Elliptic Secondary Rendezvous (LM)
- [Program 73](#) Program 73 Co-Elliptic Positive-Burn Rendezvous (LM)
- [Program 79](#) Program 79 LM-Side Automated final docking

3.1.9 Program 11 Launch Monitor

Often mistaken for the actual launch command program, Program 11 is basically a launch vehicle parameters monitor, i.e., it tracks the position, attitude and velocity vectors directly from the accelerometers to check that the values are within the launch admissible corridor.

It also serves as a last sanity check for the accelerometers/integrators to be calibrated. That said, the actual firing, gimballing and insertion into orbit was done by a different computer - the Saturn LVDC (Launch Vehicle Digital Computer). The LVDC is not simulated in the current version.

For this simulation, enabling Program 11 (Verb 37, Noun 11, ENTER) will trigger a countdown (simplified) and launch into a valid inclination orbit, which is usually 72 degrees for Apollo Moon missions.

3.1.10 Program 12 Launch to Lunar Orbit

In contrast to P11, which was merely a launch values monitor, P12 is actually controlling and governing the launch to orbit for the ascent module of the LEM. In the Lunar orbit rendezvous priority was given to absolute reliability and as such the ascent engine had no gimballing. All attitude was controlled by a oversized (without the descent engine) RCS system.

The ascent path was a very simple gravity turn with some -very minor- corrections for orbital inclination. In Apollo 11 care was taken that the CSM did not deviate from the nominal ± 5 degrees inclination, so any ascent to orbit was easily inserted into the correct orbital inclination.

To do so landmarks were chosen before launch to ascertain the absolute yaw /bearing to calibrate the LEM gyros. Those value were double checkd from command control and also fed into the Emergency Digital Computer.

The sequence went something like this:

- 1-> Wait until the signal from the CSM was above the horizon.
- 2-> Presurize turbopumps for 5 secs and fire engine.
- 3-> keep vertical for 3-5 seconds (100 m).
- 4-> Orient to the correct yaw/bearing (not really needed in Apollo 11 as the landing spot was pretty much at the Moon's equator).
- 5-> After ABSOLUTE perfect orientation was achieved, pitch down and start a gravity turn into a 80-100km orbit.
- 6-> Circularize orbit if really needed.

3.1.11 Program 15

P15: TLI (Trans Lunar Injection) .

This programs initiate a series of events, that inyect the apollo S IVb into a trans-lunar orbit . That orbit is not a real hohman transfer orbit , instead it has the APSIS (apogee) somewhere past the L1 Lagrange point of the Earth Moon system. Leaving the moon to perform the final attraction to the spacecraft , performing a 8-loop. This is the ornit that minimizes the required DELTA V. After a parking orbit , and having the spacecraft properly aligned (see P52 IMU Alignment) , the burn is performed approximately at longitude -160.0. Some 3400 m/s are added into a Earth scape-esque trayectory , enough to reach L1 lagrangian point and let the moon finish closing the orbit. All data and burn are computed and automated from earth . In this way , P15 is just little more than a timer and a integrator, shutting automatically down after the required Delta-V and Apogee is achieved.

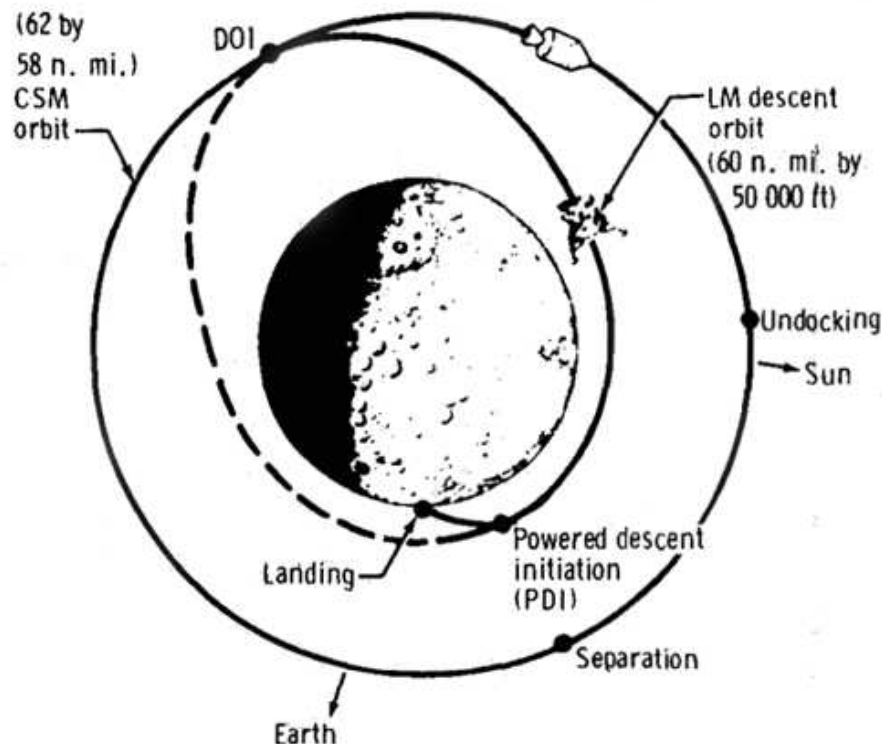
In order to avoid unexpected burns, and be able to disable the TLI for whichever reason , there is a switch in the left panel that ARM/DISARM the P15 T.L.I Burn . remember to ARM it before injection.

3.1.12 Program 17 Descent Orbit Insertion

P17 relates to the lunar circularization maneuver known as the Descent Orbit Insertion (DOI).

In the Apollo 11 flight the LM undocked and descended independently (from Apollo 13 onward a different approach was used).

Upon reaching the closest approach point in the TLI, the LM undocked from the CSM and began its descent. P17 was used to slow down the LM and reduce its altitude enough to wrap around the Moon in an elliptical 60x9 nautical mile orbit (approx 111km x 16.5km).



Once the P17 burn is correctly performed , the autopilot will run Program 63 PDI (Powered descent initiation)

3.1.13 Program 20

Prograde : This programs ,rotates the Spacecraft so it points forward in orbital velocity direction.

3.1.14 Program 21 Retrograde

Program 21 Retrograde orients the spacecraf in the opposite direction of velocity .(i.e. 'engine first'). Usefull combined with an engine burn to reduce orbital velocity

3.1.15 Program 23 Cislunar Correction Burn .

This program assure that the translunar coast will get close enough to the moon to be able to -later- decelerate and get into a circular lunar orbit.

We have seen that in theory , getting to lunar orbit is as simple as performing a hohmman transfer orbit to the moon orbital semimajor axis , and sincronize it with the time it would take the spacecraft to reach apogee.

In reality , things are more complicated.

- The gravity of earth is still attracting the spacecraft (as in a way , the gravity of the moon is also attracting the spacecraft , even before TLI butn
- After 2/3th of the translunar coast , the moon's gravity starts to overcome the earth's so we can not talk about earth orbit any more.
- As the moon is not still , but moving (reaching into the expected position, but well away from it) , the orbit (as referenced from the earth) changes shape , inclination , ascending node ,etc..
- At any point in the coast , the spacecraft will be at a lunar orbit at less excentricity that 1.0. In other words , it will be impossible to be captured by the moon without performing a burn
-

Real Trans lunar injection (and coast) will be easier throught as a hohmman transfer to L1 (Lagrangian point 1 , the point where moon-earth systems' gravities cancel each other) and from there , a freefall around the moon , with enough radial velocity to wrap around the moon and return tu Earth. All those complexities , render the original TLI (Trans lunar Injection) unable to have enough accuracy to be the final burn . Usually , with data from earth's computer aided by real time telemetry , a series of 1, 2 or 3 midcourse correction burns are needed.

And here is where program P23 comes to action.

P23 computes numerically the closer approach to the moon (remember that the point of closer approach is obviously also the one with no vertical velocity , and thus , the point at which we should perform the injection orbital burn .). also P23 allows us to compute how close would be our approach to the moon if our speed were -say - 10fps faster or slower , adjustable via the PLUS and MINUS keys on the DSKY

Lastly ,specially in the second burn , the concept of earth orbit has been blurred ,as the original orbit has nothing of the original parameters and shape ,the trajectory being much of a hyperbolic moon approach , so it should be usefull to be able to select the celestial body to which all those correction burns are referred.

Setting the Noun to 00 specifies all orbital changes will be related to the earth-referenced orbit Setting the Noun to 01 specifies all orbital changes will be related to the moon referenced (hyperbolic or not) orbit Pressing ENTR will trigger the numerical predictor , and a message will show our closer approach to the SURFACE of the moon Setting PLUS / MINUS button will increase or decrease the dV (as in delta-V) , vissible on the Data DSKY screen. Press ENTER to see WHAT THE CLOSER APPROASCH WOULD BE WITH THAT DELTA-V INCREASE Pressing PRO (Proceed) , will accept the result and execute the burn for the specified d-V in meters/sec (3.0 feet/sec).

3.1.16 Program 63 Powered Descent Initiation

Programs 63 to 67 relate to guidance and control of the powered descent. P63 is the Braking Phase Guidance Program, which was initiated near the prilune of the descent transfer orbit at approx 260 nautical miles (approx 481.5km) from the landing site.

P63 lasted until 60 seconds from landing at approx 7,000 feet (2.1km) altitude. The AGC went directly from P63 to P64, the Approach Phase Guide.

Program 64 contains the same guidance logic as Program 63, but has additional window directing function aligning the landing site with the grid on the window. This was the last opportunity for the crew to decide to land or not land.

Program 63 is the first of a series of programs (P63, P64, P66 and P88) used in the Apollo program to perform powered descent and landing. In Space Simulator P63 is also used to initiate automated descent procedures.

P63 contains an ignition burn algorithm for braking

With a preselected landing target site, P63 ignites the DPS (Descent Propulsion System), the Lunar Module descent engine. When the preselected target is reached, P63 automatically switches to P64.

Mission example:

Start with Mission/Select Scenario/Free Roam: Apollo 7 on Earth Orbit.

1. First ATTD/RETROGRADE and brake until your orbit intersects the atmosphere
2. Select SHIP/STAGE to discard the service module. You will make reentry in the command module.
3. Enter P63 in the AGC. Open COMP panel and enter "VERB 37 NOUN 63 ENTER". The autopilot powered descent program should be now turned on to guide the command module through reentry and splashdown. Reentry and landing takes approx 20 minutes.

3.1.17 Program 64 Final Moon Landing

Programs 63 to 67 relate to guidance and control of the powered descent.

Once program P63 has finished, the spacecraft orients a bit more vertical (pointing up), so the landing radar can get a readout on altitude. Until then, all the altitude data was fed by the Accelerometers in the IMUs. But in reality, due to differences in moon ratio, moon gravity fields (MASCONS), and lack of accurate measurements over the moon-earth distance, the distance from the spacecraft to surface could only be known within a few kilometers accuracy.

This few kilometers of accuracy, while being perfectly useful for orbital maneuvers, was clearly not good enough for a precision soft landing. Hence during the descent, once the altitude, velocity and vertical velocity fit through a hi/low window, the landing radar becomes operative, and starts feeding REAL altitude. (the famous 1202 alarm was partly due to this extra information arriving all at once).

Once the landing radar data is acquired, without any major discrepancies between it and the computed (inertial) expected altitude, then P64 performs the final leg of the landing based on real altitude data. Also, P64 keeps a forward diminish velocity, so the astronauts can accept the designated landing point (Apollo 12 and onwards) or "skip" for a few minutes the descent (and keeping the horizontal velocity) as in hovering over terrain too rough for landing.

3.1.18 Program 66 Rate of Descent

Programs 66 and 77 are optional modes that can be manually initiated anytime during P63, P64 and P65. P66 is initiated at approx 50-20m above the landing site. The AGC maintains the selected altitude and the crew controls the attitude.

P67 is a backup mode that allows the crew to have full manual control of the throttle and altitude in case P66 malfunctions.

3.1.19 Program 72

Program P72 (and its related co-routine P73) relate to the automated rendezvous and docking in Moon orbit. The entire procedure will be a series of P72 burns, to co-elliptically align planes and reduce orbital shift, together with P73 modes that essentially nulls any deviation from the relative distance/velocity due to the non-spherical field of moon gravity. Once the target spacecraft is well within range of the rendezvous radar, it will switch to terminal guidance mode (P79).

3.1.20 Program 73

Program P72 (and its related co-routine P73) relate to the automated rendezvous and docking in Moon orbit . The entire procedure will be a series of P72 burn , to co-elliptically align planes and reduce orbital shift , together with P73 modes that essentially nulls any deviation from the relative distance/velocity due to the non-spherical field of moon gravity . Once the target spacecraft is well within range of the rendezvous radar ,it will switch to terminal guidance mode (P79)

3.1.21 Program 79

Program P79 Terminal Guidance Mode. This program will guide the spacecraft to a presignated docking point , usually 150-50 yards in front of the docking target, and perform a very slow burn until a hard dock is achieved

3.1.22 Program 11 Launch Monitor

Often mistaken for the actual launch command program, Program 11 is basically a launch vehicle parameters monitor, i.e., it tracks the position, attitude and velocity vectors directly from the accelerometers to check that the values are within the launch admissible corridor.

It also serves as a last sanity check for the accelerometers/integrators to be calibrated. That said, the actual firing, gimbaling and insertion into orbit was done by a different computer - the Saturn LVDC (Launch Vehicle Digital Computer). The LVDC is not simulated in the current version.

For this simulation, enabling Program 11 (Verb 37, Noun 11, ENTER) will trigger a countdown (simplified) and launch into a valid inclination orbit, which is usually 72 degrees for Apollo Moon missions.

3.1.23 Program 12 Launch to Lunar Orbit

In contrast to P11, which was merely a launch values monitor, P12 is actually controlling and governing the launch to orbit for the ascent module of the LEM. In the Lunar orbit rendezvous priority was given to absolute reliability and as such the ascent engine had no gimbaling. All attitude was controlled by a oversized (without the descent engine) RCS system.

The ascent path was a very simple gravity turn with some -very minor- corrections for orbital inclination. In Apollo 11 care was taken that the CSM did not deviate from the nominal +/- 5 degrees inclination, so any ascent to orbit was easily inserted into the correct orbital inclination.

To do so landmarks were chosen before launch to ascertain the absolute yaw /bearing to calibrate the LEM gyros. Those value were double checkd from command control and also fed into the Emergency Digital Computer.

The sequence went something like this:

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3.1.24 Program 15

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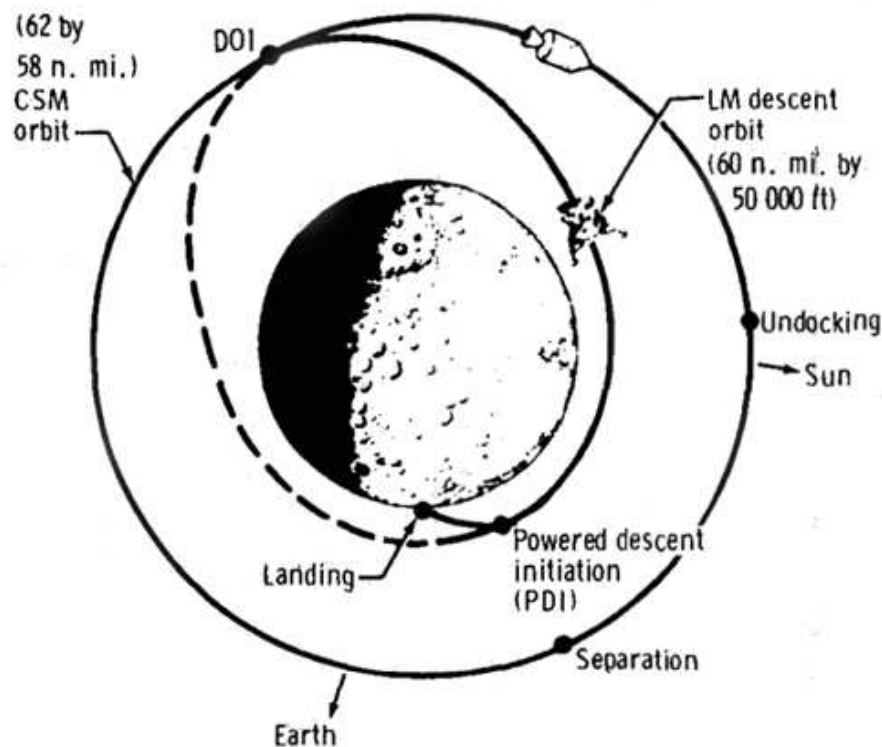
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Prograde : This programs ,rotates the Spacecraft so it points forward in orbital velocity direction.

3.1.27 Program 21 Retrograde

Program 21 Retrograde orients the spacecraf in the opposite direction of velocity .(i.e. 'engine first'). Usefull combined with an engine burn to reduce orbital velocity

3.1.28 Program 23 Cislunar Correction Burn .

This program assure that the translunar coast will get close enough to the moon to be able to -later- decelerate and get into a circular lunar orbit.

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3.1.29 Program 63 Powered Descent Initiation

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1. First ATTD/RETROGRADE and brake until your orbit intersects the atmosphere
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3. Enter P63 in the AGC. Open COMP panel and enter "VERB 37 NOUN 63 ENTER". The autopilot powered descent program should be now turned on to guide the command module through reentry and splashdown. Reentry and landing takes approx 20 minutes.

3.1.30 Program 64 Final Moon Landing

Programs 63 to 67 relate to guidance and control of the powered descent.

Once program P63 has finished, the spacecraft orients a bit more vertical (pointing up), so the landing radar can get a readout on altitude. Until then, all the altitude data was fed by the Accelerometers in the IMUs. But in reality, due to differences in moon ratio, moon gravity fields (MASCONS), and lack of accurate measurements over the moon-earth distance, the distance from the spacecraft to surface could only be known within a few kilometers accuracy.

This few kilometers of accuracy, while being perfectly useful for orbital maneuvers, was clearly not good enough for a precision soft landing. Hence during the descent, once the altitude, velocity and vertical velocity fit through a hi/low window, the landing radar becomes operative, and starts feeding REAL altitude. (the famous 1202 alarm was partly due to this extra information arriving all at once).

Once the landing radar data is acquired, without any major discrepancies between it and the computed (inertial) expected altitude, then P64 performs the final leg of the landing based on real altitude data. Also, P64 keeps a forward diminish velocity, so the astronauts can accept the designated landing point (Apollo 12 and onwards) or "skip" for a few minutes the descent (and keeping the horizontal velocity) as in hovering over terrain too rough for landing.

3.1.31 Program 66 Rate of Descent

Programs 66 and 77 are optional modes that can be manually initiated anytime during P63, P64 and P65. P66 is initiated at approx 50-20m above the landing site. The AGC maintains the selected altitude and the crew controls the attitude.

P67 is a backup mode that allows the crew to have full manual control of the throttle and altitude in case P66 malfunctions.

3.1.32 Program 72

Program P72 (and its related co-routine P73) relate to the automated rendezvous and docking in Moon orbit . The entire procedure will be a series of P72 burn , to co-elliptically align planes and reduce orbital shift , together with P73 modes that essentially nulls any deviation from the relative distance/velocity due to the non-spherical field of moon gravity . Once the target spacecraft is well within range of the rendezvous radar ,it will switch to terminal guidance mode (P79)

3.1.33 Program 73

Program P72 (and its related co-routine P73) relate to the automated rendezvous and docking in Moon orbit . The entire procedure will be a series of P72 burn , to co-elliptically align planes and reduce orbital shift , together with P73 modes that essentially nulls any deviation from the relative distance/velocity due to the non-spherical field of moon gravity . Once the target spacecraft is well within range of the rendezvous radar ,it will switch to terminal guidance mode (P79)

3.1.34 Program 79

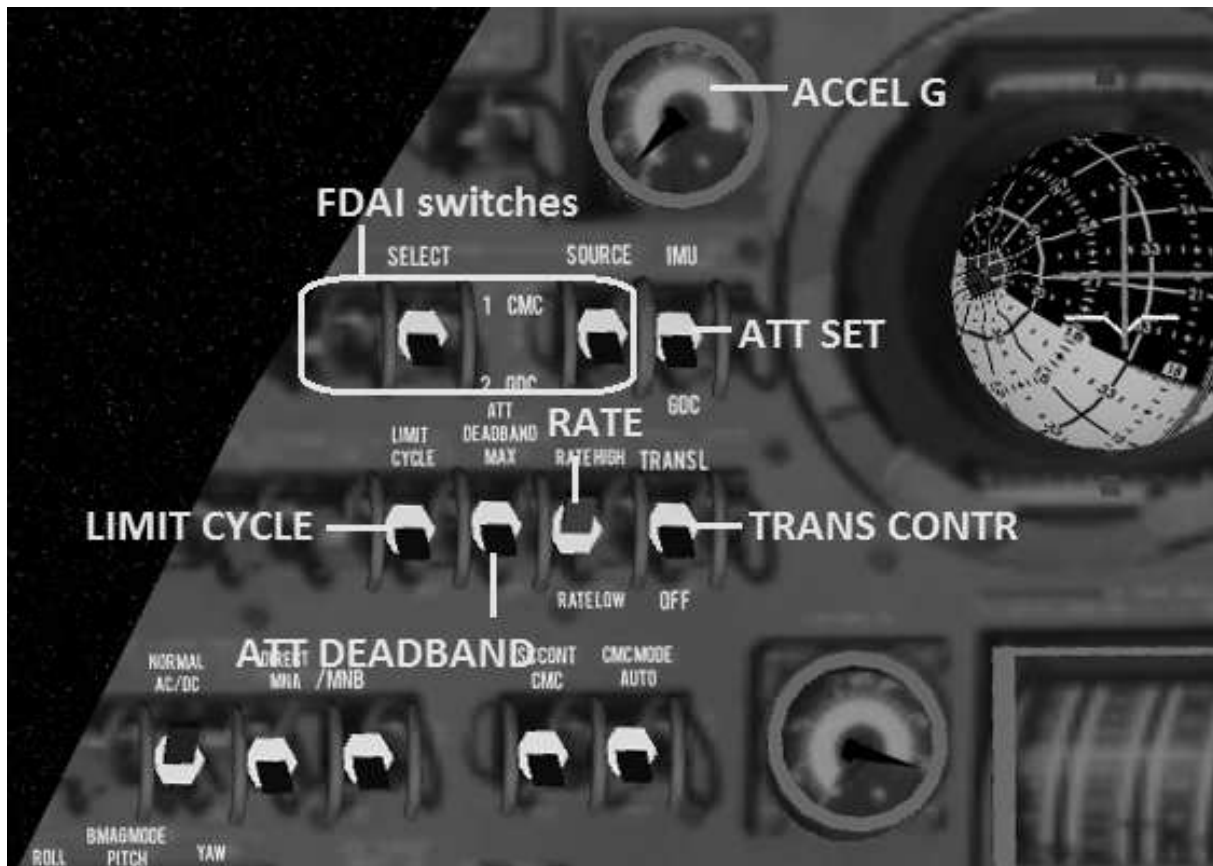
Program P79 Terminal Guidance Mode. This program will guide the spacecraft to a presignated docking point , usually 150-50 yards in front of the docking target, and perform a very slow burn until a hard dock is achieved

3.1.35 ApolloDisplayConsole

Apollo Display Console

Most flight control switches were positioned towards the left side of the Apollo cockpit panel as the flight commander sat in the left seat. The system controls were in the center in front of the Command Module Pilot. To the right were the communications controls.

Here's a breakdown of the flight control panel:



The "ACCEL G" meter indicates the G force on the spacecraft's X-axis

"FDAl switches"

- "SCALE" selects the scale of the three FDAIs
- "SELECT" chooses which FDAI to send signals to
- "SOURCE" selects the source of signals

"ATT SET" sends signals from IMU (Inertial Measurement Unit) or GDC (Gyro Display Coupler) the attitude set panel

"LIMIT CYCLE" turns on/off pseudo-rate feedback in electronic control assembly

"ATT DEADBAND" selects 4 extra degreee in attitude control electronics

"RATE" selects HIGH or LOW rate in electronic control assembly

"TRANS CONTR" turns on power for the translational hand controller

"ROT CONT switches"

- "NORMAL" switches power rotational hand controllers in normal mode
- "DIRECT" switches power rotational hand controller in direct mode

"SC CONT" provides computer control

"CMC MODE" selects computer mode

"BMAGMODE" sends signals from Body-Mounted Attitude Gyros to electronics

"delta-V THRUST" switches power injector pre-valves A or B, signaling that engine is ready

"SVS TVC" switches selects AUTO/MANUAL control of thrust vector, or stops BMAG signals

"SPS GIMBAL MOTORS" switches turn ON/OFF primary and secondary gimbal motors, which move the service propulsion in the direction of thrust

"IMU CAGE" switch cages the IMU platform with all three gyros at 0 degrees

"ENTRY switches"

- "ROLL" turns on roll attitude indicator
- "0.05G" shows roll and yaw rates

"LV/SPS IND" switches selects information displayed

"delta-V CG" is set to LM/CSM when the LM is attached

"ELS switches"

- "LOGIC" powers earth landing subsystem during entry or abort
- "AUTO" for automatical control of landing subsystem. Set to MAN if abort during 1st minute

"CM PROPELLANT JET switches" control the CM reaction propellant

- "LOGIC" activates DUMP switches and prepares for releasing propellant
- "DUMP" starts burning of propellant during descent
- "PURGE" sends helium through engine after propellant is burned

"EVENT TIMER switches" control the event timer

- "RESET" sets timer to 0
- "START" starts timer
- "STOP" halts timer
- "MIN" turn counter by minutes
- "SEC" turn counter by seconds

"Backup switches"

"LIFTOFF" turns on at liftoff and off before 1st stage separation

"NO AUTO ABORT" turns on at liftoff if either emergency abort system is not enabled

"LES MOTOR FIRE" is a backup switch to launch escape tower

"CANARD DEPLOY" is a backup switch to deploy canards on escape tower during abort

"CSM/LV SEP" separates the CSM from the launch vehicle

"APEX COVER JETT" is a backup switch to deploy the heat shield during descent

"DROGUE DEPLOY" is a backup switch to deploy the drogue parachute

"MAIN DEPLOY" is a backup switch to deploy the main parachute

"CM RCS HE DUMP" is a backup switch to start reaction control system helium dump

3.2 Autopilots

Space simulator incorporate some common autopilots, to help the user in a certain common -repetitive tasks.

- Autopilot1
- Autopilot2
- Autopilot3
- Autopilot4
- Autopilot5
- Autopilot6
- Autopilot7
- Autopilot8

Chapter 4

Introduction

Space Simulator is a realistic computer simulation of spacecrafts in orbits in the Solar System. Originally designed for mobile devices only, the game has slowly grown into a real physics full-size Solar System spaceflight simulation fit for mobiles and desktops. While it's not your typical arcade game, or space colonization game, we feel that the orbital dynamics challenges can be equally interesting and rewarding. All the physics are real so you will confront the same problems and have the same tools as real astronauts.

- [About Space Simulator](#)
- [Update History](#)
- [Space Simulator Credits](#) Credits

4.1 About Space Simulator

Space Simulator is an app originally devised for mobile phones. Development began early 2012. It was intended to be a 3D version of the classic "Moon Lander". During the development process the game kept increasing in complexity, eventually becoming one of the major simulators in the spaceflight simulation category.

- It has nearly 2 millions lines of C#
- It is around 800 Mb of code/data
- It has taken 3+ years of development
- It is currentlu available for iOS, Android and Amazon Kindle devices

- It will be available for Win/Mac/Linux/PS3 shortly
- It uses a custom made double precision physics library
- It computes n-Body for all objects (not patched conics), thus making orbits realistically unstable
- It has a numerical solver for orbits to pre-compute orbital slingshots, etc.
- The menu/config/missions/game navigation GUI is made as a wrapper around a local HTTP server
- The master mission scheduler is running on a custom-made C-ish interpreter

4.2 Update History

Version 1.0.9

Multiple orbits shown in Map/Surface mode Correct Flight/Orbital modes for FDI ball Autopilot Window , fully selectable and configurable . (In Desktops , autopilot are user-programable via LUA) GUI color/tint configuration Roundy / mobile friendly top bar icons Lockable autopilots , prevent getting out of the relevant mode Terminal T↔TY Window . allows access to the internal filesystem , tasks process,e tc.. running a micro-linux kernel. First universal Version ,essentially the same project as the 5team version ,simply with different mobile-friendly graphics Updatable content from the server ,no need to update app. Loader pre-scene splasher allowing setting up content , options, reset , etc.. Voice Synthetised radio stations, mission control XML based rocket description. Airport selectable in HSI mode (linked to auto-pilot);

Version 1.0.8

Version 1.0.7

- Add Gemini capsule option
- New tab system (hide tabs)
- New persistent GUI/windows layout
- Trunnion on S-Band Antenna points correct azzimuth
- When click on a planet in orbit computer, zoom to an appropriate distance
- fix cloud shader when getting to extreme latitudes
- Double tap on screen toggles inside/exterior view
- Fix: pause/unpause stops/pauses/resumes the audio chatter/FX at the right position

- Apollo 8 Earthrise position, timing, angle, orientation, etc.. successful sanity check.
- dual mode lerped cloud seamless integration
- MOVE inside the cockpit!
- Special keys (alt, apple, ctrl, command, etc) allowed in keyboard configuration tool
- Custom mission allows now setting time from 1957.
- Apollo 8 attract mode + Earthrise + highly compressed audio footage
- Fix bug forcing atmospheric render in earth when spacecraft has atmosphere pressure (in other planet!)
- Very cool Moon shader
- procedural Moon craters!
- Pause key (re-mappable)
- Super cool shader for seawater
- Nonlinear air diffraction density model
- Map Mode: Render satellites/moons of selected celestial body
- Map Mode: merged both (cryptic :)) horizontal sliders for the numerical orbit predictor.
- Map mode: added sensitivity/calibration slider.
- Map mode: fixed that Delta-T glitch when excentricity < 0.005 deg
- Map mode: camera transitions smoothly from one object to another
- residual Albedo as an option, useful for LORendezvous
- (Steam) procedural skymap with known nebula, milky way, etc.
- (Steam) proper launch facility, proper smoke, good 2.1 speaker-trashing Saturn V FX
- option to null Z on orbits making all the planetary orbits coplanar with ecliptic plane for ease of interplanetary transfers
- VSOP(ish) planetary model approximation, ELM2000 as it should be
- Tonemapping for Steam & hi-end iOS devices
- Log Window, providing a history of all messages/popups/events shown
- Re-implementation of full in-game documentaton browser
- All Apollo missions guided tour/tutorials
- Autoplay mode, full automated gameplay
- Trans-Earth Injection
- P23 CisLunar, P15 Trans Lunar, P16 Lunar orbit insertion
- P52 Orbital alignment implemented
- P72, P73, P79 LM Lunar orbit rendezvous implemented
- P20 Correct minimul Lunar altitude intersection
- larger fonts by default for smaller devices
- more funcional save-load with fuel, screenshots, etc
- high quality moon shaders

- Shuttle and Apollo available again in the custom mission editor
- correct sound/FX in Apollo missions
- lots of new configuration options

Version 1.0.6 (Released July 2016)

- custom missions editor - begin your mission at any position around a planet of your choosing with your favorite spacecraft
- resizable HUD windows - introducing a new GUI system with uniform windows-style resize-able and draggable control panel, MFD, camera, time and orbit planner windows
- new Space Launch System (SLS) missions - full SLS lunar missions from launch, rendezvous, docking, trans-lunar injection through to lunar landing, reentry and splashdown
- comprehensive configuration options - extensive geometry, graphics and physics options to maximize optimized performance across all devices
- multilingual support - currently supporting English, French and Spanish

Version 1.0.5 (Released November 2015)

- North American X-15 space plane missions
- Edwards air force base
- 1st person view camera mode with HUD
- Realistic atmospheric scattering rendering
- Backscatter water, sea and land renderer for accurate colorimetry, hue and chroma for Earth
- Full volumetric clouds
- Earth altimetry for selected devices
- Orbit computer and planner bug fixes
- Apollo Guidance Computer bug fixes
- Improved HSI, EHSI with normal, centered, etc.
- Improved flight director
- Tegra3 devices 'no textures' bug fix
- Menu scroll bug fix

Version 1.0.3 (Released Aug 2015)

- celestial bodies added: Mercury, Venus, Mars, Phobos, Jupiter, Io, Europa, Callisto, Ganymede, Saturn, Titan
- 3D surface textures for Mars, the Moon and Io
- 2001 Discovery spaceship added
- 3D orbiter planner and computer
- new aerodynamics model

- HUD lines for 3D view of approach landing at Kennedy Space Center
- improved autopilot
- iPhone 4S and iPhone 5 support

Version 1.0.2 (Released April 2015)

- spacecraft self shadows
- HTML browser with table and auto import of documentation
- orbital dynamics guided tutorial
- guided Saturn V launch to Orbit tutorial
- dual texture specular animated water
- Shuttle landing gear release and original sfx
- guided AGC mission
- HOVER added for Shuttle Orion
- jetliner-style FDI for Shuttle Orion
- added docking strobe on ISS ports
- reverse camera pitch to show more ground
- improved smoke trail
- fixed hollow Apollo Service Module
- fix ISS orientation and indication
- fix Atlantis autopilot to inject in correct orbit
- fix pause/unpause stop/restart reentry and ME flames
- fix Julian dates showing +1 month
- fix overlapping text on paused screen
- fix external camera and TV camera conflict
- remove camera icon when external camera disabled
- fix overflowing text
- fix SM umbilical and CM positions
- correct Mars atmosphere model and improved Mars texture with correct atmospheric haze
- release auto atthold when using joystick
- fix LEM descent stage graphic bug
- remove COMP option for non-Apollo missions
- remove dashball as we now have FD/HSI

Version 1.0.0 (First release March 2015)

4.3 Space Simulator Credits

- Main Programming : Javier Carrion
- Auxiliary Programming: Tai Chen
- Production : Brixton Dynamics
- QA/Betatest : Vincent Majoricj, Thierry, Machala
- Special Thanks to : Zapiron (The Office Cat)

Chapter 5

Apollo8ParkingOrbit

Apollo 8 Earth Parking Orbit

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

Chapter 6

Apollo8ReentryAndSplashdown

Apollo 8 Reentry And Splashdown

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

Chapter 7

Apollo8Separation

Apollo 8 Separation

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

Chapter 8

Apollo8TLI

Apollo 8 Trans Lunar Injection

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

Chapter 9

Mission Guides

Here is a list of walkthrough guides for some of our more popular missions.

- [ApolloProgramMissions](#) Program
- [SpaceShuttleMissions](#) Shuttle Program
- [TutorialsGemini](#) Gemini Program
- [Quick Launch Guides](#) Quick Launch Guides..

9.1 ApolloProgramMissions

Apollo Program Missions reference

- [Apollo8Missions](#) Apollo 8
- [Apollo 11 MoonShot WalkTrought](#) Apollo 11

9.1.1 Apollo8Missions

Apollo 8 mission guide



This spacecraft was the first of the Apollo series to successfully orbit the moon, and the first manned spacecraft to leave Earth's gravity and reach the Moon.

The mission provided operational experience and tested the Apollo command module systems, including communications, tracking, and life-support, in cis-lunar space and lunar orbit, and allowed evaluation of crew performance on a lunar orbiting mission.

The crew photographed the lunar surface, both farside and nearside, obtaining information on topography and landmarks as well as other scientific information necessary for future Apollo landings. Additionally, six live television transmission sessions were done by the crew during the mission, including the famous Christmas Eve broadcast in which the astronauts read from the book of Genesis.

All systems operated within allowable parameters and all objectives of the mission were achieved.

The mission objectives for Apollo 8 included a coordinated performance of the crew, the command and service module, or CSM, and the support facilities. The mission also was to demonstrate translunar injection; CSM navigation, communications and midcourse corrections; consumable assessment; and passive thermal control. The detailed test objectives were to refine the systems and procedures relating to future lunar operations.

All primary mission objectives and detailed test objectives were achieved. All launch vehicle and spacecraft systems performed according to plan. Engineering accomplishments included use of the ground network with onboard navigational techniques to sharpen the accuracy of lunar orbit determination and the successful use of Apollo high-gain antenna - a four-dish unified S-band antenna that deployed from the service module, or SM, after separation from the third stage.

General overview

Upon the success of Apollo 7 in testing the Command and Service Module , the next logical step would be to use the mighty Saturn V to launch a manned CSM for the first time. A few possible scenarios / missions were proposed

- CSM extended orbital stay with a final SPS burn to simulate reentry from Lunar Transfer orbit
- A dummy freeflight around the moon in a free return trajectory
- A full lunar orbital flight , requiring Translunar injection , Lunar orbit insertion , and -after a few orbits in the moon - a final Trans -Earth Insertion burn.

Consider that -until then - all manned spaceflight have been performed in the vicinity of the earth(Low Earth Orbit), of at most a few hundreds kilometers altitude. There were very little experience on manning spacecrafts beyond the Van-Allen radiation belt . Also , the service propulsion engine (the main rocket engine of the Apollo Spacecraft) haven't been tested yet in a critical maneuver. If the SPS in Apollo 7 would have failed , they would have been able to de-orbit using the RCS.

Most people at NASA were advocating for the free-return-loop mission. while not much less impressive than the full lunar orbit mission , it required much less critically untested-systems. In particular , a free loop around the moon would have not required

- No need for SPS Engine burn at all. If the Launch Vehicle's guidance was accurate (as it was) , the entire mission would have been flown without need to use the SPS
- No need for AGC (Apollo Guidance Computer) use and navigation at all. Other than final reentry attitude and control , the entire flight would have been performed as a free fall around the moon.

Besides, the original plan would have been to push one test forward (i.e.

- Apollo 8 would have been a free-return loop around the moon
- Apollo 9 Lunar Orbit mission
- Apollo 10 Earth orbit LEM /CSM docking mission.
- Apollo 11 "Dress rehearsal" of lunar landing
- Apollo 12 First moon landing . Just on time to match Kennedy's deadline.

Then , the Russians. Russias' moon program was in a state of a mess. To make things even worse , they didn't have a single Space Agency , but three. IN the second half of the 60s , there were three real manned lunar programs in the Soviet Union :

- S. Korolev's ill fated N1- LOK-LK plan for a set of lunar missions.
- Proton -> LKOB Circum Lunar missions
- Chelomey (TAI : Revisit this ,can't spell those names well)

After the fiasco of the N1 (now we know that the design was intrinsically flawed ,even if it worked- it wouldn't have been able to lift anything) , there were plans for a Soviet quick circumlunar flight . Essentially that would have saved face on the Russian side by beating the Americans "on the race to the moon" Due to exquisitely complicated formulae of celestial dynamics , the Russians had an earlier launch window for the circumlunar mission . If that were the case , then the Apollo 8 circumlunar mission would have looked like another "second" behind the Russians .It was -though- imperative to perform the much more complicated lunar orbital mission.

At the end , the Russians (wisely!) , didn't launch the manned circumlunar mission . They launched an empty spacecraft , and due to a malfunction , it would have killed its crew if it were manned. But on the US side . NASA had already taken the decision to go for the full lunar-orbit mission , shifting the entire moon program one mission ahead.

Here is a brief list of the most important programmed events in the Apollo 8 mission.

Mission Highlights

Launch



[Apollo8Launch](#) Apollo 8 launched from Cape Kennedy on Dec. 21, 1968, placing astronauts Frank Borman, James Lovell Jr. and William Anders into a 114 by 118 mile parking orbit at 32.6 degrees.

Trans Lunar Injection



[Apollo8EarthParkingOrbit](#) [Apollo8TransLunarInjection](#) During the second revolution, at two hours, 50 minutes ground elapsed time, the S-IVB third stage restarted for a five-minute, 17-second burn, initiating translunar coast. Following S-IVB/CSM separation at three hours, 21 minutes, a 1.5 feet per second radial burn of the SM reaction control engines was initiated to establish sufficient distance for S-IVB propellant dumping. Following the propellant dumping, which sent the stage into diverging trajectory and solar orbit, the separation distance still was deemed inadequate and a second SM reaction control burn of 7.7 feet per second was performed.

Mid Course Correction

The first midcourse correction occurred at about 10 hours, 55 minutes into the mission and provided a first check on the service propulsion system, or SPS, engine prior to committing spacecraft to lunar orbit insertion. The second and final midcourse correction prior to lunar orbit insertion occurred at 61 hours, 8 minutes, 54 seconds.

Loss of signal occurred at 68 hours, 58 minutes, 45 seconds when Apollo 8 passed behind the moon. At that moment, NASA's three astronauts became the first humans to see the moon's far side. The first lunar orbit insertion burn, at 69 hours, 8 minutes, 52 seconds, lasted four minutes, two seconds and reduced the spacecraft's 8,400 feet per second velocity by 2,994 feet per second, resulting in an initial lunar orbit of 70 by 193 miles. The orbit circularized at 70 miles by the second lunar orbit insertion burn of 135 feet per second, performed at the start of the third revolution, again on the back side of the moon, at 73 hours, 35 minutes, five seconds.

Lunar Orbit



[Apollo8LunarOrbitInsertion](#) [Apollo8LunarOrbit](#) During the 20-hour period in lunar orbit, the crew conducted a full, sleepless schedule of tasks including landmark and landing site tracking, vertical stereo photography, stereo navigation photography and sextant navigation. At the end of the 10th lunar orbit, at 89 hours, 19 minutes, and 16 seconds, a three-minute, 23-second trans-Earth injection burn was conducted, adding 3,522 feet per second. Only one midcourse correction, a burn of five feet per second conducted at 104 hours, was required instead of the three scheduled.

Six telecasts were conducted during the mission: two during translunar coast, two during lunar orbit and two during trans-Earth coast. These transmissions were telecast worldwide and in real time to all five continents. During a telecast on Christmas Eve, the crew read verses from the first chapter of Genesis and wished viewers, "Good night, good luck, a Merry Christmas and God bless all of you - all of you on the good Earth." All telecasts were of excellent quality. Voice communications also were exceptionally good throughout the mission.

Separation and Reentry

Apollo8TransEarthInsertion Apollo8ReentrySplashDown Separation of the command module, or CM, from the SM occurred at 146 hours, 31 minutes. A double-skip maneuver conducted during the re-entry steering phase resulted in an altitude gain of 25,000 to 30,000 feet. The re-entry velocity was 24,696 mph, with heatshield temperatures reaching 5,000 degrees F. Parachute deployment and other re-entry events were nominal. Apollo 8 splashed down in the Pacific Ocean at 10:51 a.m. EST Dec. 27. The splashdown was about 5,100 yards from the recovery ship USS Yorktown, 147 hours after launch and precisely on time. According to prior planning, helicopters and aircraft hovered over the spacecraft, and pararescue personnel were not deployed until local sunrise, 50 minutes after splashdown. The Apollo 8 crew reached the recovery ship at 12:20 p.m. EST.

9.1.2 Apollo8Launch

Apollo 8 Launch and Ascent

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

At T minus 48 hours oxygen and hydrogen are fed from tanks in the Service Module to the fuel cells to start sharing the spacecraft's electrical load with the ground supply.

At T minus 8 hours ground crew begins loading the three stages with LOX. The tanks are purged of contaminants with nitrogen gas and then precooled. The tanks are filled in just over three hours.

At T minus 7 hours 42 minutes the S-II and S-IVB, which use LH2, are conditioned. Helium which does not freeze inside the LH2, is passed through the tanks to remove air and water vapour, which will solidify. Then cold gas is pumped through the tanks to cool them.

At T minus 5 hours 49 minutes, the S-II is filled with fuel. Once the S-II is full the S-IVB is loaded.

Once the propellants are loaded, the crew can enter the spacecraft.



The Commander (CDR), Colonel Frank Borman, enters first sitting on the left seat. He will monitor the progress of the flight and use flight controls on the left panel. The Lunar Module Pilot (LMP), Major William A. Anders, enters second to the right seat. He will monitor the spacecraft's environmental and electrical systems on the right panel. The Command Module Pilot (CMP), Captain James A. Lovell, enters last to the center couch. He will monitor the caution and warning system lights in the center panel and the DSKY.

At T minus 20 minutes the TLI Procedures checklist comes into effect. First item is entering the launch azimuth into the computer.



At T minus 3 minutes and 6 seconds, firing command is in for the automatic sequence. The tanks begin to pressurize.

At T minus 2 minutes 30 seconds the computer begins operation using Program 01, which initialises all its storage locations and allows the guidance platform to be aligned. P01 leads to P02, which allows the crew to backup the lift-off discrete. Upon lift-off, it will automatically move to P11, which will operate during ascent.

Just prior to launch, the CDR pulls a handle on panel 325 just underneath his window. This bypasses the coolant to the spacecraft's radiators until orbit is achieved, which will be unable to cool due to frictional heating during ascent.

At T minus 60 seconds the vehicle is completely pressurized.

At T minus 50 minutes power usage is transferred to the flight batteries within the launch vehicle.

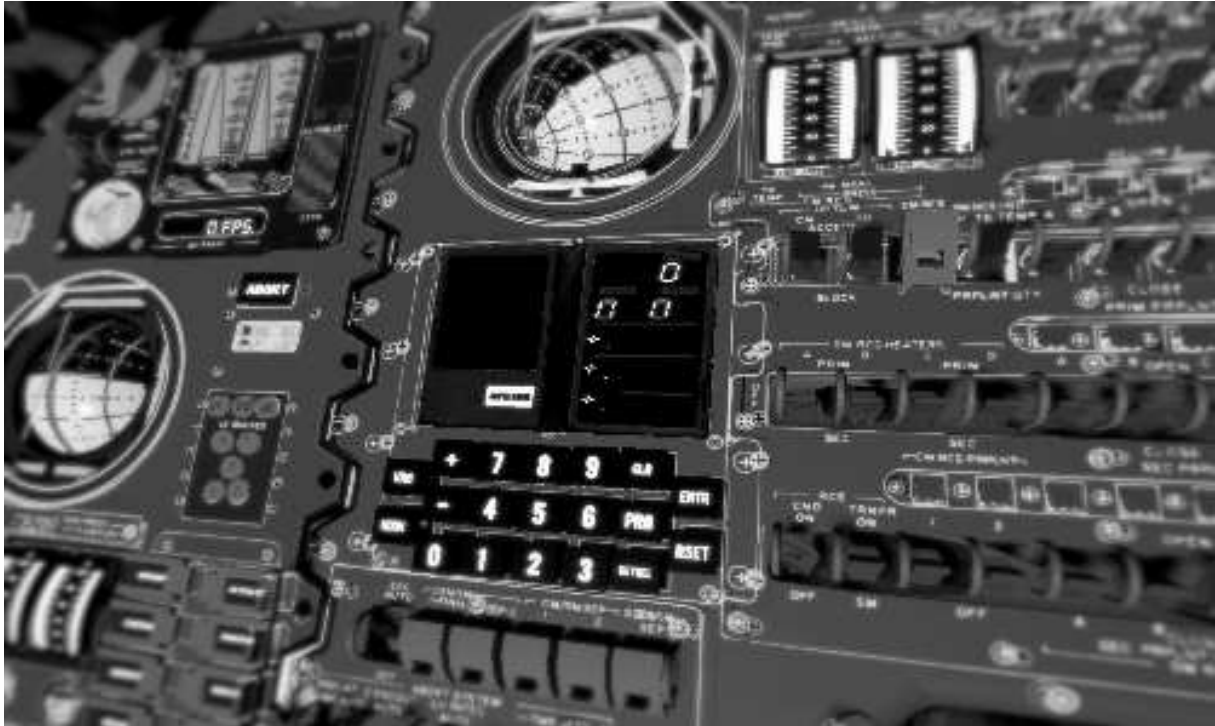
The final operation before the engines ignite is a Gyro Display Coupler (GDC) align, which provides a separate backup attitude reference via a set of strapped-down gyros, the Body-Mounted Attitude Gyros (BMAGs). For launch, it shows attitude with respect to the main attitude reference, the Inertial Measurement Unit (IMU). The GDC Align pushbutton is on the lower left of the Main Display Console next to the Attitude Set Control Panel. The GDC Align pushbutton is held until the expected attitude display of roll of 162 degrees, pitch of 90 degree and yaw of 0 degrees is achieved.



Roll is derived from the current value for roll (90 degrees) plus the flight azimuth of 72 degrees. [INSERT IMAGE]

At T minus 17 seconds the guidance platform in the IU is released, now keeping a constant orientation as the vehicle rotates around it.

At T minus 9 seconds ignition sequence starts.



At T minus 1 second the five launch vehicle engines lights go out, indicating that thrust is OK. [INSERT IMAGE]

At lift-off the lift-off light is illuminated as a verification. The lift-off light is the top-left of the safety switches with safety covers used to override the automatic abort sequences. [INSERT IMAGE]

Apollo 8 lift off at 7:51am EST.

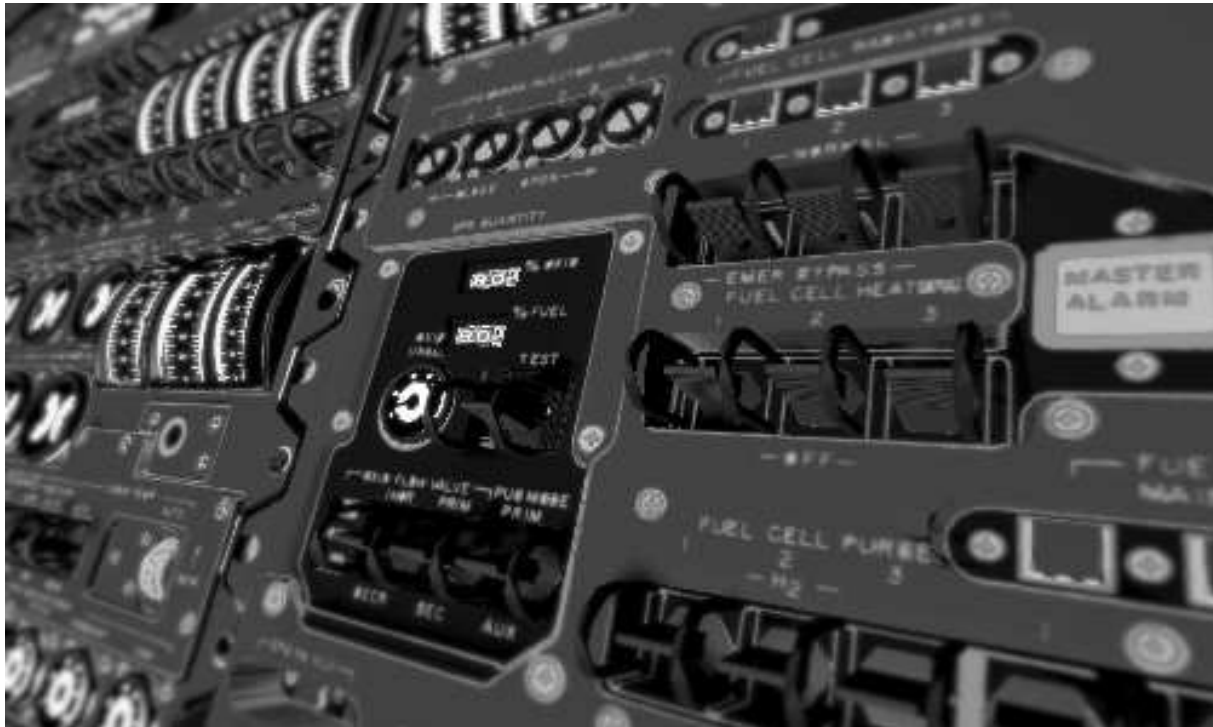
Shutdown of engines during the first 30 seconds is strictly prohibited.

The vehicle flies 1.25 degrees away from the tower for clearance.



At T 14:00 the roll and pitch program is initiated. The roll maneuver is completed by 28:00.

Abort mode 1A (one Alpha) covers the first 42 seconds of flight until 3,000 meters. Abort mode 1B extends from 42 seconds to 30.5 km.



At 1 minutes 19 seconds and 13,430 meters altitude, the stack reaches the point of maximum dynamic pressure (Max Q), the most dangerous part of the ascent.

Abort mode 1C covers flight between 30.5 km and jettison of the tower.

At T 02:25 the first stage engines cut-off. At T 02:36 is first staging.

At T 03:05, 30 seconds after the first separation, the interstage ring is dropped from the S-II. Four seconds later CDR jettisons the unused Launch Escape Tower, uncovering all the windows in the spacecraft.

Without the escape tower, Abort Mode II takes over until the end of the S-II.

At T 08:44 the S-II sends its cut-off signal, bringing the launch vehicle indicator lights on. The LV lights are extinguished at staging. At T 08:45 the stages are cut apart by explosive charges around the base of the S-IVB. The S-IVB J-2 engine then begins its ignition sequence, indicated by lamp 1 of the launch vehicle indicator lights.

Abort Mode IV covers flight to orbit with the S-IVB. Abort Mode III is enabled at the same time.

At T 11:30 the S-IVB Engine Cut-Off (SECO)

9.1.3 Apollo8LunarOrbitInsertion

Apollo 8 Lunar Orbit Insertion

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

9.1.4 Apollo8LunarOrbit

Apollo 8 Lunar Orbit

COUNTDOWN PREPARATIONS

Apollo 8 launch from Cape Kennedy on December 21, 1968.

The launch countdown began on December 15 at 19:00 EST beginning at T minus 103 hours.

9.1.5 Apollo 11 MoonShot WalkTrough

Apollo 11 Moon Landing Mission Walk Trough

- [Apollo Launch from Kennedy Space Center](#)
- [Earth Parking orbit](#)
- [Trans-Lunar Injection](#)
- [Staging , Transposition Rotation & Docking](#)
- [Mid-Course Trajectory \(Earth referenced \)](#)
- [Mid course trajectory correction,\(Lunar reference based \)](#)
- [Lunar Orbit Insertion](#)
- [Descent Orbit initiation & Powered Descent](#)
- [Final Lunar Landing](#)

9.1.6 Apollo Launch from Kennedy Space Center

The Apollo Program missions re-enact all the relevant episodes of the Moonshot. You can play them sequentially or in any order, or in one go from launch to landing on the Moon. Below are two different ways for you to reach orbit, the first using the 3D cockpit and the second using the quick launch method.

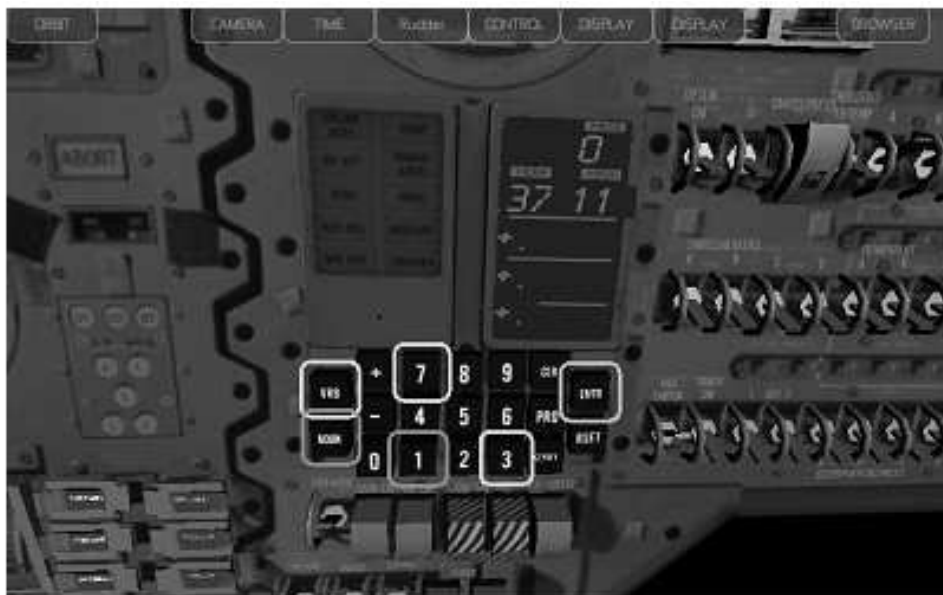
Launch to orbit Your mission begins with a fully fuelled Saturn V. Select the "Cockpit" camera view. Zoom in on the Apollo Guidance Computer.

1) Power on the Apollo Guidance Computer by pressing the **PRO** key.



You will see each of the display numbers run through 0-9. This is a brief test program to check that all lights and displays are in working condition.

2) Once the test program is completed, select **VERB 37 NOUN 11** by hitting the keys "**VERB**" "**3**" "**7**" followed by "**NOUN**" "**1**" "**1**". When the computer is idling it is set to program 00. "**VERB 37**" is to select a program. "**NOUN 11**" selects program 11 which is the launch to orbit program. When you are ready, hit "**ENTR**" to start the program!



If everything has gone well, you should see the Saturn V rise at first slowly but gaining momentum steadily. All staging is done by the Apollo Guidance Computer (AGC), however, there are still a couple of switches you need to hit to successfully inject into orbit.

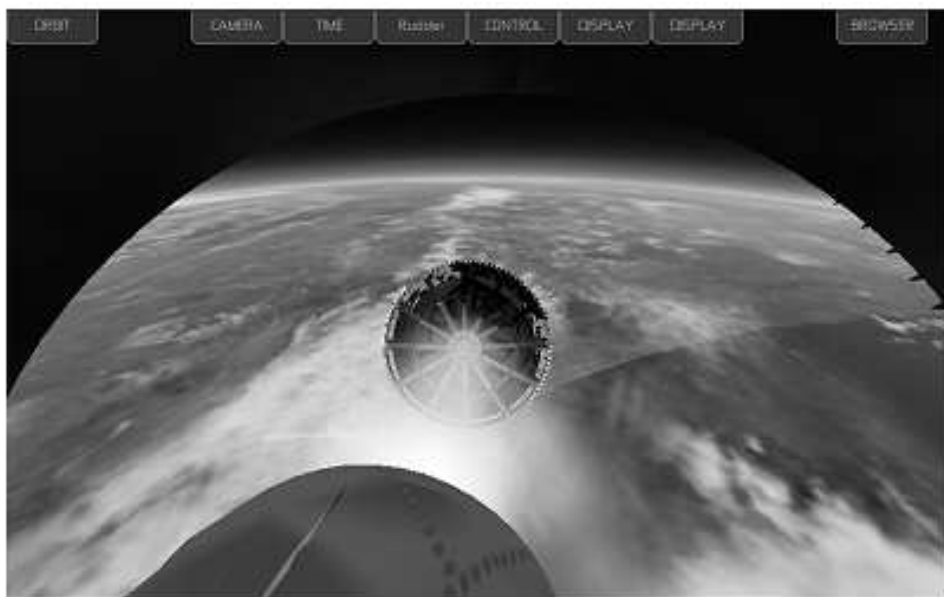
3) At about T2+ minutes, you should put the emergency system to manual control. The emergency system is by

default set to automatic as any real emergency during launch would have required the escape tower to be activated very quickly. After 2 minutes it was deemed safer to be triggered manually.

Flip the EDS Auto switch.



4) At approximately 2.55 minutes the first stage will run out of propellant. If you are in the exterior camera view you will see some classic staging footage.



5) After the first staging, the rocket is moving at a speed that makes the escape tower redundant. Now is a good time to eject the escape tower by pressing the "LES MOTOR FIRE" button, which is guarded by a plastic cover. Tap the button once to open the cover, and tap again to fire the tower.



Beyond this point there is little to do until the end of the stage. The rocket will continue gaining velocity, operating on a loop guidance until the burnout of the second stage.

A few minutes later the S-IVB engine will shutdown and you will have reached Earth orbit, approximately in the middle of the Atlantic Ocean. You can take a few minutes to enjoy the view as you approximate Africa's coast and start receiving data from the Canary Island station.



9.1.7 Earth Parking orbit

After a successful launch to earth orbit , we'll find the spacecraft just nearing the west coast of Africa . You can (as in the mission) realign the inertial platform , by using P52 IMU alignment , but this is not really necessary in the simulation. Essentially the parking orbit consists in just coasting AROUND the earth , until the precise point in which Translunar-Injection will be performed -somewhere north of New Zealand - Remember to keep your spacecraft prograded , just in case :)

9.1.8 Trans-Lunar Injection

Once over the designated (automated)point ,you need to run program P15 (*trans lunar injection) , that will fire SaturnIVb (third stage's)engine for around 5 minutes, to add 10000 feet/second of orbital velocity. Upon completion of the engine's firing ,you'll be in a highly eccentric (very elongated) orbit. That orbit will -with the help of the moon's gravitation - make your spacecraft swing around the moon , an ideal path to perform (later) a second firing to enter moon's orbit .

9.1.9 Staging , Transposition Rotation & Docking

The Apollo Program missions re-enact all the relevant episodes of the Moonshot. You can play them sequentially or in any order, or in one go from launch to landing on the Moon. Below are two different ways for you to reach orbit, the first using the 3D cockpit and the second using the quick launch method.

9.1.10 Mid-Course Trajectory (Earth referenced)

9.1.11 Mid course trajectory correction,(Lunar reference based)

The Apollo Program missions re-enact all the relevant episodes of the Moonshot. You can play them sequentially or in any order, or in one go from launch to landing on the Moon. Below are two different ways for you to reach orbit, the first using the 3D cockpit and the second using the quick launch method.

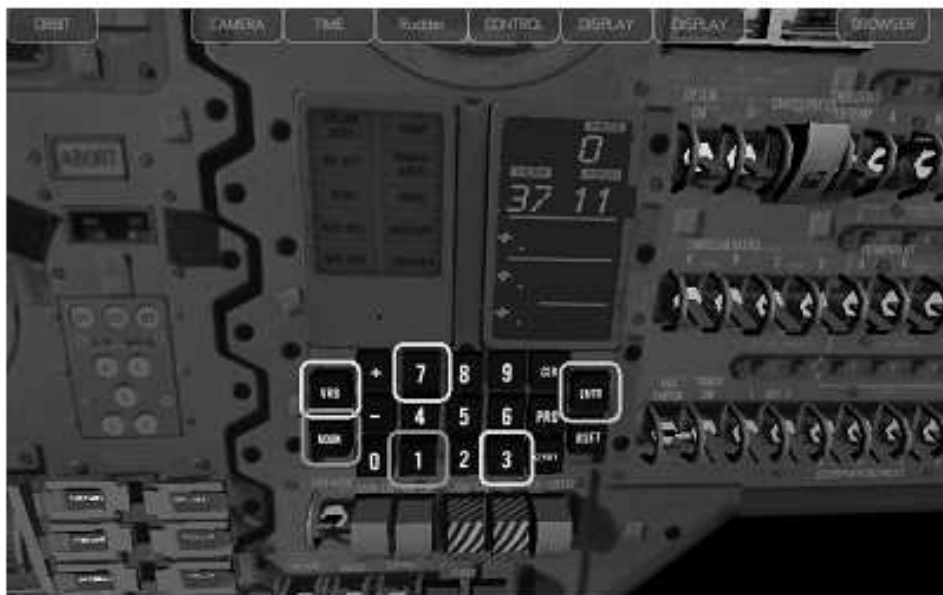
Launch to orbit Your mission begins with a fully fuelled Saturn V. Select the "Cockpit" camera view. Zoom in on the Apollo Guidance Computer.

1) Power on the Apollo Guidance Computer by pressing the **PRO** key.



You will see each of the display numbers run through 0-9. This is a brief test program to check that all lights and displays are in working condition.

2) Once the test program is completed, select **VERB 37 NOUN 11** by hitting the keys "**VERB**" "**3**" "**7**" followed by "**NOUN**" "**1**" "**1**". When the computer is idling it is set to program 00. "**VERB 37**" is to select a program. "**NOUN 11**" selects program 11 which is the launch to orbit program. When you are ready, hit "**ENTR**" to start the program!



If everything has gone well, you should see the Saturn V rise at first slowly but gaining momentum steadily. All staging is done by the Apollo Guidance Computer (AGC), however, there are still a couple of switches you need to hit to successfully inject into orbit.

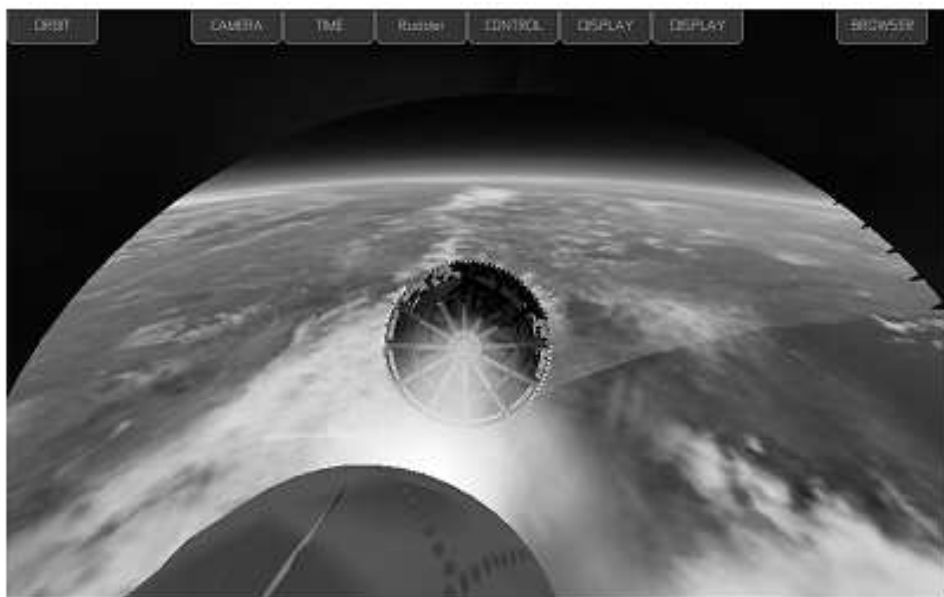
3) At about T2+ minutes, you should put the emergency system to manual control. The emergency system is by

default set to automatic as any real emergency during launch would have required the escape tower to be activated very quickly. After 2 minutes it was deemed safer to be triggered manually.

Flip the EDS Auto switch.



4) At approximately 2.55 minutes the first stage will run out of propellant. If you are in the exterior camera view you will see some classic staging footage.



5) After the first staging, the rocket is moving at a speed that makes the escape tower redundant. Now is a good time to eject the escape tower by pressing the "LES MOTOR FIRE" button, which is guarded by a plastic cover. Tap the button once to open the cover, and tap again to fire the tower.



Beyond this point there is little to do until the end of the stage. The rocket will continue gaining velocity, operating on a loop guidance until the burnout of the second stage.

A few minutes later the S-IVB engine will shutdown and you will have reached Earth orbit, approximately in the middle of the Atlantic Ocean. You can take a few minutes to enjoy the view as you approximate Africa's coast and start receiving data from the Canary Island station.



9.1.12 Lunar Orbit Insertion

The Apollo Program missions re-enact all the relevant episodes of the Moonshot. You can play them sequentially or in any order, or in one go from launch to landing on the Moon. Below are two different ways for you to reach orbit, the first using the 3D cockpit and the second using the quick launch method.

9.1.13 Descent Orbit initiation & Powered Descent

The Apollo Program missions re-enact all the relevant episodes of the Moonshot. You can play them sequentially or in any order, or in one go from launch to landing on the Moon. Below are two different ways for you to reach orbit, the first using the 3D cockpit and the second using the quick launch method.

Beyond this point there is little to do until the end of the stage. The rocket will continue gaining velocity, operating on a loop guidance until the burnout of the second stage.

A few minutes later the S-IVB engine will shutdown and you will have reached Earth orbit, approximately in the middle of the Atlantic Ocean. You can take a few minutes to enjoy the view as you approximate Africa's coast and start receiving data from the Canary Island station.



9.1.14 Final Lunar Landing

The Apollo Program missions re-enact all the relevant episodes of the Moonshot. You can play them sequentially or in any order, or in one go from launch to landing on the Moon. Below are two different ways for you to reach orbit, the first using the 3D cockpit and the second using the quick launch method.

Launch to orbit Your mission begins with a fully fuelled Saturn V. Select the "Cockpit" camera view. Zoom in on the Apollo Guidance Computer.

9.2 SpaceShuttleMissions

Space Shuttle Missions

A typical Space Shuttle missions includes the following stages: prelaunch, ascent, orbit, entry and postlanding.

- [TutorialShuttle1](#) Taking off to orbit
- [TutorialShuttle2](#) Rendezvous with the ISS
- [TutorialShuttle3](#) Docking to the ISS
- [TutorialShuttle4](#) Undocking and deorbiting
- [TutorialShuttle5](#) Reentry
- [TutorialShuttle6](#) Final approach and landing

9.2.1 TutorialShuttle1

Space Shuttle Prelaunch Procedures

- L 9:00 GO FOR LAUNCH is given; event timer is started
- L 8:00 PLT connects essential buses to fuel cells
- L 7:30 The access arm retracts. The crew checks seat positions, suit closures and restraints.
- L 6:15 PLT performs APU prestart and verifies three gray 'ready to start' talkbacks. IDP displays 1-3 are GNC LAUNCH TRAJ, GNC SYS SUMM1, AND BFS, SM SYS SUMM 2. IDP 4 displays BFS SM SYS SUMM 2.
- L 5:00 Pilot start APUs and verifies normal pressure. CDR turns off flash evaporator feedline heaters.
- L 3:25 Main engine nozzles are gimballed for 30 seconds.
- L 2:30 PLT clears hardware and software.
- L 0:07 Ignition sequence for main engines begins.
- L 0:03 Main engines have Pc's above 90%.

9.2.2 TutorialShuttle2

Space Shuttle Ascent Procedures

A typical Space Shuttle missions includes the following stages: prelaunch, ascent, orbit, entry and postlanding.

The ascent phase can be broken down into 3 stages: powered flight, OMS burns and post insertion.

POWERED FLIGHT

- T 0:00 SRM ignition, software transitions to MM 102, main engines are at about 100% Pc, and event timer count up from 0. The crew monitors vehicle performance and ascent trajectory using DPS and dedicated displays, Flight Instruments, ADI, No-Comm Ascent Abort Mode Boundaries and Contingency Abort cue cards.
- T 0:01 Set FCS (pitch and roll/yaw) in Auto if not already in Auto.
- T 0:04 Main engines are commanded to 104%
- T 0:07 At velocity ≥ 127 fps, the vehicle rolls, yaws and pitches to the heads-down ascent attitude. If maneuver does not begin automatically, the crew engages the BFS. The CDR/PLT select LVLH on ADI ATTITUDE switch. Control Stick Steering may now be selected if PASS guidance is not nominal. When both SRB Pcs fall below 50 psi ASCENT TRAJ will display PC < 50 . SRB separation should occur shortly thereafter, no later than MET 2:20. When the SRBs are separated, GNC changes to MM 103. BFS commands flash evaporator system on via payload buses. Post-SRB separation, the crew checks that PASS and BFS TMECOs values.
- MM 103 + 10 seconds On some missions an OMS assist burn may be used. SPEC 51 displays the manual dump quantity and timer followed by the OMS assist information.
- T 3:00 Check the flash evaporator is working with T < 60 F and decreasing on EVAP OUT T RTHU (roll to heads up) roll maneuver is performed at 5 deg/sec with a pitch attitude change of 20 degrees to 30 degrees.
- T 7:30 The BFS GPC command changes S-band PM Communication from STDN-HI to TDRS mode.
- T 8:25 MECO (main engine cutoff) occurs. Main engine Pc on the OMS/MPS display drop to 0. MAIN ENGINE STATUS lights turn red. The cutoff bug on the PASS and BFS ASCENT TRAJ 2 shows the MECO velocity. After MECO velocity should be approximately 25,820 fps.

OMS BURNS

If OMS 1 burn is required, the crew selects INRTL on ADI ATTITUDE switch to begin the automatic maneuver. When in the proper attitude the error needle is centered and ADI inertial attitude matches burn attitude on the MNVR display. EXEC key is pressed on CDR/PLT keyboard within 15 sec of OMS TIG to enable burn.

POST INSERTION

The following operations are performed in post insertion phase:

- reconfigure to on-orbit software and GPC configuration
- activate radiators
- open payload bay doors
- Doff and stow LES, reconfigure cockpit for orbit operations

9.2.3 TutorialShuttle3

Space Shuttle Orbit Operations

OMS (RCS) BURNS

OMS/RCS burns are used on orbit to raise or lower the orbital attitude, for rendezvous phasing and deorbit. The burn can be done with one or both OMS engines or the RCS, depending on the delta-V required.

On-orbit burns require OPS 202 (302 for entry) with GNC ORBIT MNVR EXEC and GNC SYS SUMM 2 displays.

RENDEZVOUS

These are the major steps of the final phases of a Space Shuttle rendezvous.

NC BURNS

NC Burns are phasing maneuvers used to initiate or modify the rendezvous approach (closing rate). The last burn is designed to place the orbiter 8 n mi behind the target (Ti point) in one or two revs.

START TRACKER NAV

After the final NC burn, the orbiter is moved to a -Z target track attitude to point the Star Tracker at the target.

NCC BURN

The NCC burn is the first onboard targeted burn using the Star Tracker data. This is a corrective combination burn that tried to create a node at and correct the transfer to the Ti point, 1200 feet below and 48,600 feet behind the target.

RADAR NAV

The rendezvous radar is locked at approx 150 kft.

TI BURN

The Ti burn initiates the final (transition) phase. It is targeted onboard using the FLTR vector. The Ti burn is a posigrade phasing burn designed to put the orbiter at 900 ft behind and 1800 ft below the target.

RADAR TRK NAV

NAV is updated with radar or ST data that is used to target four midcourse correction burns and perform the out-of-plane null.

PLANAR NULL

Use the GNC 33 REL NAV display to watch for the point when the out-of-plane distance between the two orbits (Y) becomes zero (nodal crossing). The NODE time on SPEC 33 gives an estimate of when this should occur. At nodal crossing the crew will null the rate (Y-DOT) to put the orbiter in the same orbital plane as the target.

MC2 BURN

The MC2 Burn is a burn based on the elevation angle to the target. It sets up the standard trajectory and reduces the dispersions in subsequent burns.

MC3 BURN

The MC3 BURN is typically a trim burn similar to MC1.

MC4 BURN

The MC4 burn targets to 600 ft on the +R-bar. This should coast the orbiter to the desired range on the +R-bar. Generally MC4 will be mostly a non-zero +X burn.

MANUAL PHASE

After MC4 the orbiter is on a coasting trajectory to the 600 ft point on the +R-bar. An attitude maneuver is performed to put the orbiter in the +R-bar attitude by the time it reaches the R-bar. Braking gates will be performed.

FINAL APPROACH

Final approaches are flight specific. They could be:

R-bar: fly up the +R-bar from the 600-ft point TORRA: fly to the +R-bar until 600 ft then transition to the -R-bar at twice orbit rate TORVA: fly to the +R-bar until 600 ft then transition to the +V-bar at twice orbit rate INERTIAL: orbiter maintains inertial attitude hold during final approach to target

9.2.4 TutorialShuttle4

Undocking and Deorbiting

To prepare for undocking, the external and internal airlocks must be closed, the docking lights and cameras are on, press the airlock vestibules using the A6L switches, and perform leak checks.

Press the APDS CIRC PROT OFF pushbutton to enable the UNDOCKING, OPEN HOOKS, OPEN LATCHES, and RING OUT pushbuttons.

Press the APDS CIRC PROT OFF and UNDOCKING pushbuttons to initiate the undocking sequence. OPEN HOOKS and OPEN LATCHES are required only in certain failure modes.

UNDOCKING opens the hooks. Four spring plungers compressed between the mating surfaces create a combined force of approx 700lb to separate the ISS/orbiter.

Sep burns are performed and the docking system is powered off.

Deorbit preparation:

- -4:00 Set CRT timer for deorbit TIG using teh GNC 2 TIME display and SM timer
- -3:56 Put RAD CNTLR OUT TEMP switch to HI posiiton to initiate radiator coldsoak and activate topping FES to minimize propulsive venting.
- -3:42 Compute N2 quantity to check for entry cabin leaks and identify depleted H2 tanks.
- -3:52 Activate APU water boiler steam vent heaters and terminate hyd thermal conditioning.
- -3:15 Power up FCS, DDUs and navigation aids for entry.
- -2:55 Initiate radiator bypass to retain Freon coldsoak. H2O crossover volve is verified open to allow water tanks to feed the FES.
- -2:51 Prepare for PLBD closing by activating PLB lights, prepare cameras.
- -2:40 Close PLBDs using SM PL BAY DOORS display on IDP 4 (SM OPS 2).
- -2:16 Configure DPS to place GPCs 1-4 in PASS OPS 3 and GPC 5 in BFS OPS 3.
- -1:58 Deactivate star tracker and close doors.
- -1:55 entry switch list configuration and verification
- -1:42 Receive readup of PADs. Deorbit targets uplinked.
- -1:40 Enable MPS helium system pressure C/W.
- -1:06 Perform final IMU alignment to reset RM threshold prior to deorbit burn.

Deorbit Burn

- -2:00 Take OMS ENG switches to ARM/PRESS in prepartion for the burn
- -0:46 Receive final deorbit update.
- -0:40 OMS TVC fimbal check using OMS MNVR EXEC display. Initiate APU pre-start procedures. Check APU status using BFS, SM SYS SUMM 2. Conduct horizontal situation configuration using GNC 50 HORIZ SIT; BFS GNC 50 HORIZ SIT; and GNC 51 OVERRIDE for both PASS and BFS. Initiate OMS burn preparation by checking engine trims and placing OMS and RCS valve switches in pre-burn configuration.

- -0:25 Perform vent door closure with the GNC 51 OVERRIDE display. Receive final deorbit update if required. GO/NO-GO is given for deorbit burn.
- -0:15 Initiate maneuver to deorbit burn attitude on OMS MNVR EXEC display. Verify ADI switches in proper positions. Place OMS/RCS heater switches in proper configuration for entry.

Hit EXEC key to trigger OMS ignition

- -0:05 Perform single APU start. One APU must be operating in low pressure prior to the burn. Verify orbiter is in the deorbit burn attitude ± 5 degrees.
- 0:00 Deorbit burn TIG. Monitor burn using delta VTOT, VGO, TGO and Hp from GNC OMS MNVR EXEC. BFS GNC SYS SUMM 2 display is used to OSM systems data. As burn termination nears current perigee (HG) approaches targeted HP and delta VTOT approaches 0. Typical burn times are 2-3 minutes.

OMS Cutoff

- +0:02 Secure OMS engines following the automatic purge and trims residual X and Z velocities. Verify RCS switch positions and close OMS HE and crossfeed valves. Initiate maneuver to the EI -5 min attitude. Perform OMS gimbal powerdown.

9.2.5 TutorialShuttle5

Entry Interface

- -32:14 Orbiter reaches EI (400,000ft) at approx 24,600fps and H-dot of approx 500fps. ENTRY TRAJ 1-5, HORIZ SIT, and GNC SYS SUMM 1 displays are monitored. The BFS ENTRY TRAJ display can be used to compare PASS and BFS guidance. The GBS SYS SUMM displays can be used to check system operation.
- -29:35 Automatic elevon trim begins at a q -bar = 0.5 psf
- -28:42 Aerosurface control begins at q -bar = 2.0 psf
- -27:29 Closed loop guidance initiated at q -bar = 8 psf. Guidance box appears on ENTRY TRAJ to indicate closed loop guidance.
- -27:14 Roll RCS jets deactivated at q -bar = -10 psf.
- -26:56 First non-zero bank command issued by guidance at H-dot -240 ft/sec.
- -26:04 Maximum surface temperature region begins.
- -24:10 Pitch RCS jets deactivated at q -bar = 40.
- -20:25 Drag H updates begin in NAV filter at drag = 11 fps².
- -18:34 First roll reversal issued by guidance when azimuth error = ± 10.5 degrees.
- -17:32 Check MPS TVC isolation valves are closed. Pitch and roll RCS activity lights are reconfigured when q -bar = 50 psf to indicate RCS saturation.
- -16:23 PASS and BFS TRAJ displays mode to ENTRY TRAJ 2.
- -15:14 NAVAID power is verified and I/O RESET performed.
- -14:17 PASS and BFS ENTRY TRAJ mode to ENTRY TRAJ 3.
- -13:17 Initiate radiator coldsoak usage in preparation for FES becoming inactive. Radiator bypass valves are placed in automatic and radiator controller loops are put in AUTO.

- -12:54 PASS and BFS ENTRY TRAJ mode to ENTRY TRAJ 4.
- -12:11 Speedbrake opens to 81%.
- -09:33 PASS and BFS ENTRY TRAJ displays mode to GNC ENTRY TRAJ 5.
- -08:44 Begin aileron and rudder trim monitoring.
- -07:14 Check air data using GNC 51 OVRD, GNC 50 HORIZ SIT and instrument tapes.
- -06:34 Software transitions automatically to OPS 305. Guidance enters TAEM phase. VERT SIT 1 displays replace PASS and BFS ENTRY TRAJ displays.
- -06:19 Forward, aft and midbody vents open.
- -04:21 RCS yaw jets are deactivated.
- -03:57 Select pitch, roll and yaw CSS. Speed brake is now controlling energy. PLT flight controller is verified ON.
- -03:14 Verify landing gear extend isolation valve is open. PASS and BFS VERT SIT displays transition to VERT SIT 2. The glide slope indicator GSI is now accurate enough to use.
- -02:14 Upon MLS acquisition all residuals and ratios disappear from PASS GNC 50 HORIZ SIT. An overbright MLS will appear in the middle right of the display. Start landing comm protocol

9.2.6 TutorialShuttle6

Approach and Landing

- -1:14 At 10,000ft verify Approach and Landing guidance (flashing A/L on VERT SIT display), body flap to TRAIL and LES visors down.
- -0:50 Compare ALT 1 vs ALT 2
- -0:39 Check speed brake command percentage.
- -0:33 Initiate preflare and begin transition onto ball bar. Arm landing gear.
- -0:23 Shuttle will be lined up on ball bar. Check speed brake command percentage.
- -0:20 Deploy landing gear. Check gear indications down.
- -0:10 Final flare begins.
- 0:00 Main gear touchdown. Control drift with rudder, maintain wings level with RHC. Check HUD display for WOW lock on (WOWLOM). Velocity vector disappears.
- +0:01 Deploy drag chute.
- +0:02 Initiate beep trim derotation.
- +0:10 Nose gear touchdown. Select SRB SEP to AUTO/MAN or ET SEP to MAN and put the corresponding button to backup automatic discreates for elevon load relief, NWS and anti-skid circuitry. Check elevons down, make sure elevons have load relief and NWS FAIL and anti-skid fail lights off.
- +0:20 Post midfield, apply brakes at 140 knots ground speed or 5000 ft runway remaining.
- +0:32 Jettison drag chute.
- +0:36 Reduce braking to $< 6 \text{ ft/sec}^2$ until wheelstop/
- +0:42 Orbiter stops. Speed brake is closed.

9.3 TutorialsGemini

Gemini Program Missions

- [TutorialGemini1](#) Taking of to orbit
- [TutorialGemini2](#) Rendezvous to the ISS
- [Agena Docking](#) Docking to the ISS
- [Gemini Reentry](#) UnDocking and deorbiting
- [TutorialGemini5](#) Reentry
- [TutorialGemini6](#) Final approach and landing

9.3.1 TutorialGemini1

Space Shuttle Missions

9.3.2 TutorialGemini2

Space Shuttle Missions

9.3.3 Agena Docking

Gemini 8 and Agena Target Docking

Gemini 8 was the most complicated mission to date. The Agena Target Vehicle was launched into orbit. Gemini 8 would follow to catch up to dock.

9.3.4 Gemini Reentry

Gemini Reentry

It became obvious in the early Gemini flights that we would not have enough control in reentry to land on land, where precision was paramount.

Just before reentry the retrograde section is jettisoned, leaving only the cone-shaped capsule containing the crew. All Gemini reentries were completed successfully. Two reentry techniques were developed. The rolling reentry technique was used to steer the spacecraft towards the target. Control was achieved by modulating the lift vector of the spacecraft during reentry. On symmetric bodies such as the Gemini capsule, aerodynamic lift is controlled by changing the center of gravity so that the angle of attack provides the desired lift.

9.3.5 TutorialGemini5

Space Shuttle Missions

9.3.6 TutorialGemini6

Space Shuttle Missions

9.4 Quick Launch Guides

Space travel involves an extraordinary level of complexity. Most advanced orbital maneuvers take a long time to master. Even launching a spacecraft to orbit can be a daunting task, especially if using realistic fuel constraints.

As this game is designed for beginners and advanced users alike, there are different ways to play a missions. Here we have compiled a series of Quick Launch Guides demonstrating the easiest ways to play some of our popular missions:

[Shuttle Launch Guide](#) Shuttle Launch Guide

[Apollo Quick Launch Guide](#) Apollo Launch Guide

9.4.1 Shuttle Launch Guide

The Space Shuttle STS023 Launch mission is a popular mission to start with.

Open the BROWSER, select "Mission/Real Scenario/Space Shuttle Missions/Space Shuttle STS023 Launch" and "Launch Scenario".

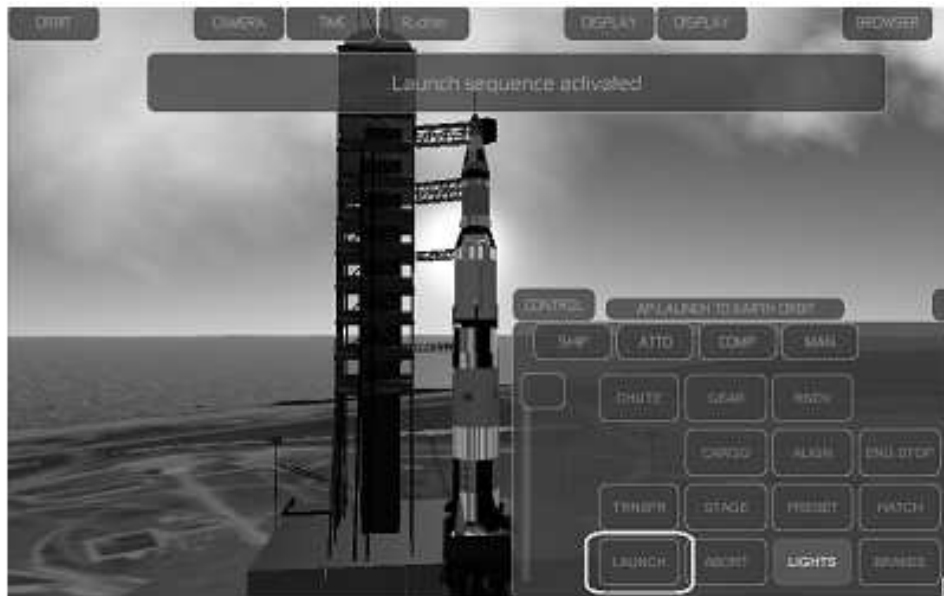
After a brief loading time of 5-15 seconds, depending on your device, you'll see an exterior view of the Shuttle stack on the launch pad ready for takeoff.

Spacecraft are highly optimized machines and they follow carefully designed trajectories to achieve Low Earth Orbit. It is actually incredibly difficult to launch to orbit by any other means than using the pre-programmed onboard computers.

All Space Simulator spacecrafts come with a quick start LAUNCH button. While we encourage use of the 3D virtual cockpits, the "LAUNCH" button is a convenient option to activate the launch sequence.

Bypassing the details of the launch procedure for now, open the "CONTROL" window and select the "SHIP" panel. You will see the "LAUNCH" button

When you are ready, crank up the volume and hit "LAUNCH".



Now simply sit back and enjoy.

Chapter 10

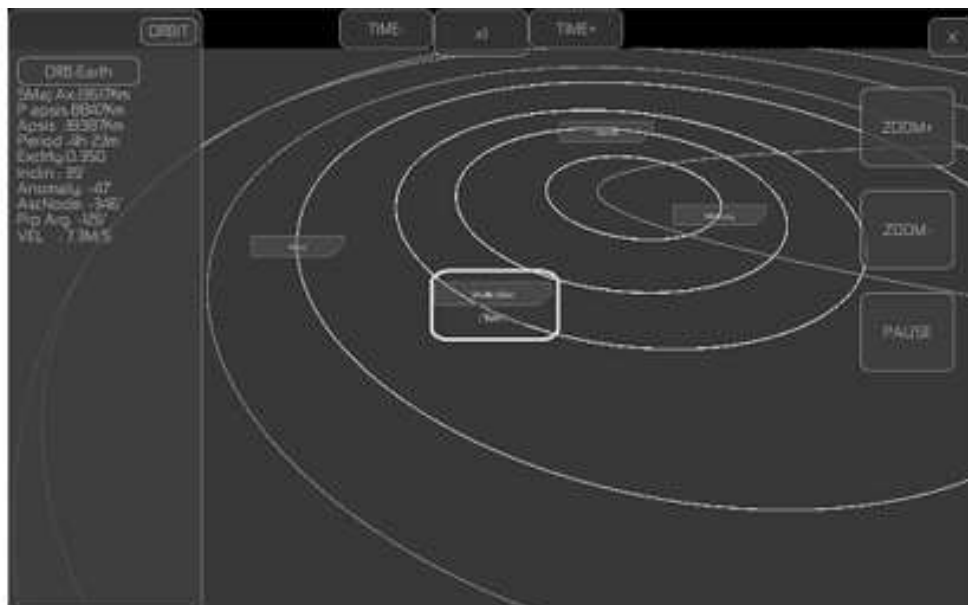
Orbit Planner Introduction

The orbit planner is a powerful tool to plan, design, modify and launch orbits in a schematic view bypassing the need to use the internal cockpits. The orbit planner is designed for beginner and advanced users like, to represent complex orbital maneuvers in a more visually clear format.

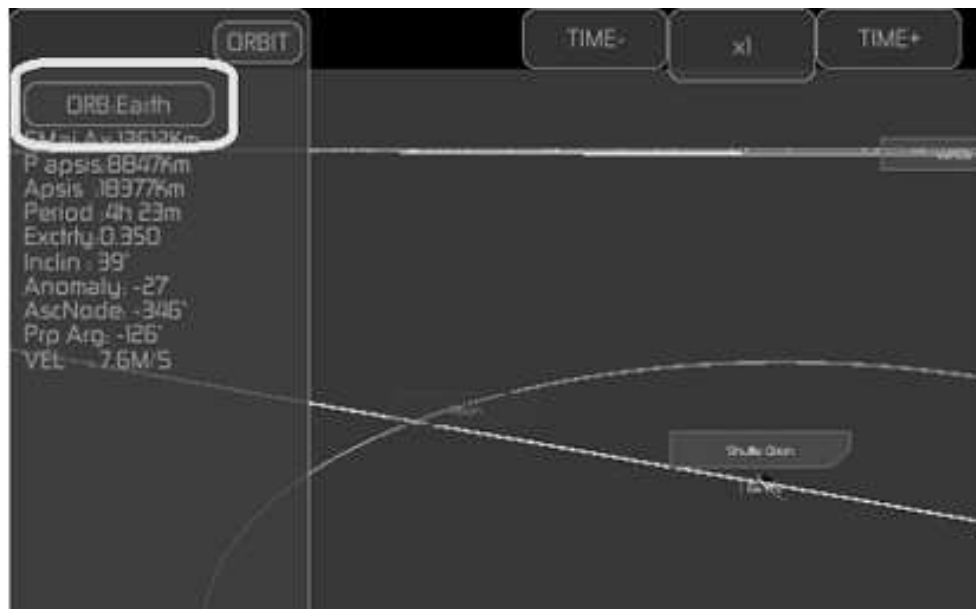
Orbit Planner Panel To open the orbit planner panel, open the "ORBIT" window located at the top-left corner of the screen.



Once the orbit planner panel is open, you will see the analytic orbit paths of each planet in the scene. Zoom in and out to get a sense of your location in the Solar System. In this game all the planets orbit in the same plane, although in reality the Earth's orbit is about 23.4° off the ecliptic plane.

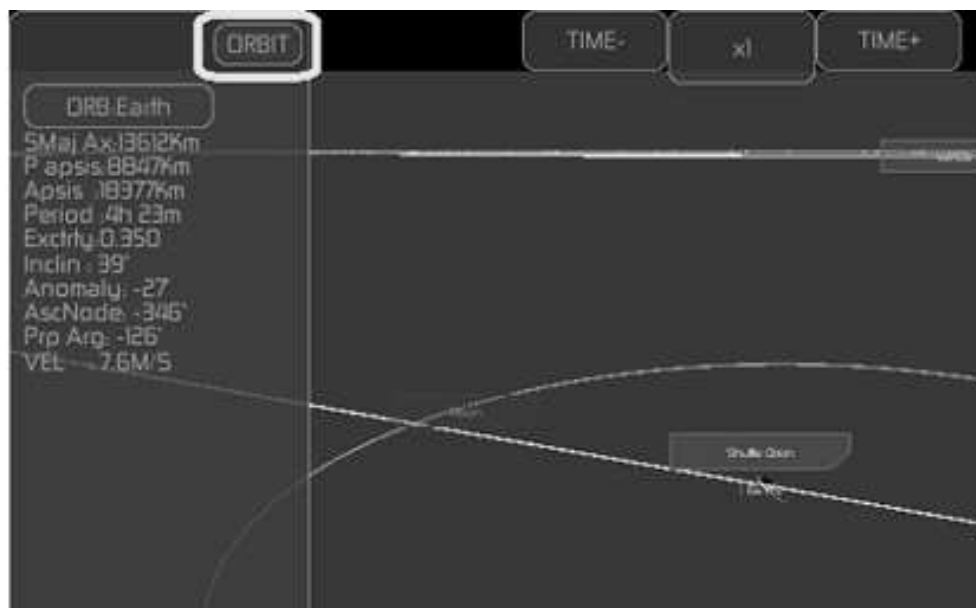


Orbit Reference The "ORB:Earth" button selects the reference of the orbit of your spacecraft. By tapping this button you can see the orbit of your spacecraft from the point of view of the Earth, Moon and Sun.

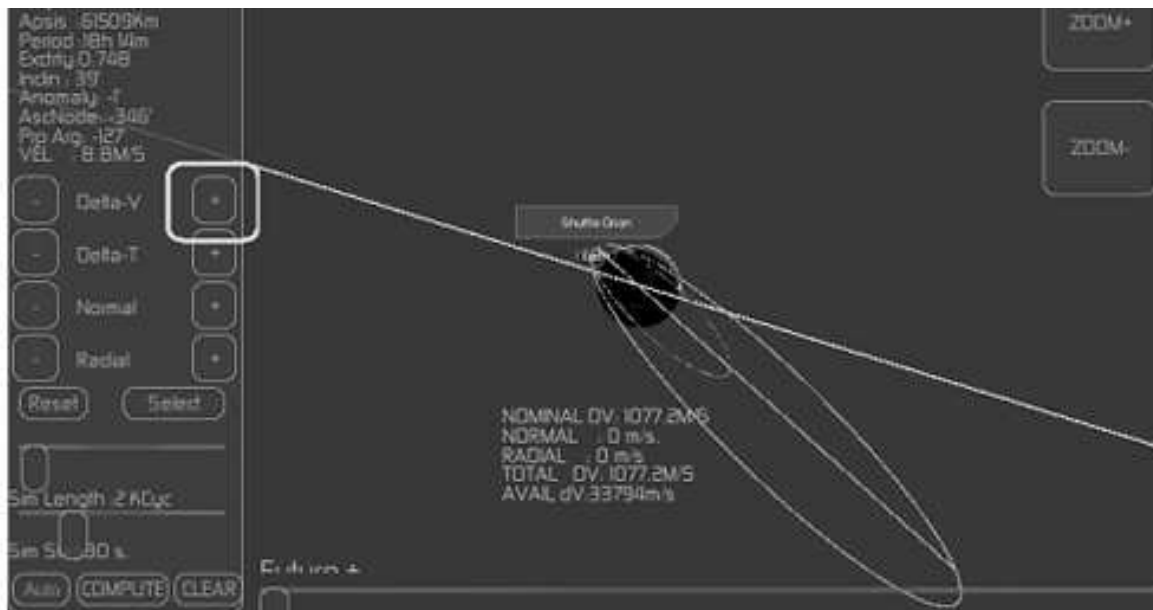


Modify Orbits

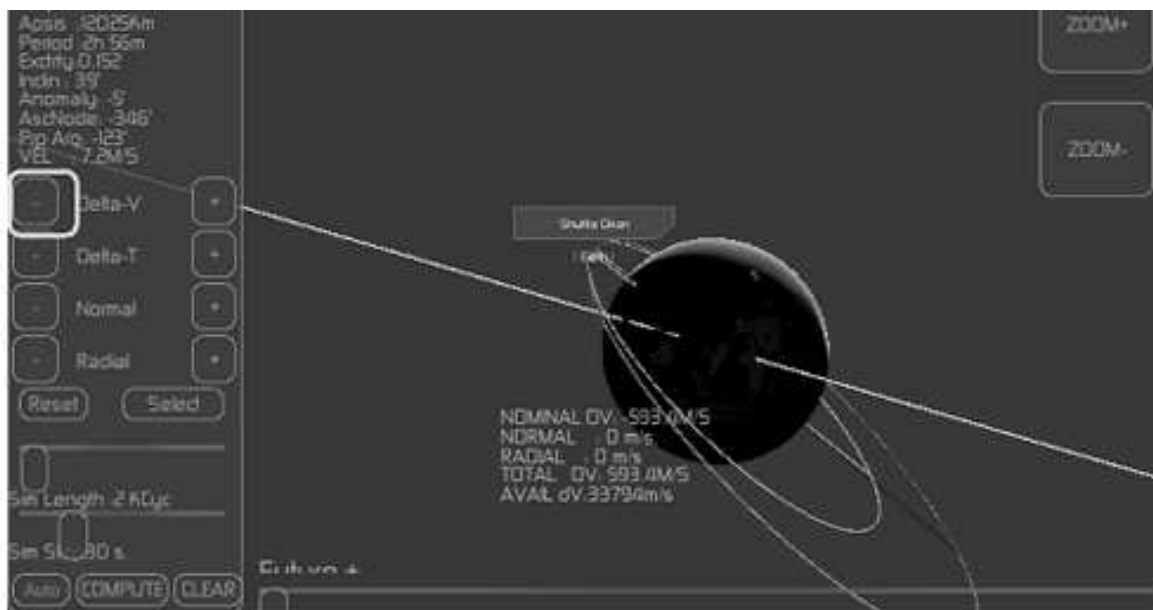
To modify your current orbit, select the "ORBIT" button.



Delta V Delta V refers to the change in velocity of your spacecraft. By increasing the Delta V of your spacecraft you will increase your orbital altitude on the opposite side of the orbit, ie, you can increase the radius of your orbit at the point opposition to where you apply thrust, ie, increase Delta V.



Likewise, by decreasing the Delta V you will reduce the orbital radius at the opposite point.



Learn more about:

[Circularize Orbits](#) Circularize Orbits

[Coplanar Orbits](#) Coplanar Orbits

[Trans Lunar Injection](#) TransLunar Injection

[Free Return Trajectory](#) Free Return Trajectory

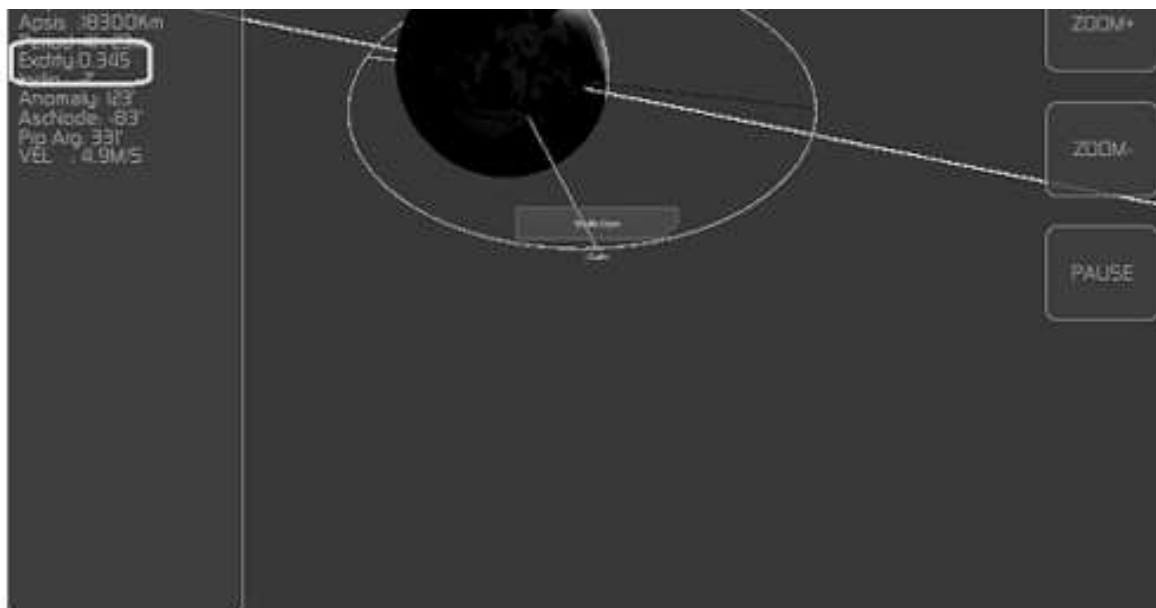
10.1 Circularize Orbits

One of the most useful concepts in orbital mechanics is the **Hohmann Transfer Orbit**. The Hohmann Transfer is the most common way to get a spacecraft to a different orbit. You can use this technique to increase or decrease your orbital altitude, or change the shape of your orbit.

>The most important point to note is that the thrust you apply at any point in the orbit will affect the orbital altitude at the opposite side.

Increasing Delta-V will increase the orbital altitude at the opposite side and decreasing the Delta-V will decrease the orbital altitude at the opposite point of the orbit.

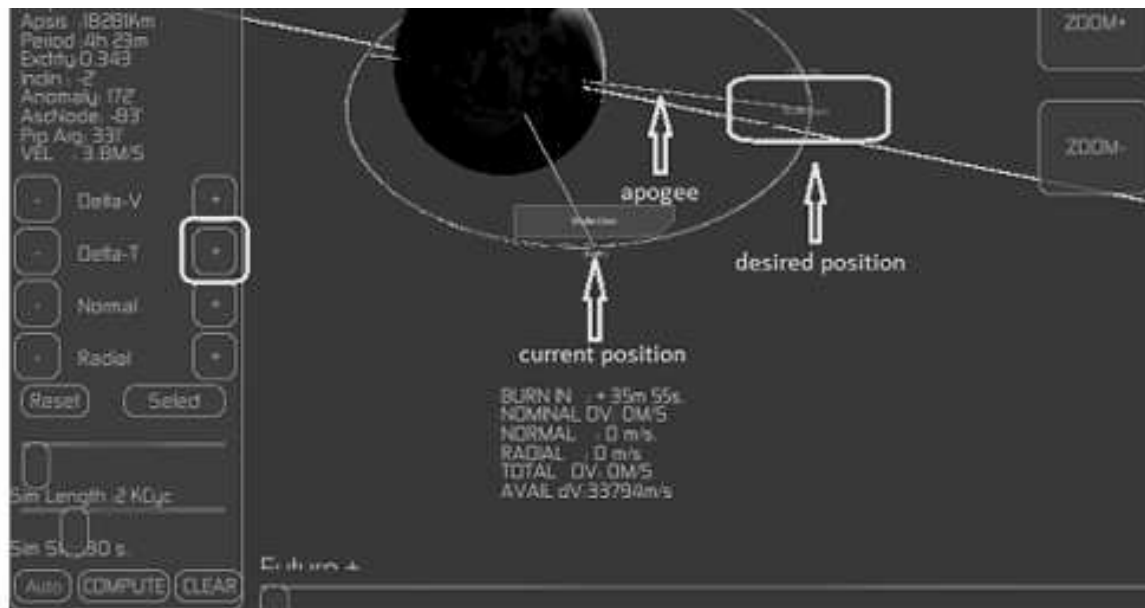
The below example is a custom mission of the Shuttle Orion orbiting Earth. In this example the orbit has already been made coplanar for visual clarity, although this is not necessary. You can circularize and coplanar in any order.



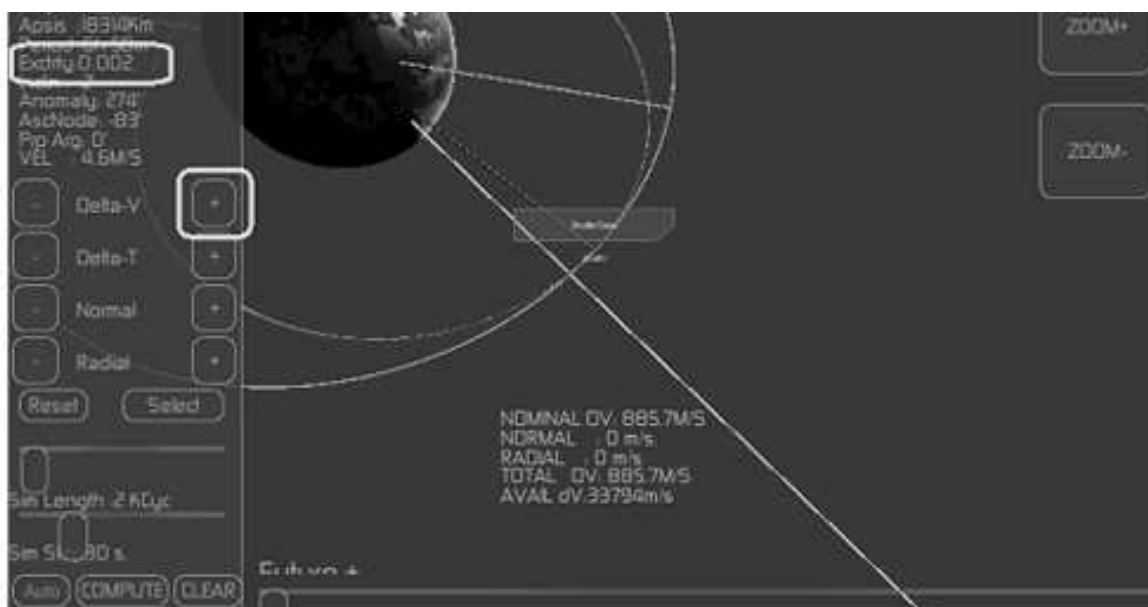
Here we have an orbit with eccentricity of 0.345. A perfectly circular orbit will have eccentricity 0.

There are no ways to circularize this orbit. One is to apply thrust at the farthest point to raise the altitude to the same distance on the opposite side, and the other to brake at the closest point to reduce the altitude of the orbit on the other side. In this example we will do the former.

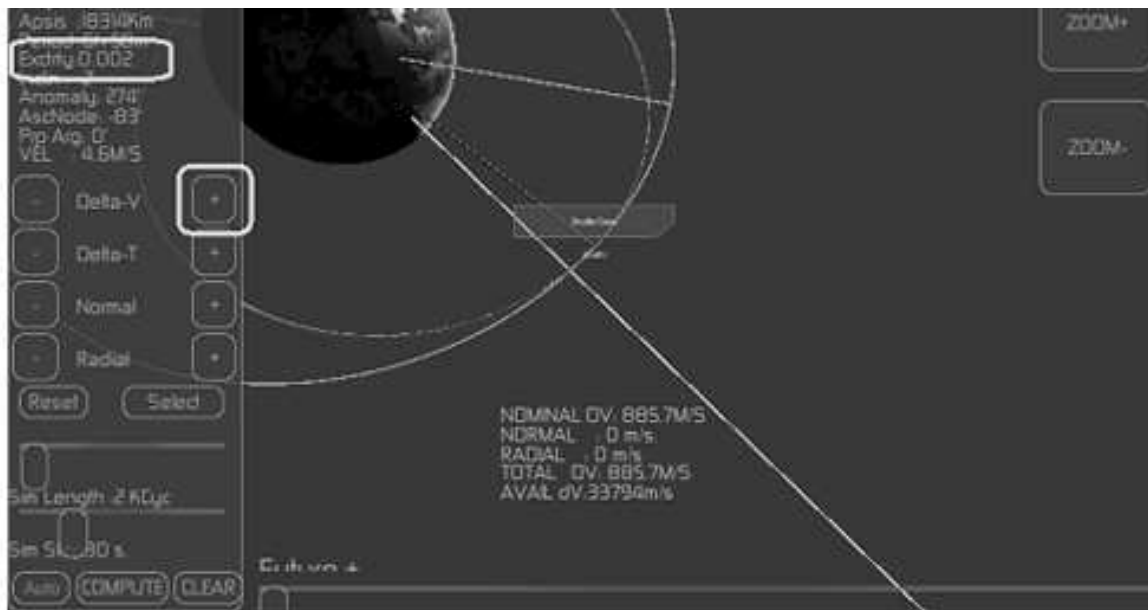
In the "Orbit" panel, increase Delta-T until your shuttle is at the apogee - the point on the orbit where you are the farthest away from the Earth. Hit "Select" to put your shuttle in that point.



Once at the apogee, increase Delta-V until the eccentricity is as close to 0 as possible. How close to 0 you can get depends on how close you managed to get to the apogee. You will see the new orbit grow and circularize.



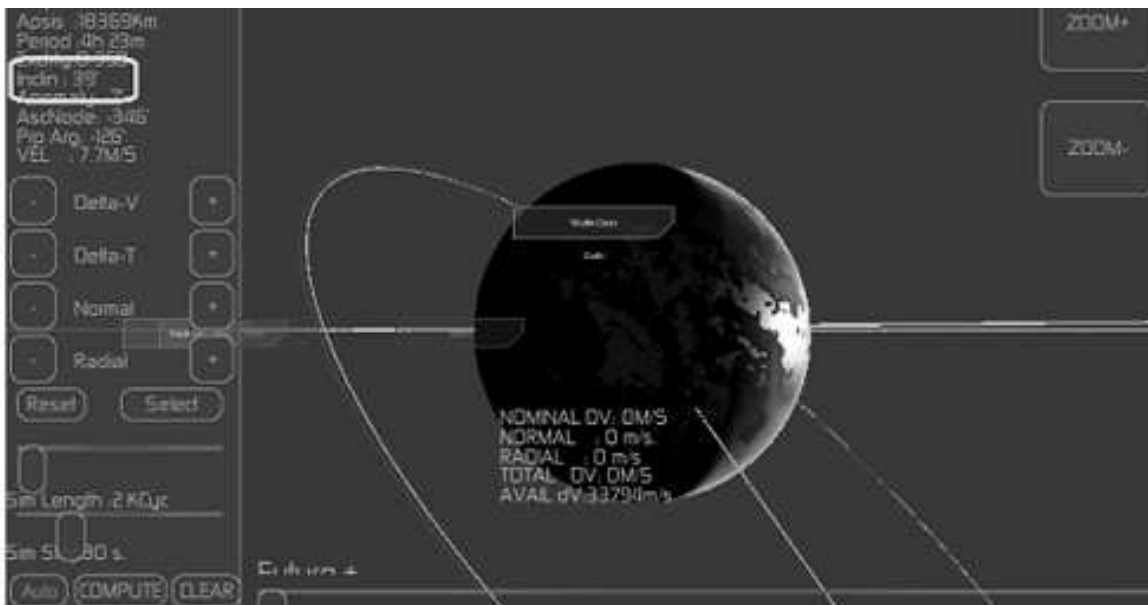
Once you've gotten the minimum eccentricity, hit "Select" to apply the changes and you will have your new circularized orbit.



10.2 Coplanar Orbits

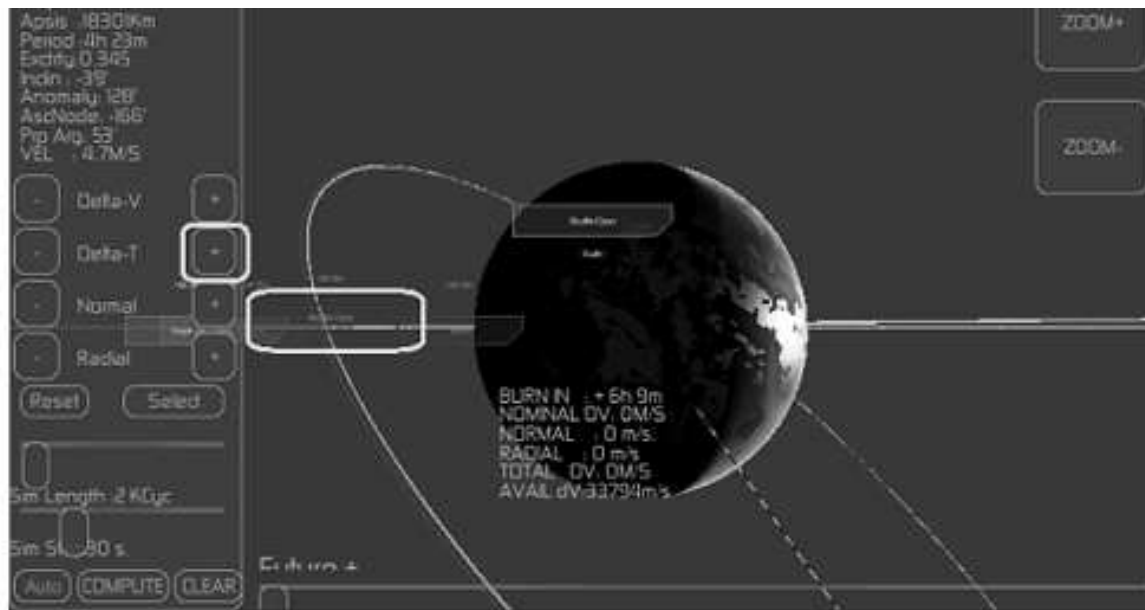
Coplanar orbits are orbits that are in the same plane. In Space Simulator all the planets orbiting the Sun are coplanar, ie, they lie on the same plane. In order to perform any useful orbital maneuvers, you will generally need to align the orbit of your spacecraft with your destination orbit.

Here we will learn to use the Orbit Planner to change the angle of an orbit in order to align it with a particular planet. Below is a typical scenario of a spacecraft orbiting around the Earth at an arbitrary inclination. We know that the orbit of the spacecraft is not coplanar to the ecliptic plane because it has an inclination of 39 degrees.



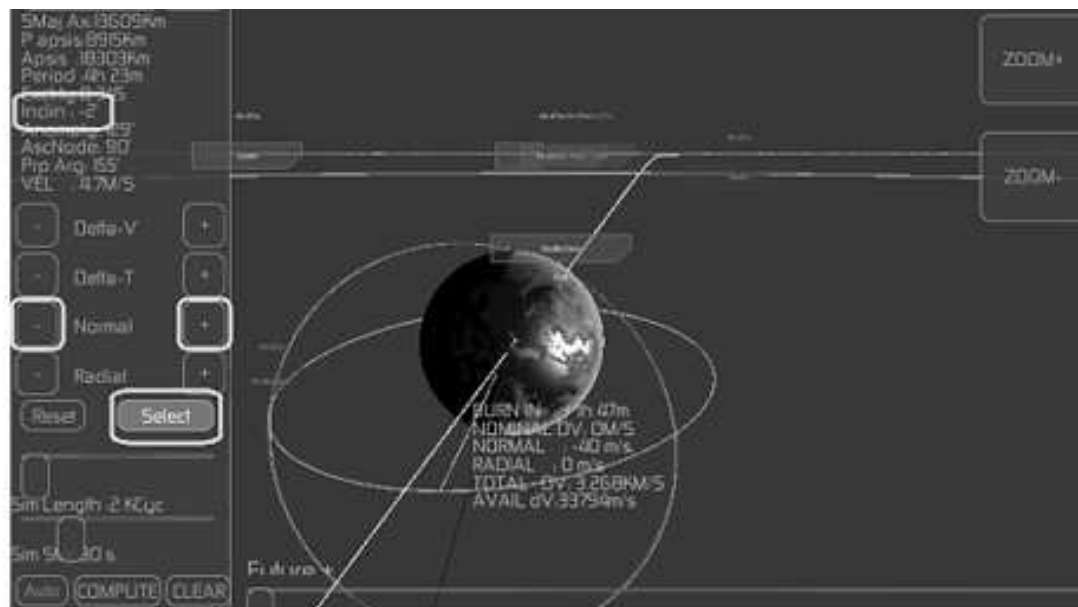
To make our orbit coplanar to the ecliptic plane, we can follow these simple steps:

- 1) Drag and rotate the view so that you visually align the ecliptic plane so that all the orbits are overlapping on one level. This step is not necessary but it later helps to see clearer the points of intersection.
- 2) Our aim is to tilt our orbit until it becomes coplanar with the ecliptic plane. The correct time to tilt our orbit is when our spacecraft **intersects** with the ecliptic plane.



Once you have arranged the view so that you can clearly see where your spacecraft is in relation to the ecliptic plane, hit Delta-T until your shuttle intersects with the ecliptic plane. In the above image the intersection is indicated by the yellow rectangle.

3) Once in that position, change the Normal up or down until your orbit becomes coplanar. The aim is to get the inclination as close to 0 as possible. How close you get to 0 will depend on how well you chose the position of intersection. The more accurately you choose the position of intersection with the ecliptic plane, the more coplanar your orbit will be. You can fine-tune the inclination by adjusting the Delta-T and Normal+/-.



Once you are satisfied with the result, hit "Select" to save the changes and you will be on the new orbit.

10.3 Trans Lunar Injection

Trans Lunar Injection is an orbital maneuver to get your spacecraft from an Earth parking orbit to the Moon. By burning the rocket engines at the appropriate time, we are able to increase Delta-V enough to change a circular orbit to a highly eccentric orbit capturing the Moon on the other side.

In this walkthrough we'll use the custom Earth Shuttle Orion mission scenario. Open Missions/Custom Scenario. Select Earth as the reference and Launch, leaving all other default settings.



We begin our mission with the Shuttle Orion orbiting the Earth in an orbit with eccentricity of 0.35 and inclination of 39 degrees.

A basic TransLunar Injection consists of 4 steps:

STEP 1: make orbit COPLANAR

First thing to do is align our orbit with the ecliptic plane. Move the shuttle forward in time, using either the Delta-T buttons or Time+, until it intersects the ecliptic plane and adjust the normal until the inclination is as close to 0 as possible. For detailed instructions of this step please see the page .CoplanarOrbits.

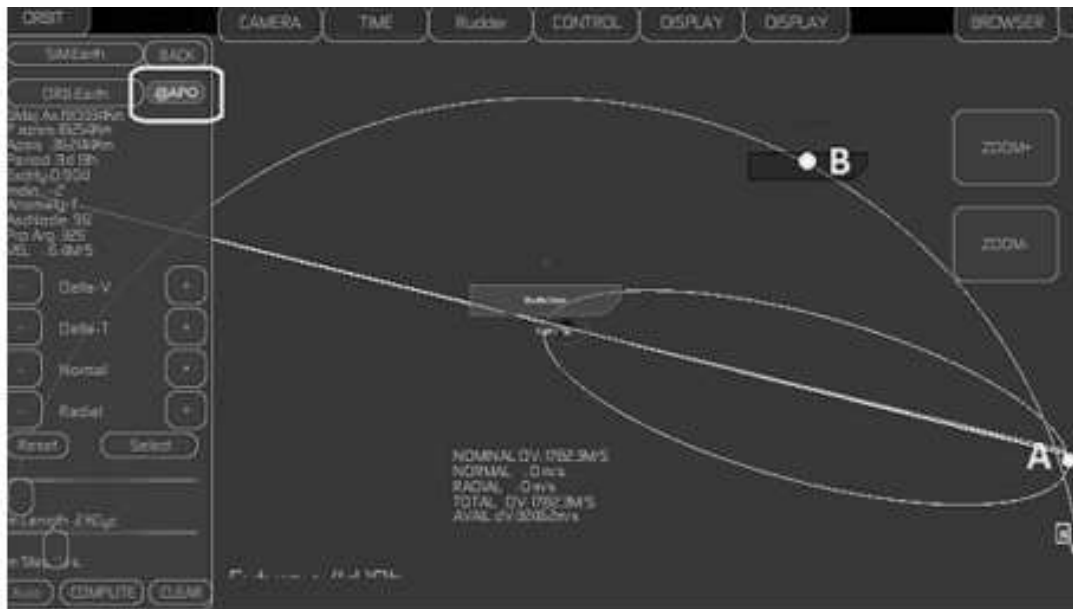
STEP 2: make orbit CIRCULAR

The next step is to circularize our orbit. Move the shuttle to the apogee using either the Delta-T or Time+. Once at the apogee, increase Delta-V until the orbit is circularized. An orbit is circularized when the eccentricity is 0. For detailed instructions of this step please see the page .CircularizeOrbits.

STEP 3: Hohmann Transfer to the Moon

Once our orbit is coplanar and circular we are ready to transfer to the Moon. Increasing Delta-V until the orbit just reaches the Moon on the other side.

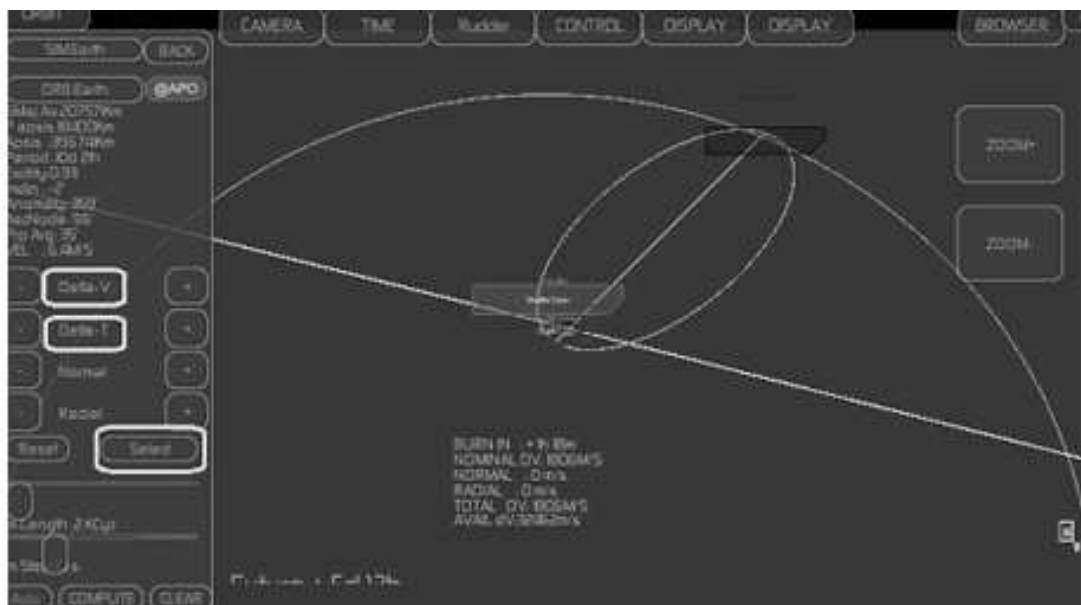
Now we need to find the right combo of Delta-T and Delta-V that takes us to the Moon. For this we need to use the button "APO":



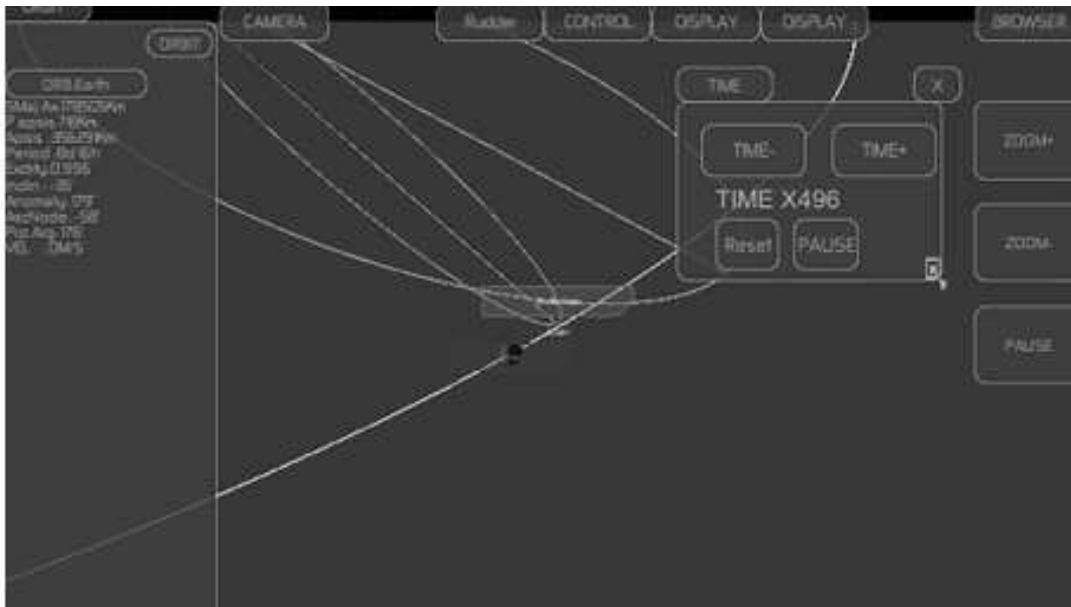
APO shows where the Moon would be when you are at the apogee on the other side of the orbit.

In the above image, using APO we see that by the time we are on far side of the orbit at **Point A**, the Moon will be at **Point B**. In this case, the Moon will have already moved forward by the time we get to the other side of our orbit so we will have missed it.

Now adjust Delta-V and Delta-T until the apogee captures the Moon.

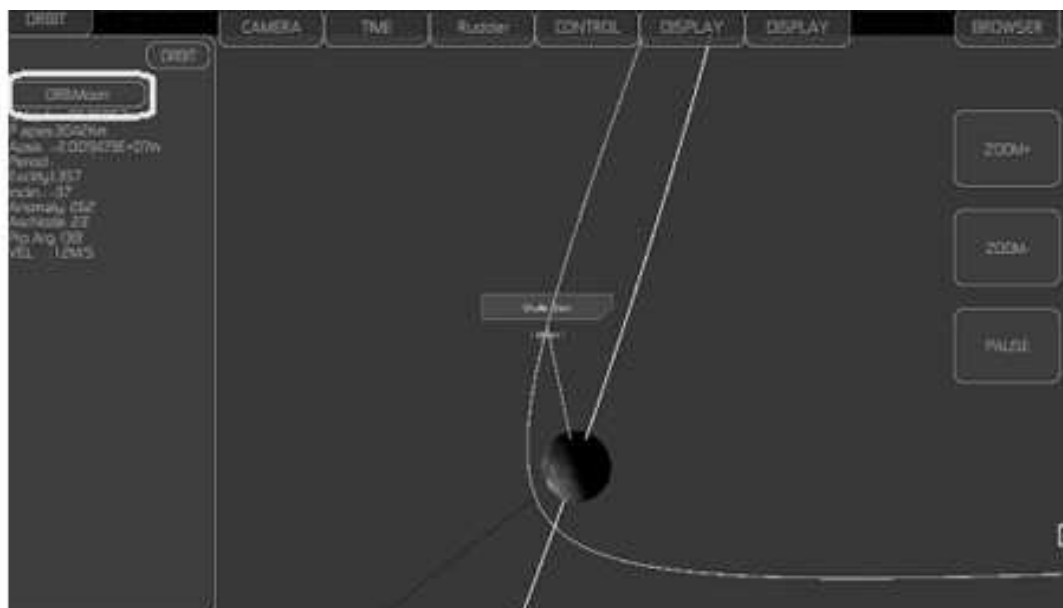


Once you're happy with the positions, hit "Select" to save changes. You are now set for the Moon. Use **Time+** to speed up this part of the journey. Slow down as you approach the Moon, making sure to not overshoot.

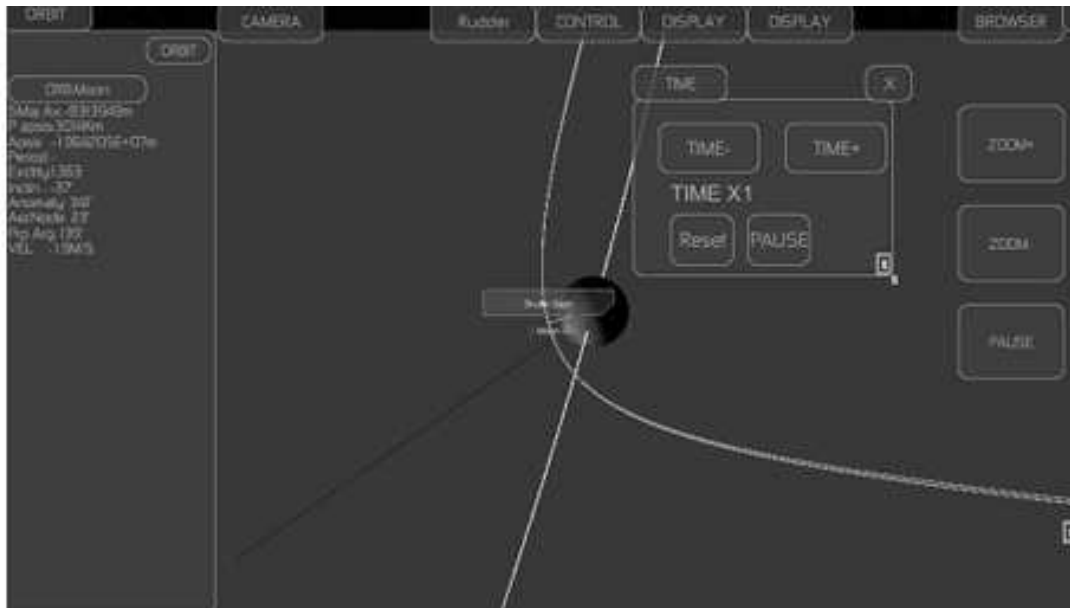


STEP 4: Moon orbit insertion

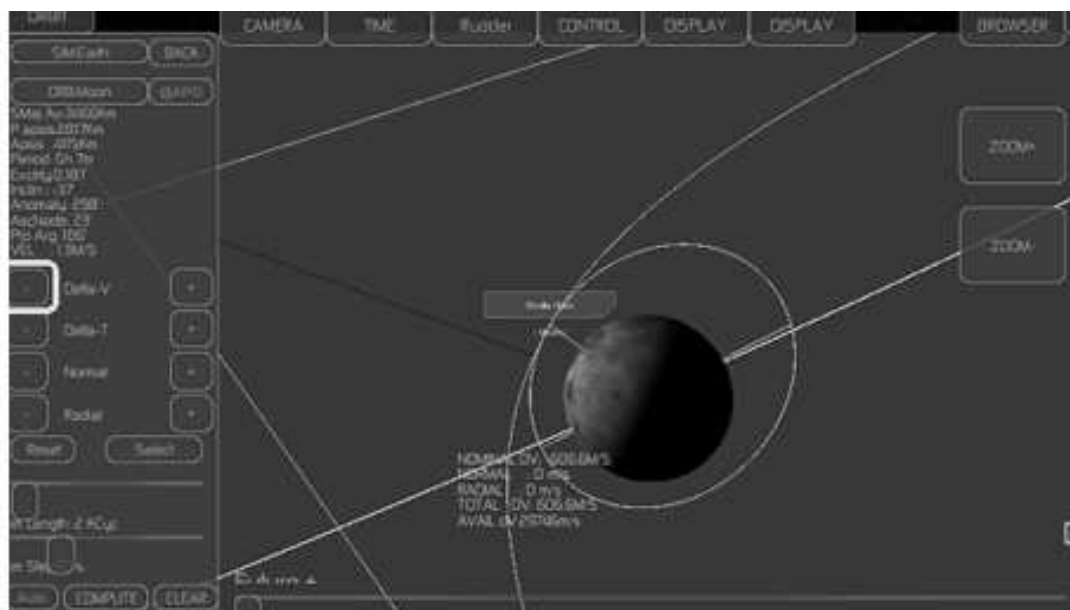
Finally, once you are within range of the Moon orbit, change your orbit reference to Moon.



You will see that you are in a hyperbolic orbit with respect to the Moon. Decrease Delta-V until you have a circular orbit.



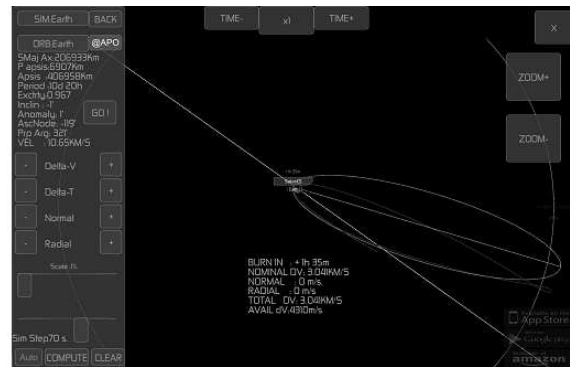
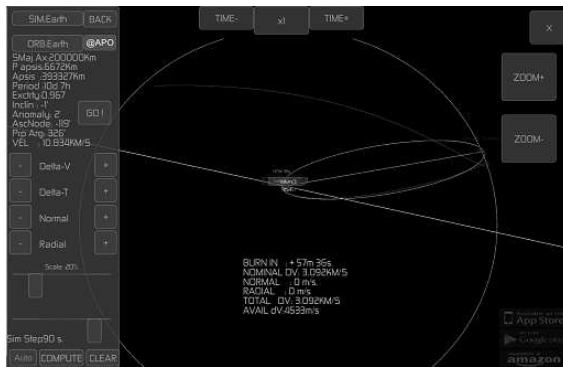
You have now successfully completed your mission.



10.4 Free Return Trajectory

In Apollo 8, 10 and 11 the Earth-Moon free return trajectory was used as a backup method for returning the crew back to Earth.

Using the orbit predictor, we can easily visualize how the free return trajectory is played out. Your trans-lunar injection path will often take the shape of the path in the left image. Decreasing delta-v will wrap the path around the Earth.



Chapter 11

Spacecrafts

Space Simulator comes with a number of different spacecrafts and airplanes. You can choose from historically relevant rockets to futuristic spaceships that allow you to roam the Solar System without much concern for fuel or remaining Delta-V.

- [SpaceCraftSaturnC5](#) Apollo Program SaturnC5 + CSM
- [Apollo Eagle Lander](#) Apollo Program SIVb + LEM
- [Space Shuttle](#) Space Shuttle
- [Gemini](#) Gemini
- [Shuttle Orion](#) Shuttle Orion
- [Space Launch System Block I](#) Space Launch System + Orion CEV
- [Altair Lander](#) Altair lander
- [X15 Experimental Spaceplane](#) X-15 experimental rocket plane

11.1 SpaceCraftSaturnC5

Apollo SpaceCraft



The Saturn V was the most powerful rocket ever designed by NASA in the 60s to take humans to the Moon for the first time.



The Saturn V (spoken as "Saturn five") was an American human-rated expendable rocket used by NASA between 1967 and 1973.[7] The three-stage liquid-fueled super heavy-lift launch vehicle was developed to support the Apollo program for human exploration of the Moon and was later used to launch Skylab, the first American space station. The Saturn V was launched 13 times from the Kennedy Space Center in Florida with no loss of crew or payload. As of 2017, the Saturn V remains the tallest, heaviest, and most powerful (highest total impulse) rocket ever brought to operational status, and holds records for the heaviest payload launched and largest payload capacity to low Earth orbit (LEO) of 140,000 kg (310,000 lb), which included the third stage and unburned propellant needed to send the Apollo Command/Service Module and Lunar Module to the Moon.[5][6] The largest production model of the Saturn family of rockets, the Saturn V was designed under the direction of Wernher von Braun and Arthur Rudolph at the Marshall Space Flight Center in Huntsville, Alabama, with Boeing, North American Aviation, Douglas Aircraft Company, and IBM as the lead contractors. To date, the Saturn V remains the only launch vehicle to launch missions to carry humans beyond low Earth orbit. A total of 15 flight-capable vehicles were built, but only 13 were flown. An additional three vehicles were built for ground testing purposes. A total of 24 astronauts were launched to the Moon, three of them twice, in the four years spanning December 1968 through December 1972. Saturn V refers to the rocket vehicle as a whole. It is formed by the Launch Vehicle (LV) and the Apollo SpaceCraft , commonly referred as the command & service module (CSM)

Apollo's Launch Vehicle

STAGE 1:



Stage one carried the rocket to 42 miles (68 miles) into the air and the empty fuel tank discarded. Fuelled with jet fuel/diesel and liquid oxygen , the 5 F-1 rockets are still the largest liquid fuelled rocket engines ever made. The S-IC was built by the Boeing Company at the Michoud Assembly Facility, New Orleans, where the Space Shuttle External Tanks would later be built by Lockheed Martin. Most of its mass at launch was propellant, RP-1 fuel with

liquid oxygen as the oxidizer.[22] It was 138 feet (42 m) tall and 33 feet (10 m) in diameter, and provided over 7,600,000 pounds-force (34,000 kN) of thrust. The S-IC stage had a dry weight of about 289,000 pounds (131 metric tons) and fully fueled at launch had a total weight of 5,100,000 pounds (2,300 metric tons). It was powered by five Rocketdyne F-1 engines arrayed in a quincunx (five units, with four arranged in a square, and the fifth in the center). The center engine was held in a fixed position, while the four outer engines could be hydraulically turned (gimballed) to steer the rocket.[22] In flight, the center engine was turned off about 26 seconds earlier than the outboard engines to limit acceleration. During launch, the S-IC fired its engines for 168 seconds (ignition occurred about 8.9 seconds before liftoff) and at engine cutoff, the vehicle was at an altitude of about 36 nautical miles (67 km), was downrange about 50 nautical miles (93 km), and was moving about 7,500 feet per second (2,300 m/s).[23]

STAGE 2:



Stage two took the spacecraft to just below Earth orbit and discarded. Fuelled by liquid hydrogen and oxygen, it made the better part of the lifting to Earth Orbit. The five J-2 rockets, among the most efficient rocket engines ever made, were started well outside the atmosphere, above 50 km, so they could be finetuned to space environment. The S-II was built by North American Aviation at Seal Beach, California. Using liquid hydrogen and liquid oxygen, it had five Rocketdyne J-2 engines in a similar arrangement to the S-IC, also using the outer engines for control. The S-II was 81 feet 7 inches (24.87 m) tall with a diameter of 33 feet (10 m), identical to the S-IC, and thus was the largest cryogenic stage until the launch of the Space Shuttle in 1981. The S-II had a dry weight of about 80,000 pounds (36,000 kg) and fully fueled, weighed 1,060,000 pounds (480,000 kg). The second stage accelerated the Saturn V through the upper atmosphere with 1,100,000 pounds-force (4,900 kN) of thrust in vacuum. When loaded, significantly more than 90 percent of the mass of the stage was propellant; however, the ultra-lightweight design had led to two failures in structural testing. Instead of having an intertank structure to separate the two fuel tanks as was done in the S-IC, the S-II used a common bulkhead that was constructed from both the top of the LOX tank and bottom of the LH2 tank. It consisted of two aluminum sheets separated by a honeycomb structure made of phenolic resin. This bulkhead had to insulate against the 126 °F (70 °C) temperature gradient between the two tanks. The use of a common bulkhead saved 7,900 pounds (3.6 t). Like the S-IC, the S-II was transported from its manufacturing plant to the Cape by sea.

STAGE 3:



The 3rd Stage (also known as Saturn IVb) , had a dual purpose :

- To finish lifting the Apollo Spacecraft , etc.. to Earth parking orbit
- To perform a second firing of the single J-2 Engine , to help the apollo stack to achieve trans lunar injection, that is , propell the spacecraft to an orbit high enough that can be trapped by the moon's gravity .

The S-IVB was built by the Douglas Aircraft Company at Huntington Beach, California. It had one J-2 engine and used the same fuel as the S-II. The S-IVB used a common bulkhead to separate the two tanks. It was 58 feet 7 inches (17.86 m) tall with a diameter of 21 feet 8 inches (6.604 m) and was also designed with high mass efficiency, though not quite as aggressively as the S-II. The S-IVB had a dry weight of about 23,000 pounds (10,000 kg) and, fully fueled, weighed about 262,000 pounds (119,000 kg).[24] The S-IVB-500 model used on the Saturn V differed from the S-IVB-200 used as the second stage of the Saturn IB, in that the engine was restartable once per mission. This was necessary as the stage would be used twice during a lunar mission: first in a 2.5 min burn for the orbit insertion after second stage cutoff, and later for the trans-lunar injection (TLI) burn, lasting about 6 min. Two liquid-fueled Auxiliary Propulsion System (APS) units mounted at the aft end of the stage were used for attitude control during the parking orbit and the trans-lunar phases of the mission. The two APSs were also used as ullage engines to settle the propellants in the aft tank engine feed lines prior to the trans-lunar injection burn.

Apollo SpaceCraft

Service Module:



The big chunk of the apollo SpaceCraft, provides propulsion, rotation ,electricity , power, water , . . . The entire module is discarded prior to Reentry.

Command Module:



The only part of the spacecraft to return to Earth , houses the Astronauts , and a few equipment critical for reentry.

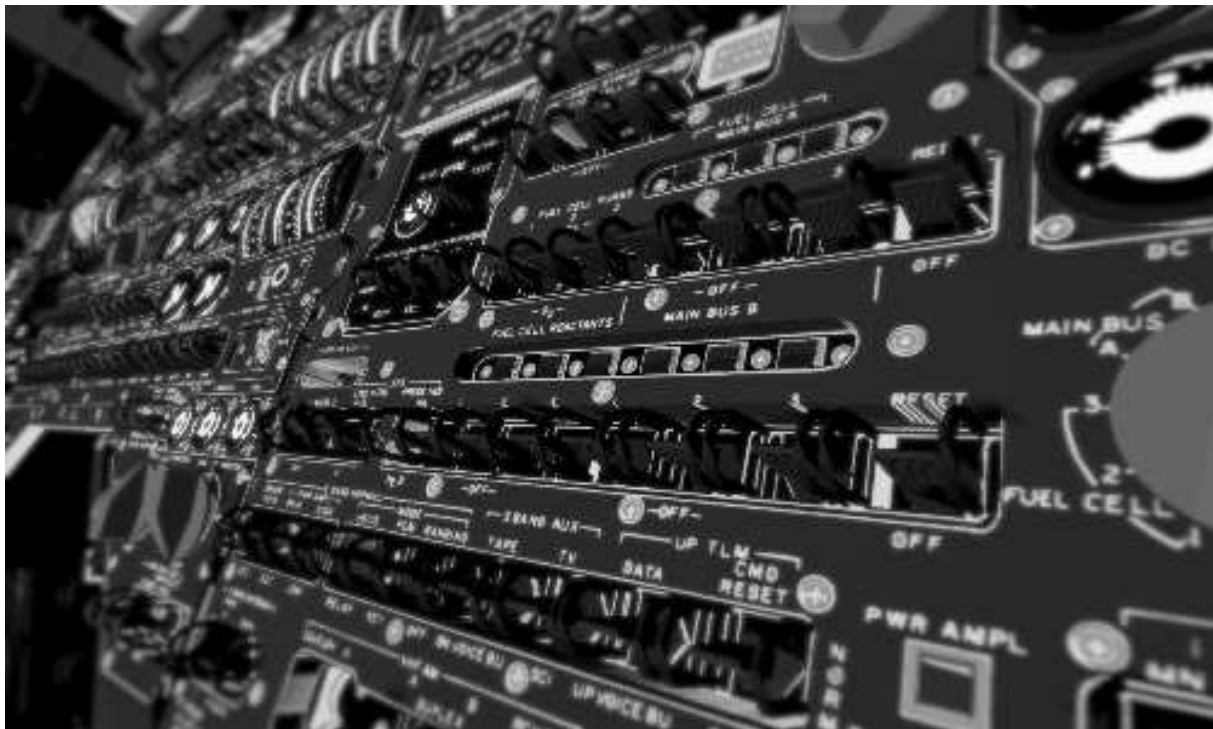
Due to the tremendous complexity of the controls of the Apollo Spacecraft , we have divided into functional sections ie : Service Engine or Electrical Subsystem. However those systems are deeply interconnected , so be sure to read all the control documentation to understand the whole of the sub-systems controls & instruments.

The Command Module was a truncated cone (frustum) 10 feet 7 inches (3.23 m) tall with a diameter of 12 feet 10 inches (3.91 m) across the base. The forward compartment contained two reaction control engines, the docking tunnel, and the components of the Earth Landing System. The inner pressure vessel housed the crew accommodations, equipment bays, controls and displays, and many spacecraft systems. The last section, the aft compartment, contained 10 reaction control engines and their related propellant tanks, fresh water tanks, and the CSM umbilical cables.

[ApolloSpaceCraftControls](#) Apollo Controls

11.1.1 ApolloSpaceCraftControls

Apollo SpaceCraft Controls



There are hundreds of controls and displays located in the cabin of the Apollo command module. A majority of these are on the main display console, which faces the three crew couches and extends on both sides of them. The console is nearly seven feet long and three feet high, with the two wings each about three feet wide and two feet deep. The console is the heart of the command module: on it are the switches, dials, meters, circuit breakers, and other controls and displays through which the three-man crew will control the spacecraft and monitor its performance. Crew members can see and operate controls on the console while in their restraint harnesses. Other displays and controls are placed throughout the cabin in the various equipment bays and on the crew couches. In general, these are controls and displays that do not need frequent attention or are used during parts of the mission when crewmen can be out of the couches. Most of the guidance and navigation equipment is in the lower equipment bay, at the foot of the center couch. This equipment, including the sextant and telescope, is operated by an astronaut standing and using a simple restraint system. The non-time-critical controls of the environmental control system are

located in the left-hand equipment bays, while all the controls of the waste management system are on a panel in the right-hand equipment bay. The rotation and translation controllers used for attitude, thrust vector, and translation maneuvers are located on the arms of two crew couches. In addition, a rotation controller can be mounted at the navigation position in the lower equipment bay. The main display console has been arranged to provide for the expected duties of crew members. These duties fall into the categories of commander, CM pilot, and LM pilot, occupying the left, center, and right couches, respectively. The CM pilot, in the center couch, also acts as the principal navigator. While each astronaut has a primary responsibility, each Apollo crewman also must know all the controls and displays in the spacecraft. During a mission each might at some time take over the duties of the other crewmen: during sleep or rest periods, while other crewmen are occupied with the LAUNCH VEHICLE EMERGENCY DETECTION • PROPELLANT GAUGING • FLIGHT ATTITUDE • ENVIRONMENT CONTROL • MISSION SEQUENCE • COMMUNICATIONS CONTROL • VELOCITY CHANGE MONITOR • POWER DISTRIBUTION • ENTRY MONITOR, and, of course, during an emergency. Flight controls are located on the left-center and left side of the main display console, opposite the commander. These include controls for such subsystems as stabilization and control, propulsion, crew safety, earth landing, and emergency detection. One of two guidance and navigation computer panels also is located here, as are velocity, attitude, and altitude indicators. The astronaut in the center couch (CM pilot) faces the center of the console, and thus can reach many of the flight controls, as well as the system controls on the right side of the console. Displays and controls directly opposite him include reaction control propellant management, caution and warning, environmental control and cryogenic storage subsystems. The right-hand (LM pilot's) couch faces the right-center and right side of the console. Communications, electrical control, data storage, and fuel cell subsystem components are located here, as well as service propulsion subsystem propellant management. All controls have been designed so they can be operated by astronauts wearing gloves. The controls are predominantly of four basic types: toggle switches, rotary switches with click-stops (detents), thumbwheels, and push buttons. Critical switches are guarded so that they cannot be thrown inadvertently. In addition, some critical controls have locks that must be released before they can be operated.

These are the main spacecraft systems..

- [ControlAndWarningSystem](#) Control And Warning System.
- [ElectricalControlSystem](#) Electrical Control System
- [EnviromentalControlSystem](#) Enviromental control system
- [GuidanceAndNavigationSystem](#) Guidance and Navigation system
- [ReactionControlSystem](#) Reaction Control System
- [SequentialSystem](#) Sequential System
- [ServicePropulsionSystem](#) Service Propulsion system (Main Engine)
- [StabilizationAndControlSystem](#) Stabilization and controls system.
- [TelecommunicationsSystem](#) Telecommunications System.

11.1.1.1 [ControlAndWarningSystem](#)

Control and Warning System

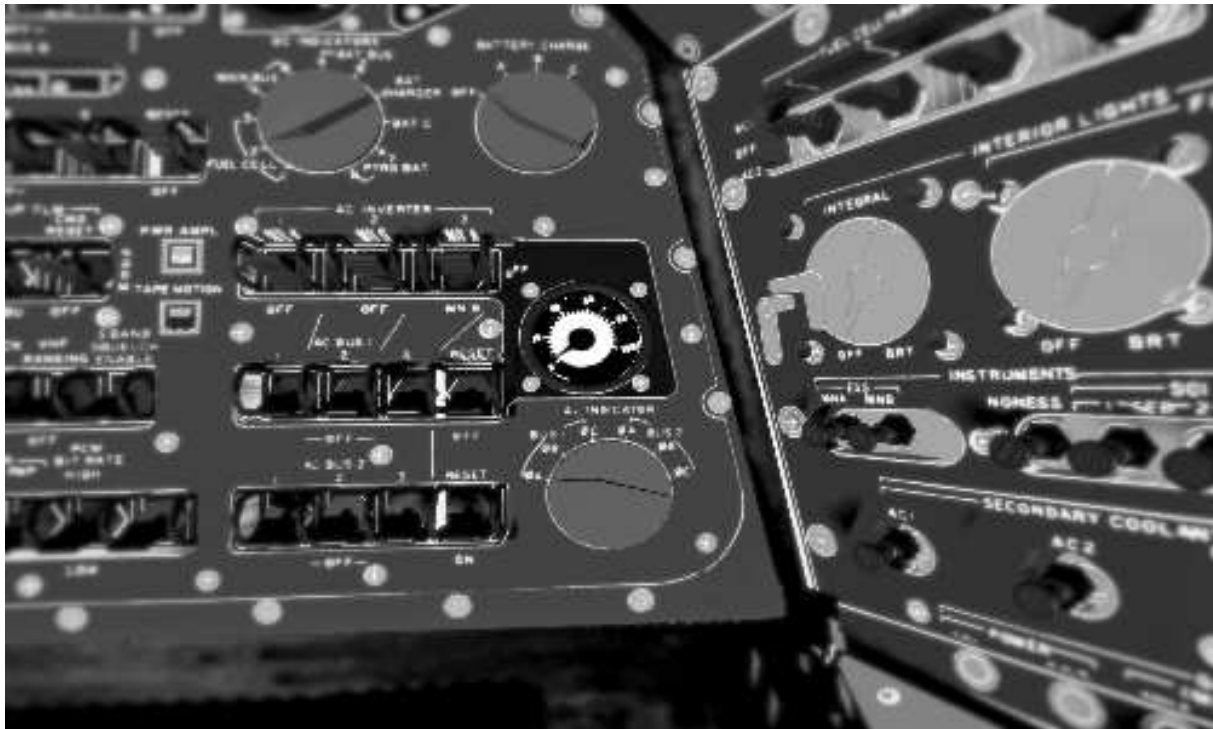
Critical conditions of most spacecraft systems are monitored by a caution and warning system. A malfunction or out-of-tolerance condition results in illumination of a status light that identifies the abnormality. It also activates the master alarm circuit, which illuminates two master alarm lights on the main display console and one in the lower equipment bay and sends an alarm tone to the astronauts' headsets. The master alarm lights and tone continue until a crewman resets the master alarm circuit. This can be done before the crewmen deal with the problem indicated. The caution and warning system also contains equipment to sense its own malfunction.

11.1.1.2 ElectricalControlSystem

Electrical Control System



Electrical power was produced by three fuel cells, each measuring 44 inches (1.1 m) tall by 22 inches (0.56 m) in diameter and weighing 245 pounds (111 kg). These combined hydrogen and oxygen to generate electrical power, along with some of the water used for drinking and other purposes. The cells were fed by two hemispherical-cylindrical 31.75-inch (0.806 m) diameter tanks, each holding 29 pounds (13 kg) of liquid hydrogen, and two spherical 26-inch (0.66 m) diameter tanks, each holding 326 pounds (148 kg) of liquid oxygen (which also supplied the environmental control system). On the flight of Apollo 13, the EPS was disabled by an explosive rupture of one oxygen tank, which punctured the second tank and led to the loss of all oxygen. After the accident, a third oxygen tank was added to prevent operation below 50% tank capacity which allowed removal of the tank's internal stirring fan equipment, which had contributed to the failure. Also starting with Apollo 14, a 400 Ah auxiliary battery was added to the SM for emergency use. Apollo 13 had drawn heavily on its entry batteries in the first hours after the explosion, and while this new battery could not power the CM for more than 5–10 hours it would buy time in the event of a temporary loss of all three fuel cells. Such an event occurred when Apollo 12 was struck twice by lightning during launch.



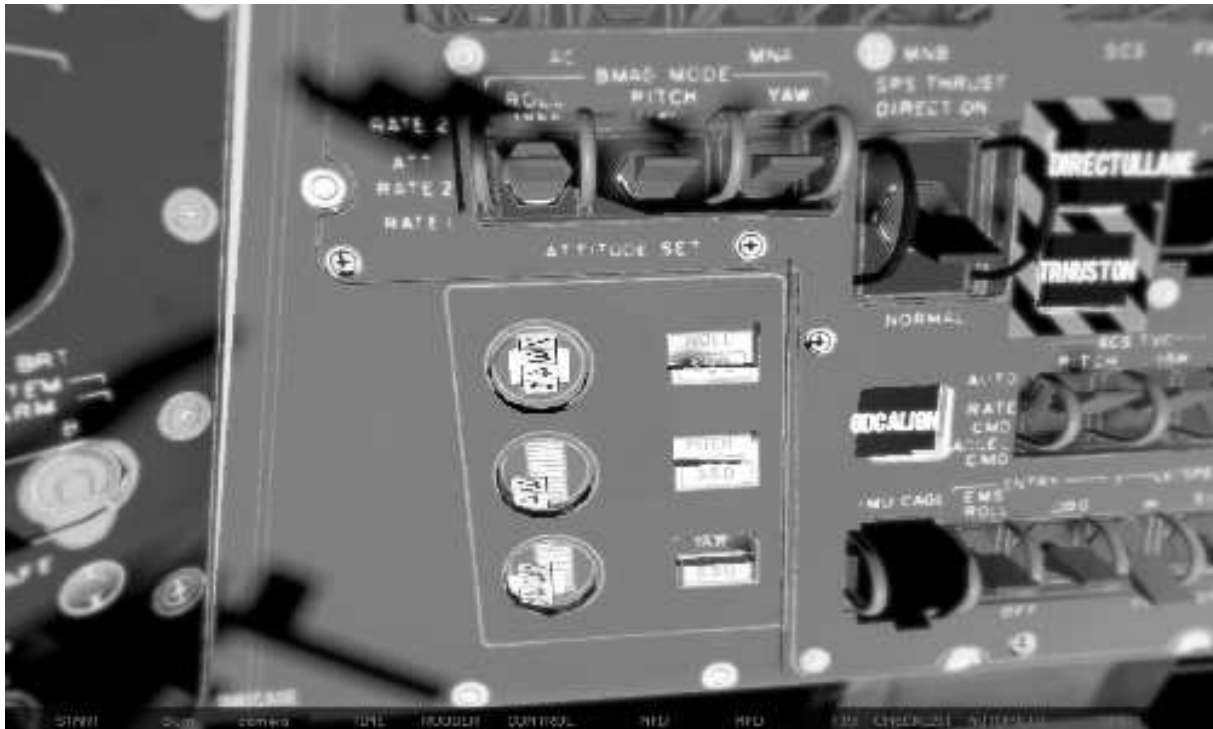
11.1.1.3 EnviromentalControlSystem

Enviromental Control System

Cabin atmosphere was maintained at 5 pounds per square inch (34 kPa) of pure oxygen from the same liquid oxygen tanks that fed the electrical power system's fuel cells. Potable water supplied by the fuel cells was stored for drinking and food preparation. A thermal control system using a mixture of water and ethylene glycol as coolant dumped waste heat from the CM cabin and electronics to outer space via two 30-square-foot (2.8 m²) radiators located on the lower section of the exterior walls, one covering sectors 2 and 3 and the other covering sectors 5 and 6.[15]

11.1.1.4 GuidanceAndNavigationSystem

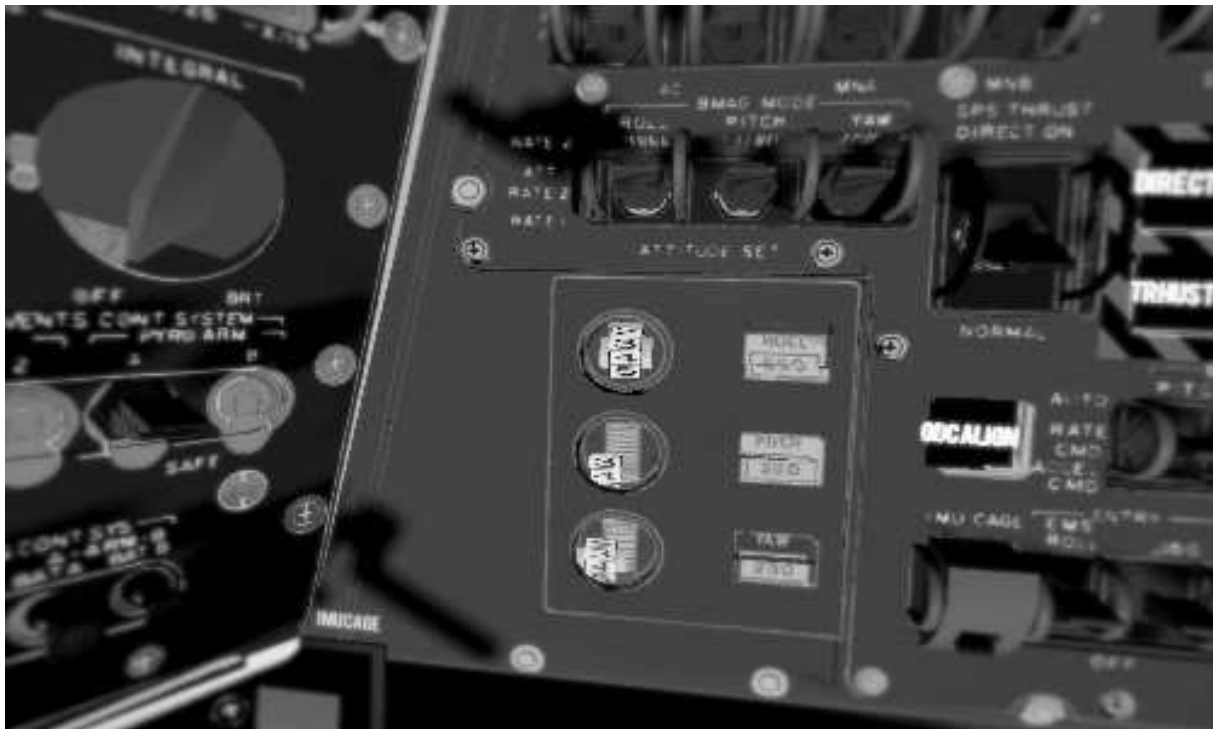
Guidance And Navigation System



The Apollo Primary Guidance, Navigation and Control System (PGNCS) (pronounced pings) was a self-contained inertial guidance system that allowed Apollo spacecraft to carry out their missions when communications with Earth were interrupted, either as expected, when the spacecraft were behind the Moon, or in case of a communications failure. The Apollo Command Module (CM) and Lunar Module (LM), were each equipped with a version of PGNCS.

PGNCS, and specifically its computer, were also the command center for all system inputs from the LM, including the Kollsman Instrument built Alignment Optical Telescope, the radar system, the manual Translation and Rotation device inputs by the astronauts as well as other inputs from the LM systems. PGNCS was developed by the MIT Instrumentation Laboratory. The Prime Contractor for PGNCS and manufacturer of the Inertial Measurement Unit, IMU was the Delco Division of General Motors. Development was under the direction of Charles Stark Draper and MIT Draper Labs and consisted of the following components:

*an Inertial Measurement Unit (IMU) *the Apollo Guidance Computer *resolvers to convert inertial platform angles to signals usable for servo control *an optical unit *a mechanical frame, called the Navigation Base (or Navbase), to rigidly connect the optical device and, in the LM, the rendezvous radar to the IMU *the AGC software



11.1.1.5 ReactionControlSystem

Reaction Control System

Four clusters of four reaction control system (RCS) thrusters were installed around the upper section of the SM every 90°. The sixteen-thruster arrangement provided rotation and translation control in all three spacecraft axes. Each R-4D thruster generated 100 pounds-force (440 N) of thrust, and used monomethylhydrazine (MMH) as fuel and nitrogen tetroxide (NTO) as oxidizer. Each quad assembly measured 8 by 3 feet (2.44 by 0.91 m) and had its own fuel tanks, oxidizer tanks, helium pressurant tank, and associated valves and regulators. Each cluster of thrusters had its own independent primary fuel (MMH) tank containing 69.1 pounds (31.3 kg), secondary fuel tank containing 45.2 pounds (20.5 kg), primary oxidizer tank containing 137.0 pounds (62.1 kg), and secondary oxidizer tank containing 89.2 pounds (40.5 kg). The fuel and oxidizer tanks were pressurised by a single liquid helium tank containing 1.35 pounds (0.61 kg).[13] Back flow was prevented by a series of check valves, and back flow and ullage requirements were resolved by containing the fuel and oxidizer in Teflon bladders which separated the propellants from the helium pressurant.[14] All of the elements were duplicated, resulting in four completely independent RCS clusters. Only two adjacent functioning units were needed to allow compete for attitude control.[14] The Lunar Module used a similar four-quad arrangement of the identical thruster engines for its RCS.

11.1.1.6 SequentialSystem

Sequential System

Sequential systems include certain detection and control subsystems , of the launch vehicle (LV) and the Apollo spacecraft (SC) . They are utilized during launch preparations, ascent, and entry portions of a mission, preorbital aborts, early mission terminations, docking maneuvers and SC separation sequences.

Requirements of the sequential systems are achieved by integrating several subsystems.

Part of the elements controlled by the Sequential events system are

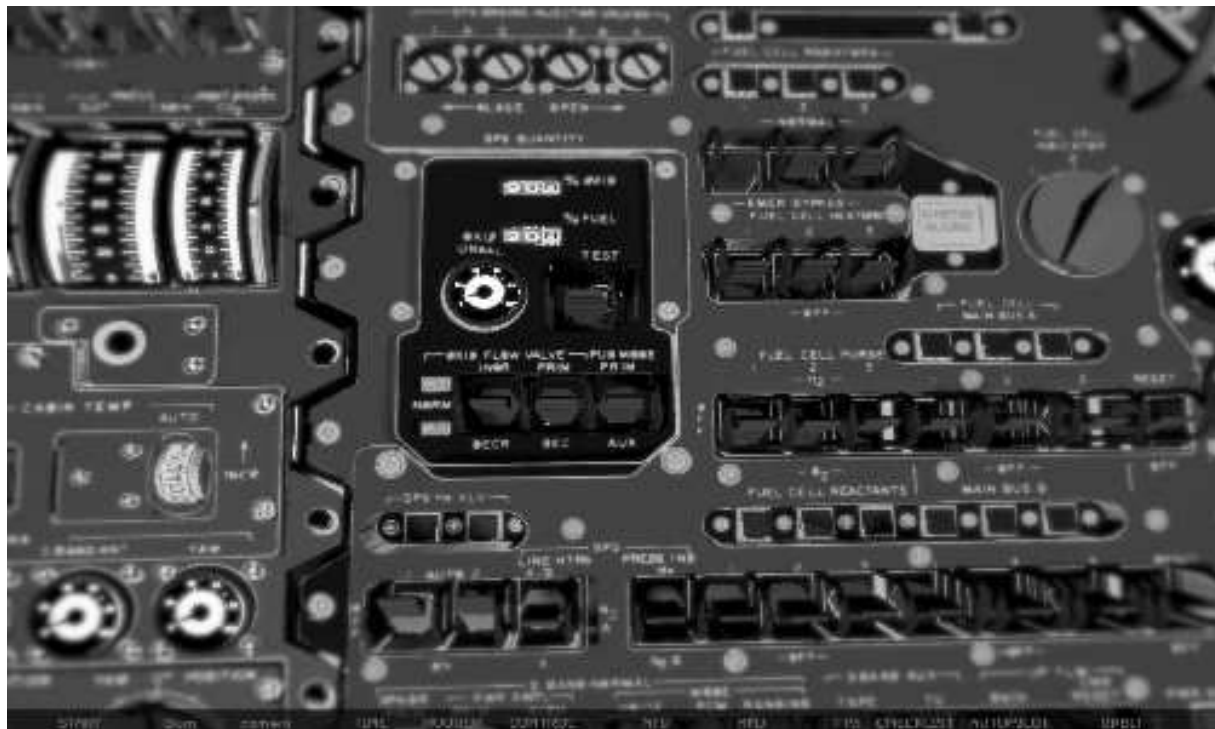
- Displays and controls
- Emergency detection
- Electrical power
- Stabilization and control
- Reaction control system
- Docking
- Telecommunications
- Earth Landing
- Emergency Launch Escape
- Structural , and LV integrity .

11.1.1.7 ServicePropulsionSystem

Service Propulsion System

The SPS engine was used to place the Apollo spacecraft into and out of lunar orbit, and for mid-course corrections between the Earth and Moon. It also served as a retrorocket to perform the deorbit burn for Earth orbital Apollo flights. The engine selected was the AJ10-137,[9] which used Aerozine 50 as fuel and nitrogen tetroxide (N₂O₄) as oxidizer to produce 20,500 lbf (91 kN) of thrust. The thrust level was twice what was needed to accomplish the lunar orbit rendezvous (LOR) mission mode, because the engine was originally sized to lift the CSM off of the lunar surface in the direct ascent mode assumed in original planning¹⁰ A contract was signed in April 1962 for the Aerojet-General company to start developing the engine, before the LOR mode was officially chosen in July of that year.[11] The propellants were pressure-fed to the engine by 39.2 cubic feet (1.11 m³) of gaseous helium at 3,600 pounds per square inch (25 MPa), carried in two 40-inch (1.0 m) diameter spherical tanks.[12] The exhaust nozzle engine bell measured 152.82 inches (3.882 m) long and 98.48 inches (2.501 m) wide at the base. It was mounted on two gimbals to keep the thrust vector aligned with the spacecraft's center of mass during SPS firings. The combustion chamber and pressurant tanks were housed in the central tunnel.

Fuel Quantity Usage



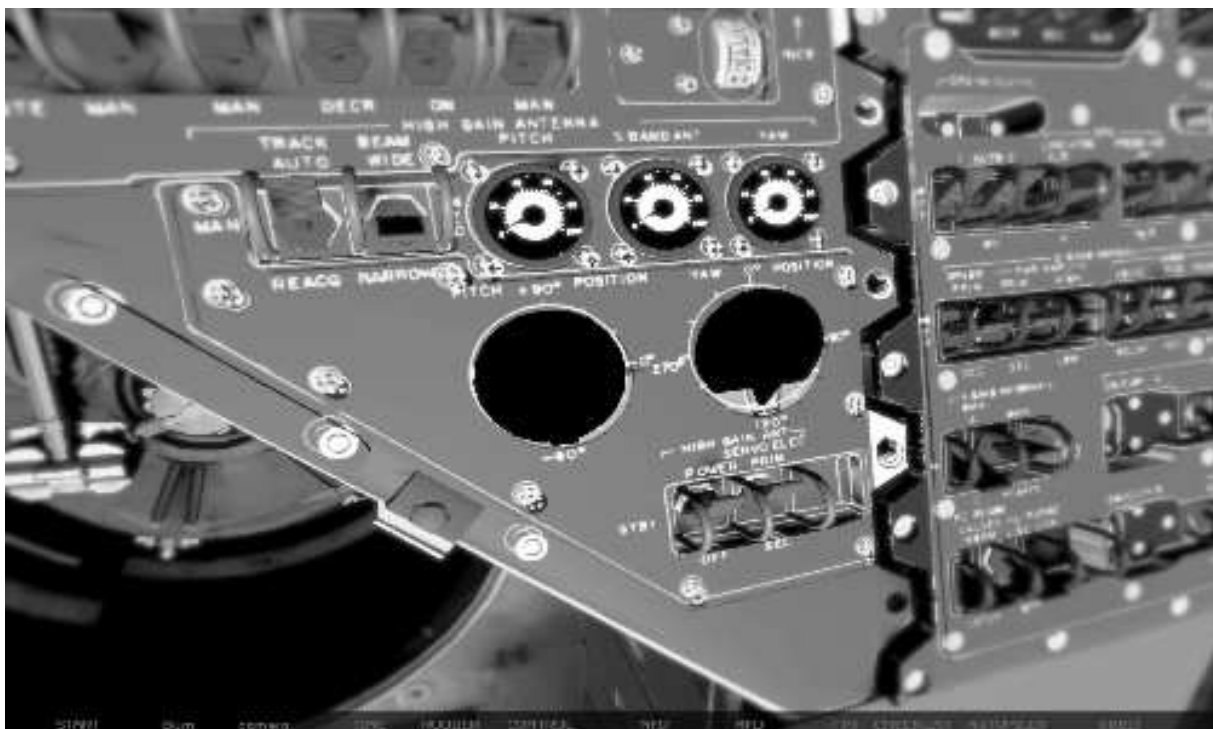
11.1.1.8 StabilizationAndControlSystem

StabilizationAndControlSystem

The launch escape assembly houses a system of solid-fuel rockets which is employed to separate the command module from the rest of the space vehicle if it is necessary to abort the mission during the atmospheric phase of the launch trajectory. The abort maneuver is passively stabilized, and no control system is employed. In normal missions, the launch escape assembly is jettisoned after the space vehicle has left the atmosphere. The command module houses the three-man crew during the entire mission, except for the excursion trip from lunar orbit to the moon's surface and return which is accomplished with the lunar excursion module. The command module, which also provides protection to the crew against reentry heating and acceleration, has a system of hypergolic rocket engines for three-axis control during the final earth entry phase of the mission. The guidance and control system which includes the sensing devices, electronics, displays, and controls which constitute the automatic and manual control systems for the spacecraft. It also houses the command-service module. The service module houses the service propulsion system and the major support elements for providing environmental control and electrical power for the spacecraft. The service propulsion system includes a gimbaled engine which provides the major velocity corrections for changing the trajectory after separation from the launch vehicle, and a system of hypergolic rocket engines similar to those on the command module for providing three-axis attitude control and vernier translational control for the spacecraft. The lunar excursion module (LEM) which houses a two-man crew separates from the command-service module (CSM) in lunar orbit for the excursion trip to the moon's surface and return. The LEM has a descent engine, which is staged on the moon's surface, an ascent engine, and a system of hypergolic rocket engines similar to those on the CSM for three-axis attitude control and vernier translational control. The LEM includes sensors, electronics, displays, and controls. The LE24 employs The LEM has its own independent guidance and control system. The Saturn instrument unit is a part of the Saturn launch vehicle and contains the Saturn guidance and control system which controls the space vehicle during all the boost phases of the mission. The guidance system in the command module provides data to the crew for monitoring the performance of the Saturn guidance system. The command module system is also capable of providing the steering signals to the Saturn control system as a back-up to the Saturn guidance system. The command module can also provide attitude control commands to the Saturn control system, and steering interfaces of the command module system with the Saturn system are discussed.

11.1.1.9 TelecommunicationsSystem

Telecommunications System



Short-range communications between the CSM and Lunar Module employed two VHF scimitar antennas mounted on the SM just above the ECS radiators. A steerable unified S-band high-gain antenna for long-range communications with Earth was mounted on the aft bulkhead. This was an array of four 31-inch (0.79 m) diameter reflectors surrounding a single 11-inch (0.28 m) square reflector. During launch it was folded down parallel to the main engine to fit inside the Spacecraft-to-LM Adapter (SLA). After CSM separation from the SLA, it deployed at a right angle to the SM. Four omnidirectional S-band antennas on the CM were used when the attitude of the CSM kept the high-gain antenna from being pointed at Earth. These antennas were also used between SM jettison and landing.[16]

11.2 Apollo Eagle Lander

Eagle Lander

The Apollo 11 Lunar Module, also known as the "Eagle", took the first astronauts Aldrin and Armstrong to the Moon.



The Lunar Module had two functions: to land on the Moon and to lift off the Moon to re-dock with Command and Service Module (CSM) that had been orbiting the Moon waiting for Aldrin and Armstrong's return.

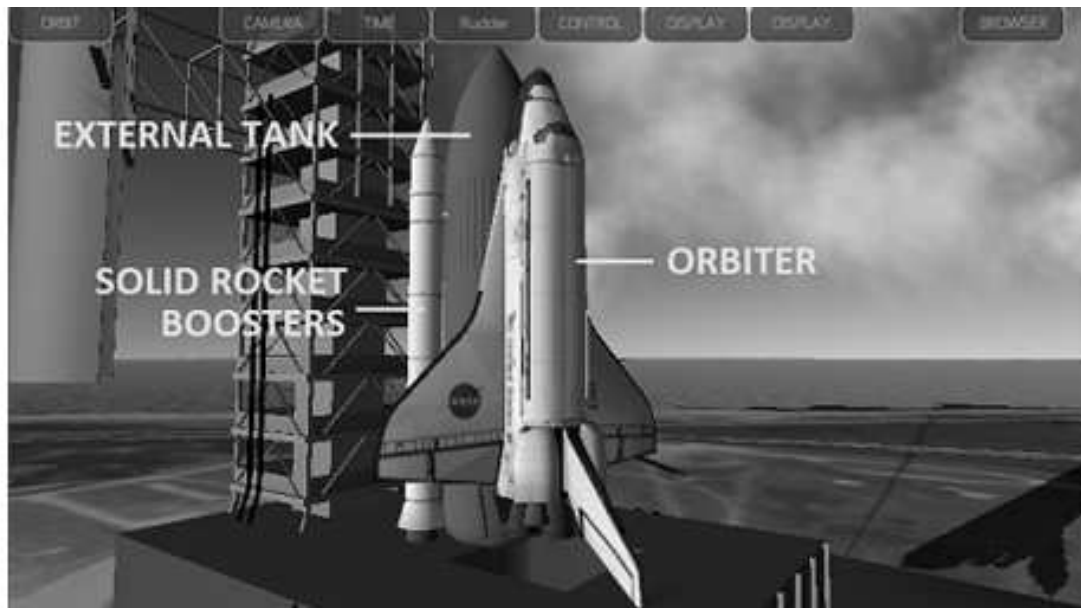
Lunar Descent During the lunar landing, the Lunar Module undocked from the CSM at 17:44:00 UT. The descent engines were fired for 30 seconds to put the Eagle into its descent orbit with the closest point being 14.5km from the Moon. At 20:25 UT the descent engines were fired for 756.3 seconds to descent to the lunar surface. On 20:17 UT 1969 July 20 the Eagle carrying Aldrin and Armstrong landed in the Sea of Tranquility.

Lunar Ascent The Eagle lifted off the Moon at 17:54 UT on July 21 and re-docked with the CSM at 21:34 UT. After all the astronauts transferred back to the CSM the Lunar Module was ejected into lunar orbit to crash back on the Moon.

11.3 Space Shuttle

Space Shuttle

The Space Shuttle was a reusable vehicle designed by NASA to carry people into space. The Shuttle was used for 135 missions.



The Space Shuttle was made of three main parts:

ORBITER The orbiter carried the astronauts to space. NASA made five orbiters - Atlantis, Challenger, Columbia, Discovery and Endeavour.

EXTERNAL TANK The iconic orange external tank contained liquid hydrogen fuel and oxygen oxidizer.

SOLID ROCKET BOOSTERS The twin solid rocket boosters contained solid fuel and provided the main source of thrust for lift off during the initial couple of minutes. The solid rocket boosters were picked up from the ocean and reused.

AEROSURFACE CONTROLS ELEVONS - used for pitch and roll controlled **RUDDER** - used for rudder control and as speed brake **BODY FLAP** - used to protect main engines from entry heating

The onboard Flight Control System (FCS) consists of 5 General Purpose Computers (GPC), one of which is a backup.

Space Shuttle flights are divided into flight segments: first stage ascent; second stage ascent; abort to launch site, abort once around; on-orbit operations; entry, terminal area energy management; and approach and landing. There are manual and automatic modes for all flight segments.

ASCENT is controlled by the Orbiter and SRB engines. **ORBIT INSERTION** and **ON-ORBIT CONTROL** is controlled by the 46 RCS jets and 2 orbit maneuvering systems. **ENTRY** is controlled by RCS jets and aerosurface controls. **TAEM** and **APPROACH AND LANDING** is controlled by aerosurface controls.

11.4 Gemini

The purpose of the Gemini missions was to gain as much of the experience needed for Project Apollo as possible. Project Gemini was a flight program as well as a scientific research program.

The Gemini Launch Vehicle consisted of the two stage Titan booster and the Gemini capsule and adaptor.

LAUNCH Most flight duties were automated, requiring only few switch throws during powered flight. At lift off the crew activates the mission timer and report activation to mission control. At 10 seconds the launch vehicle began the roll maneuver. At 23 seconds the launch vehicle began the pitch program. The roll and pitch program put the vehicle on the correct azimuth. At 50 seconds the vehicle clock is synced with the mission control clock and activate a backup timer. Through ascent mission control calls out abort mode boundaries. At 2 minutes 35 seconds the 1st staging occurs. The 1st stage shuts down and the 2nd stage ignites. At 5 minutes 57 seconds the 2nd engine cutoff is scheduled to occur. Weightlessness occurs at this point. After 2nd engine cutoff the crew align the guidance platform and begin the next phase.

INSERTION Insertion to orbit is where the launch vehicle transitions from ascent to orbit. The crew go through the insertion checklist. The spacecraft is configured for orbital activities. At 55 minutes an orbital adjustment maneuver was performed to change the perigee altitude.

ON ORBIT OPERATIONS On orbit operations varied mission to mission. They included extravehicular activities, rendezvous and docking, navigation tests, orbital maneuvers, Earth observations, astronomy, medical tests and long flight tests.

DEORBIT Deorbit is the transition from orbit to reentry culminating in retro fire which provided the delta-V required for the spacecraft to reenter the atmosphere.

REENTRY After retro burn is complete, the retro rocket system is jettisoned to expose the blunt heat shield. The spacecraft reenters the atmosphere at about 400,000ft. During reentry communication was lost. The crew had minimal control over the g load by changing the center of gravity of the spacecraft via the RCS. The high altitude drogue chute was deployed from 50,000ft to 10,700ft.

11.5 Shuttle Orion

Space Shuttle Orion

The Shuttle Orion is a general purpose fictional spaceship. We recommend that you use the Shuttle Orion for free flight missions. It is an easy to use spaceship with unlimited fuel and hover engines.

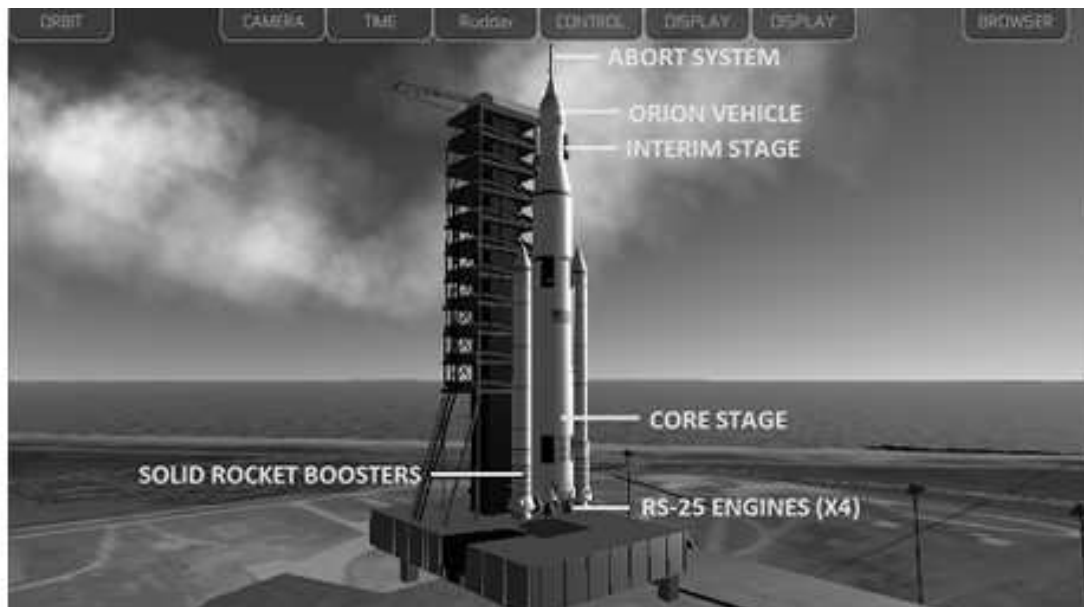


11.6 Space Launch System Block I

SLS Block I

The Space Launch System (SLS) is NASA's latest program signalling a new era of space exploration. The goal is to take astronauts to Mars and beyond. The SLS is NASA's most powerful space vehicle launch system yet with unprecedented payload capacity and long mission capabilities.

Although the SLS is still very much on the drawing board for NASA, you can have a sneak peek play here at Space Simulator.



11.7 Altair Lander

The Altair Lunar Lander is a multi-purpose vehicle intended to land up to four astronauts on the Moon. The foundations of the Altair Lander design follows in the footsteps of the original Apollo design with a two stage vehicle design but employing modern materials and technologies, consisting of a main descent module and a smaller ascent module.



11.8 X15 Experimental Spaceplane

X15 Space-plane

The North American X-15 hypersonic rocket-powered plane was part of a research program investigating all aspects of piloted hypersonic flight. The plane flew over a 10 year period and set speed and altitude records - 4,520mph (Mach 6.7) and 354,200 feet. The X-15 was designed to be carried and dropped from under the wing of a B-52.

Use the STAGE button to drop launch the X-15:





