>>Controls: Rotation

The LEFT and RIGHT arrow keys control the rotation of the spacecraft. The craft rotates using electrically-powered reaction wheels inside while the keys are pressed. No need to worry about fuel or consumption when turning, because all our spacecrafts have solar panels!

>>Controls: SAS

Most of our spacecrafts have stability assists systems (SAS) on board. These systems measure the craft’s rotation and automatically work the reaction wheels to reduce it, unless you are manually operating the wheels already. Use the SHIFT key to toggle the SAS.

>>Controls: Thrust and Velocity

The UP and DOWN arrow keys increase and decrease the thrust of the spacecraft respectively. Considering that thrust is proportional to acceleration instead of velocity, staying still in space is actually quite hard!

>>Controls: Camera

The A and S keys control the camera zoom. Zooming in might be a good idea when there are many obstacles around and zooming out would help to see far away.

>>Controls: Estimating Trajectory and Showing Forces

We have established connection with the supercomputer back at the university! We can use it to estimate our trajectory in real-time. It can also show all the (gravitational) forces acting on the spacecraft! Press the \_\*\_ key to toggle trajectory estimation, and the \_\*\_ key to toggle the force display.

It seems that some of the transmitted data can be lost on the way, so beware of occasional glitches.

>>Controls: Maximizing and Minimizing Thrust

Sometimes the throttle just isn’t quick enough. So, most of our crafts have additional controls to rapidly maximize and minimize their thrust. Pressing the Z key will turn up the thrust to its limit while the X key will cut it entirely within seconds.

>>Fuel

The fuel on board is both critical for the spacecraft to go anywhere, but it also weighs it down. The more fuel the craft burns, the lighter it will become, and so the less it will be affected by gravity while the more it will be affected by thrust. The differences are quite noticeable, as most of the mass of a fully-fueled spacecraft is the fuel.

The \_\*\_ bar on the \_\*\_ will show how much fuel the craft has left. It would be a good idea to keep track of it because running out of fuel mid-flight can leave the craft stuck in the emptiness of space!

>>Obstacles

Space might not be so empty after all. Even the smallest rock or space junk piece can cause serious damage to the craft, especially at higher speeds, so it would be best to avoid even touching anything!

>>Reentry and Landing

The parachutes and the Autopilot of the spacecraft (if they exist) can handle the take-offs and landings for you. All you need to do is get close to the location you need to land. However, bear in mind that trying to land at high speeds might cause the spacecraft to crash.

>>Newton's law of universal gravitation,

Everything in our universe with a mass attracts everything else with a mass. However, the attraction force cannot be noticed unless we’re talking about really heavy objects, like planets!

Newton’s Law of Universal Gravitation gives the details of this attractive force. For any two bodies:

F = *G* \* m1 \* m2 / r^2

Where F is the force, m1 and m2 are the masses of the bodies, r is the distance between the bodies’ centers of mass and G is a constant discovered by Newton that is equal to …\*

>>Newton’s First Law of Motion

A body will continue to move at constant speed or continue to not move at all, unless a force is being applied to it. In outer space, that could mean moving forever…

>>Newton’s Second Law of Motion

Momentum (inertia) is the quantity of a body that describes its “desire” to continue moving the way it is.

The force (F) acting on a body can be described as the change of its momentum (p) per unit time (t). Hence, applying a force on a body is like trying to convince it to move another way. Hence:

F = Δp / Δt = m\*Δv / Δt = m\*a

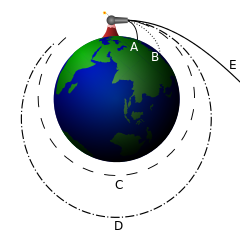
if m is the body’s mass, v is its velocity and a is its acceleration

>>Newton’s Third Law of Motion

Forces always exist in pairs, acting in opposite directions. In other words, two bodies applying forces on each other are always arguing about which way to move, and this affects both of them.

>>Newton’s Cannonball Model

Orbits can be thought of as falling towards a planet but never making it to the ground. Newton offered a way of describing this. Imagine firing cannonballs from a cannon that has increased power every time, on a planet with no air resistance. The cannonball would fly farther each time before hitting the ground, but if it runs out of ground it will be stuck flying and falling. That’s an orbit!

(https://en.wikipedia.org/wiki/Orbit#Understanding\_orbits)

>>Orbits and Orbit Terminology

An orbit around a planet depends on 3 things: the masses of the orbiter and the planet, the distance between them, and the velocity of the orbiter. \*\*

…Low orbit, high orbit, apoapsis, periapsis, eccentricity

>>Orbiting and Energy

GPE, KE

>>Escape velocity

>>Changing orbits: the bi-elliptical transfer

>>Gravitational assists

We usually think of a planet’s gravity as something that holds us down in space travel, but actually we can also use this force to our advantage!

>>Changing orbits: the Hohmann Transfer

* + - Additional topics that may be covered are … Kepler’s laws of planetary motion, the delta-v concept, and uniform circular motion.
    - Trivia topics: Murphy’s Law, Sputnik, Werner von Braun, Apollo 11, current space technology (satellite prices, etc), Laika, orbiting is actually falling with style!, …
    - EasterEggs: Angry Pluto (still a planet!), Kerbals, Gandalf , Death Star, Bender/Planet Express Ship, monolith computer from 2001, sputnik

[Idea 1: captain temel is drunk/oxygen-deficient

Idea 2: temel is not the designated pilot of the ship and is inexperienced, the other guy fainted.]

[Part 1: Newton’s Laws of motion & arrow key ctrl]

MC: Captain Temel! Captain Temel! Do you copy?

CT: Yes, I’m here…

MC: Are you all alright?

CT: Yeah, I just had a hilarious adventure with these other European astronauts that people will tell each other for years, but I’ll tell you that later.

MC: What? Temel this is a solo mission. Are you oxygen-deficient or something?

CT: Oh… yeah… The readings say I am.

MC: Pull yourself together! You are out in deep space! We need to recalibrate your sensors to check if everything’s working before we can get you back towards Earth!

CT: Alright. Let’s see now… This ship is spinning like crazy! But the accelerometer reads zero… So I’m moving at constant speed right?

MC: Yeah, that’s Newton’s First Law! Remember the conservation of momentum and all? [\*\*\*pop-up]

CT: Then why am I even spinning?

MC: Because by the same principle angular momentum is preserved too! Activate those thruster blocks and regain your orientation!

CT: Ok…

MC: The reaction wheels are back online. Turn that nose back to Earth now!

[\*\*\*left-right keys pop-up]

MC: Right, you seem to be facing the right direction now. But some the sensors seem damaged… we can’t get many readings… It seems like you can’t accelerate harder than one G or two [\*\*\* G-Force (acc.) pop-up] or the flight instruments might give up on you entirely.

CT: Then let’s go for a nice round 1G then…

MC: According to our records the total mass of the vessel should be \* kg. How much force can your thrusters deliver right now?

CT: Uh… looks like the usual \*kN.

MC: Good, let’s check our calculations now… [\*\*\*second law pop-up]

MC: Ok go for \*\*\*% thrust!

[\*\*\*up-down keys pop-up; player does so , game doesn’t let you go higher than \*\*\*% for now]

CT: That’s more smoke than usual…

MC: Wait that’s weird… Are the engines not burning properly? Let me just crunch the numbers here…

[\*\*\*third law used to determine mass ejected per second using acc reading and stuff]

CT: Ok, that looks like waaay more than a few kg…

MC: Cut the engines!

CT: Done!

MC: That should have gotten you enough momentum towards Earth anyway…

[Part 2: Newton’s Law of Gravitation & prograde, retrograde]

CT: The accelerometer is showing \*\*\*. But the engines are off and nothing is leaking from the ship…

MC: Then that must be Earth’s gravity pulling you. You’re getting pretty close to Earth. Let’s just make sure that gravity’s the only force acting on the ship… [\*\*\*pop-up; note about Earth also being pulled, but with way less acc because of way higher mass]

MC: Good news, only gravity’s at work here… However, you’ll fly by unless you slow down. [\*\*\*trajectory updated]

CT: Uh oh, where are the breaks?

MC: A space ship doesn’t have breaks! Seriously, what are your oxygen readings?! Just turn your nose around and burn retrograde when you reach the marked position! [\*\*\*pop-up about prograde/retrograde] And don’t go over 2G/\*m/s^2!

CT: Workin’ on it…

[…player does it…\*\*\*]

…

…

[\*\*\*\*… he gets into a legit orbit…]

[Part 2: Work and Energy]

CT: Ok, so if I just let this ship stop orbiting and fall…

MC: You can’t do that! The work needed to stop this ship is tremendous! [\*\*\*work and energy pop-up] You don't have enough fuel for that…

Plus even if you do manage to stop, all that gravitational potential energy will make you crash at a terrible speed! [\*\*\*GPE/KE pop-up]

CT: Ok ok, you didn’t have to give me so many numbers!

MC: We’ll send another ship to rendezvous with you in orbit to pick you up!

CT: Much appreciated…