EHC Mission V

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Introduction

One of the rudimentary skills of space flight is orbiting. Orbiting allows satellites to function and acts as the initial stage for moon flights. In this mission, the players will blueprints to assemble an R-7 rocket to carry Sputnik I back to orbit.

The students will learn about different directions on the navball and rudimentary ways to modify their orbits. They will also tackle a more challenging building task with the R-7. The mission will also offer the possibility to learn about potential and kinetic energy and reference frame on orbit.

Age of Student(s)

10 - 18 years

Objectives

Game concepts:

- Staging
- Navball markers
- Orbiting

Physics concepts:

- Orbiting
- Orbital potential and kinetic energy
- Reference frame

Working skills:

- Documenting work
- Reflection of the learning process

Historic concepts

- R-7 rocket

Timeline

The mission consists of two parts: assembling the rocket and testing it and the orbital flight tutorial.

Students progress through the mission at their own pace and it might take several attempts to complete. If the students manage to complete activities on their first attempts, they should spend around **15 minutes** constructing the R-7 based on blueprints and **10-15 minutes** to complete the orbital mission.

As students can be at different levels, it's recommended to that you allocate the whole lesson for the activities and have the faster students help the slower ones or have them tackle the optional activities listed below.

Even with an advanced group, if you choose to include research activities, orbital energies and mission log entries, you can flesh the activities out to a complete 45 minute lesson.

Learning Activities

Part I: Assembling R-7

Before you can begin, you can watch together a video about Sergei Korolev, the man who designed the R-7 and the events leading up to its popularity and lasting fame as a warm up:
https://youtu.be/YQfy5u3yOZQ

R-7 is the most popular rocket family to date and its variants have been used as carrier rockets ever since the late 50s. In this first activity, students are presented with blueprints of the rocket that they will need to follow to assemble the rocket.

The total parts required: (tabs for each part in parentheses)

- Sputnik Nose Cone (structural)
- Sputnik Satellite (pods)
- Sputnik Payload Base (structural)
- R-7 Core Stage (fuel tanks)
- 4x TT-38K Radial Decoupler (structural)
- 4x R-7-Strap-On Booster Fuselage (fuel tanks)
- Core Stage Quad-Coupler (structural)
- Strap-On Booster Quad Coupler (structural)
- 8x EAS Strut Connector (structural)
- 4x Winglet (aerodynamics)
- 12 x Vernier Thruster (engines)
- 4x RD-108 Engine (engines)
- 16x RD-107 Engine (engines)

Note that the attached blueprints below that the students see in the game list the parts symmetrically: there are four Strap-On Boosters and four decouplers to attach them to the Core Stage but they are only listed once to make the blueprint easier to read. E.g. the 16 RD-107 are divided to the four Strap-On Boosters evenly, four each.

Some of the assembly requires some fine-tuning and precision: when attaching the thrusters it helps to turn the camera angle. You can turn the camera angle by holding down the right mouse button and moving the mouse. You can also zoom in and out holding down **SHIFT** and scrolling the mouse wheel.

R-7 is more complex than the previous rockets we've assembled so give the students a while to complete it. If you have Kerbal-experts in your class who finish earlier, have them help the others before progressing to the next activity.

Part I: Testing R-7

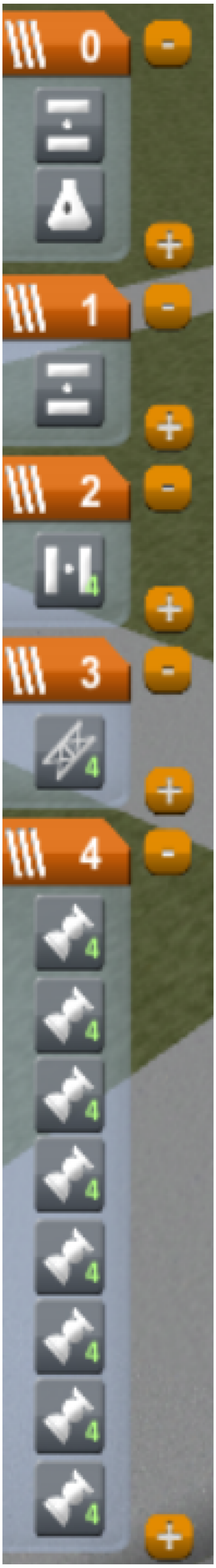
When your students are ready to launch, they hit the green Launch button to proceed to the launch pad.

On launch pad, they are asked to address the staging of the rocket before the lift off. Designing staging is a key skill in space flight: it determines the order in which actions take place. You can find a suggested order in the below image for the R-7 test flight. There are four main stage groups in the suggestion: engines, launch clamps, strap on booster detachment and final stages for detaching the remaining parts on orbit.

First stage activates the engines, second releases the rocket from clamps, third stage detaches the empty strap on boosters and the final stages separate the remaining parts and launch Sputnik to its orbit. It is a matter of taste if you want to group the final stages together and execute them together or divide them into separate stages to be launched individually.

After your students complete the activity, they can continue to part II where they use the R-7 to return the Sputnik-satellite to orbit around Kerbin. Part II needs to be launched separately!

Alternatively, you can wrap up the lesson by assigning the students to study the variants of the rocket and the space programs it was used in. You can find a list of the variants and launches here (Wikipedia).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Part II: Orbital mission

In part II, the students are guided through the orbital flight.

The main events are:

- Launch
- Gravity turn
- Lift apoapsis to 70km
- Reaching apoapsis
- Lift periapsis to 70km
- Launch Sputnik I

The mission is self-guided: the students progress through the activity at their own pace by following the instructions. To help them if they struggle each event of the flight is described below.

Launch

Launching is relatively simple and if students played through the previous missions they shouldn't have any trouble with it.

If they do, you can remind them about the controls:

- SHIFT - Increase throttle
- Control - Decrease throttle
- Z - Set throttle to max
- X - set throttle to min
- SPACE BAR - Activate next stage

You can also tell your students to active SAS (Stability Assistance System) that will stabilize the rocket during the right. SAS can be activated by pressing **T**.

The first stage of the launch starts the engines but the rocket is still attached to the launch clamps, so the students will need to activate the second stage to detach them.

Gravity turn

After the launch, students are prompted to start their gravity turn by tilting the rocket 5-10° east (right side of the navball) by pressing **D**. A larger rocket like R-7 takes a while to turn!

The point of the gravity turn is to let gravity change the heading of the rocket, instead of using the thrust of its own engines to achieve the same results. As the rocket accelerates upwards, gravity slowly bends the trajectory down.

Lift apoapsis to 70km

After the first fuel tanks run out of fuel, the students are told to drop the empty tanks by activating the next stage.

Soon after, they should have accelerated long enough to lift their apoapsis, the highest point of their trajectory to 70km. At this point, they are told to kill the engines in order to not to waste fuel by lifting it unnecessarily high.

While waiting for the rocket to reach the highest point of the trajectory, student will take a look at the orbital map. They can open it by pressing **M**. On it they will see a blue trajectory line depicting their current course. A blue AP-marker shows the highest point of the trajectory.

Students can also manage their thrust and heading in map view by bringing up the navball from the center bottom of the screen.

*Note: due to a problem with the original Kerbal Space Program, thrust is sometimes automatically activated when changing to map view. If the students see the apoapsis still rising, they can kill the engines again by pressing **X**.*

Reaching apoapsis

When students are nearing the apoapsis, they will be prompted to turn the rocket **prograde**, i.e. aligned to their trajectory. It's marked by a yellowish-green marker on the navball. Students will see a list of the markers in the game.

Lift periapsis to 70km

After turning the rocket towards the prograde marker, the students are asked to accelerate forward at full speed. They can open up the orbital map with **M** to see how the acceleration affects the trajectory. It should expand the arch to a full circle around Kerbin.

They should keep accelerating until their periapsis, the lowest point of the trajectory is above the atmosphere at 70km. This will let the rocket orbit around the planet almost indefinitely without being slowed down by the atmospheric drag.

Once the orbit is complete, students have a while to play with it or just admire the view. You can tell them fastforward time to see how the rocket orbits the planet.

Orbital energies

If you choose to, you can also tell the students to activate the Energy Spheres to study orbital energies. Energy Spheres can be activated by pressing the EDU-button in the top-right corner and selecting Energy Spheres.

You can also do this together by showing this on the teacher's computer or a projector. Pay attention how the potential and kinetic energies change between apoapsis (the highest point of the orbit) and periapsis (the lowest point). You can ask the students if this resembles the situation with kinetic and potential energy in other situations you've studied.

Launch Sputnik I

At the end of the mission, students are asked to launch Sputnik I to the orbit. They are then prompted to write a log of the mission, documenting what they did during the flight. You can either do this in game or outside the game with notebooks, LMS etc.

You can scaffold the reflection by asking them the following questions:
- What was the goal of the mission?
- What where you doing to achieve it?
- What was hard? What was easy?
- Did you learn anything? Facts or skills?

Orbital energies

If you choose to, you can also tell the students to activate the energy spheres to study orbital energies. You can also do this together by showing this on the teacher's computer or a projector. Pay attention how the potential and kinetic energies change between apoapsis (the highest point of the orbit) and periapsis (the lowest point). You can ask the students if this resembles the situation with kinetic and potential energy in other situations you've studied.

Low Kerbin Orbit & Low Earth Orbit

LKO and LEO are important concepts: the low orbits are where most of the satellites reside and many space flights make their orbital manoeuvers. While we are used to thinking of space as an empty place surrounding us, Low Earth Orbit is far from empty. Decades of satellites and space flights have left it cluttered with now nonfunctional space junk. It's is a growing problem for space flight these days and it's a topic you could bring up with your students as well.

A great place to start is Space.com's article on space junk.

Assessment

Students will produce a reflective mission log at the end of the lesson to show their learning. Use this as a basis for assessment.

You can also be quite sure that they now know how to construct a rocket and use it to reach orbit if they managed to play through the mission. If you want to control this, you can add questions for the mission log, for example:
- Why do you need to design stating?
- Describe the process of reaching orbit.

Alignment with Curricula and Standards

MS-PS3-1	Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
HS-PS2-2	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.