There's dangerous radiation on the moon, so we can't stay outside for too long. Robot rovers could map the entire planet, while we stay inside, safe and sound.

Chapter 4 - Working nine to five on the moon

Now that's a warm welcome!

Once we've settled in, robots can help us explore!

There's dangerous radiation on the moon, so we can't stay outside for too long. Robot rovers could map the entire planet.

In the moon base, they can be a big help too! They can do experiments, farm our fruits and veggies. And ehh… ever tried putting a plaster on your own back? Yeah… these robots can help out too! So what robot friend will you bring to the moon?
Although we humans are pretty cool, we’re not perfect. There’s only so much we can carry, we need air, food and water to function and if we don’t get our 8 hours of sleep… we’re useless.

We need robots! Give them a little power, and they’re good to go! They can even collect power themselves with solar panels on their back!

So what could they do? It starts with building our base.

With all that heavy stuff, we could use some extra strong robots! They could even finish our entire moon base before we arrive!

Our biggest friends on the moon!

Content

Chapter 1: Fly me to the moon!

You might think going to moon is a simple trip from A to B. But in fact, it’s an adventure with big rockets, gravity and no gravity at all. Your adventure starts here!

Chapter 2: Moon life 101

If we want to live on the moon, we’re going to need some basics. Right now, there is no air, water or food. So how can we make it through the day?

Chapter 3: Architect to the stars

Where would you build your house on the moon? And what would it look like? Discover everything you need to design and build your dream moon home!

Chapter 4: Working nine to five on the moon

There’s tons of stuff to do on the moon! Cool places to see, experiments to do and new ways to travel around. This is your travel guide to the moon!
Bye earth, hello moon!

Have you ever jumped off the earth and into space? Probably not. Gravity always pulls us back. That's 40 times faster than a jumbo jet! Well, rocket engines do the same. You need to jump 40,000 kilometers per hour to leave earth. To go that fast, you need special engines. Rocket engines!

You know when the air goes out of a balloon? The air goes one way, and the balloon goes the other, right? Well, rocket engines do the same.

The newest way of communication is with lasers. Doesn't just sound cool, it's very fast as well! It's 20 times faster than the average internet connections we have here on earth! Downside is that you always need to stay in sight. A laser needs to directly hit the receiver. Do you need high towers for example to stay in touch with an exploring rover?

Distance won't be an issue though. It can reach 300,000 kilometers... in a second. Video calling to your friends won't be a problem! So, what will your moon phone look like?

Chapter 4 - Working nine to five on the moon
Did you know that you can’t talk on the moon? Air carries the sound of your voice from one place to another. On the moon there is no air, so you won’t hear a peep.

Phones won’t work either, they need a satellite connection.

And we don’t have those circling the moon yet. So how can you say hello?

In the past we used radio waves, the same we use for radios on earth. Radio waves can also send files, about 1 megabyte per hour, but... loading an episode of your favorite show will probably take a few days.

But with fuel, by burning fuel, gas is pushed out one way, that pushes the rocket the other way. Insanely fast.

Fuel burns up quick though, so you need a lot. That’s why 90 percent of a rocket is fuel. The more stuff you bring, the more fuel you’ll need!

But because you burn up the fuel, the engines have less and less weight to carry. So you go faster and faster!

When you go that fast, air can’t get out of the way fast enough anymore, it will slow you down.

To help air get out of the way, your rocket needs to be aerodynamic, so super thin and smooth.

Only then, can you go fast enough to leave earth.
If we fly somewhere on earth, we fly directly from A to B.

So you'd think that if you fly from earth to the moon, you'd simply fly directly too, right?

Well, in space, it's not that easy! First... you can't fly directly from A to B, because A and B are moving!

Right now, earth is spinning at 1600 kilometers per hour and moving around the sun at more than 100,000 kilometers per hour! And the moon is doing it again!

Going from earth to the moon, is like jumping from one ridiculously fast turning merry-go-round to another, and trying to land on one specific spot. Good luck! But that's not all!

The moon's surface is not very human friendly though, so we might need robots to set up everything.

We could also look the other way, from the far side of the moon.

There you have a much clearer view into space as there is no interference from radio waves, or earth's atmosphere.

But our biggest experiment... will be us!

So we need to take a lot of pictures, skin samples, do physical exams. Everything!

What kind of experiment would you do on the moon?

The Moon's surface is not very human friendly though, so we might need robots to set up everything.

Yes, we'd mostly be testing how we deal with lower gravity, radiation and living on the moon.

Do we need to take a lot of pictures, skin samples, do physical exams, everything? What kind of experiment would you do on the moon?
Say, we go to the moon, what would we do there?

Just gaze back at Earth! Well, the whole reason we want to go to the moon, we will be discovering new stuff about the universe.

Is to research how we can live on a different planet. So we’d be testing all sorts of cool new gear and technologies that we want to use on Mars for example.

We are here

As the moon has no atmosphere, the meteorites that hit the surface are completely intact, with all the materials from wherever they came from.

That could be the other end of the universe!

The Earth, the moon… even the sun!

But you can use this to your advantage! By launching along with the earth’s rotation, to the east, you get an extra boost to go into earth’s orbit!

Now it’s all about timing! By blasting away at just the right moment… you fling yourself towards the moon.

Secondly, flying directly to the moon is difficult, because at all times you feel the gravitational pull of something...

So if your timing is perfect, you can slingshot yourself to the moon!
There are two ways to land on the moon. A hard-landing and a soft-landing.

A hard-landing is so hard we wouldn’t survive it. In the past decades a lot of unmanned space crafts landed that way on the moon.

For a manned space craft, we need a soft-landing. But it’s difficult.

In orbit, there it’s about kicking yourself out of orbit at the exact right time, with special engines, called thrusters. Just a second too late, and you miss your target!

One of the few times we soft-landed on the moon was in 1969. “One small step for” you know the one.

There are deep craters on the north and south pole, where sunlight can’t reach the bottom.

Other “must see” are the cold traps.

There, on the bottom is a layer of frost that’s so old that it probably saw the beginning of our solar system.

And just like studying earth layers helped us understand our planet’s past, studying the moon layers will probably teach us a lot about the moon too.

Who knows what information we’ll find!

There are deep craters on the north and south pole, where sunlight can’t reach the bottom.

Other “must see” are the cold traps.

Just one sunbeam will evaporate the frost… and let billions of years of history go up in smoke.

Other “must see” are the cold traps.

Chapter 4 - Working nine to five on the moon
Local lunar sights

But that's not why it's worth a visit. It's so deep, the deeper layers of the moon's crust are visible.

You can't be on the moon, and not go see the local sights!

You must go and see the Aitkens Basin on the South Pole!

It's the biggest impact crater on the moon.

In the whole solar system actually!

At 10 kilometers, it's all about slowing down. But how?

Once you're at 2 kilometers, you have just 2 minutes to scan the surface, find a safe spot in time… you can soft-land on the moon… and navigate there. Good luck! So only if you leave orbit at the right moment, slow down, and find a safe spot in time… you can soft-land on the moon… and take your very own “one small step for man”.

100 km

10 km

2 km

2 Minutes

13 km

Getting down will be tricky, so we'd need a special climbing vehicle to get there safely.

And navigate there. Good luck! So only if you leave orbit at the right moment, slow down, and find a safe spot in time… you can soft-land on the moon… and take your very own “one small step for man”.

There's no air, so a parachute won't work.
There are only so many groceries you can bring to the moon. Sure, astronaut food is an option, but isn’t there something... better?

Well, there’s plenty of sunlight on the moon, so you could grow your own food! Great!

But how long does the sun shine exactly? Well, for 14 earth days straight!

So how will you travel on the moon?
Your daily commute on the moon!

Living on the moon wouldn’t do much good.

If you couldn’t go anywhere, right?

But how can you travel around? The surface of the moon has no roads of course and is extremely messy.

Covered in rocks, boulders and craters. So a standard four-wheel drive won’t do.

In past moon visits we used rovers. They’re like a space buggy with two seats and a lot of stuff on it. But they’re not closed, so next to your space suit, you’d need an air tank.

You could travel about 90 kilometers tops.

For longer trips, you’d need a closed rover, with its own air supply.

90km

If you find a way to give your plants their 8 hours of sun a day, you’re guaranteed a nice dinner every night!

Your plants can’t handle the sun all the time of course.

If you find a way for your plants to flourish! But ehm… then 14 days of night follow. And your harvest won’t survive.

Plenty of time for your plants to flourish! But ehm… then 14 days of night follow. And your harvest won’t survive.

There are a few plants that are ready for harvest within 14 days, but then you’ll probably eat the same every night.

You could use artificial light, but that means you need more power as well.

You could also go to the lunar poles! There, the sun almost always shines.

Plenty of time for your plants to flourish!

But ehm… then 14 days of night follow. And your harvest won’t survive.

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Do how will your space farm look like?

Chapter 2 - Moon life 101
Quenching your lunar thirst

Having a glass of water on the moon won’t be easy. Most areas are as dry as our driest deserts! So bringing water with us, sounds like the obvious choice. We need about two liters every day.

It recycles everything. The used water from the space dishes, and water we humans produce. Every time we breathe, and yes... every time we pee.

The water recycling system used in the international space station will help make the water last.

Or we use several locations, so there’s always one in sunlight. Solved? Not quite. The moon has lunar eclipses, when the earth is between the sun and moon. These last for hours and happen several times a year. So we need a backup.

The water recycling system used in the international space station will help make the water last.

We can store solar power in fuel cells!

They’re like huge rechargeable batteries that, when fully charged, can last 17 days straight. Plenty to survive a lunar night!

But the moon base won’t necessarily be in the same place as the solar panels.

So you’d need a moon delivery guy, to move your fuel cells around. How will you power your moon base?

Chapter 3 - Architect to the stars
If we want to live on the moon, we need power. There’s no weather there, so no wind... but also no cloudy days! That’s a lot of power! But... the nights are just as long.

Solar power then? Well, a lunar day last for 14 earth days.

Sounds disgusting perhaps, but the recycling system is so effective, that the recycled water is cleaner than what most of us drink on earth.

Even though it’s good, recycling 100% is impossible.

Even though it’s good, recycling 100% is impossible.

Simply opening a door somewhere will already let out precious water.

Perhaps special airlocks might help, but we’d still need regular water deliveries.

The only thing is... it’s trapped in the soil, so it needs to be mined, and it’s colder than anything we’ve ever mined before.

There are places on the poles where the sun always shines. For example, on the rim of the Shackleton crater on the South Pole!

The sun does move of course. So either we need something that moves along with the sun, like flowers do.

There is a local option. Water ice has been discovered on the lunar poles.

Perhaps special airlocks might help, but we’d still need regular water deliveries.

So we need to invent new digging tools to get to it. Perhaps super sharp shovels, or heated drills? What do you think will quench our thirst on the moon?
Gasping for air on the moon

8

Gasping for air on the moon

HOW LONG CAN YOU HOLD YOUR BREATH? A MINUTE, TWO?

Nature can help us out! Plants and algae make oxygen from the air that we breathe.

120 sec

THAT'S ABOUT IT. So when we arrive at the moon, we'll need air... and quick!

ON THE INTERNATIONAL SPACE STATION, WE NOW USE ELECTROLYSIS TO MAKE OXYGEN.

THE KEY INGREDIENT IN AIR THAT WE NEED IS OXYGEN.

IT Splits UP WATER INTO OXYGEN AND HYDROGEN.

THE OTHER SHIELD CONTESTANT IS WATER. BUT THAT CAN'T BE COMPRESSED VERY MUCH, SO THE WATER SHIELD NEEDS TO BE THICKER TO KEEP US SAFE.

BOTH WILL PROTECT YOU DURING NORMAL SPACE WEATHER, BUT THE MOON ALSO SUFFERS FROM SOLAR FLARES. EXTREME BRIGHT FLASHES FROM THE SUN, THAT GIVE OFF A SUPER DOSE OF RADIATION.

THE SOLUTION? POOL PARTIES! BY STAYING IN THE WATER FOR A FEW HOURS, YOU'RE NOT ONLY WELL PROTECTED, YOU ALSO HAVE A GOOD TIME!

AND JUST TEN TO TWENTY CENTIMETERS THICK SHEILDING ALREADY GIVES ENOUGH PROTECTION FROM RADIATION.
How much sunscreen do you need on the moon?

Even though we love the sun here on Earth, on the moon it's not a friendly guy in the sky.

Not only does it heat up the surface to 123 degrees Celsius – ouch! – it also gives off dangerous radiation.

So forget sunblock. You need a sun shield!

Even though we love the sun here on Earth, on the moon it's not a friendly guy in the sky.

In just one year, you've already received the max amount of radiation you can handle in a lifetime.

Polyethylene

One shield option is polyethylene. Sounds unfamiliar perhaps, but it's actually what most plastic bags and bottles are made of.

It can be super compressed into plastic that's so strong.

Algae are nice and small and we'd need about 8 square meters per person.

Other types of small organisms, like spirulina, are also good to eat; two birds, one stone.

Plants are also an option.

Although they need a bit more space than algae, they don't just make fresh air; they grow into a nice dinner too!

A local option is regolith, better known as lunar soil. It contains a lot of oxygen!

But getting it out is tricky. You'd need to heat up the soil, filter out the oxygen and store it somehow.

If you find a way, you can definitely breathe easy on the moon!
From useless trash to space tools!

Up until now, we’ve just been a few days on the moon. However, we’ve already left behind vehicles, boots, golf balls... and more. It comes down to about 180,000 kilograms. Well, for organic trash, like greens, it’s easy! We can throw everything on one heap, close it off from air and let nature do its thing. That’s called anaerobic composting. It turns the waste into nice fertile soil... produces heat, perfect for those long lunar nights... and methane gas, which can fuel our rockets.

And look at how much trash we’ve already left behind! Vehicles, boots, golf balls... and more. It comes down to about 180,000 kilograms. Composting it turns the waste into nice fertile soil. Produces heat, perfect for those long lunar nights. And methane gas, which can fuel our rockets.

We’d be covered in trash in no time! So we have to be smart from day one! That’s the size of a house! Yeah, try to protect yourself from that!

And opening a window? Not an option. You need airlocks as doors to get in and out.

And look at how much trash we’ve already left behind! Vehicles, boots, golf balls... and more. It comes down to about 180,000 kilograms. Composting it turns the waste into nice fertile soil. Produces heat, perfect for those long lunar nights. And methane gas, which can fuel our rockets.

In those few days! Imagine when we live there...

Well, for organic trash, like greens, it’s easy! We can throw everything on one heap, close it off from air and let nature do its thing. That’s called anaerobic composting. It turns the waste into nice fertile soil. Produces heat, perfect for those long lunar nights. And methane gas, which can fuel our rockets.

And opening a window? Not an option. You need airlocks as doors to get in and out.

Your moon home also has to stay air tight at all times. The surface of the moon gets hit by small meteorites. The size of golf balls all year long (100,000/year).

The moon is big though, so the chance you get hit while you’re on a moon walk is very small.

Bigger issues are the bigger rocks. About 180 new craters 10 meters big appear on the moon every year.

Lastly the sun, our big friend in the summer isn’t very friendly on the moon! On the next page you see how much sunscreen you need on your next moon trip!
If you want to survive on the moon longer than a day, your moon base needs to protect you. This means that there’s no air and no protection from incoming stuff or the sun. The moon doesn’t have a cozy atmosphere like Earth does.

Pretty sweet right? But what about the rest? With 3D printing you can reuse certain materials, like plastic or metals. So even before you go to the moon, you have to think what you’ll bring along, what that’s made of and what you’ll need the most once you’re there. Tools? Spare parts? A clear tagging system would also come in handy. So you’ll know what something’s made of, and materials, like plastic or metals, do even before you go to the moon, you have to think what you’ll bring along, what that’s made of and what you’ll need the most once.

You’re there. Tools? Spare parts? A clear tagging system would also come in handy. So you’ll know what something’s made of, and materials, like plastic or metals, do even before you go to the moon, you have to think what you’ll bring along, what that’s made of and what you’ll need the most once.

If you’d like to breathe in your moon home, your house needs to be air tight. Literally. It has to be made from materials that don’t let air through.

The trash? Well... of the trash, you’ll need the most once. Can easily re-use it.
What is the best place to live on the moon?

Let’s be honest. The moon isn’t a very nice place to live. And it has no atmosphere, so you’re not protected at all from meteorites. The temperatures are much nicer, between minus 50 and zero degrees.

And it has no atmosphere, so you’re not protected at all from meteorites.

The poles! On our Earth the worst places, on the Moon the best!

Nope, not your average holiday location. So, if you had to choose, what would be the best options?

First up, the poles! On our Earth the worst places, on the Moon the best!

What’s the best place to live on the Moon? Let’s even take it a step further! Just like we use bricks from Earth to build on Earth, can we use something from the Moon to build on the Moon?

With a giant printer you can print a kind of wall!

Living on the moon is tricky business, though. In the next chapter you’ll discover how strong your house needs to be!
When you think of building, you probably think of stacking bricks, right? Those are made from stuff we have on earth. But to build on the moon, you’d need to move all the bricks with a rocket. So instead of bricks, we have to think smaller, lighter and well… perhaps even inflatable! Why not? That’s already going to save a lot of rocket trips!

Billions of years ago, lava spurted out of the tiny core of the moon and left behind tunnels. Some are 300 meters wide! Around 40 meters deep, you’re covered from the harsh space weather and the temperatures are much nicer too. Simply put them on a truck, move them to the building site and build! Moving all the bricks for an entire house is probably going to take much more than one trip.

Around minus 20 degrees, still not beach weather, but doable with a thick coat and a gigantic scarf. And moving all the bricks for an entire house is probably going to take much more than one trip.

But to build on the moon, you’d need to move all the bricks with a rocket. So instead of bricks, we have to think smaller, lighter and well… perhaps even inflatable! Why not? That’s already going to save a lot of rocket trips!

But look at that view. Perfect for research, but even more amazing to gaze at… and dream away. Last but not least, the far side of the moon! Ok, it doesn’t have nice temperatures or provide any cover what so ever. BUT, WHERE WOULD YOU STAY ON THE MOON?
So you’re an aspiring moon architect. Well, you’ve got your work cut out for you! But keep in mind... this is the only home on the moon. No store, no office. This is everything!

Before you start designing, you have to decide: are you going to build on, in or under the moon surface? Let’s pick on for now.

Next, the spaces. What do you need? A place to sleep of course, and a place to eat.

Lastly, work-out rooms. Living in low gravity on the moon, makes your muscles weak really quick. So working out is essential to stay healthy! Don’t bring your normal weights, though. They ehm... won’t be much use.

Now we can start tanning shape! No need to stick to a house shape! Make it a dome, a blob, a triangle!

Lastly, work-out rooms. Living in low gravity on the moon, makes your muscles weak really quick. So working out is essential to stay healthy! Don’t bring your normal weights, though. They ehm... won’t be much use.

And do you even need stairs?

On the moon you can jump from floor to floor. Also much more fun, isn’t it?

Turn the page to learn what you can use to make your house!