[[[Time: 0 minutes]]]
.
Good evening!
My name is Kurt Leucht and I'm a software developer for NASA at the Kennedy Space Center!
.
And it's my honor to be here in Tallahassee.
And talk to you about how partners and collaborators will help NASA live off the land on Mars!
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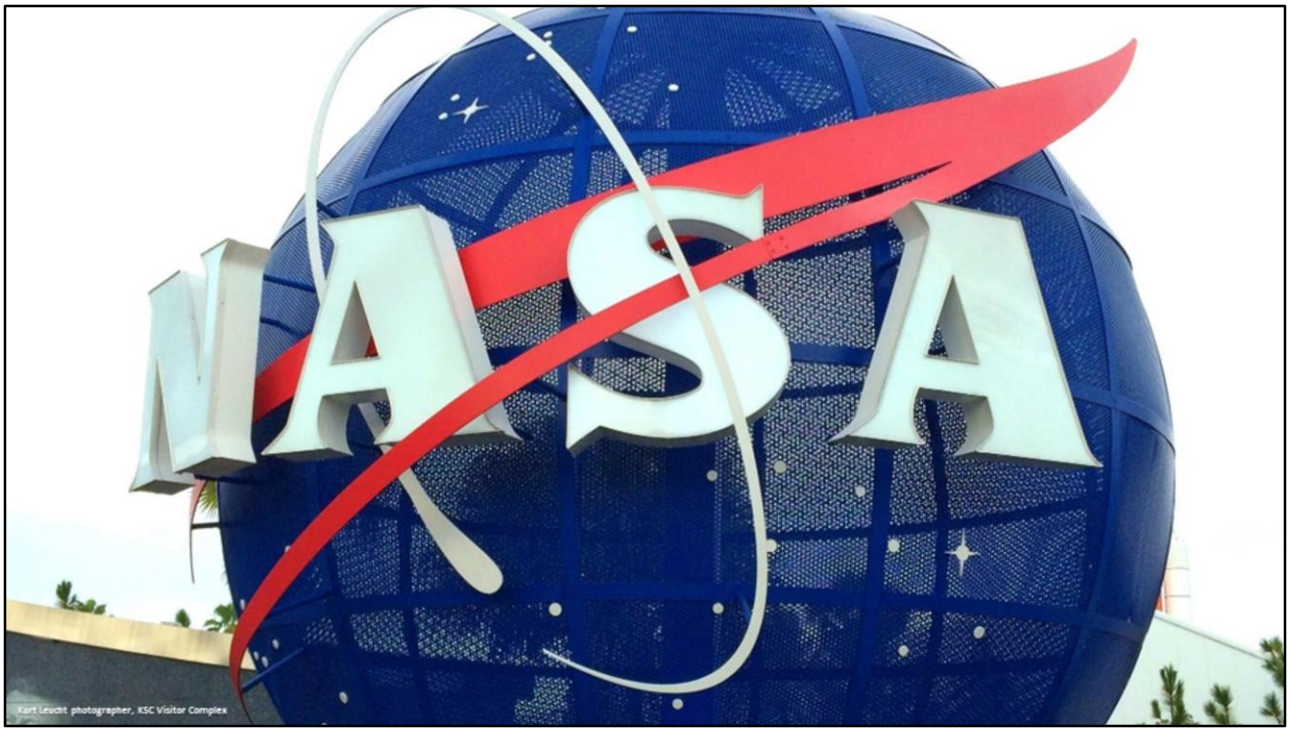
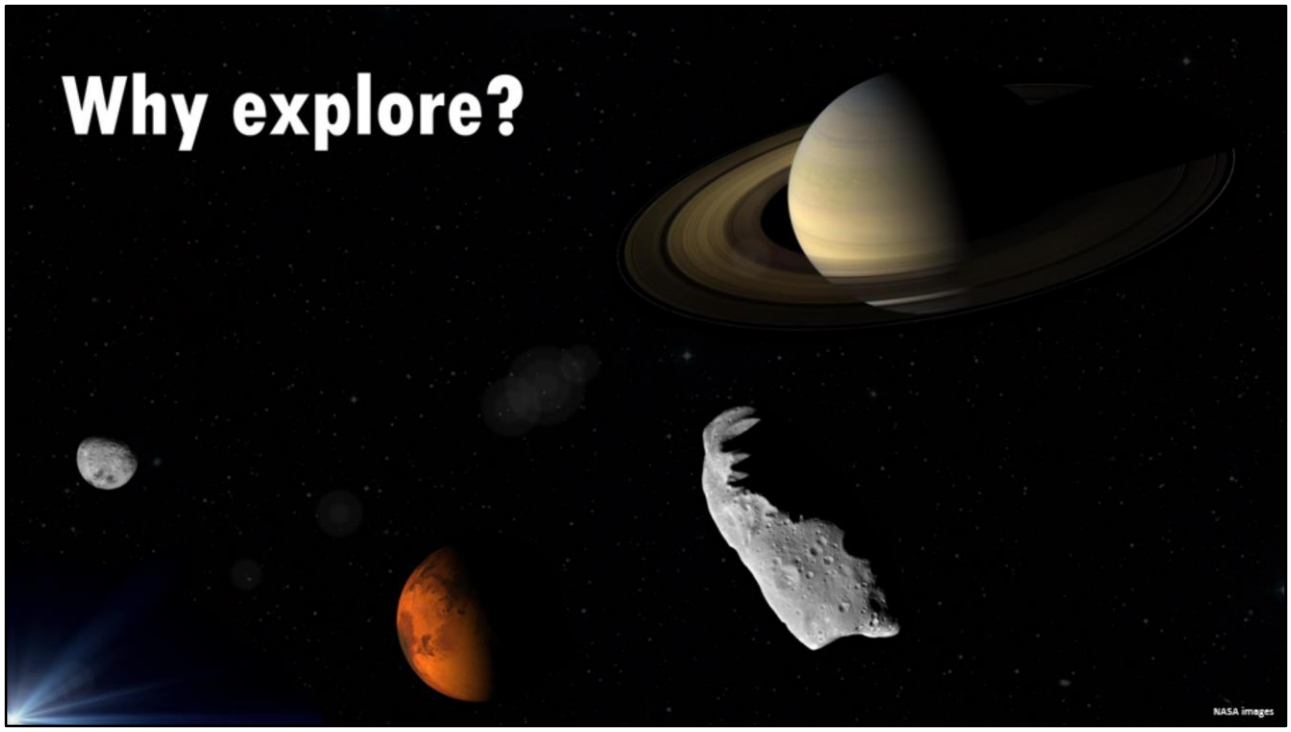
[this is the bottom line, must be able to read this]



So as I said, I work for NASA.
Which is pretty cool.

But NASA isn't fully understood by a lot of the general public.
People often ask me …



Why DO we explore outer space, asteroids, and other planets?

Well, there are lots of reasons, actually.
So let's talk about that for a few minutes.

Probably the BIGGEST reason NASA explores is the TECHNOLOGICAL return!

Just about every time NASA takes on a new mission
it has to INVENT NEW technologies or at least ADVANCE existing ones.

ENTIRE INDUSTRIES have been built on space technology
including personal computers and natural resource mapping.

This is a picture of 13 year old me playing on my Apple IIe personal computer.
I loved that thing!
I'm playing a game here but I DIDN'T just use this computer to play games.
This computer taught me how to PROGRAM.
And it helped mold me into the NASA Software Engineer I am today.

I might not have ever become an ENGINEER if it weren't for this computer.
I might not have ever WORKED FOR NASA if it weren't for this computer.

We're ALL influenced and molded by lots and lots of people,
and lots and lots of experiences growing up.
But I HONESTLY BELIEVE that this computer played an important role.

And I DON'T believe this computer would have been invented
if it weren't for the space program pushing that technology,
and miniaturizing it for space.

Another reason for exploring outer space is the SCIENTIFIC return!

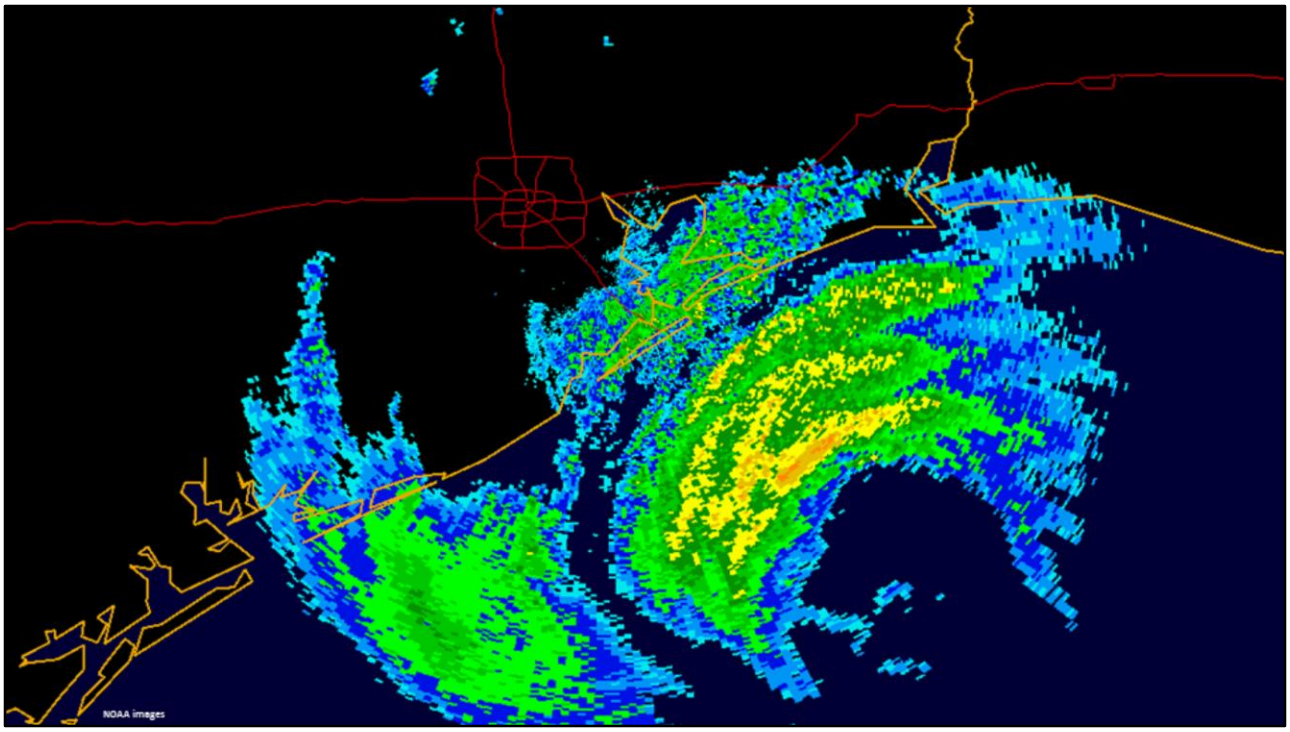
Space exploration almost ALWAYS leads to NEW discoveries!
And it leads to us learning NEW information about our world!

AND about our universe!

It EXPANDS our human knowledge!
And it can COMPLETELY change our perspective!

SOMETIMES this new information changes our perspective
of our OWN PLANET!

It can show us our planet's FRAGILITY and SMALLNESS!
It can give us new respect for our planet AND for our neighbors!



It often helps us be more safe
and be more prepared.

From WEATHER disasters, for example.

[pause]

Those are all pretty great reasons to explore outer space.

But there's also a huge EDUCATIONAL return!

Space exploration can INSPIRE future generations unlike ANY other field!
Raise your hand if you, at some point in your life,
EVER wanted to be an astronaut.

See!
Space exploration is INSPIRING … and it's INTRIGUING!

Even for the majority who DON'T end up actually becoming astronauts
Just the SEED of inspiration that's sometimes planted at a young age
can change that person's perspective on their OWN EDUCATION!

That seed of inspiration MIGHT get them more interested in MATH!
Or SCIENCE!
Or ENGINEERING!

ANOTHER wonderful benefit of space exploration is HOPE!
Hope for the FUTURE!
We COULD actually outlive this planet someday.

But, space exploration gives us REAL HOPE … based on REAL SCIENCE,
and not just science-fiction … that we might be able to COLONIZE
outer space and EVEN other planets someday!

[pause]

So, there you have a handful of benefits or arguments
for exploring outer space, asteroids, and other planets.

But, to be fair, it's NOT gonna be easy.

We've faced DANGER
and DEATH
in our efforts to conquer the frontier of space travel.

And although we go to great lengths to make missions and space vehicles as safe as we can,
There are still unknowns out there.
And there are SOME risks that can never be COMPLETELY and 100% mitigated.

Space exploration will ALWAYS be risky.

[dramatic pause]

Exploration even here on planet Earth is risky.

In addition to the risks and dangers they faced,
these early American pioneers had some LOGISTICS problems to overcome
when they set out to conquer their frontier of westward expansion.

They couldn't bring absolutely everything with them
on that long and difficult journey.

They had to live off the land,
and use local resources in order to survive.

And it turns out that we are also gonna have to live off the land.
So to SPEAK.
In OUR efforts to CONQUER the FRONTIER of SPACE travel.

EXPLORATION for more than just a couple of days
outside low earth orbit won't be possible, otherwise.

[[[Time: 5 minutes]]]

In the context of space exploration,
living off the land is known as in-situ resource utilization or ISRU.

In-Situ is Latin for “on site”.
So it’s actually On Site Resource Utilization.
Or using the resources that you find on site.

ISRU is pretty EXCITING,
because it’s a way to reduce the mass.
AND the COST,
of space exploration!

So what do I mean when I suggest living off the land …
In SPACE?

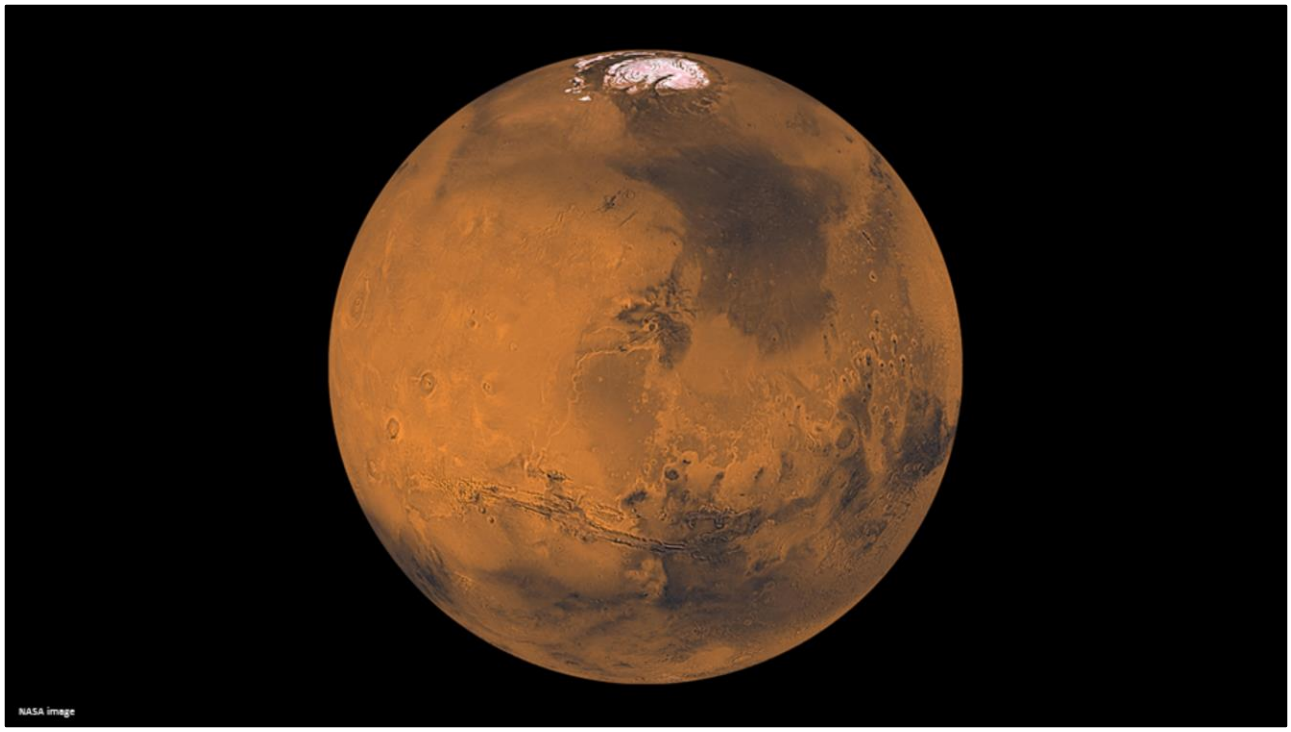
Well, you might be surprised to hear
that there are QUITE a LOT of useful resources OUT THERE.

The earth's moon for example.
It may look like a dry useless rock.
But it's not!

NASA has proven that there's water-ice
located in permanently shadowed regions of the moon!

And scientists believe there's even MORE water ice under the surface,
HIDING from our instruments!

What precious resources might there be …



… on Mars?

Well, the Martian atmosphere, although thin, is MOSTLY made up of Carbon Dioxide.

And like our moon, Mars has evidence of water-ice hiding beneath the surface.

When we travel to these destinations and stay for long periods of time,
living off the land is just NOT gonna be an option!

There's just NO WAY, economically,
that we'll be able to pull off those missions where
astronauts will LIVE, WORK, and be productive on another PLANET
WITHOUT living off the land.

I'm about to introduce you to several ISRU technologies
that are being investigated
for NASA's Journey to Mars.

If you're wondering … what IS NASA's Journey to Mars?

It's NASA's plan to develop TECHNOLOGIES the astronauts will use
to one day LIVE and WORK on Mars,
AND safely return HOME
from that NEXT giant leap for humanity!

NASA is RIGHT NOW developing the technologies
and the capabilities needed to send HUMANS to Mars!
We're targeting putting humans on Mars in the 2030's.

Human missions to Mars will rely on the ORION space capsule,
shown here in this artist's rendering.

HUMAN missions to Mars will ALSO rely on the Space Launch System,
or SLS rocket that's planned to be the
most POWERFUL launch vehicle ever flown!

Our planned human missions to Mars are risky, though.
There WILL BE DANGERS and UNKNOWNS
that we'll have to deal with along the way.

But the PAYOFF is GREAT!
Se we're EXCITED to go!

But to WORK and OPERATE on Mars for the LONG TERM,
we're gonna need help from some ISRU technologies!

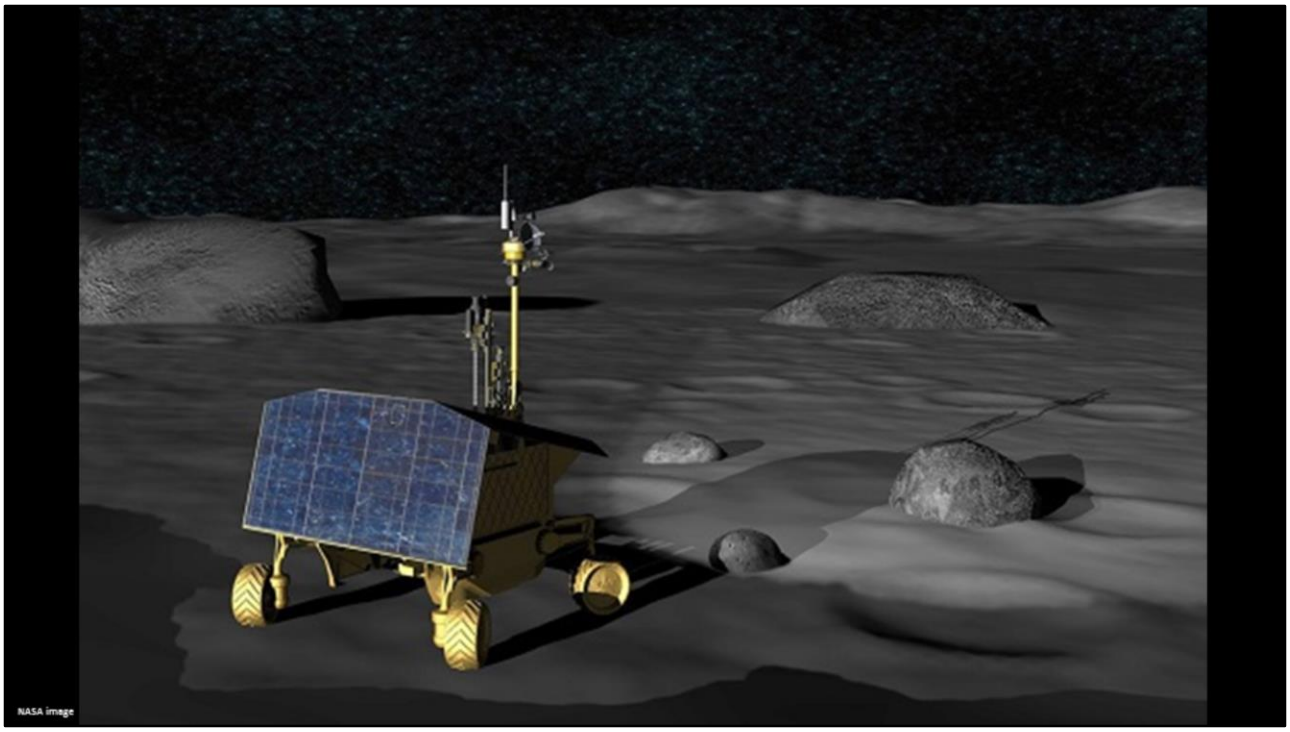
The FIRST thing we'll need to do is
LOCATE the precious resources on site.

Probably the easiest way to look for precious resources
on another planetary body is to send a rover
and operate it from the comfort and safety of Earth.

This rover is called Resource Prospector.
It's ABOUT the size of a TYPICAL golf cart.

Resource Prospector is designed to WORK on the MOON.
But it will be DRIVEN and OPERATED remotely by a team here on earth.

Resource Prospector is out to prove that we can SUCCESSFULLY perform ISRU operations, by HARVESTING RESOURCES
found on another planetary body.

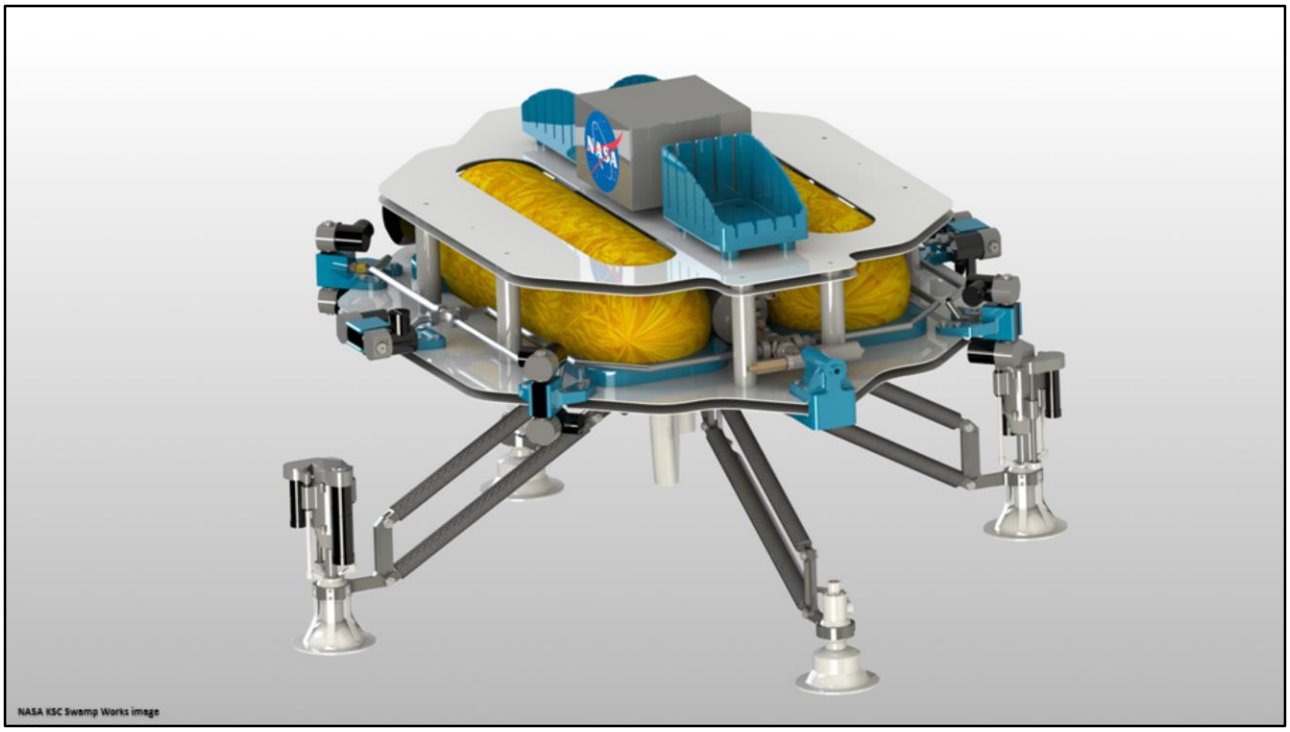


It's designed to drill 1 FULL meter below the SURFACE.
It will then RETRIEVE a small sample from 1 meter down
and then HEAT that sample up to RELEASE any WATER molecules.
Then it will COLLECT or CONDENSE those water molecules
and STORE the water onboard.

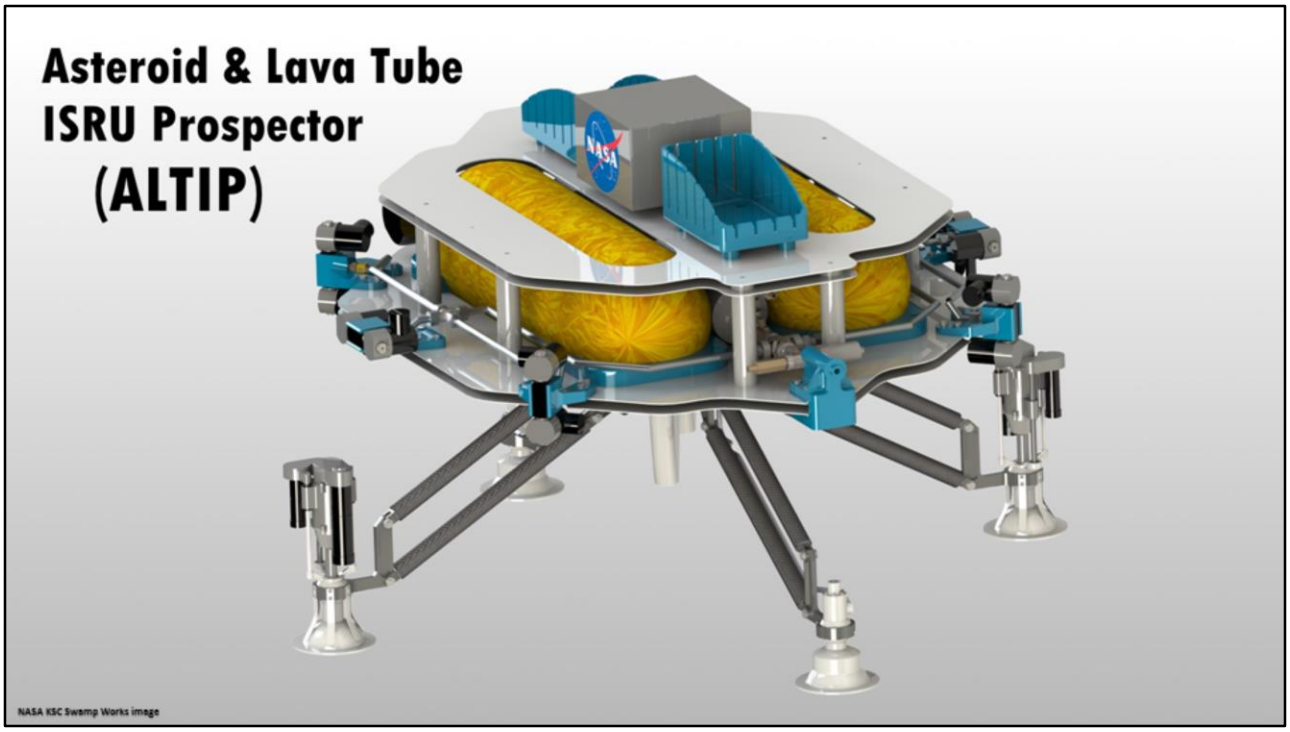
Once we've proven this technology on the MOON, we can start planning
for more distant and more complex ISRU missions on MARS!

[pause]

But what if a WHEELED rover can't GET to the precious resource?
What if the resource is down at the bottom of a very DEEP
and steep walled crater?
What if the resource is inside a CAVE?



Well, in that case, one solution would be to use a FLYING robot rather than a DRIVING one.



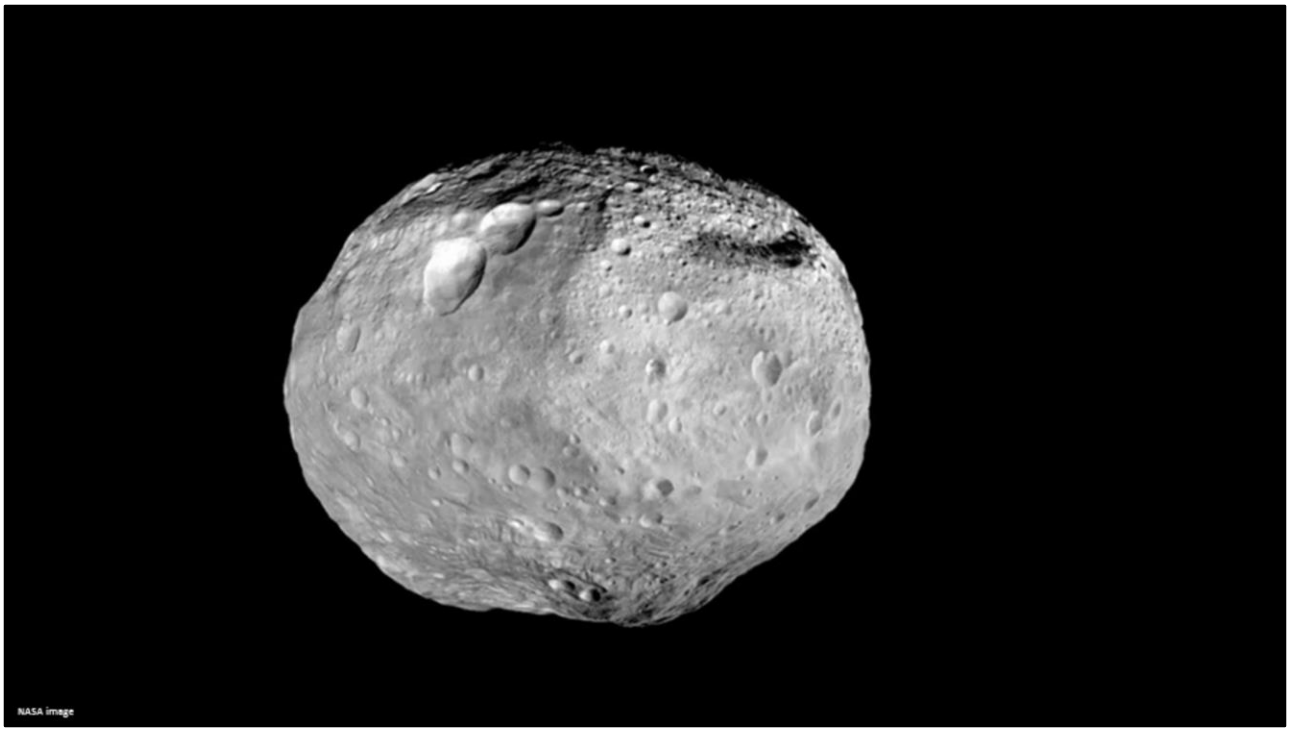
This robot is called the Asteroid and Lava Tube ISRU Prospector or ALTIP.

This is a PNEUMATICALLY propelled FLYING robot.
It uses compressed gas thrusters
to fly around in environments that contain LITTLE or NO atmosphere.
It's sort of like a quad-copter or drone
but it uses THRUSTERS instead of PROPELLERS.

It's not very big … about 1 meter across.

This robot is out to prove that we can successfully prospect
or search for resources in VERY hard to reach areas.

So let's talk about prospecting on asteroids.

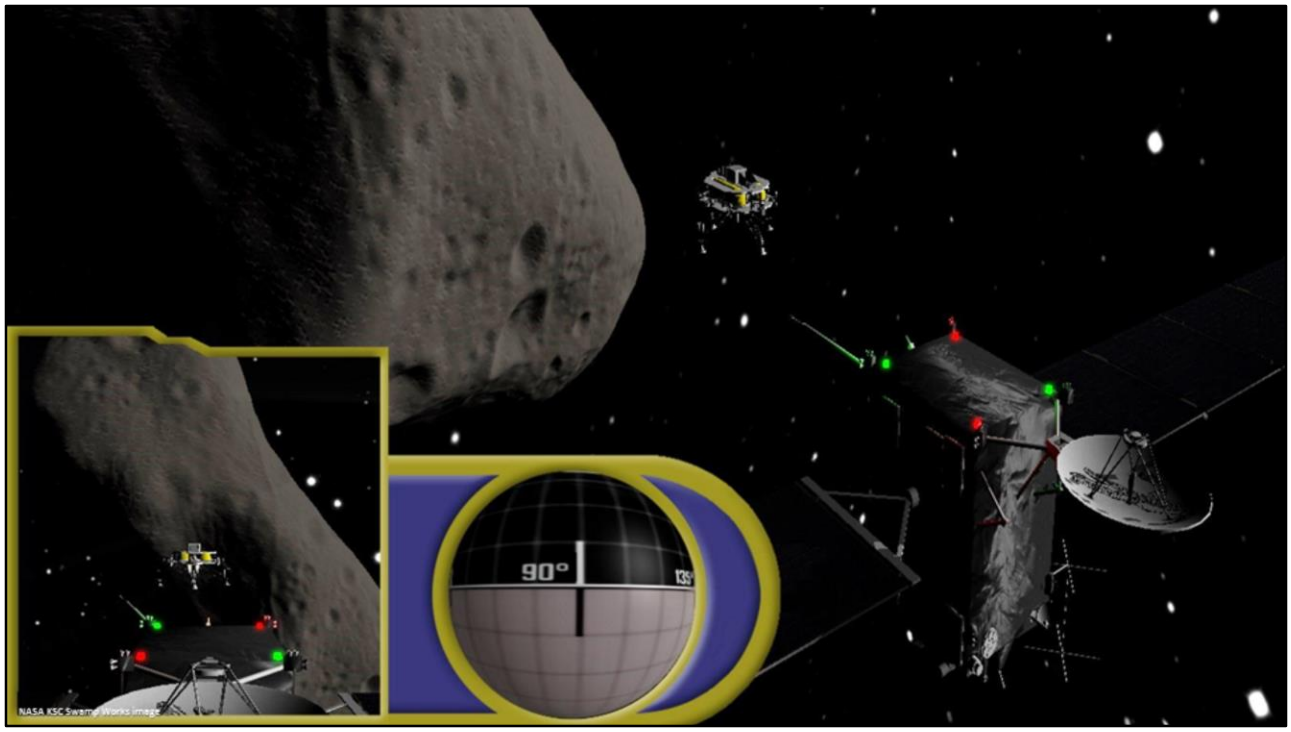


[[[Time: 10 minutes]]]

Picture a rock a FEW kilometers across.
There's NOT a lot of gravity associated with a rock this size
to pull your spacecraft down and to HOLD it down.
Only about one one-thousandth of our gravity here on earth.

And you're NOT going to be able to DRIVE around on it
with a WHEELED rover.
One small bump and your rover would just go airborne
for a long long time.

So what you do is you send a MOTHER ship
along with the ALTIP FLYING robot.



Once the mother ship is orbiting the asteroid,
ALTIP separates from the mother ship
and uses its THRUSTERS to maneuver down to the surface.

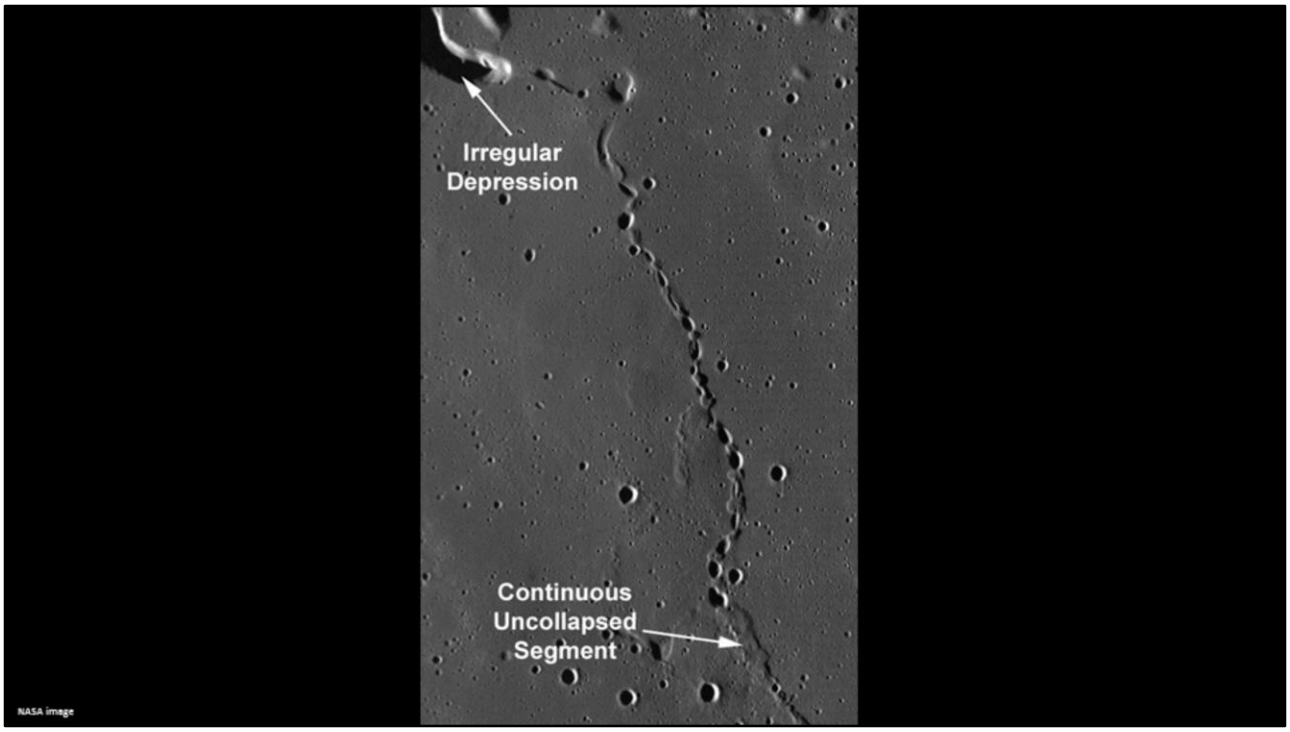
ALTIP uses a small micro-drill to drill into the surface
and collect a small sample.
Then it flies back to the mother ship
where the sample can be processed and analyzed.

This type of mission SHOULD tell us what kinds of
PRECIOUS RESOURCES the asteroid is MADE of.

NOW let's look at lava tubes.
Lava tubes are natural CAVERNS or CAVES
beneath the SURFACE of a planet that are formed by VOLCANIC processes.

This is a photo of a SKYLIGHT or an OPENING
in a hot lava FLOW in Hawaii.

You can ACTUALLY SEE the hot lava through the opening
and there's BASICALLY a CAVE that the hot lava is flowing inside.
This is essentially the BIRTH of a LAVA TUBE!

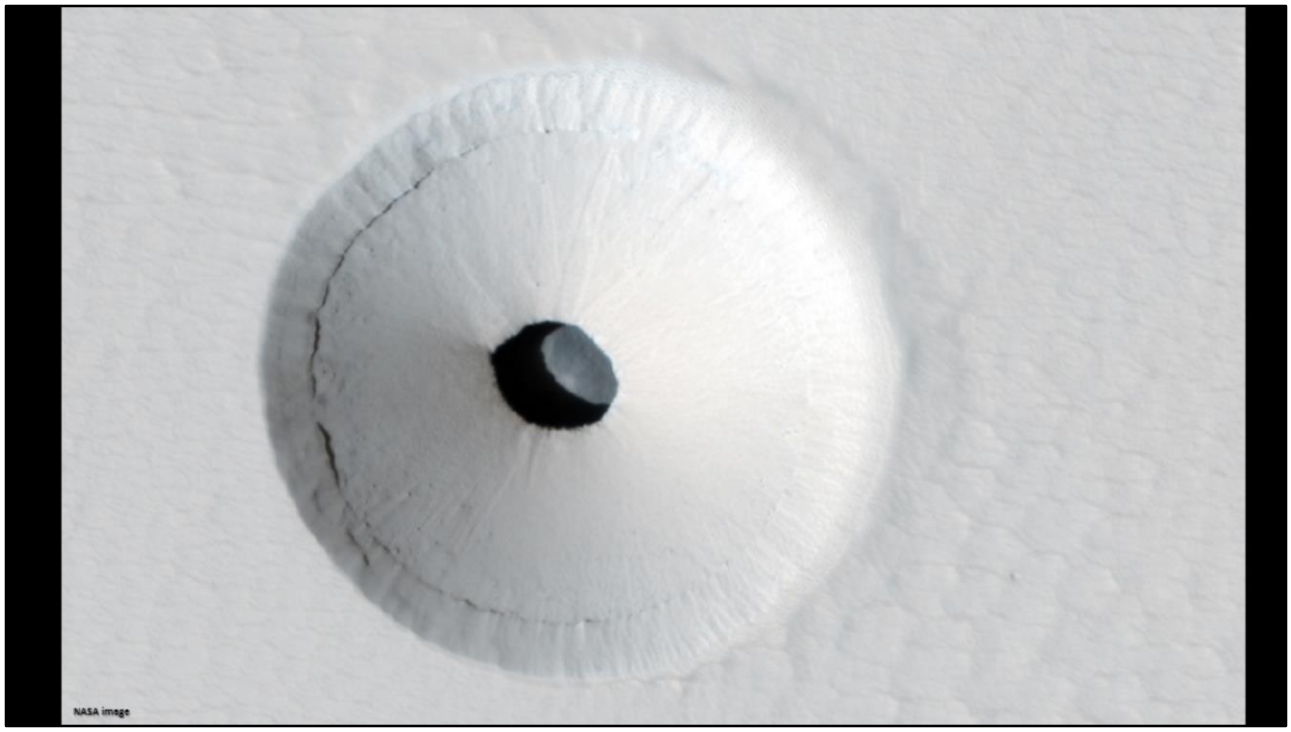


THIS is a photo taken from LUNAR orbit and it CLEARLY shows
a LAVA tube on the MOON.

You can see a chain of COLLAPSED sections
transitioning into a continuous UNCOLLAPSED area
toward the BOTTOM of the photo.

This photo kind of points out the DANGERS
of exploring inside lava tubes.

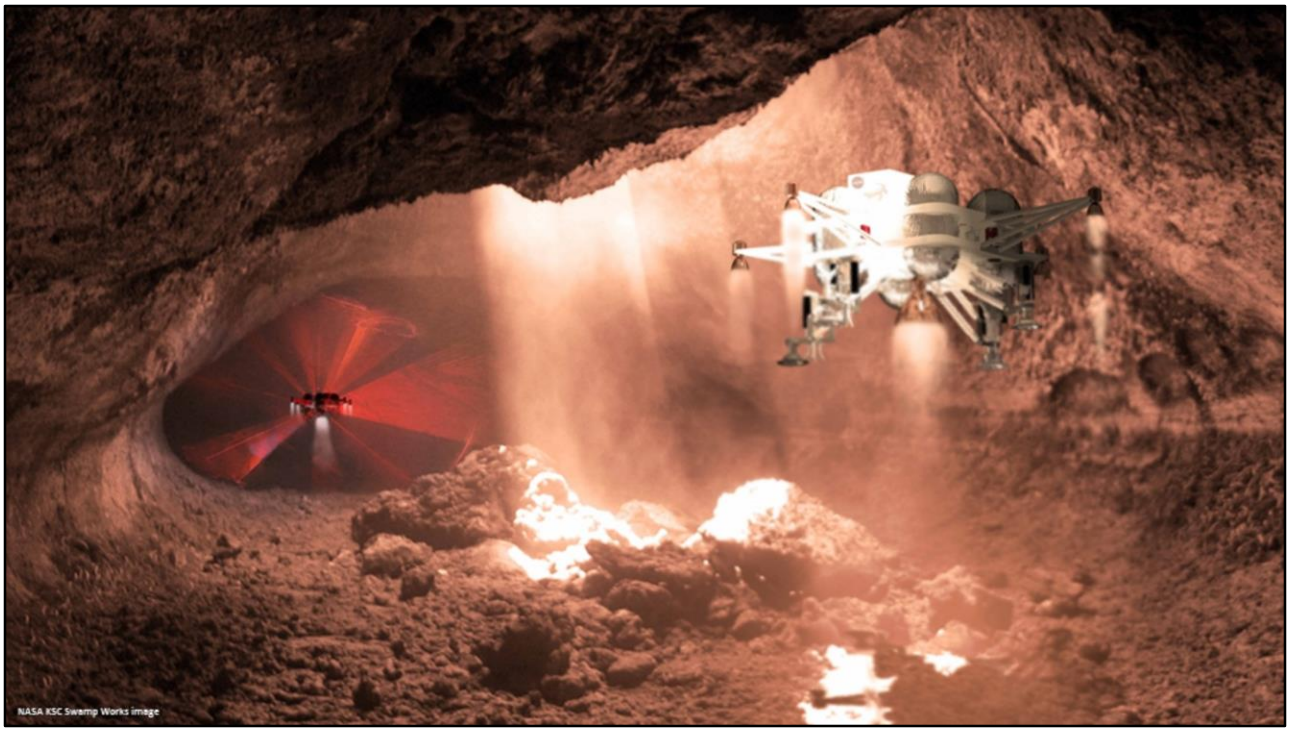
They can COLLAPSE on top of you!
So EXPLORING them and prospecting INSIDE would be best accomplished
with UNMANNED and FULLY AUTONOMOUS robots, like ALTIP.



Lava tubes have been found on Mars too!
This photo shows a skylight opening in a lava tube on Mars!

To give you a feel for scale, the hole is about 35 meters across.
Scientists believe that the larger crater looking formation isn't an impact crater but was actually formed over time as the rock and dust fell into the hole.
Sort of like a sink hole or an hourglass effect.

Wouldn't it be cool to explore this underground cavern on Mars?



There might be frozen water down there that NEVER sees ANY sunlight.
There might also be other cool mineral deposits
or other precious resources down there.

Now, manually controlled rovers and autonomous flying robots
are WONDERFUL inventions!
But what if you're looking for hidden resources
that are sparsely DISTRIBUTED over a WIDE area?
One or two robots just isn't gonna be all that efficient
at searching a VERY LARGE area.

So what IS efficient at searching a VERY LARGE area?

It turns out that ANT colonies are.
At LEAST for their SIZE and for their BRAIN capacity,
ants are quite GOOD at SEARCHING an area,
FINDING food and water, and BRINGING those resources back home.

And they accomplish ALL these tasks without ANY real leadership or direction.
AND without a MAP of any kind.

Each individual ANT is just BORN knowing what to do.

And so scientists have studied ants.
And they've taken CAREFUL notes on how the ants behave …
when searching for FOOD and bringing that food HOME to the nest.

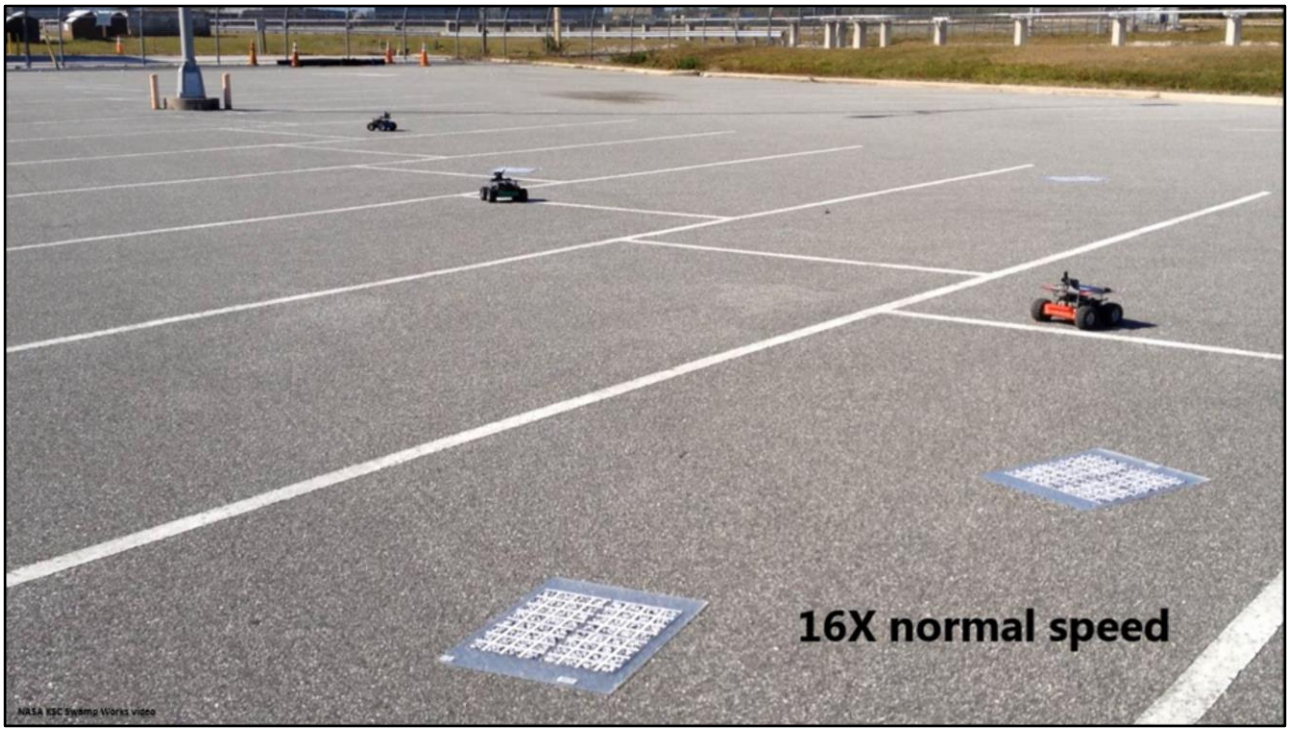
It turns out that these ant FORAGING behaviors can be reduced …
to just a SMALL set of relatively SIMPLE rules.

Which makes sense, since ants have such SMALL brains.

And so we've programmed these ant behaviors, these rules,
into a GROUP of small robots.

We call them the SWARMIES!

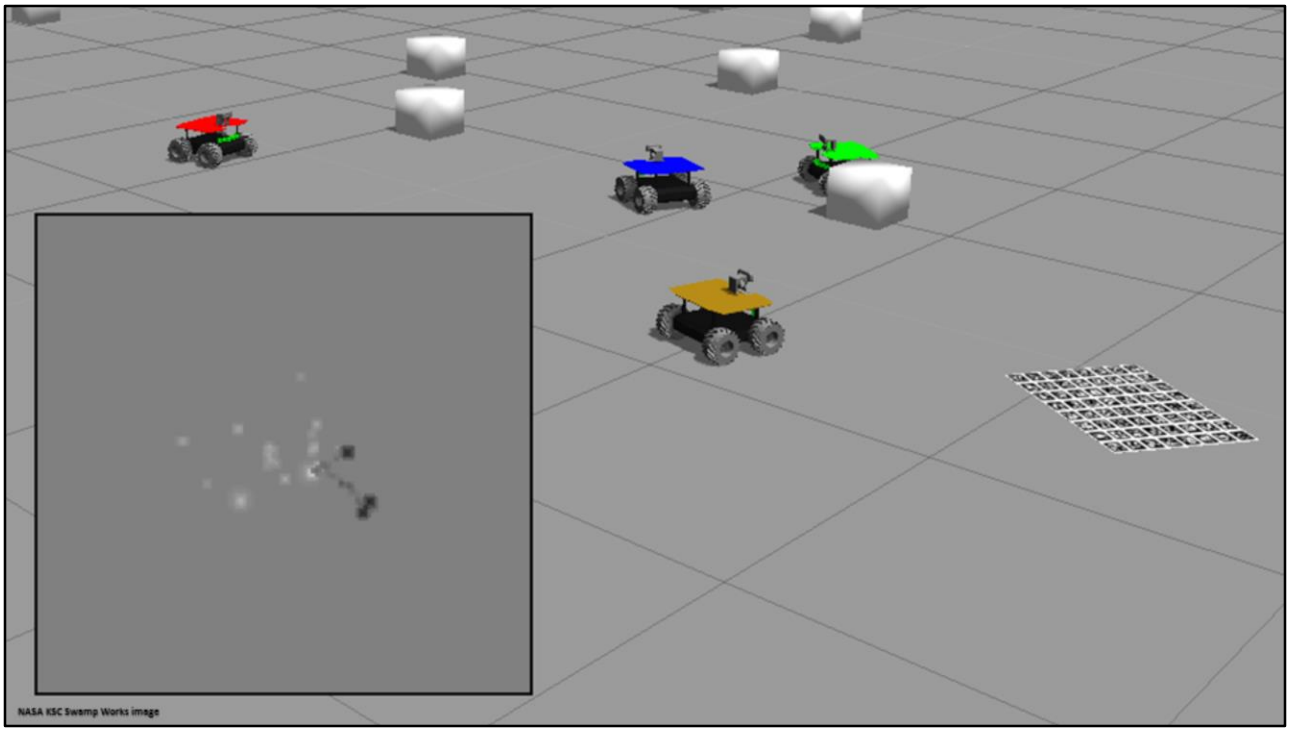
The Swarmie robot platform is a low-cost,
ground-based research and demonstration platform.



[VIDEO]

The Swarmies are able to find and collect simulated resources
from an unknown area that's filled with obstacles.

That's COOL
because it might be useful to perform that type of foraging operation
for precious resources on Mars someday.



The robots use simulated pheromone trails to communicate with other robots.

THAT'S cool
because pheromone trails are an INDIRECT communication mechanism
that COULD scale up to LARGE numbers of ROBOTS.

[VIDEO]

It’s difficult to manually control a large swarm of robots.
So this system is designed to be FULLY autonomous
and require NO operator interaction once activated.

Now, once you're done PROSPECTING and FINDING the precious resources, your task switches to COLLECTING or GATHERING those resources.

I want to pause and define a word at this point.
Because I'm gonna start using this word quite a bit.

The word is "regolith".
Regolith is a fancy scientific word for dirt.

When we talk about the dirt or the dust on the surface of the moon
or on the surface of Mars, we usually call it regolith.

[[[Time: 15 minutes]]]

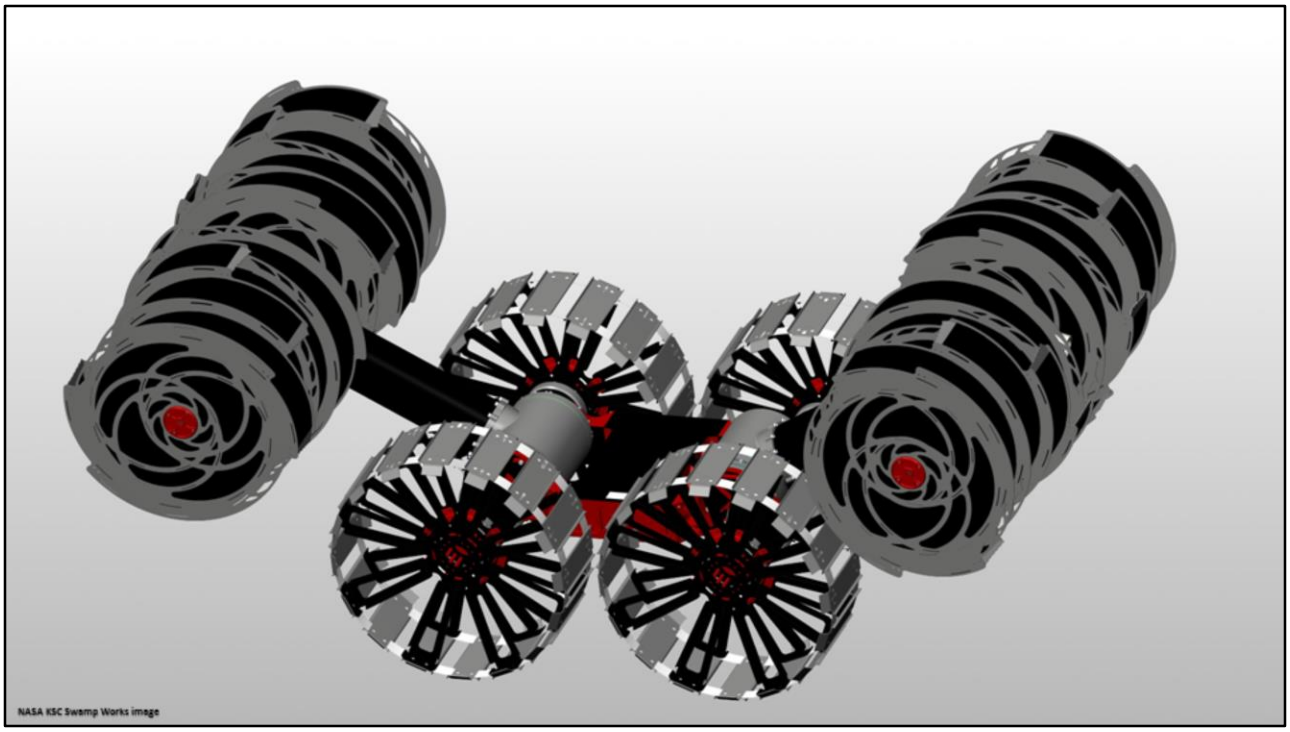
So in order to collect or gather resources on another planetary body,
We're gonna need some mining equipment.

Here on Earth, when we excavate or mine,
we use really heavy digging equipment like this.

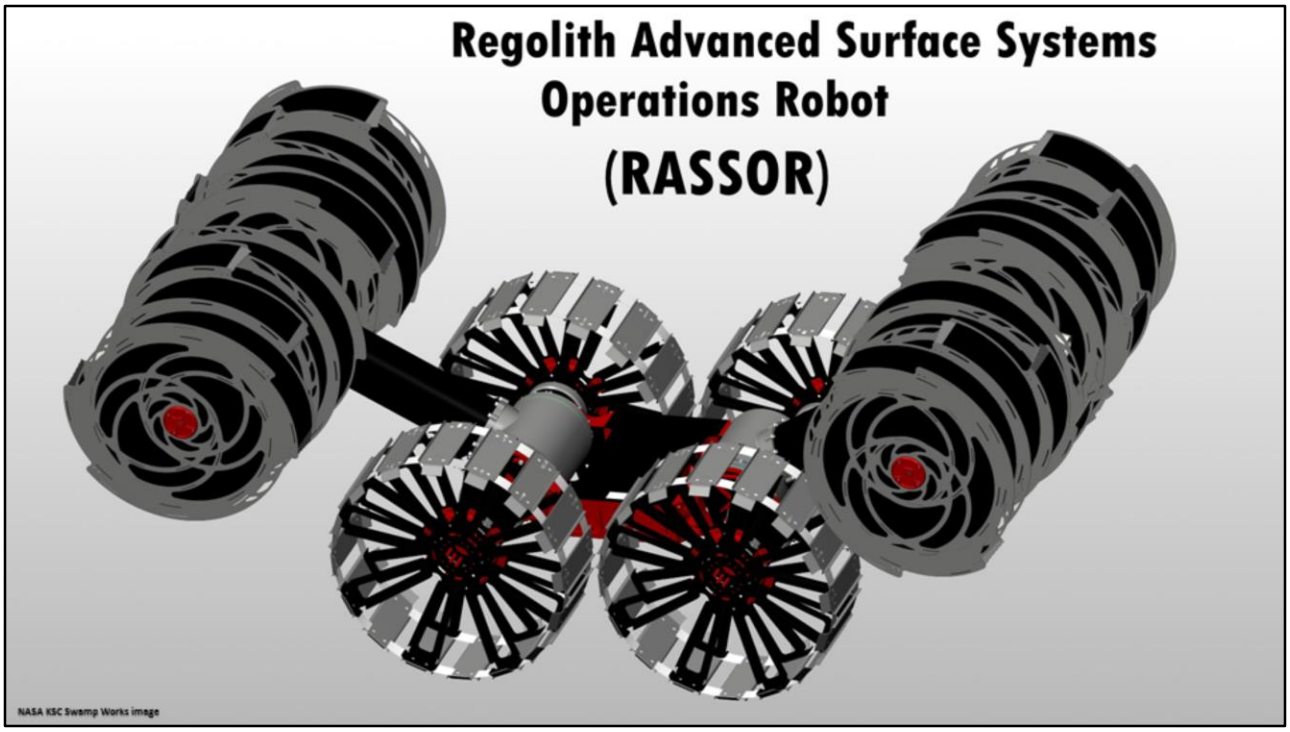
"Eco-Drive Bagger", Wikimedia Commons

Heavy equipment like this doesn't really translate very well into space operations because every kilogram that we launch into space is PRECIOUS and VERY costly.

So we've been researching ways …



to dig or excavate using very lightweight equipment.



Meet the Regolith Advanced-Surface-Systems Operations Robot,
otherwise known as RASSOR.

This robot is not very big.
It's only about the size of a go-cart.

But RASSOR is designed to be a WORKHORSE of regolith excavation.
It's also very SIMPLE,
and very LIGHT WEIGHT.

[VIDEO]

Here's how it operates.

The two sets of spinning drums on the FRONT
and on the REAR of the robot spin.

[wait a few seconds]

[VIDEO]

Then the arms lower down into the regolith
and small digging buckets or scoops
mounted on the drums scoop up the regolith.

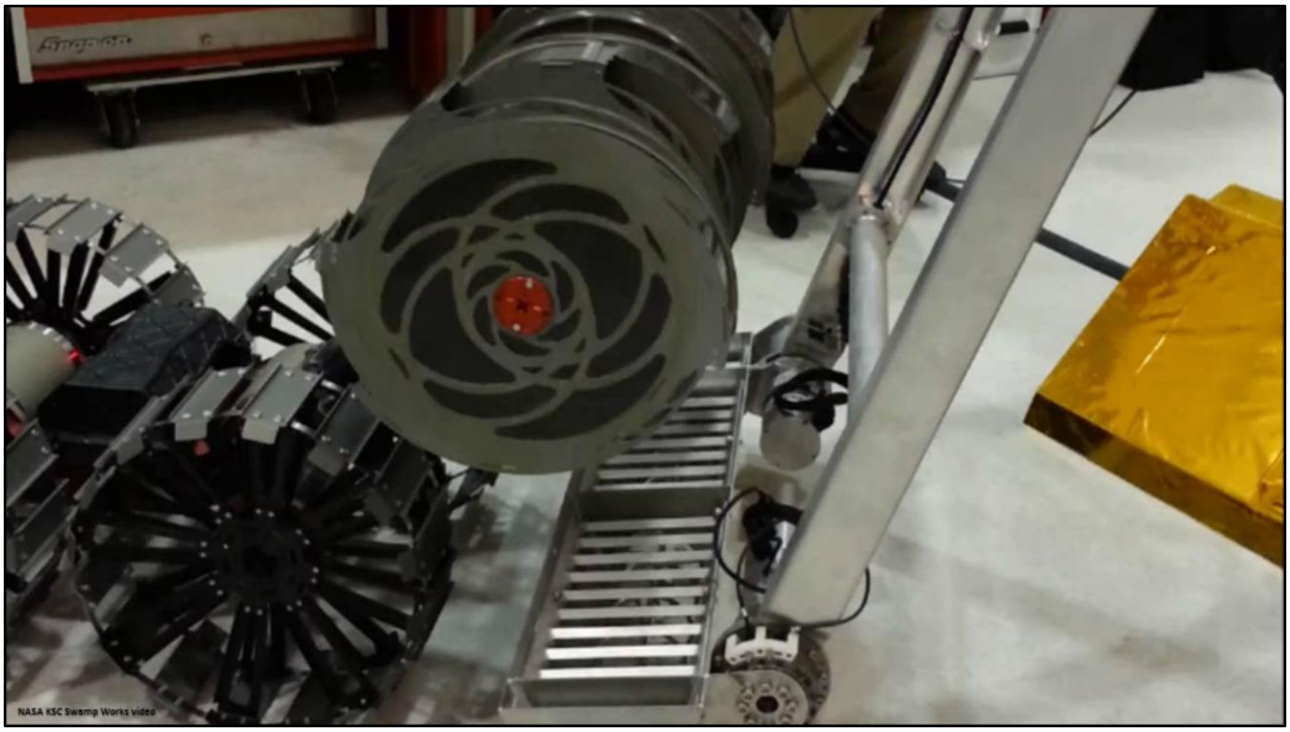
The drums are hollow with baffles inside to hold the excavated material.

[wait a few seconds]

[VIDEO]

The robot actually drives forward while digging in order to dig a shallow but long trench.

Once the drums are full, the arms lift back up and the robot drives off with it’s load of regolith.



[VIDEO]

When the robot reaches the processing plant back at the lander
it reverses the drum rotation direction to unload the regolith.

Then RASSOR goes back and digs in the same slot trench,
over and over again.
Each time, digging down just a centimeter or two.

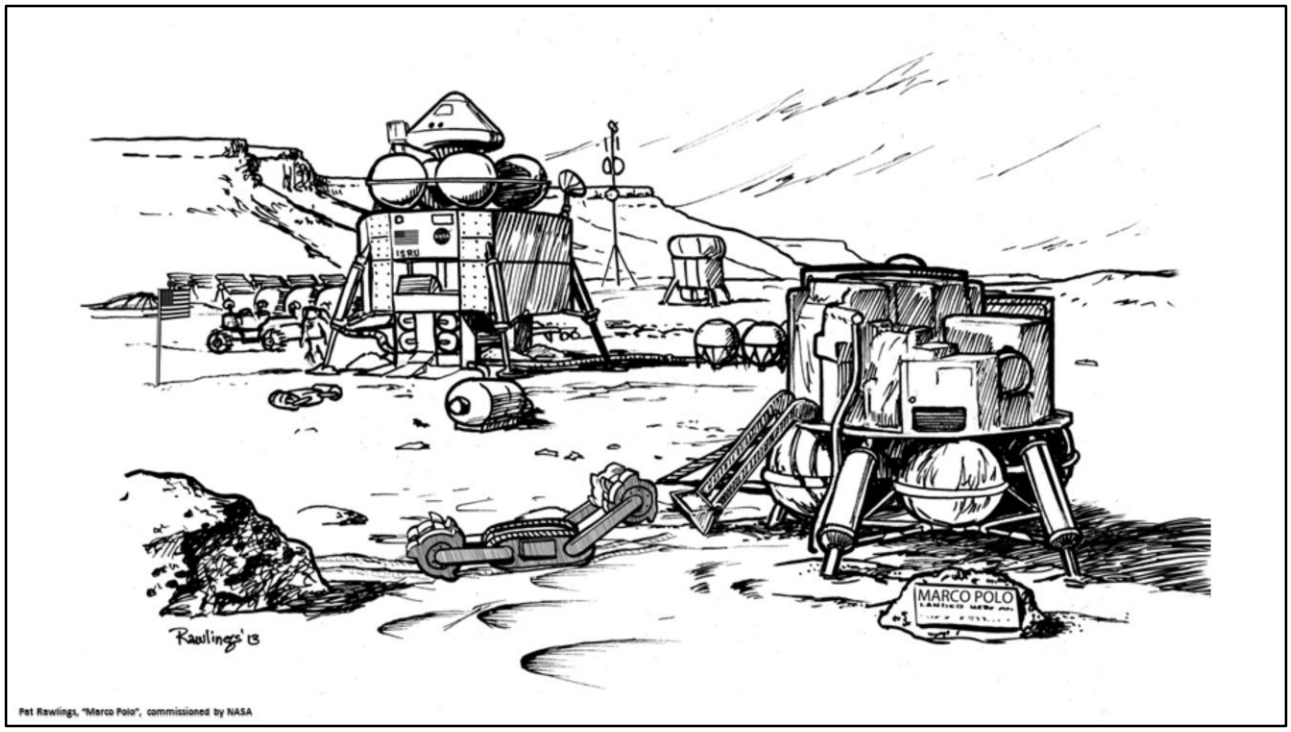
Over time, RASSOR will dig down far enough
to reach the regolith that's holding the water ice.

By testing this excavation design in the lab and lifting up on the robot,
we've proven that this robot can dig in very low gravity conditions.
And THAT is gonna be very useful on the MOON or on MARS someday!

Okay, so we've LOCATED the precious resources.
And we've GATHERED and COLLECTED piles and piles of raw material.

But the precious resources are EMBEDDED inside those raw materials.
And we have to get them out of there
and into a FORM that we can ACTUALLY use.

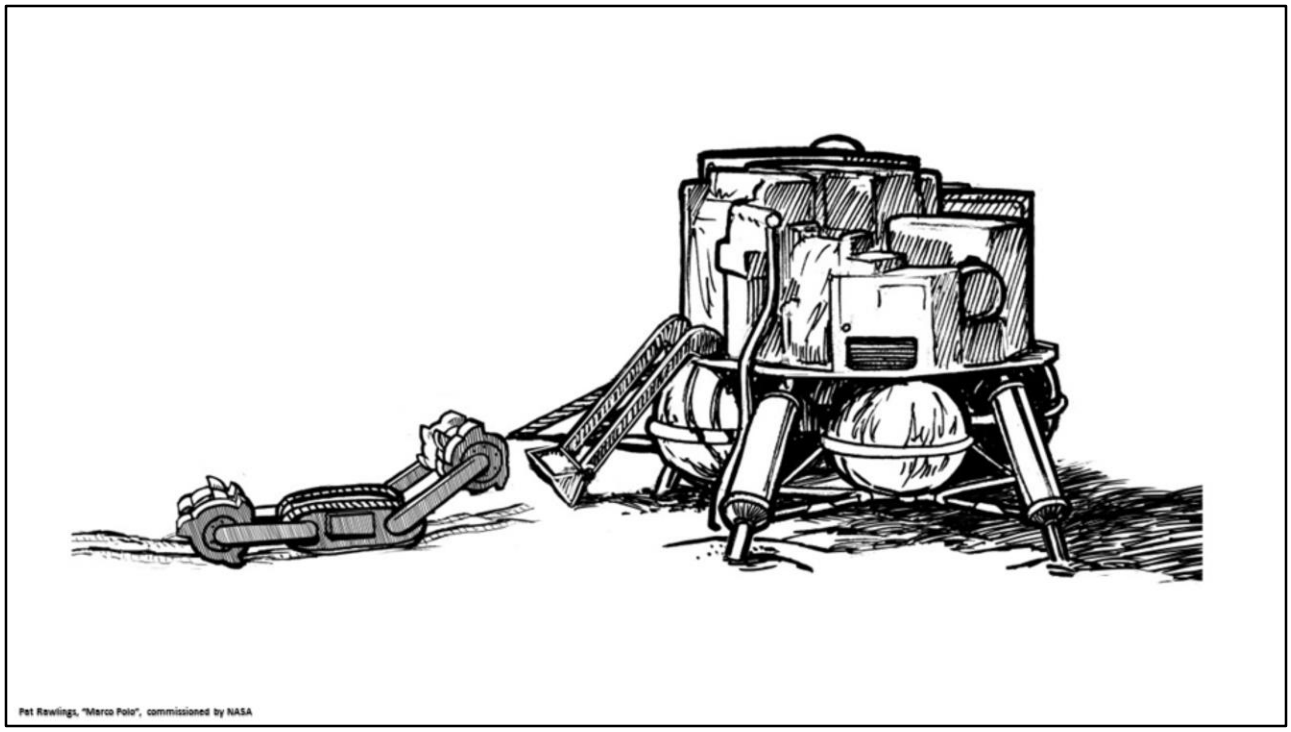
So we're gonna need some sort of PROCESSING plant on site
to EXTRACT the precious resources from the raw materials.



Pat Rawlings, "Marco Polo", commissioned by NASA

This is an artist's concept of a regolith processing plant on Mars.
It shows an older design of our RASSOR robot
bringing regolith to the processing plant.

Once RASSOR digs down to the regolith that has water-ice embedded in it
we're in business.
Because we can SEPARATE the water from that regolith.
And then we can separate the Hydrogen and the Oxygen molecules from that water!



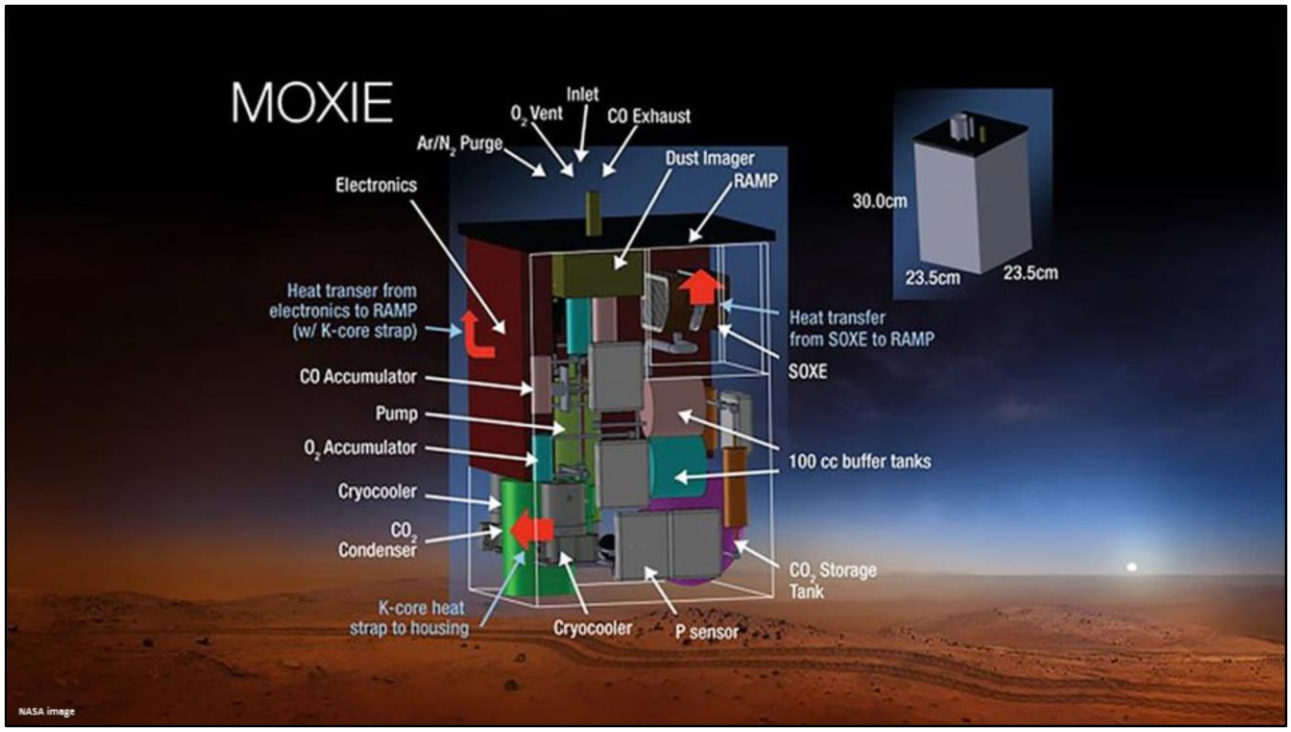
Once we store them in liquid form we've got ourselves a gas station on Mars!

Yes, liquid Hydrogen and liquid Oxygen make awesome rocket propellants!
And we can create them both on Mars!
And we can use the energy from the sun to power this processing plant on Mars.

[pause]

There's another important raw material on Mars,
and we DON'T have to send robots out into the depths of craters to find it.

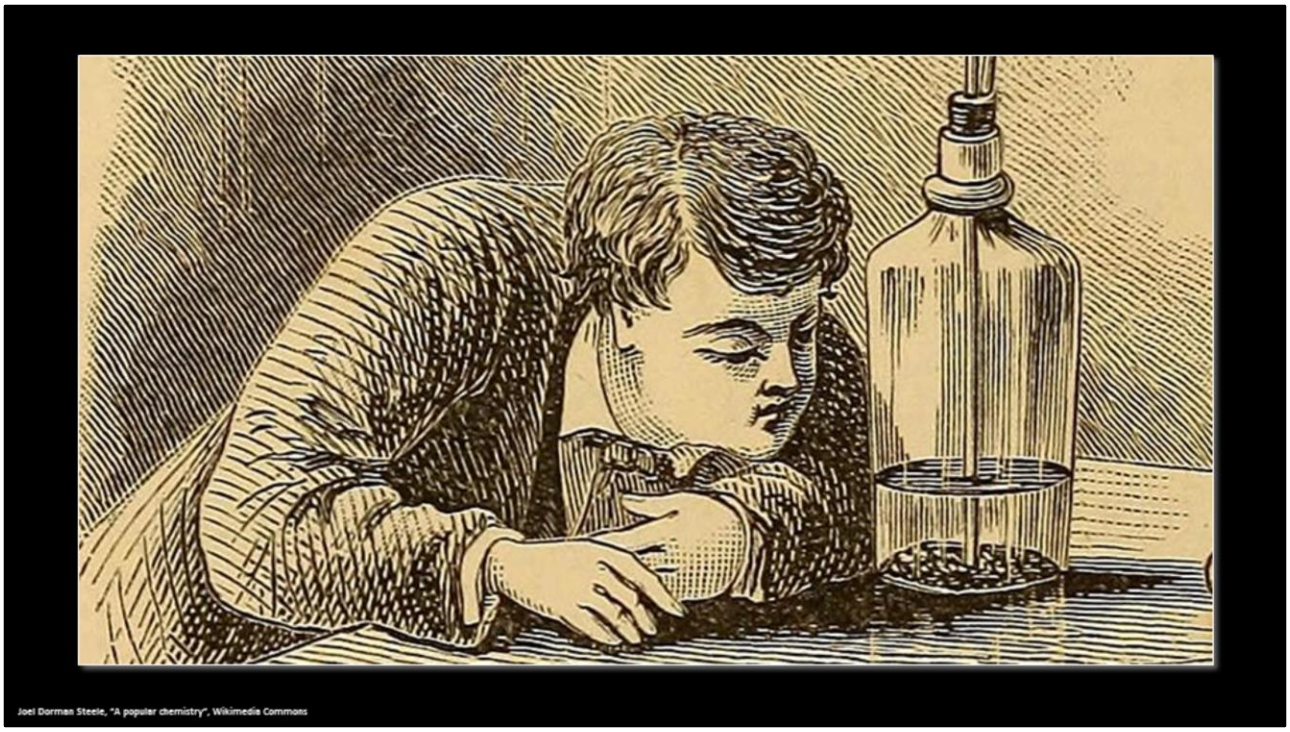
It's the ATMOSPHERE!



This is a diagram of MOXIE, which is short for Mars OXygen ISRU Experiment.
MOXIE is one of several scientific experiments that are gonna fly
onboard the Mars 2020 Rover and operate on Mars in the year 2021.

MOXIE pulls in Carbon Dioxide from the Martian atmosphere.
And it produces pure OXYGEN!

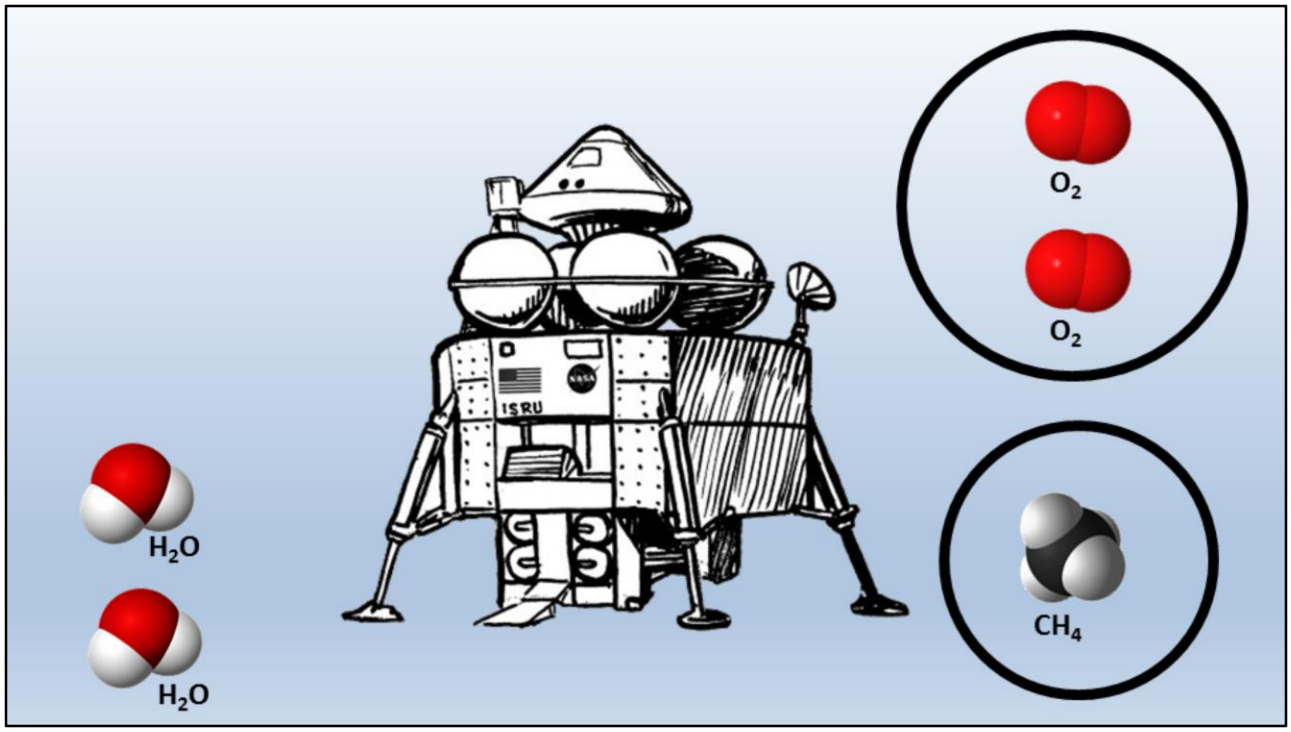
A machine similar to this one
could operate on Mars someday to create breathing oxygen for the astronauts!



Here's another idea for an on-site Mars processing plant.
There's a really cool chemical reaction called the Sabatier reaction
that NASA is looking at sending to Mars someday.

The Sabatier reaction when paired with electrolysis,
turns WATER from the regolith
and CARBON DIOXIDE from the atmosphere
into liquid oxygen and liquid methane.

Another pair of awesome rocket propellants!



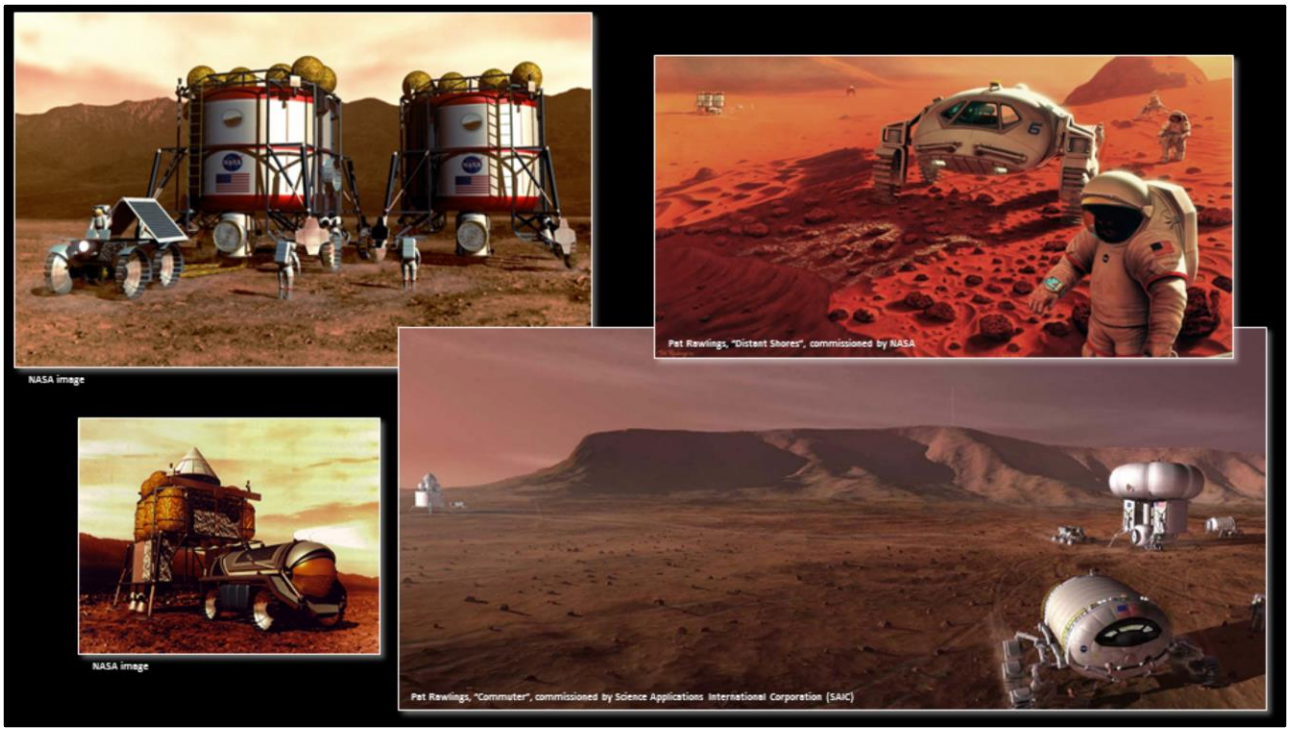
And if we can create rocket propellants on the surface of Mars.
We can use them to fuel our Mars Ascent Vehicle, for example.
Which will be used to get the astronaut crew back into Mars orbit.
That's the first leg of their return trip back to Earth.

[pause]

We've been talking a lot about precious resources
that are embedded in the Martian regolith.
Like Water, Hydrogen, and Oxygen.

But the RAW FORM of the regolith might ALSO be useful.
Couldn't we just use the crushed rock ITSELF to BUILD stuff?

The answer, of course, is YES!



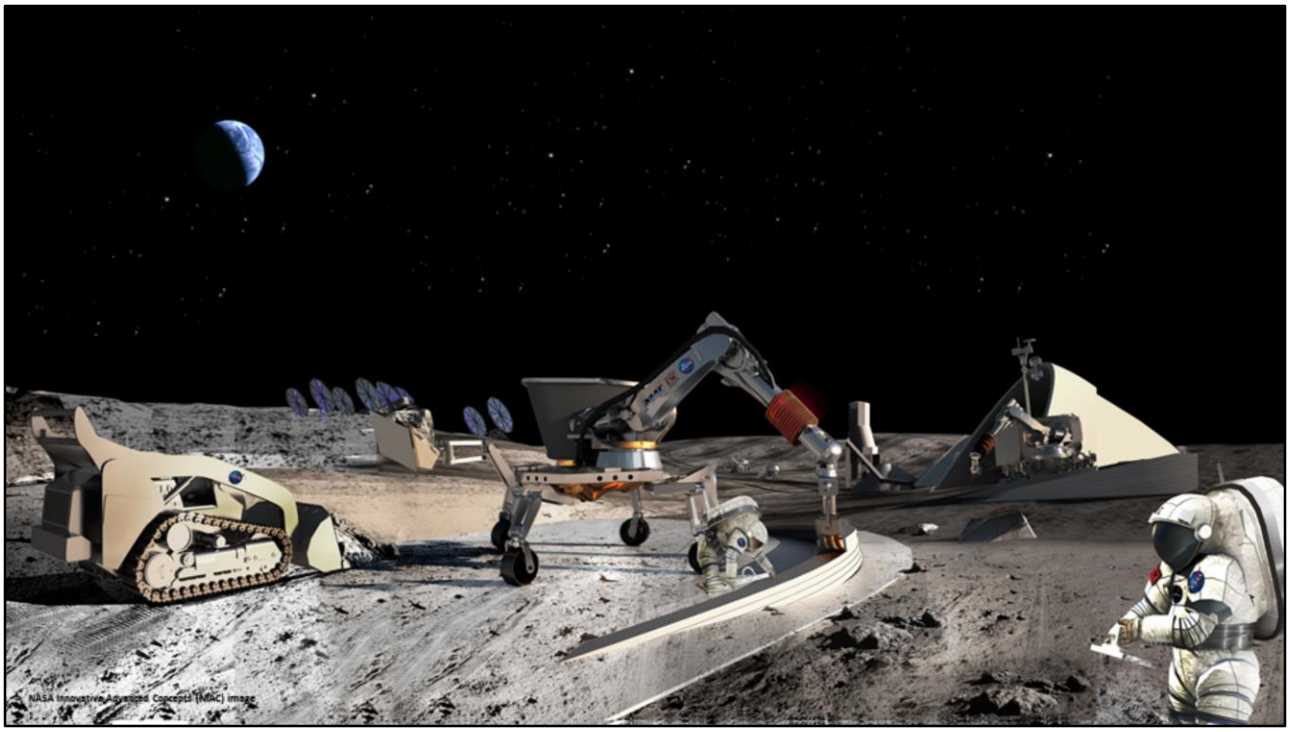
[[[Time: 20 minutes]]]

Most proposals for building outposts on the Moon or on Mars involve sending prefabricated modules all the way from Earth and then putting them together on site.

There are some limitations with this kind of thinking, though.

Everything we ship from Earth is VERY costly.
Everything we ship from Earth is ALSO limited in SIZE.

ISRU researchers are thinking outside the box, though.



We're now looking into the possibility of sending CONSTRUCTION EQUIPMENT to the Moon or to Mars.

To build roads.
Or landing pads.
Or even large structures!
Right there on site.

One technology area being explored is 3D printing with regolith.
You might be familiar with common 3D office printers.
They melt plastic and they extrude that molten plastic out a nozzle
to lay down very thin layers of material to create a 3 dimensional object.

NASA researchers are looking into the possibility
of 3D printing on a large scale using MOLTEN REGOLITH.

This on-site 3D printing technology could be used to build
roads, landing pads,
dust barriers,
micro-meteorite protection shields,
garages,
and pretty much ANY standing structure that you can THINK of!

Another area of on-site construction research,
besides 3D printing with regolith …

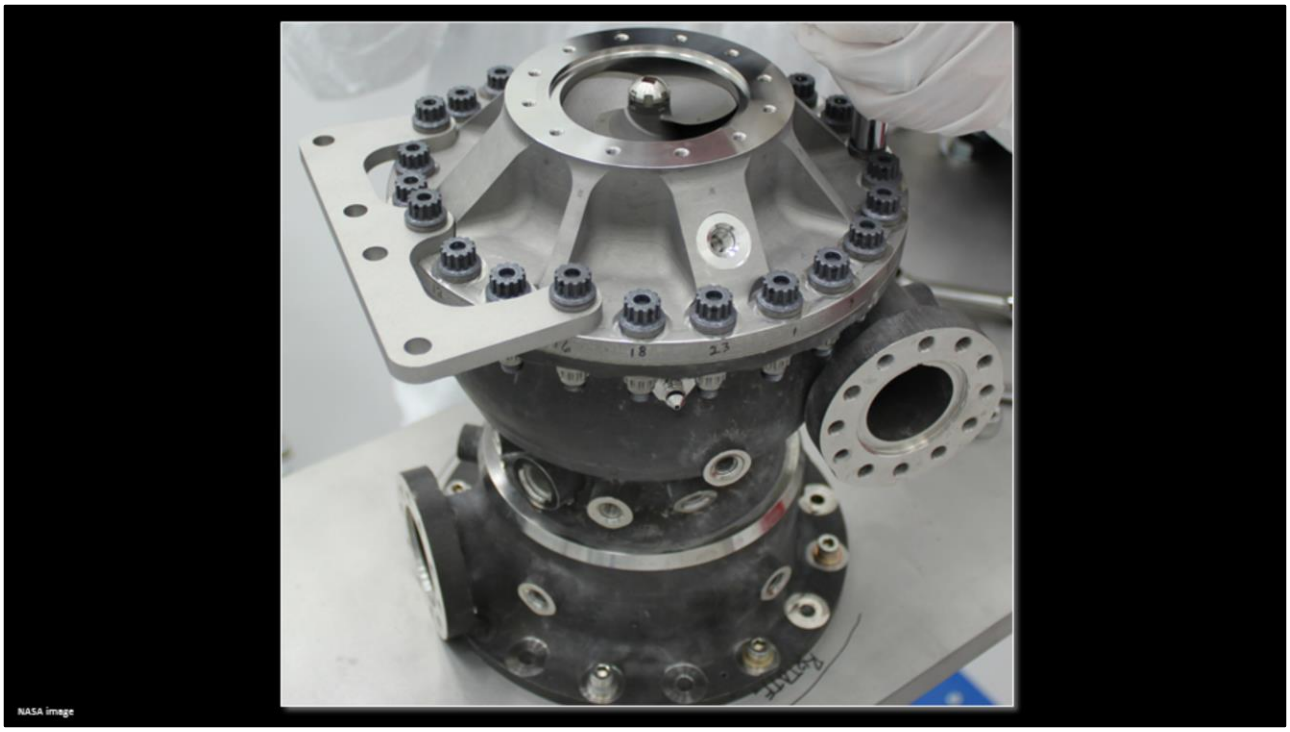
is the creation of durable, interlocking tiles on-site
that can be used for road or landing pad construction.

The robot in this photo is placing interlocking tiles on the ground
in a field demonstration in Hawaii.
And we controlled this robot from Florida!
These tiles were created COMPLETELY from crushed volcanic rock
using a high temperature BAKING technique.

So basically we used THEIR DIRT and a remotely controlled ROBOT
to BUILD a LANDING PAD!
Which is almost EXACTLY what we'd like to do on MARS someday!

[dramatic pause]

Mars and Lunar regolith both contain useful metals like Iron, Aluminum, and
Magnesium.



All of which could be extracted from the regolith
and used to 3D print metal components and parts!

NASA along with several aerospace companies are right now
perfecting the process of 3D printing complex metal
rocket engine parts to speed up manufacturing.

Like the 3D printed liquid hydrogen turbo-pump, shown in this photo.

If we can 3D print very complex rocket engine parts here on earth.
Then 3D printing of metal tools or metal replacement parts
might not be that difficult on the site of a Mars colony.

Assuming that we have the right raw materials on site to feed the printer!

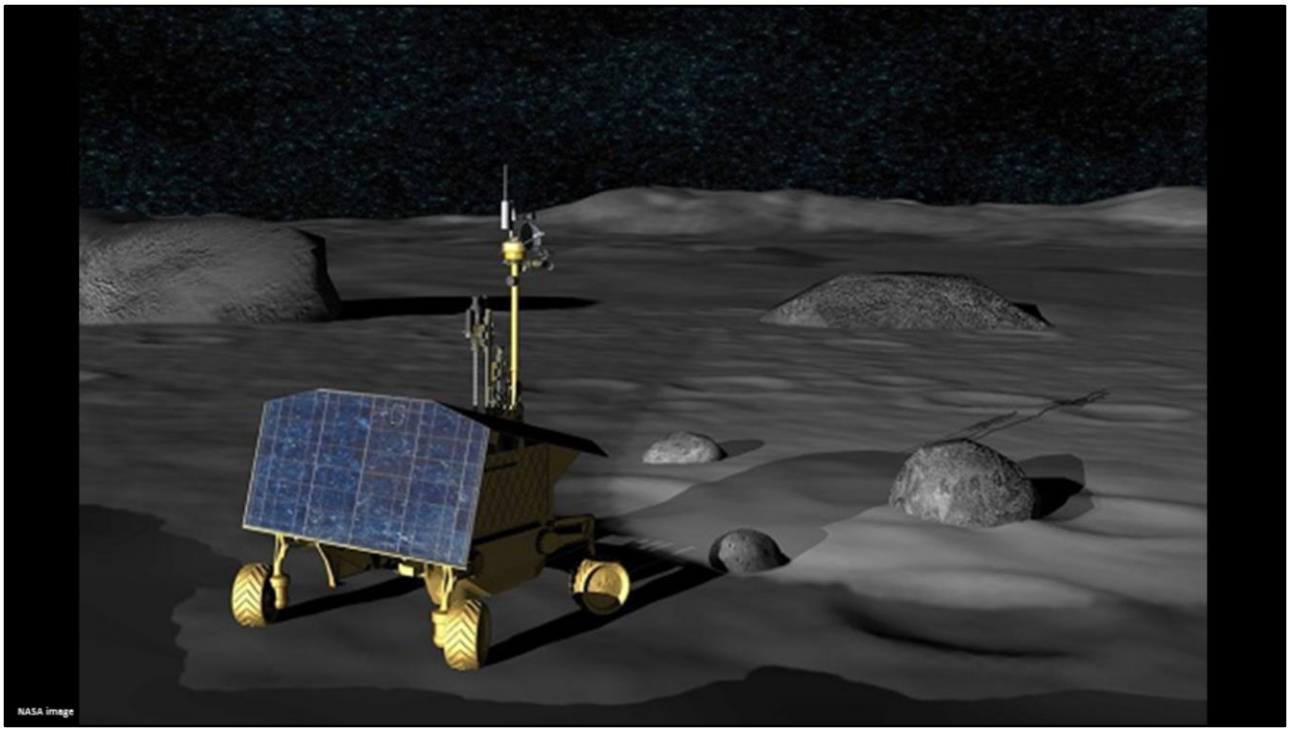
SWAMP WORKS

NASA KENNEDY SPACE CENTER

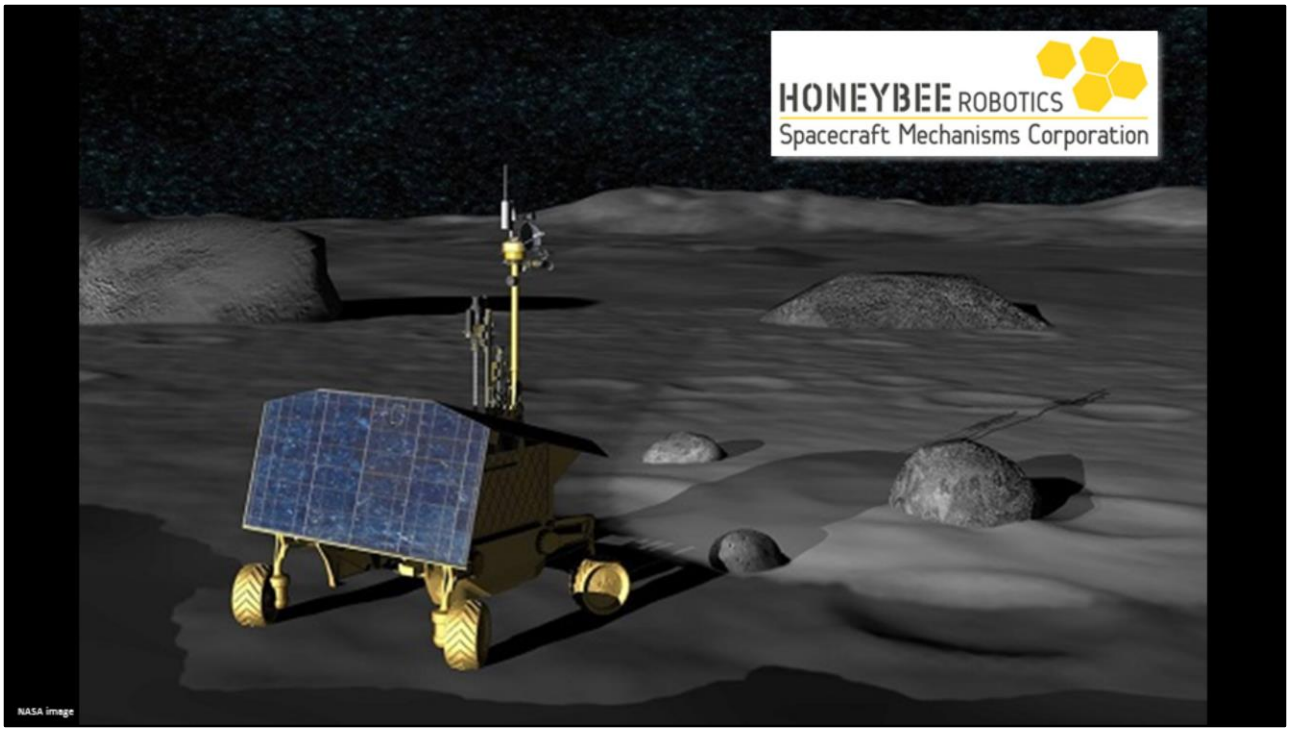
I've shown you LOTS of different ISRU TECHNOLOGIES.
And many of them are being developed by NASA/Kennedy's Swamp Works group.
On which I'm a team member.

The Swamp Works group uses a lean development processes
and a hands-on approach to developing new space technologies.

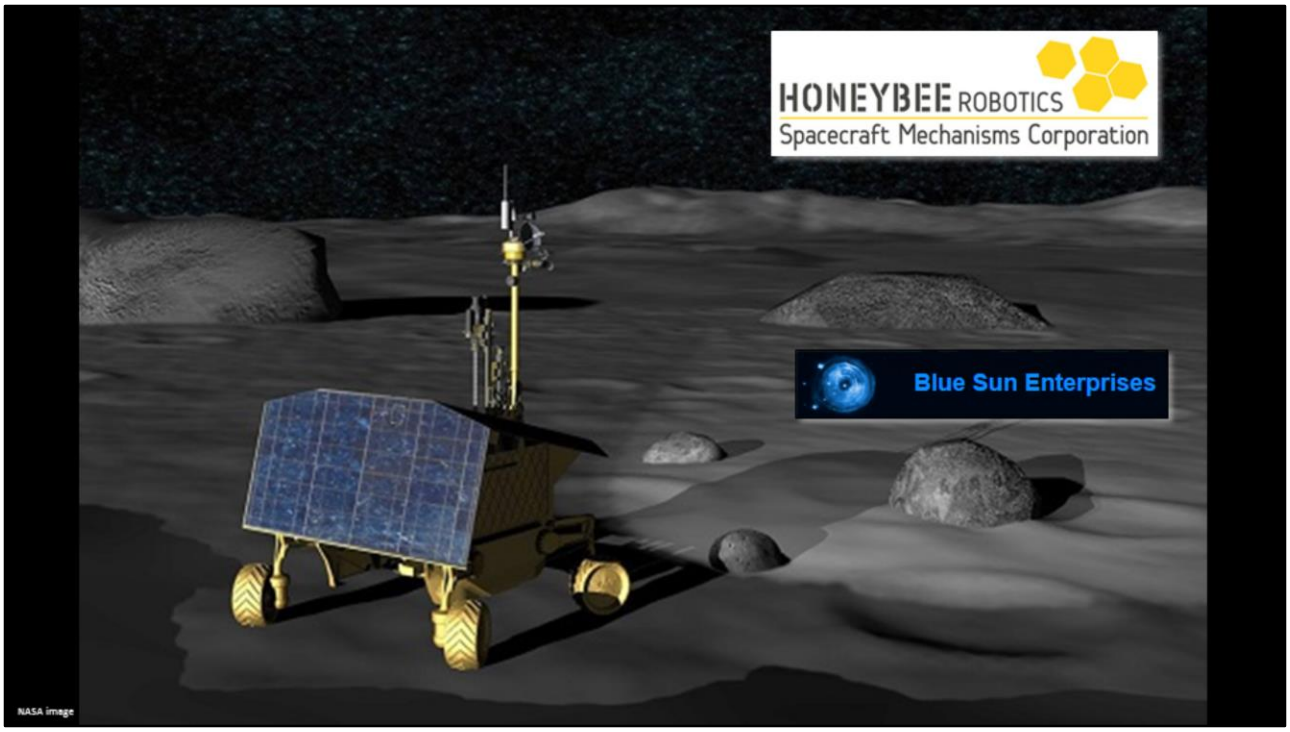
We partner with expert university researchers
and commercial entities from all over the country
on most of our research & technology projects.



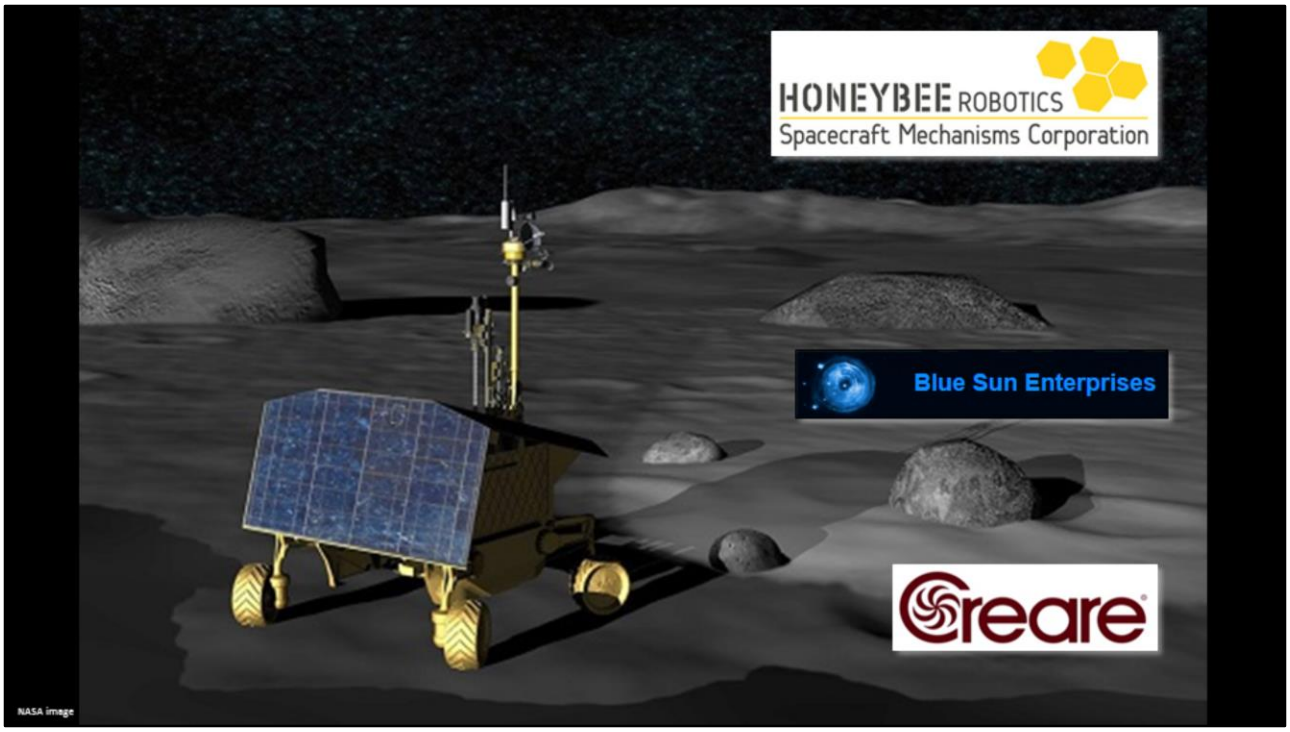
For example, the Resource Prospector project
Has several major partners and collaborators.



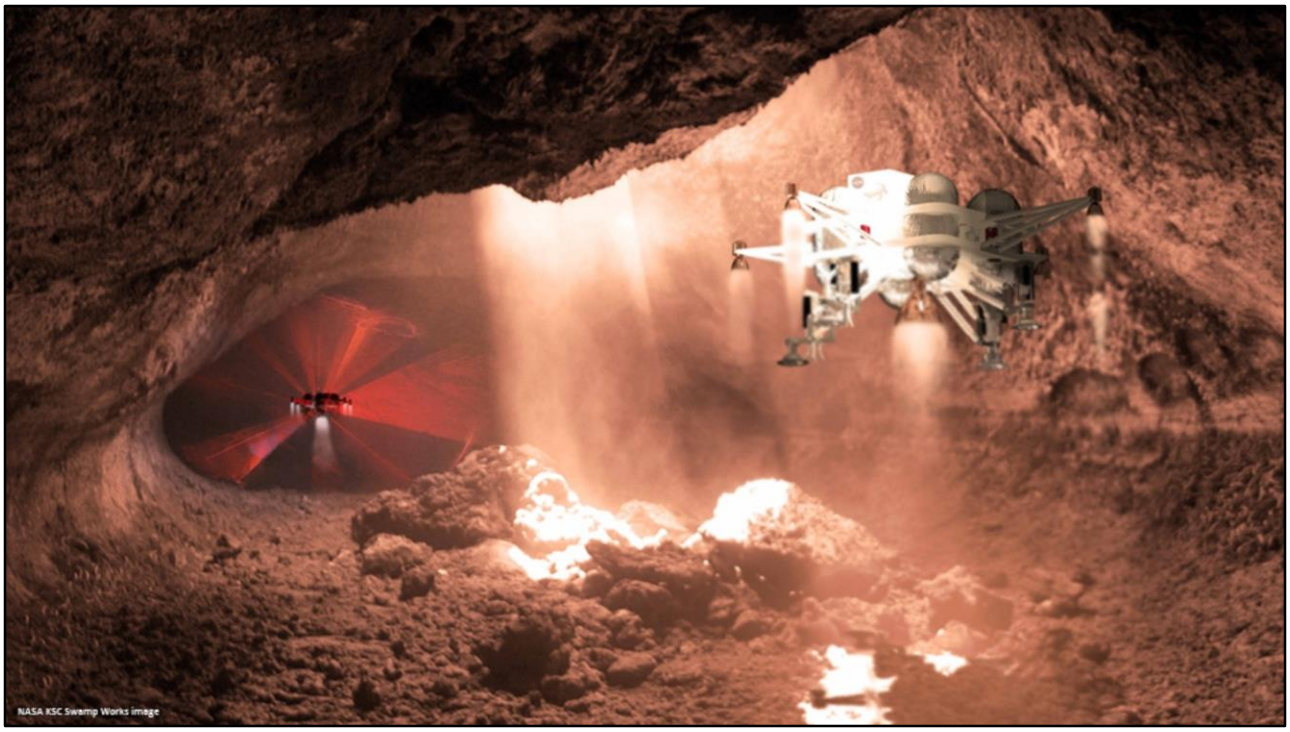
Honeybee Robotics is supplying the
one meter deep drilling system for the rover.



And Blue Sun Enterprises is supplying the flight software sequencer, called Virtual Machine Language.



And Creare has developed a compact, lightweight
gas chromatograph - mass spectrometer that is being used onboard.



And the Asteroid and Lava Tube ISRU Prospector project
Also works closely with Honeybee Robotics

who are developing several different types
of small and lightweight prospecting drills and scoops
for use onboard for sampling.

Also, Embry-Riddle Aeronautical University
has been tasked with developing
flight control architectures specifically for this project.

The Swarmie project actually evolved from a University of New Mexico project that had nothing to do with ISRU at all.

We partnered with the UNM team to take their
ant-inspired foraging robot idea and turn it into an ISRU project
that NASA might be able to use on Mars or the moon someday.

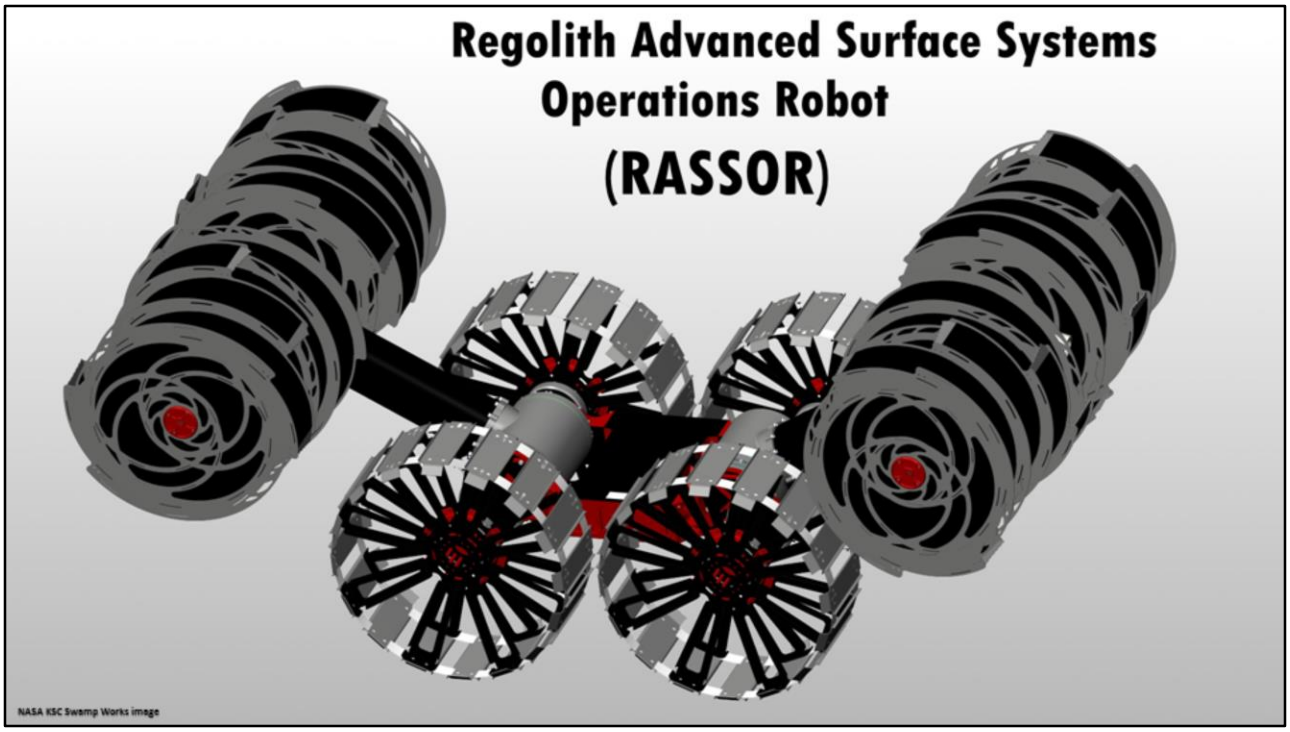
But this biologically inspired search algorithm has several earthly uses as well.
It could be used for search and rescue efforts following a natural disaster.
Or it could be used for infrastructure inspection and repair.

Another cool technology transfer aspect of the Swarmie project is the
collegiate competition that spun off, called the NASA Swarmathon.

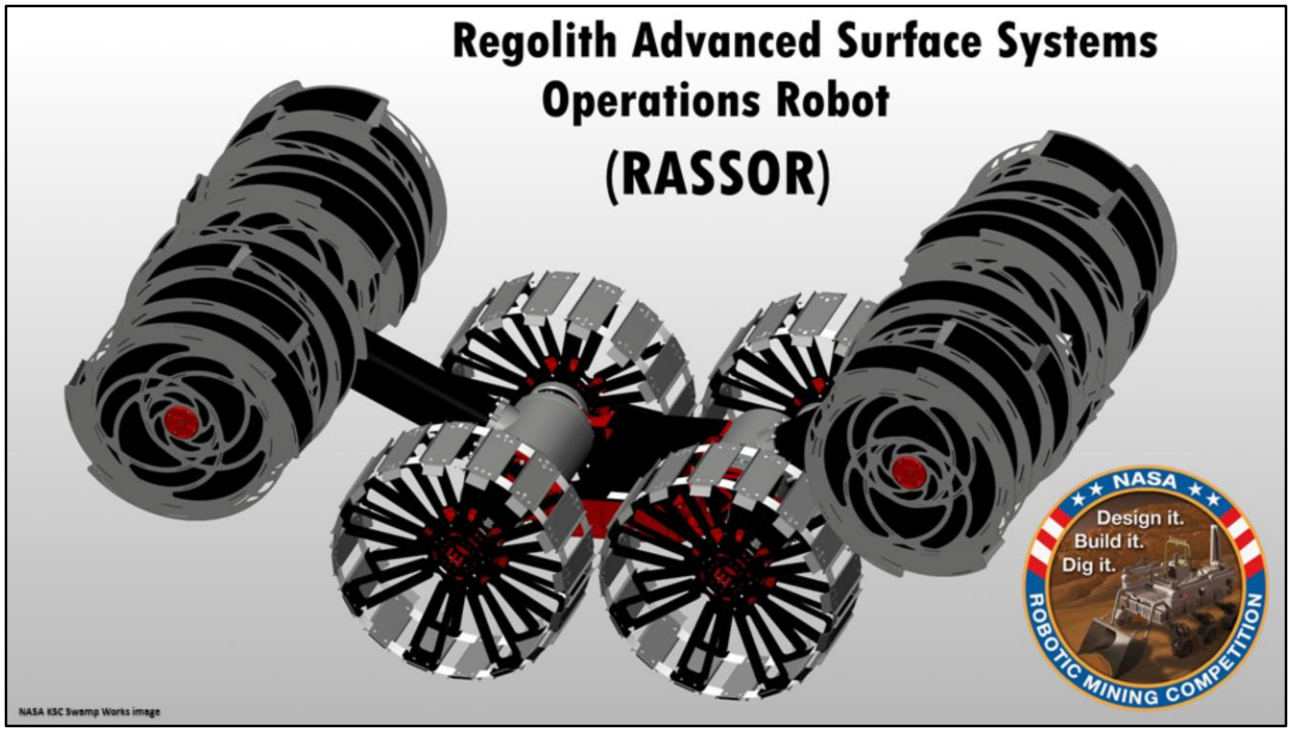
[[[Time: 25 minutes]]]

This competition requires student teams from all over the country
to create their own foraging algorithm
to help the robots find and collect resources.

It's great educational outreach for NASA
but it also has the added benefit of crowdsourcing robotic algorithms
that might be useful to NASA in the future.



The RASSOR robot was mostly designed and manufactured in house. But the Swamp Works engineers have the enormous benefit of a NASA collegiate robotic mining competition.

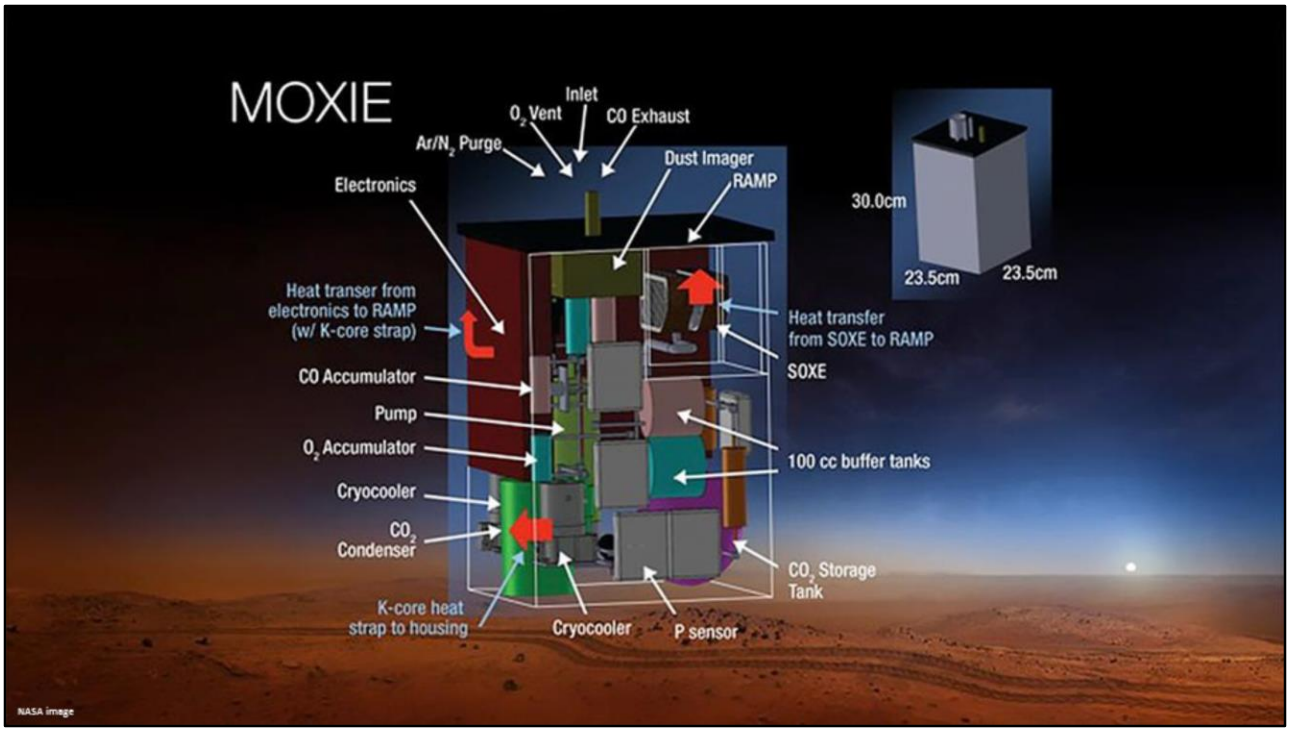


This annual competition brings lots of different
excavation robot design ideas to the Kennedy Space Center.
Which allows the Swamp Works engineers to see what works

[pause]

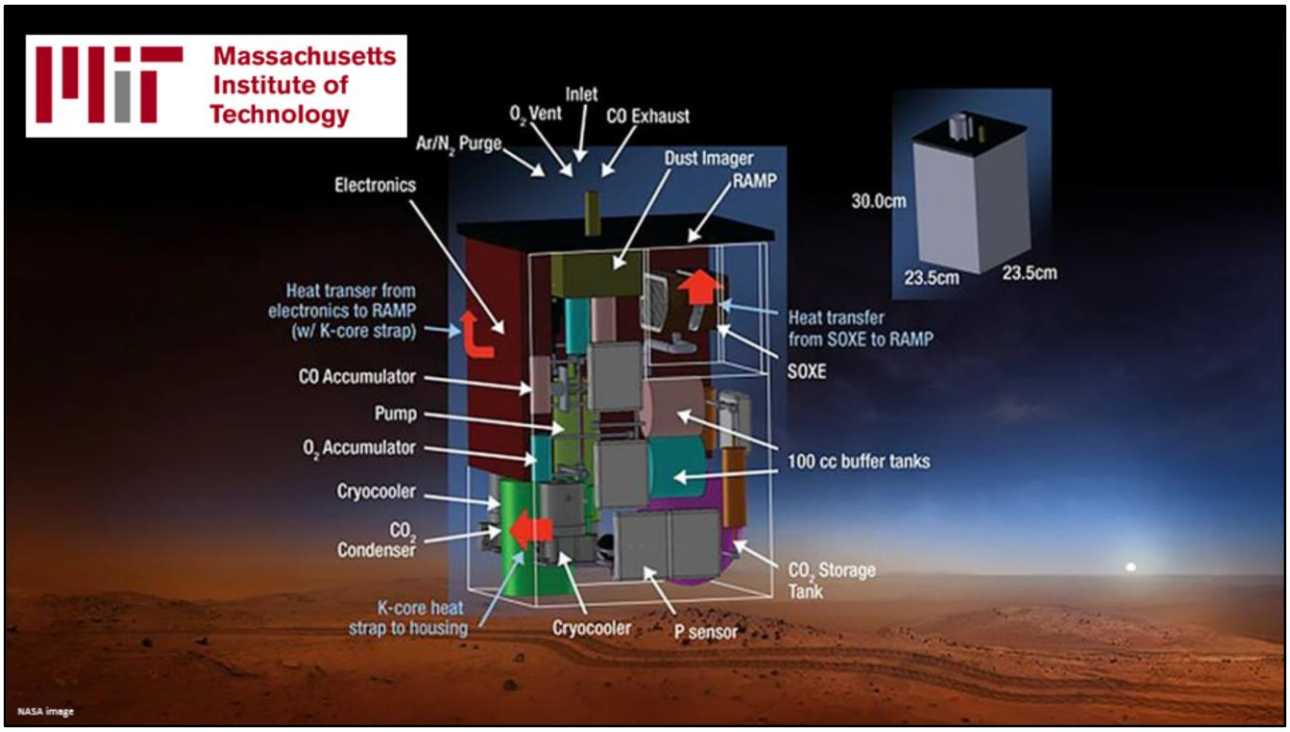
and what doesn't.

So this is sort of a silent and uncredited collaboration
between Swamp Works and universities from all across the country.

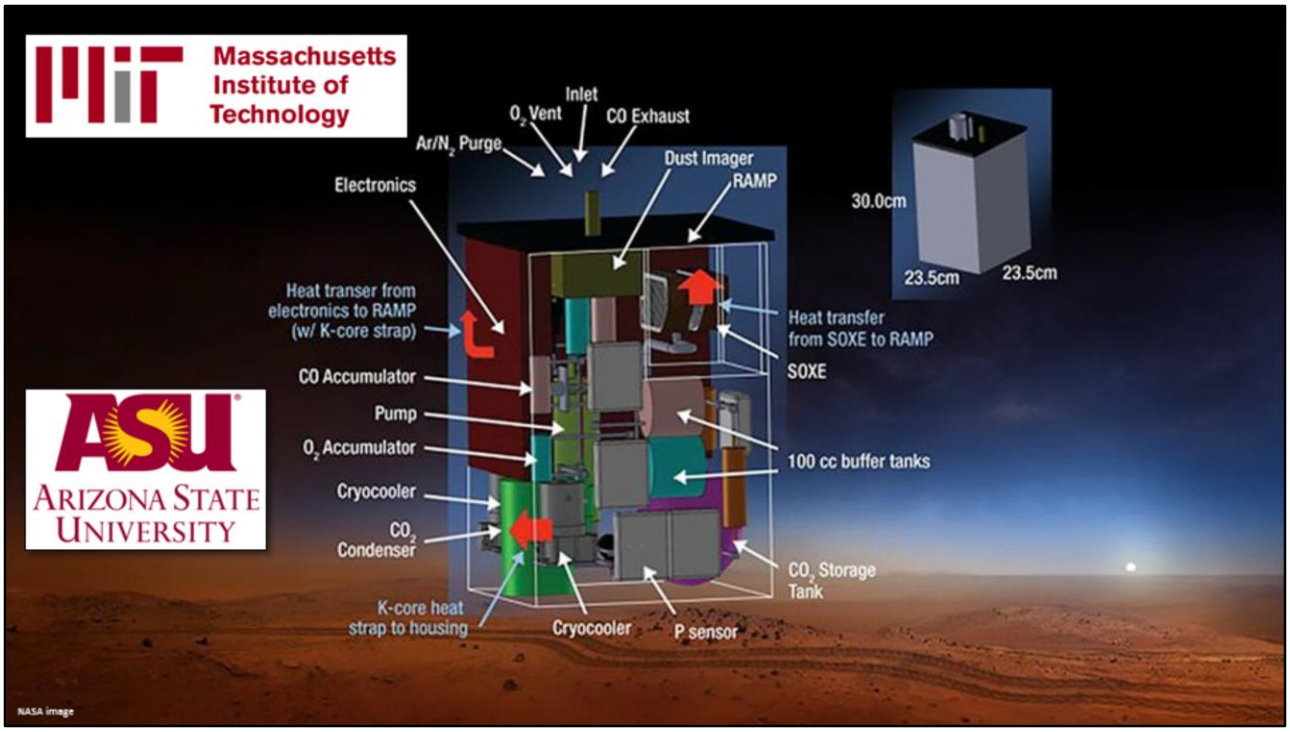


The Mars Oxygen ISRU Experiment that's flying to Mars in 2020 has several partners and collaborators.

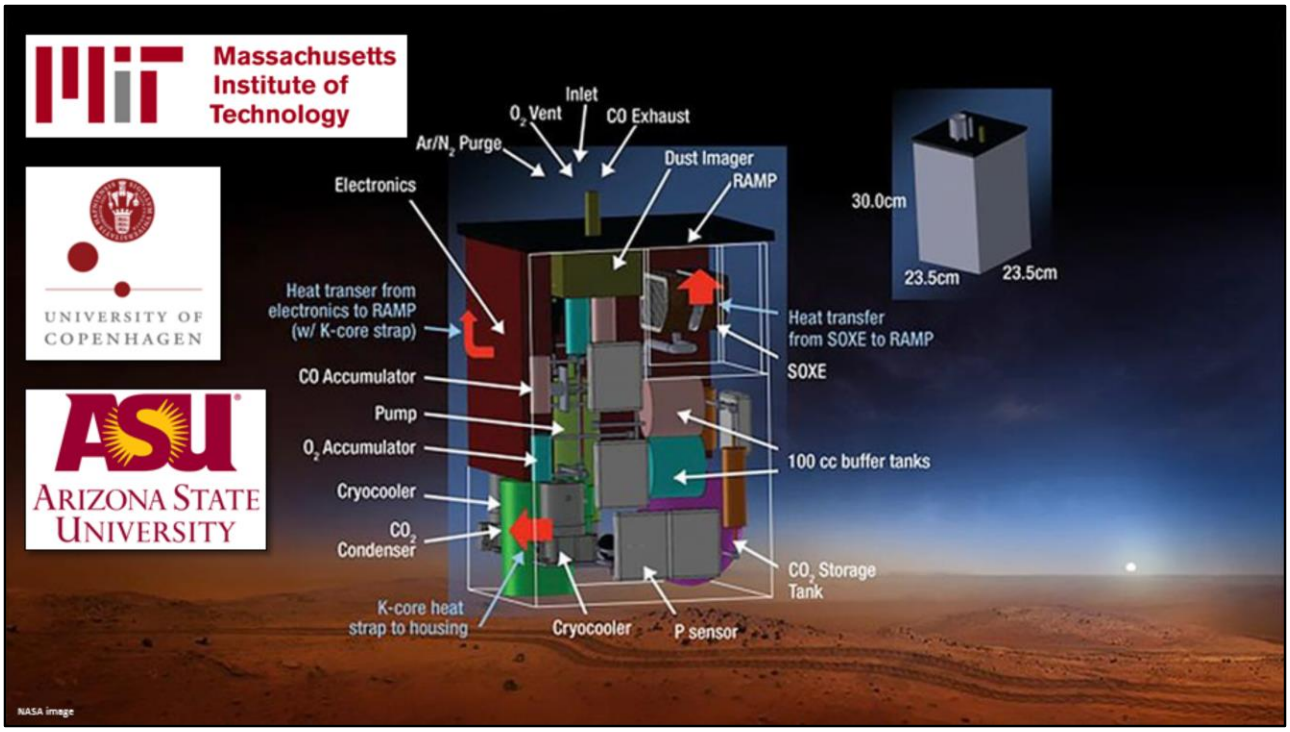
The entire project is lead two MIT professors.



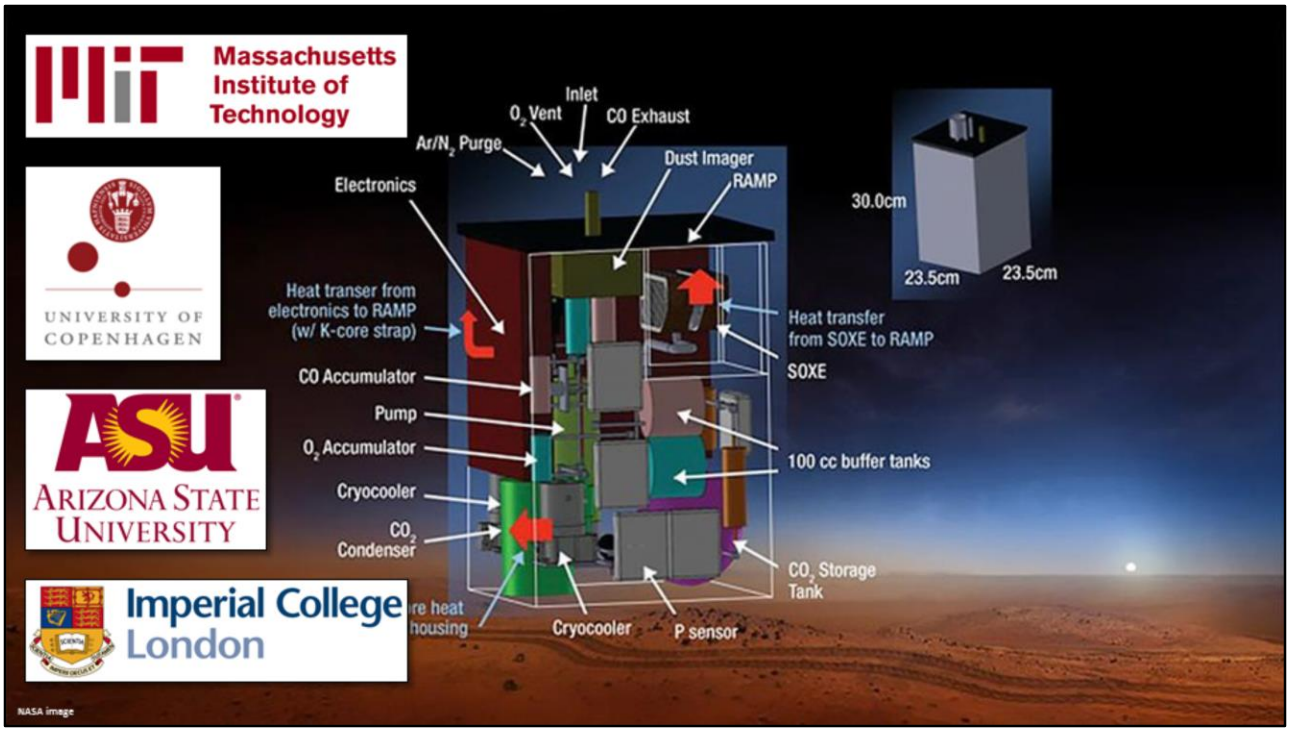
But they have team members from Arizona State University,



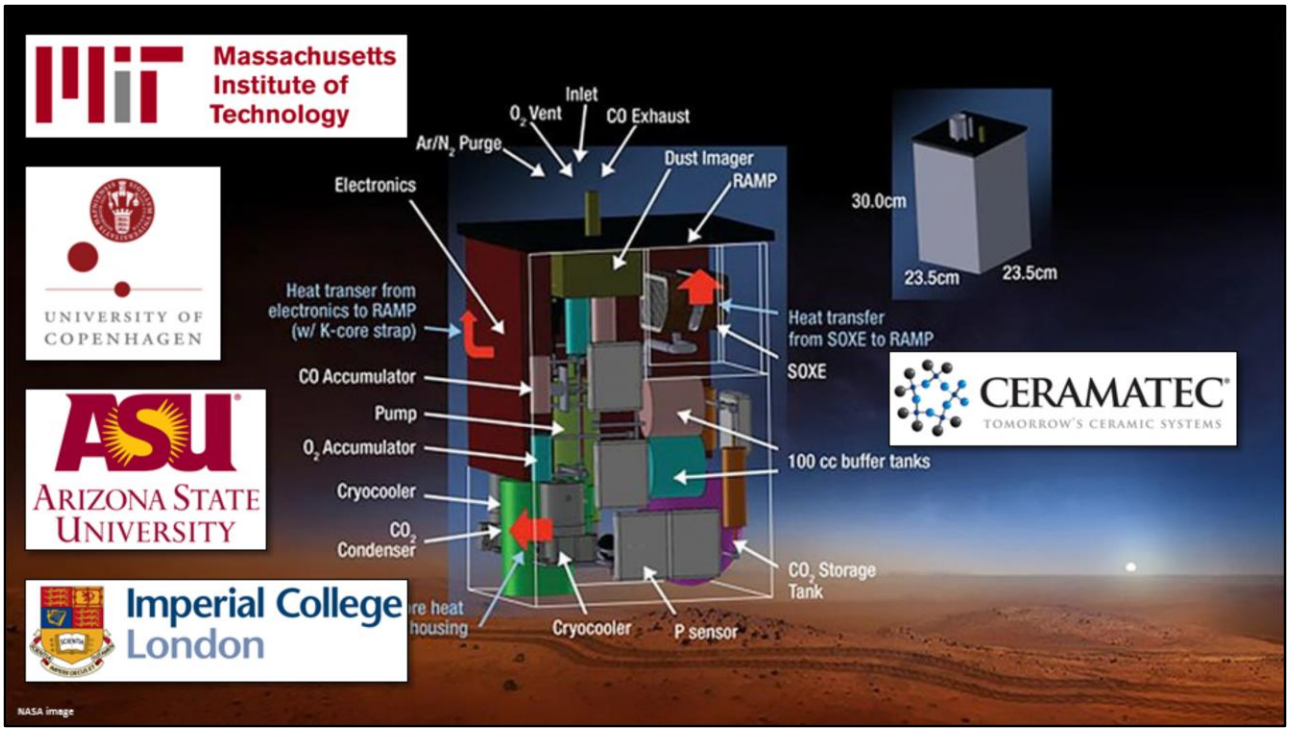
The University of Copenhagen,



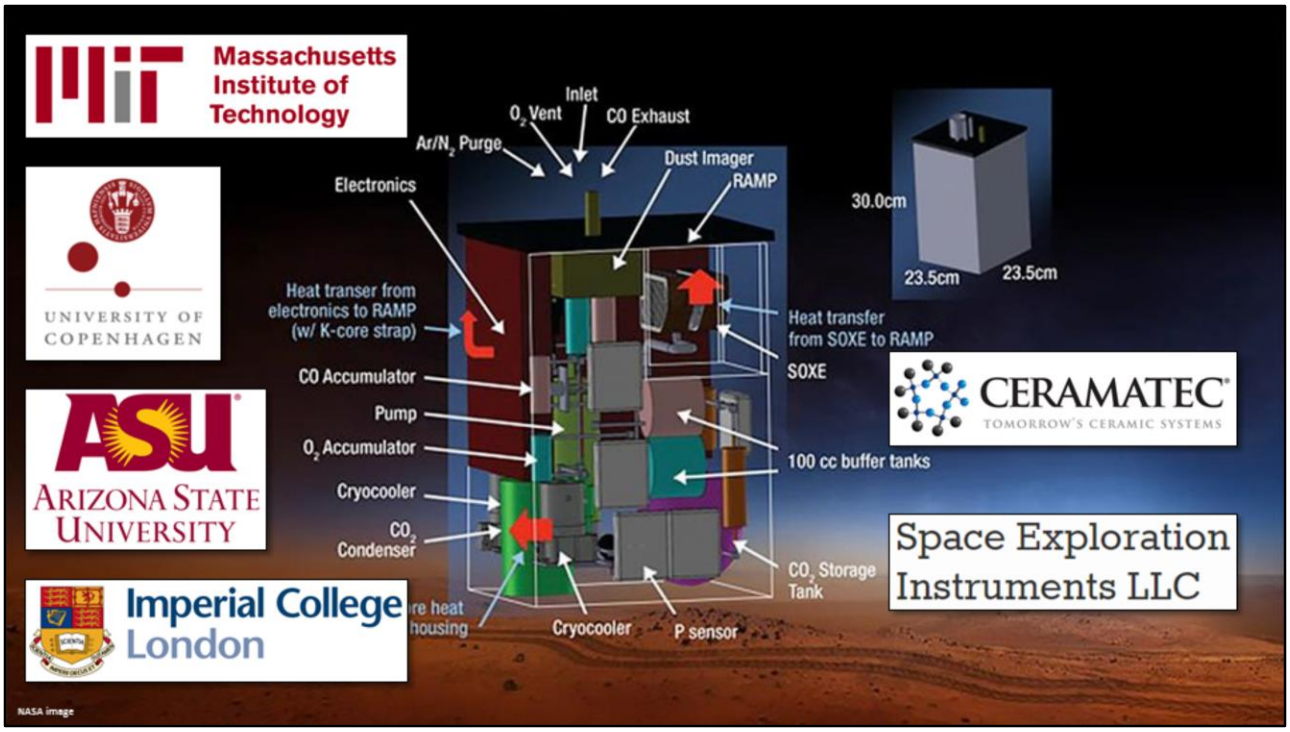
and Imperial College in London.



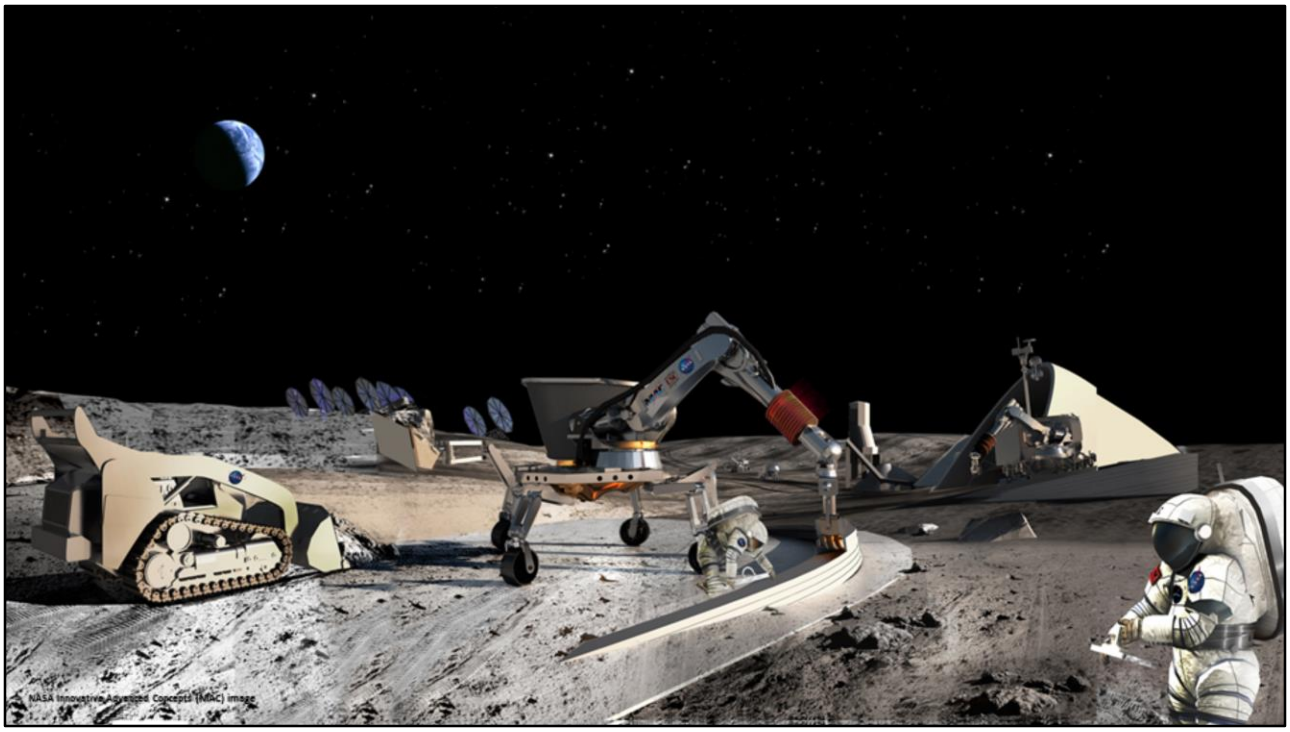
Some of their commercial partners include Ceramatec,



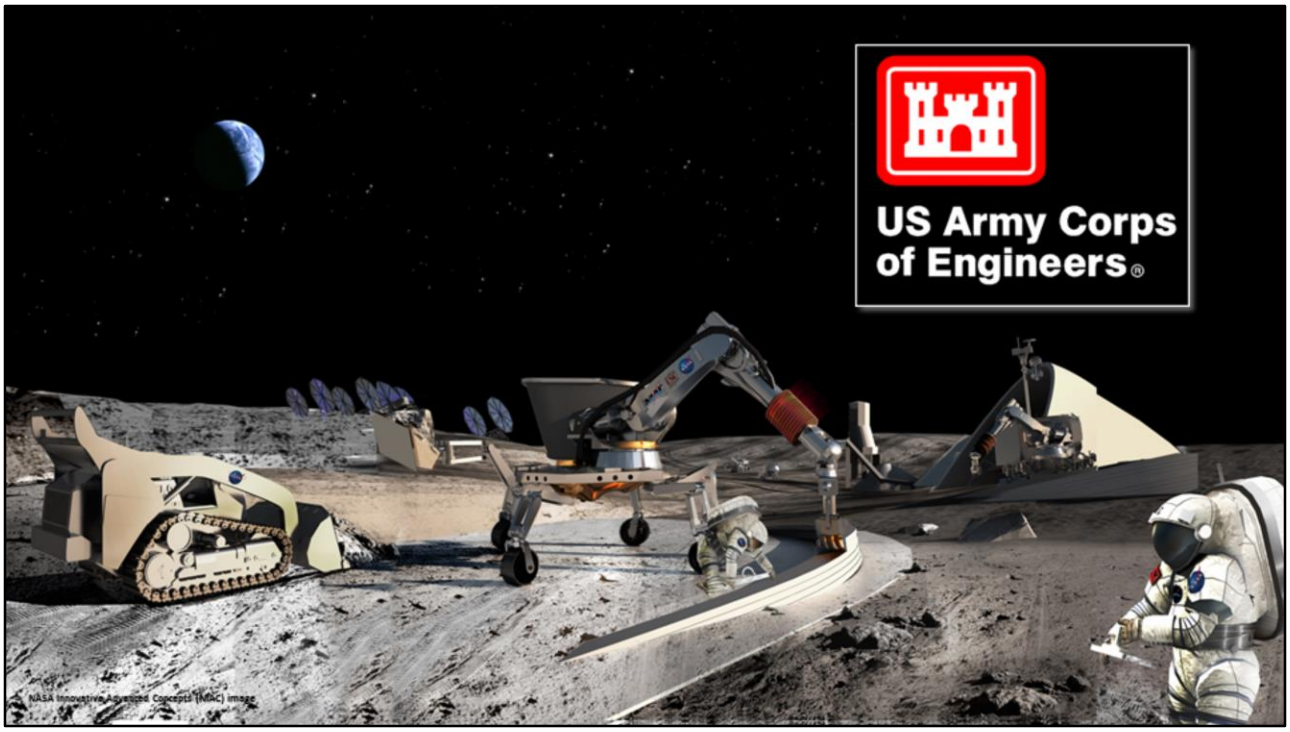
and Space Exploration Instruments.


Massachusetts Institute of Technology
UNIVERSITY OF COPENHAGEN
ASU ARIZONA STATE UNIVERSITY
Imperial College London
Inlet
O_2 Vent
CO Exhaust
Ar/N_2 Purge
Electronics
Dust Imager
RAMP
30.0cm
23.5cm
23.5cm
Heat transer from electronics to RAMP (w/ K-core strap)
Heat transfer from SOXE to RAMP
SOXE
CO Accumulator
Pump
O_2 Accumulator
Cryocooler
CO_2 Condenser
100 cc buffer tanks
CO_2 Storage Tank
CERAMATEC TOMORROW'S CERAMIC SYSTEMS
Space Exploration Instruments LLC
Cryocooler
P sensor
NASA image

[pause]



The United States Army Corps of Engineers …



is actually partnering with us
on our 3D printing with regolith project.

The Corps of Engineers wants to be able to build structures
out in the field using local resources and minimal personnel.
If they succeed, it should simplify logistics significantly.
And should also save money.

Our interlocking tile project partners with PISCES

Which is the Pacific International Space Center for Exploration Systems.
That's a Hawaii State Government Aerospace Agency that
conducts environmentally safe tests on Hawaii's volcanic terrain
to validate advanced space technologies.

This idea of using local volcanic rock to build roads or structures
has some really cool spinoff potential.

Because volcanic islands like Hawaii don't have the
natural resources onsite to make traditional concrete.
They actually have to import raw materials from the mainland!

We might really boost the local economy once we perfect the process of making
construction-grade building material from crushed local volcanic rock.

So in closing.
I want to encourage you all to invest
in technology research and development.

It truly IS an investment in OUR FUTURE!

The potential benefits are mind-boggling.
And only time will tell what all that technology will touch and impact.

And how it will benefit all of our lives.

Both here on planet Earth.
And also destinations outside of our home planet!

Now real quickly before I get off the stage.
I want to put in a plug for the
NASA Technology Transfer Office.

They support commercialization efforts for NASA developed technologies.
They help transfer technologies to companies, universities,
non-profits, other government agencies, and even individuals.

All with the goal of benefiting the U.S. economy and the general public.

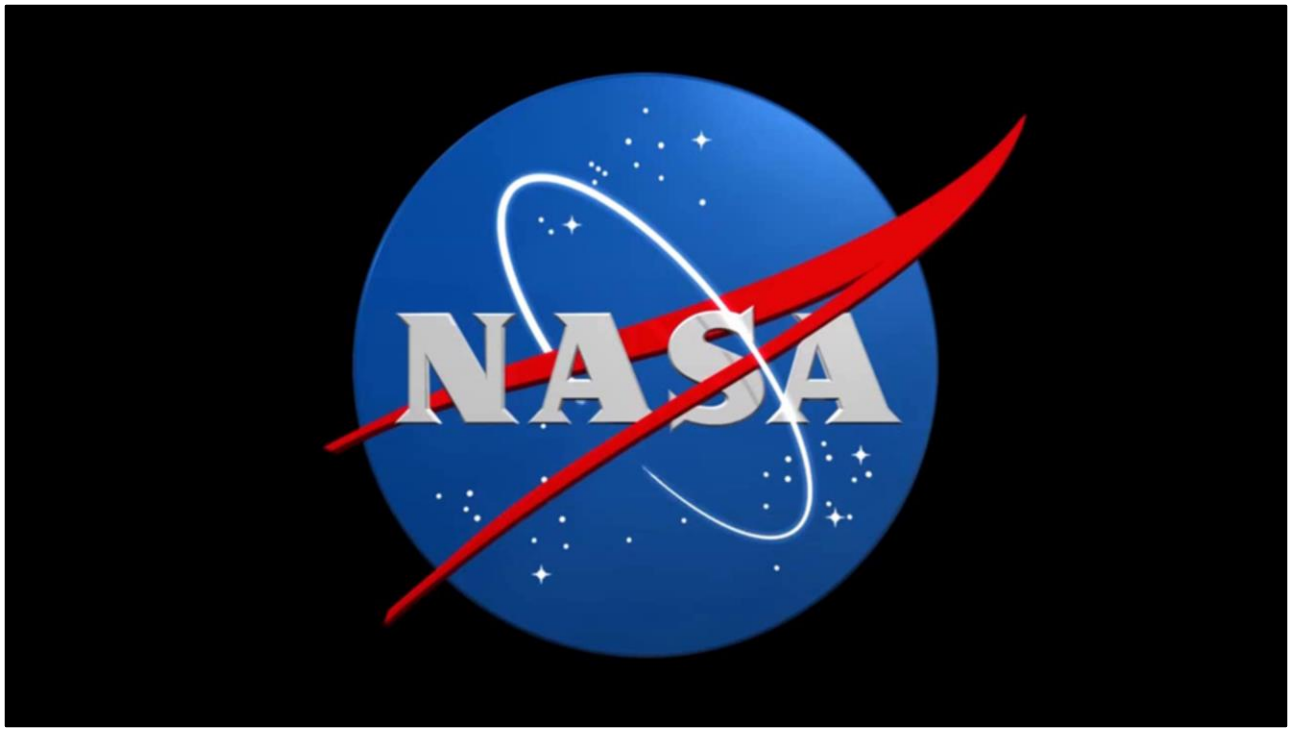
Their website is easy to remember.
It's simply technology dot nasa dot gov!

SWAMP WORKS

NASA KENNEDY SPACE CENTER

Also, I do have a booth set up in the exhibit hall
that I'll be manning later.
And I have some fliers with details
on several of the ISRU technologies that were in my presentation.

So please drop by my booth and say hi!



[[[Time: 30 minutes]]]

I thank you for your attention
And for your interest!

Now have a great evening here at Discovery On Parade!
Thank you!