YouTube Storyboard:

People, Space & the 21st Century

Part 3, Habitation

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Final

Description:

To settle the Moon or even fly to Mars, you must have substantial radiation protection. On the Moon and Mars, we can address this problem by digging in. Here is why and how much to dig in for full habitat protection.

People need the positive, look-ahead vision of the future that space exploration provides, particularly in these challenging times. The way we did Apollo to the Moon in the 1960s, with a huge government program, simply will not work today. Fortunately, we have all the elements we need to build a 21st century human space program over the Internet.

Purpose: This video proposes a space exploration program for the 21st century.

Intended Audience: Young Adult.

YouTube: https://www.youtube.com/watch?v=APlFibFU-v0
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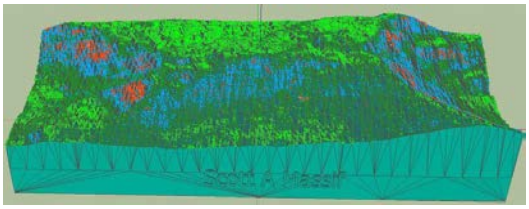
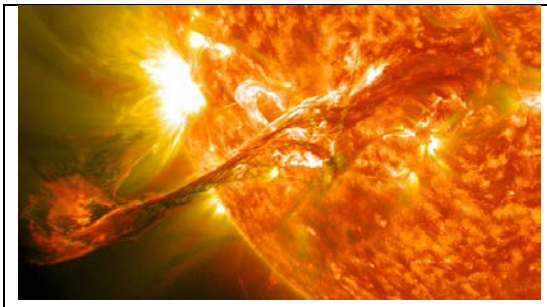
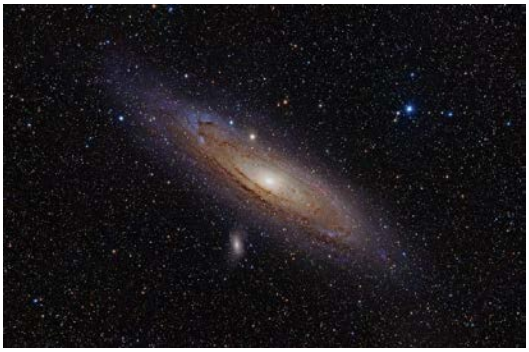
Storyboard:

Graphic	**Dialog** (Critical column for editing)
 Rocket time: 4 s **A** time: 21 s	Rocket sounds (4 seconds) **People, Space and the 21st Century:** In Part 1 of this series, we talked about how we can return to human space exploration in the 21st century with MOVE. In Part 2, we talked about a great location, the Scott A Massif.

	In this Part 3, we will look at designing a lunar settlement and why radiation is the key.
   Caption: Inflatable Habitats B time: 56 s	**Habitat Design:** What do you need from your living spaces to create a successful lunar or Mars settlement? First, you need a good location, like our Scott A Massif, where power can be had simply and there are plenty of resources nearby. This is easy living space style. You then need buildings that will keep you alive even in such harsh conditions. The buildings must provide protection from radiation, thermal extremes, and small meteors. These are no small design tasks. Beyond that, your construction must be made as much as possible from local stuff. Material shipped from Earth costs a huge fortune, not just a paltry small one. The Big Moon Dig, like most lunar planners, calls for inflatable habitats shipped from Earth in a collapsed configuration. However, if you have a thin-walled blow-up house, how can you make it safe?
	**Radiation:** In space, radiation is a killer. This one problem is the tail that wags the dog of habitat design for all spaceships and off-Earth settlements. The radiation problem is compounded when it's ignored. The vast majority of spaceships that you see in movies are simply deathtraps. You might get away with living with this danger for a few days, like Apollo to the Moon, but you cannot ignore the problem for either a trip to Mars or a long-term settlement.



Caption: Coronal Mass Ejection (DME)



Caption: Galactic Cosmic Rays (GCR)

C Time: 102 s

There are two types of deadly space radiation:

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- Coronal Mass Ejections from the sun.
- Galactic Cosmic Rays from deep space.

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Coronal Mass Ejections (CMEs) are generated by great storms on the sun. Like Earth storms, they last from a few hours to a few days. Their radiation is intense and dangerous to humans, but it does not penetrate well. One meter of ground rock, called regolith, will stop CMEs.

At any given location on the Moon or Mars, or on a trip through our solar system, you can expect zero to five CMEs per year. You would have to count yourself lucky if you did not experience a health-threatening event every quarter.

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Galactic Cosmic Rays (GCRs) are generated by distant, enormous explosions like supernovas. They are fewer in number but penetrate very well indeed. And, they are shooting through you 24/7/365.

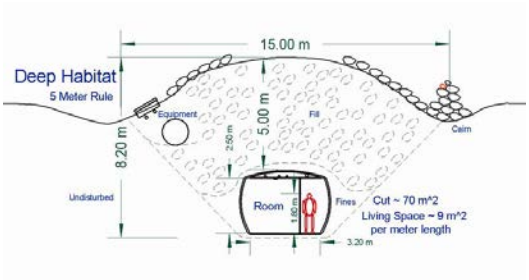
The first meter of shielding simply converts GCRs from a few high-energy particles to a much larger number of moderate-energy particles. The radiation danger actually increases.

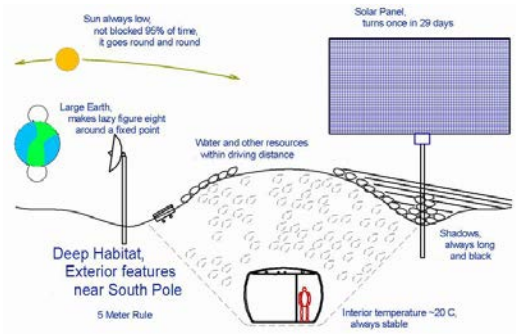
Regolith Shield:

So, for a long-term settlement on either the Moon or Mars, we must provide effective radiation protection, period. This shielding must also provide protection from temperature extremes and micro-meteorites.

The best, and by far the cheapest, shielding material available is the local regolith, the finely ground rock that covers the landscape. Some materials would be a little better at shielding, but hauling bulk materials from the Earth is simply ruinously expensive.

Caption: Boot print in lunar regolith





D Time: 121 s

The question then is: How thick a coat of regolith is needed to match the radiation protection on the surface of the Earth under which we evolved?

One meter of regolith would provide protection from CMEs, thermal extremes, and micro-meteorites, but it would only amplify the danger from GCRs. We will need more.

Radiation protection on Earth is provided by the atmosphere, the body of the planet, and Earth's magnetic field.

If you are on the Moon or Mars, then half your exposure to radiation is blocked by the planet. A good start.

Neither the Moon nor Mars has any magnetic field to speak of, or any atmosphere density for that matter.

We simply need to match the level of protection found on Earth with a thick layer of the local regolith. The Big Moon Dig started this calculation with the regolith density measurements from Apollo to the Moon and the atmospheric pressure on Earth. The answer we got was that a layer of typical lunar regolith four to five meters thick (about 16 feet) will provide a conservative amount of shielding.

Hopefully, through actual measurements at our site, we will find that less is acceptable. However, we feel it is unrealistic to set this number below four meters in our planning.

Allowing 3.2 meters for the height of the inflatable habitat, we will need a trench about 8 meters (27 feet) deep.

By any measure, we need to dig some substantial trenches.

Lunar Roof Regolith Support

Location	Pressure kPa	Support meters
Sea level	101.32	36.15
Denver	84.00	29.97
Mexico City	81.40	29.04
Apollo Suits	32.40	11.56

Regolith Density kg/m^3 1719.6

E Time: 29 s

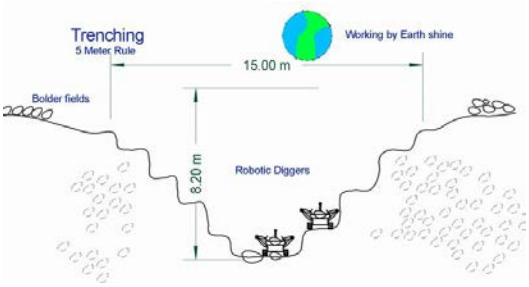
Roof Support:

This then brings up the question: Will the internal habitat pressure support such a thick regolith shield on the roof?

The Big Moon Dig calculated the answer to be a definite yes.

In fact, even internal pressure as low as suit pressure of only 32.4 kilopascal would hold the weight given the Moon's only one-sixth g.

Normal air pressure, around 100 kilopascal, handles the problem very well and would even support a robot or other equipment on the roof.



Digging:

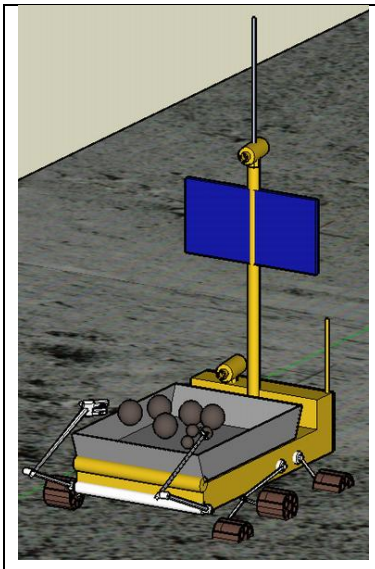
So, our major challenge is how to dig a big trench on the Moon. Let's be clear; this is a show-stopper if we cannot.

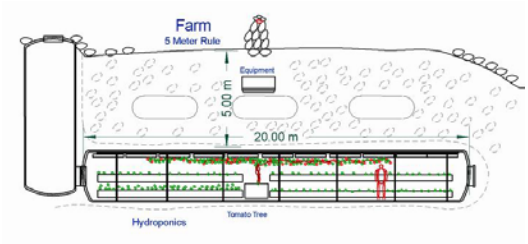
We know that it is very difficult to dig in the Moon's one-sixth gravity, or Mar's three-eighths g for that matter. We also know that the ever-present grit can destroy equipment quickly.

What we do not know is how the size of rocks varies with depth. It will take a first trench on site to learn the answer to that question.

Power and lighting for digging are also real problems once you are in the trench.

We at the Big Moon Dig propose the MOVE (see Part 1 of this series) to get thousands of volunteers to work on basic digger design and then operation. Paying someone to do these tasks would simply break the budget.

 Caption: Digger03 on the Moon F Time: 69 s	We appreciate that these tasks will take years, but it will get a lot of people directly involved in human space exploration as never before. A finished trench will be a capital space asset that will attract major resources for the inflatables. One of our short stories is about this big dig and interaction of the people and robots involved.
  Caption: Cairn on Earth G time: 50 s	**The Art of the Cairn:** For perhaps a million years, human beings have marked trails with stacks of rocks called cairns. The cairn is an art that we must now revive for the Moon and Mars. We certainly need to mark our trails. We certainly need to use local materials to do this. The tricky bit is making an art of it, particularly if the actual work is done by robots that are remotely controlled. Our cairns can contain bits of human-made materials, like metallic multi-layered insulation (MLI), our boast that people were here. They could also contain flat rocks with the names of an exploration crew scratched on them with a diamond stylus. On the Moon, a good cairn could last a million years. On Mars, it needs to be big enough to avoid being buried by a dust storm.
	The Farm:



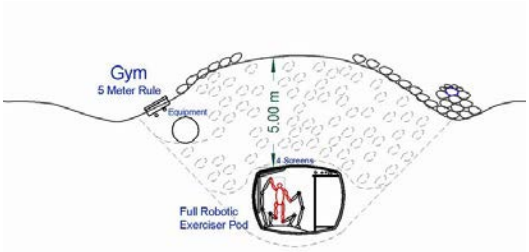
Caption: Tomato Tree
H Time: 47 s

If you want to stay for any length of time at all, you have to grow your own food locally.

The farms are thus critical elements created in long sections of the basic inflatable building. The plants would be grown hydroponically under L E D lights.

The planting base will be a double-sieved regolith with both the dust and large rocks removed. It will have to be washed thoroughly as it will never have been in contact with water before and will likely contain many salts.

This approach has already been tested on Earth, sometimes with striking results. For example, tomato plants can live under these conditions for many years, grow a snarly trunk 10 centimeters thick, and produce tons of fruit, earning the plant the name Tomato Tree.



Caption: Stupendous Exercise Machine

I Time: 66 s

Gym:

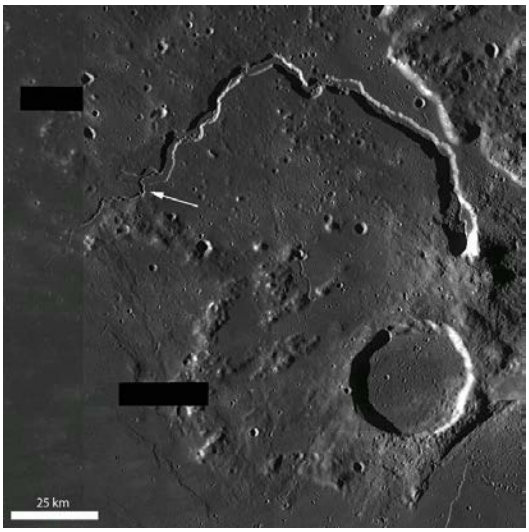
In low gravity, one-sixth g for the Moon and three-eighths g for Mars, and zero in between, the human body atrophies. Every day, each settler must exercise for about two hours, but hours spent outside will be very limited and the inside living spaces very restrictive. We must therefore design a truly stupendous exercise machine.

Big Moon Dig proposes a four-robot-armed, five-screened People Pod. Two arms are for your hands and can match any movement you make while providing any level of resistance. The other two arms are for your feet and do the same.

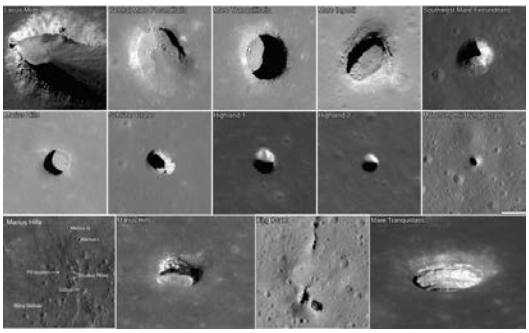
The five screens will provide a visual environment that breaks you out of your claustrophobic existence into open visual space, including a lot of Earth views, but it will also show the space just beyond your shield in real time.

It will have a great sound system, too.

	The People Pod will be programmed to play a vast array of sports and video games. This will require a major development effort and is critical to moving to Mars.
  Caption: Mars, here we come J Time 31 s	**Fly in the Pantry:** Shielding for a Mars ship is difficult. One reasonable way is to fly-in-the-pantry, that is, to surround the people with all their supplies. To make this work, the crew pods must be as small as possible and the crawl spaces between them the home primarily of many small robots, descendants of Roomba. Being confined without apparent open space would clearly drive people nuts. Providing this extended experience into virtual reality could make all the difference.
 	**Lava Tubes:** Oh, I wish, I wish we had a lava tube. Lava tubes form when a stream of liquid lava runs downhill long enough to form a rivulet with a thick crust over its top. Sometimes, just sometimes, the source of the lava is then cut off while the liquid continues to run away, leaving an empty tube.



Caption: Lunar Lava Tube



Caption: Lunar Skylights

K Time: 88 s

There are many lava tubes on Earth and a few are suspected on both the Moon and Mars. If a lava tube can be found off-Earth, it might offer a marvelous solution to our shielding problem.

Several examples appear to exist on the Moon judging from photography from orbit. The problem is that it is not known whether they drained out to form actual cavities.

Also, several skylights, deep holes that may be places where the roofs of lava tubes have caved in, can be seen on both the Moon and Mars. However, there is as yet no proof that they lead to open side chambers. They could just be deep holes.

In addition, the grit on both the Moon and Mars contains magnetic particles of iron, which make ground-penetrating radar measurements from orbit extremely difficult. Consequently, nobody has come up with a way to map lava tubes.

If we can find a lava tube in an area of interest, and its entrance is not a deathtrap, then and only then can it be counted as a great resource.

So, we simply cannot base our planning on them.

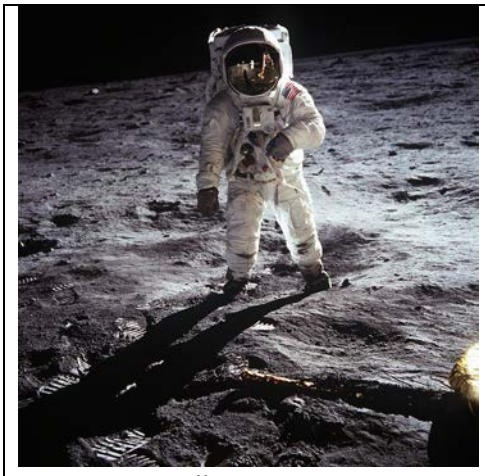
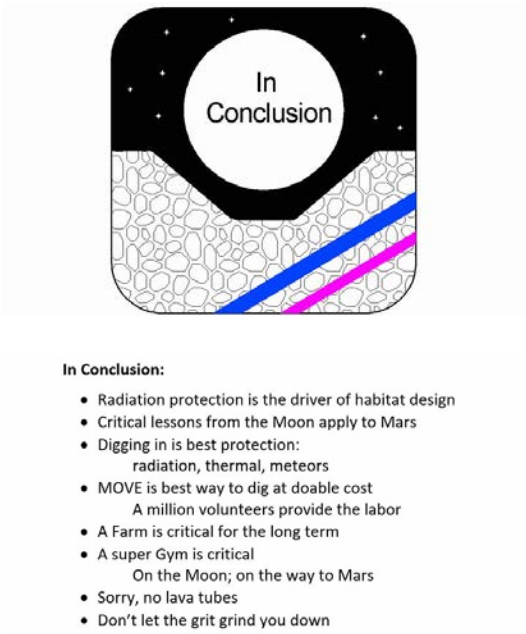
True Grit:

The next killer design problem is the grit.

Both the Moon and Mars are covered with very finely ground rock particles. These particles tear up seals and grind away at any exposed moving parts.

The Apollo spacesuits were wrecked by the lunar grit in just three days.

The design of grit-stopping seals is then our next great problem after radiation.

 Caption: Apollo 11 Astronaut L Time: 24 s	
 M Time: 51 s	**In Conclusion:** Radiation protection is the keystone to habitat design on both the Moon and Mars. Digging in is the best protection option available, as hard as it may be. The Big Moon Dig's MOVE (Massive, Online, Vetted, Expedition) is our proposal to undertake a big lunar dig at achievable cost. A farm is critical for the long-term survival of any settlement. You cannot stay without a good one. If you don't eat, you don't live. A gym is also critical everywhere off-Earth, especially on your way to Mars. We must exercise our way across the solar system. Sorry, no lava tubes. Unless we get really lucky, lucky, lucky. But then, take heart from our great vision of expanding into space and don't let the grit grind you down.
	Series Conclusion: If we want to see human beings restart space exploration in our lifetimes, we cannot just wait for someone else to do it. We need to take action ourselves.

Series Conclusion: • Do not wait to restart human space exploration • Do not wait to generate a positive, forward-looking view of the future • Do use 21st century technology to get the ball rolling again. Join us, The Big Moon Dig N Time: 36 s	If you think the positive forward-looking attitude you get from working on human space exploration is of critical importance in the 21st century, then you need to get into action yourself. We cannot sit around doing nothing. We can apply the technologies of the 21st century to this problem, starting today. Please join us, Tom Riley and Digger03. The Big Moon Dig
Attributes 1: • Attribution-NonCommercial-ShareAlike (CC BY-NC-SA) • Voice: Paul NaturalReader13 • Titian 3 sounds by NASA • Inflatables by NASA • CME by NASA • Andromeda Galaxy by NASA Time: 4 s	Rocket sound fading in
Attributes 2: • Astronaut footprint by NASA • Cairn by Wikipedia • Lunar lava tubes by NASA • Lunar skylights by NASA • Astronaut by NASA • All other graphics by author Time: 4 s	Rocket sound
References: • The Big Moon Dig, http://bigmoondig.com/BigMoonDig.html	Rocket sound fading out

• Digger03, BMD@BigMoonDig.com #BigMoonDig References: Time: 4 s **Total:** ~ 13:36 mm:ss	

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YouTube text description: (First sentence is critical for editing)

To settle the Moon or fly to Mars, you must have substantial radiation protection. On the Moon and Mars, we can address this problem by digging in big time. Here is why and how much is needed.

People need the positive, look-ahead vision of the future that space exploration provides, particularly in these challenging times. The way we did Apollo to the Moon in the 1960s, with a huge government program, simply will not work today. Fortunately, we have all the elements we need to build a 21st century human space program over the Internet.

Please join us.

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Enjoy,

- The Big Moon Dig, http://bigmoondig.com/BigMoonDig.html
- Digger03, BMD@BigMoonDig.com

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