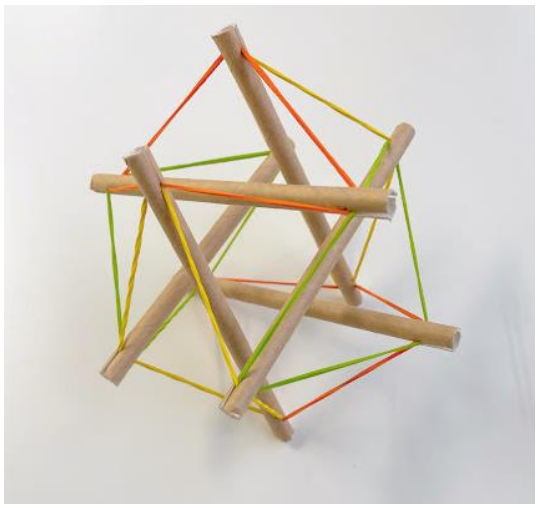


Let's Enjoy Tensegrity Structures!

Seiji Inoue
Hachinohe Technical High School

Hello, I am Seiji Inoue from Hachinohe Technical High School. And I'm a physics teacher.
I've really been looking forward to meeting you at this workshop.

First explored by
Kenneth Snelson in the 1960's

Named by **Buckminster Fuller**

Tensegrity
＝"**Tens**ion"+"Structural Int**egrity** "

1

Tensegrity is first explored by American sculptor Kenneth Snelson in the 1960's .
And it was named by an inventor from Massachusetts, Buckminster Fuller.
Tensegrity is a word, combining Tension and Structural Integrity.

Example: Falcon 9

Payload to LEO 22,800kg
$ 67,000,000 / launch
About $ 2,900 / kg

Standard payment plan through 2022

Exploration goals

1 Small

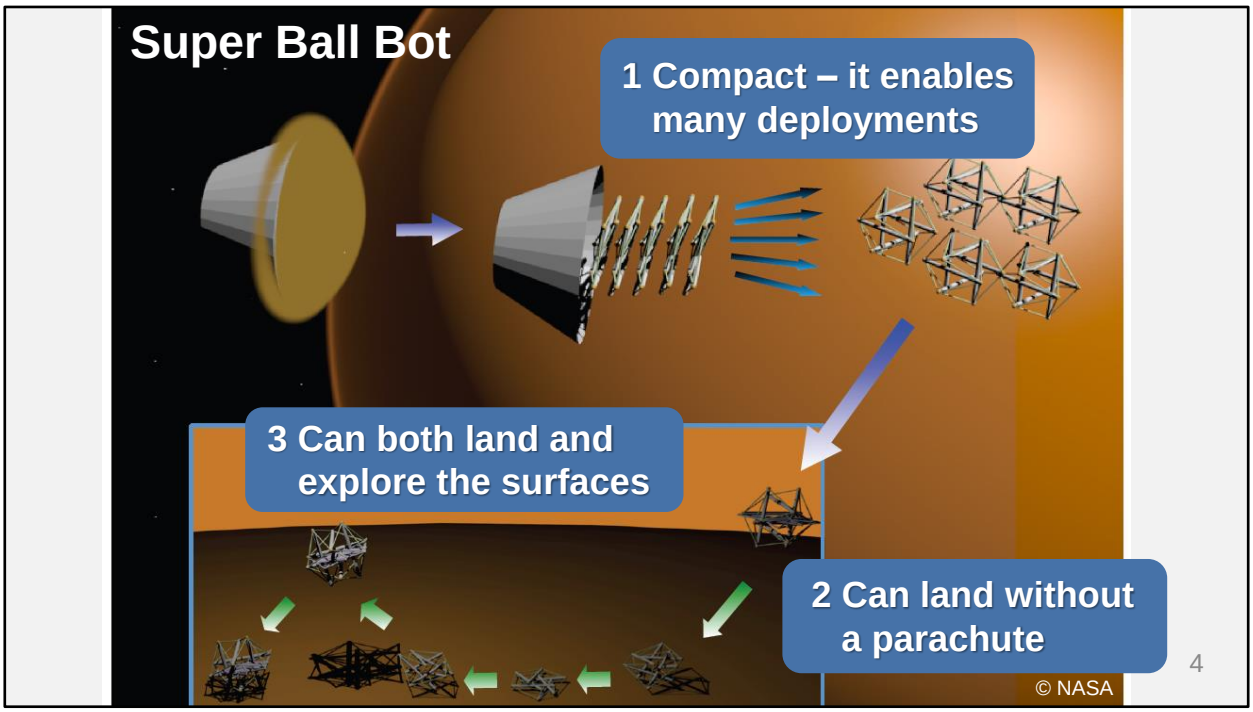
2 Light-weight

3 Low-cost

2

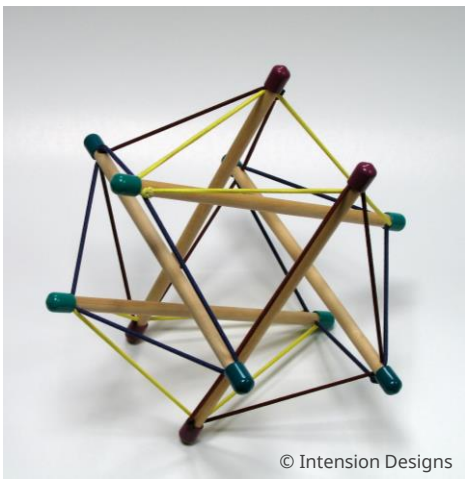
Why is this important? Let us first see an example of rockets. This is Space-X's rocket, Falcon9.
The heaviest payloads flown to the Low Earth orbit(LEO) were 22,800 kg.
With much efforts, the launch cost went down to $67,000,000.
But it is still expensive. It costs $2900 per kg.
NASA would go even further. It aims to create small, light-weight, low-cost missions!
Tensegrity is a technology that will make rockets smaller, light-weight, and low-cost.

Let me now show you an actual example.
This mysterious robots is called a “super ball bot”. = Show the video =



This kind of robots would be able to land on the hazardous surfaces such as Titan.
It enables to create dramatically simpler mission profiles and reduces costs.

What is GREAT about Tensegrity ?



Two Main Points:

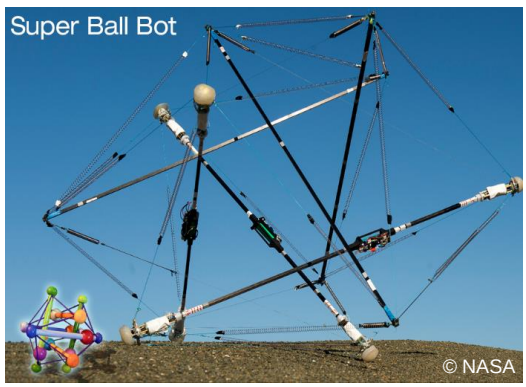
1 Materials do not touch each other.
2 Sustained by a good balance.

5

So, there are two great things about Tensegrity.

First, materials do not touch each other.
Second, it is well-balanced with tension.

Tensegrity's advantages



1 Small

2 Light-weight

3 Low-cost

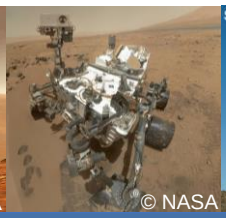
4 Absorb shock

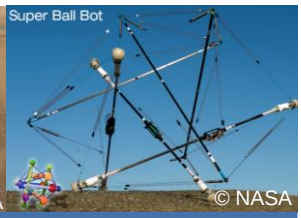
Would be a game changer!!

6

There are four advantages for Tensegrity.
First, it can be folded small.
Second, it's light-weight while strong.
Third, it doesn't cost as much.
Fourth, it absorbs strong impacts.
These features make Tensegrity a game changer.

Rover vs Tensegrity





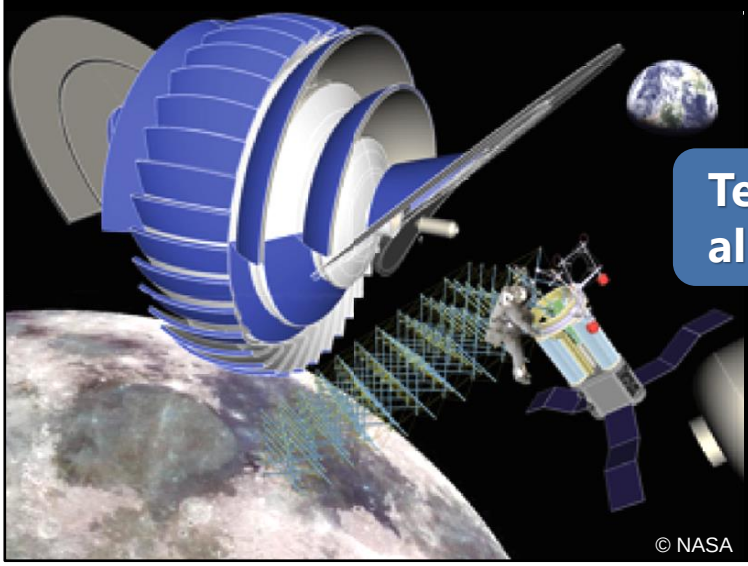
	Mars Exploration Rover	Mars Science Lab	Tensegrity
Entry Mass (kg)	831	3301	140
Landed Mass (kg)	540	943	100
Rover Mass (kg)	175	943	100
Science Payload and Support Avionics(kg)	146	723	70
Productive Science Mass Percentage	17 %	22 %	**50 %**

7

Super Ball Bot - Structures for Planetary Landing and Exploration

Compared to rovers, too, tensegrity is light-weight and much cheaper.
Here is the data.
It is much more efficient, too.

Large-Scale Space Structure

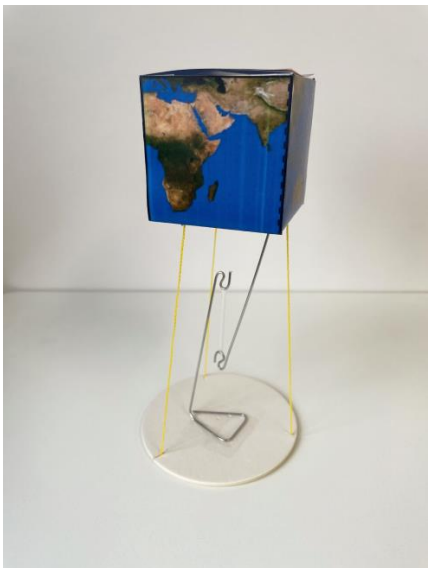


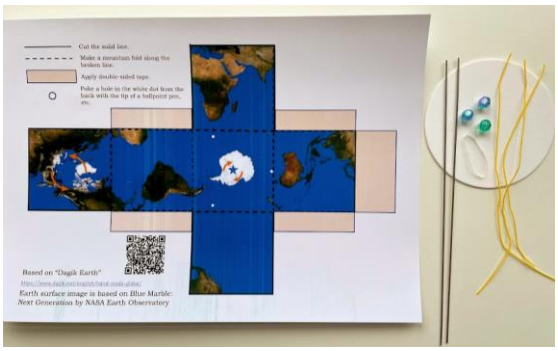
Tensegrity technology allows minimum mass

8

It would probably be useful if we were to build a large space structure in space.

Cubic Earth Tensegrity



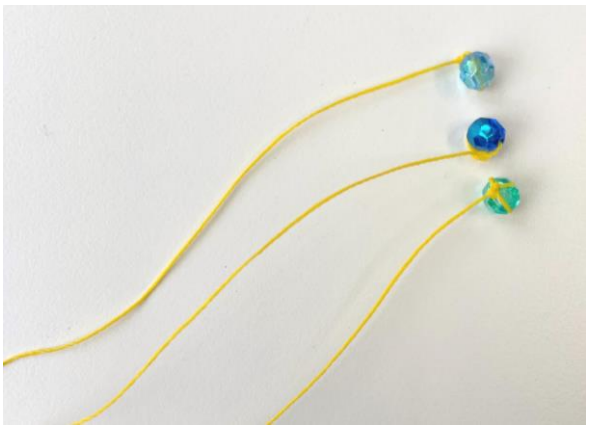


Materials used
- Cubic Earth Paper Craft
- leveling string (20cm)×4
- Stainless steel rod(20cm, Φ1.2mm) ×2
- Beads×4 ・Paper coasters
- Rubber band (inner diameter 2.5 cm)

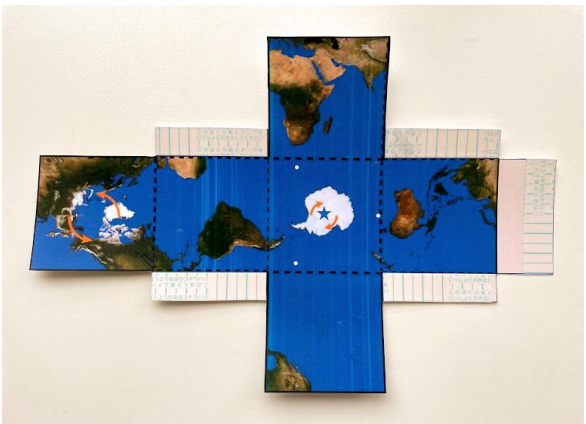
9

Now, let's try to create an example together with paper.
Let's make work – here is a cubic earth tensegrity model.

Preparation 1



1 strings with beads



2 Cut paper
with double-sided tapes

10

1. You have threads with beads.
2. You also have a paper, with double-sided tapes.

Preparation 2

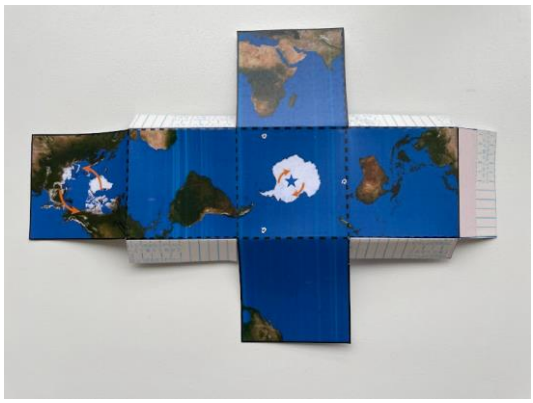
3 Two stainless steel rods

4 A white coaster with 1cm cuts

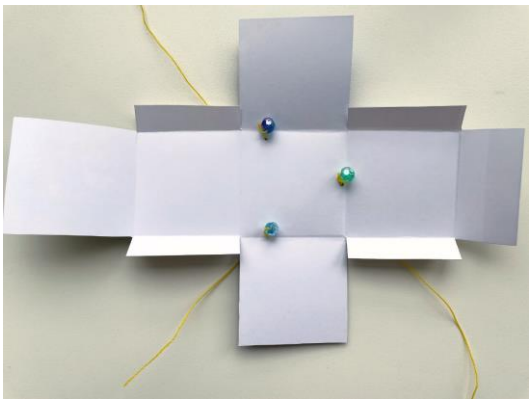
11

3 You have two stainless steel rods, with S-shaped heads.
4 You also have a white coaster, with three cuts

Assembly



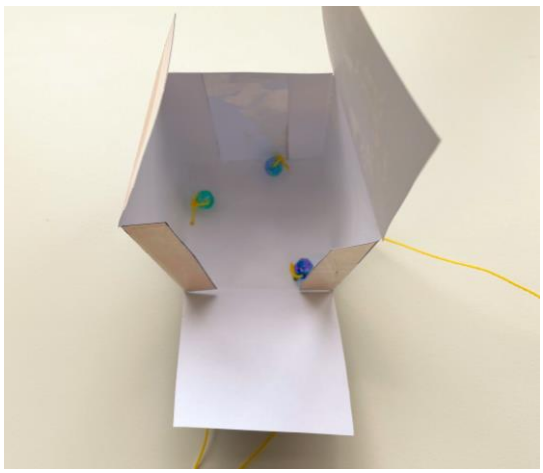
5 Three holes on one side of the panel (You see the Antarctica)



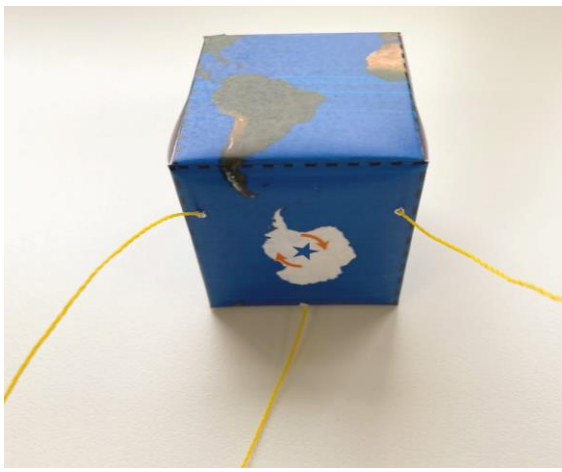
6 Flip over, string through the 3 holes

12

5. You see three holes on one side of the panel (the one with Antarctica!)
6. Please flip it over. string through the 3 holes



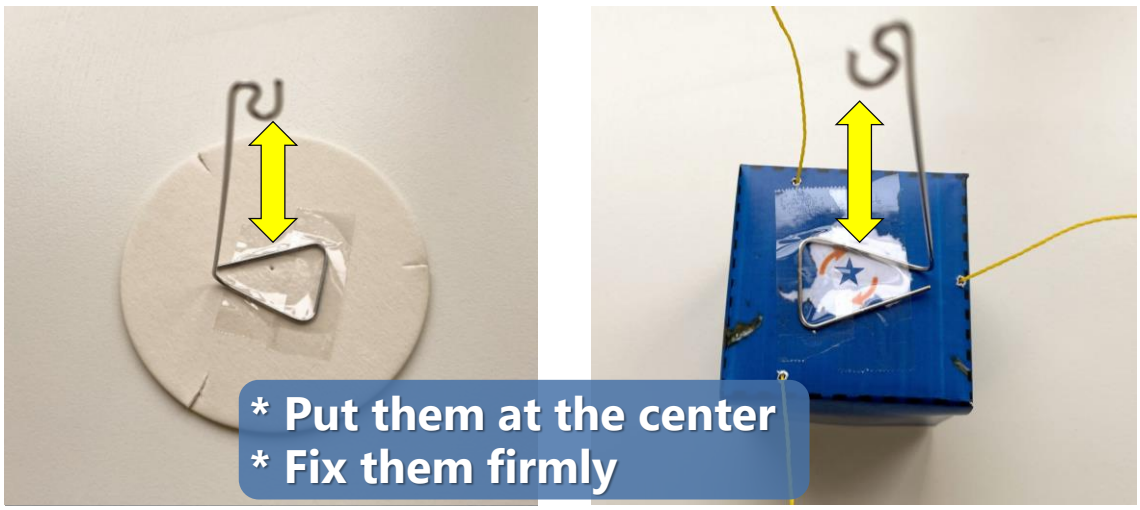
7 Stick the sides and make a cube



8 A cube is completed.
Do you see 3 strings coming out from one side?

13

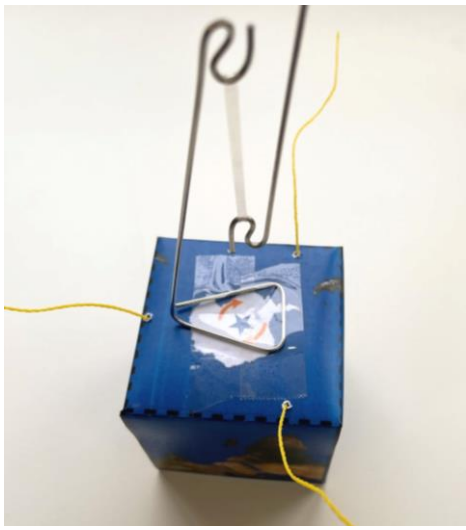
7 Stick the sides and make a cube.
8 A cube is completed. Do you see 3 strings coming out from one side?



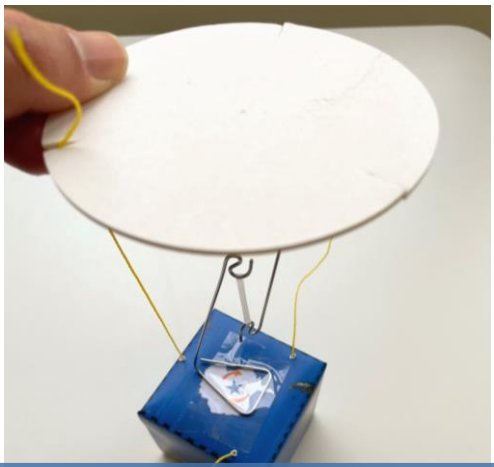
9 Put the rods on the cube with tape as above so that the S-shaped heads will be at the center. See this example!

14

9. Put the rods on the box with tapes, like this. The S-shaped heads will be at the center. See this example!



10　Place a rubber band between two rods.

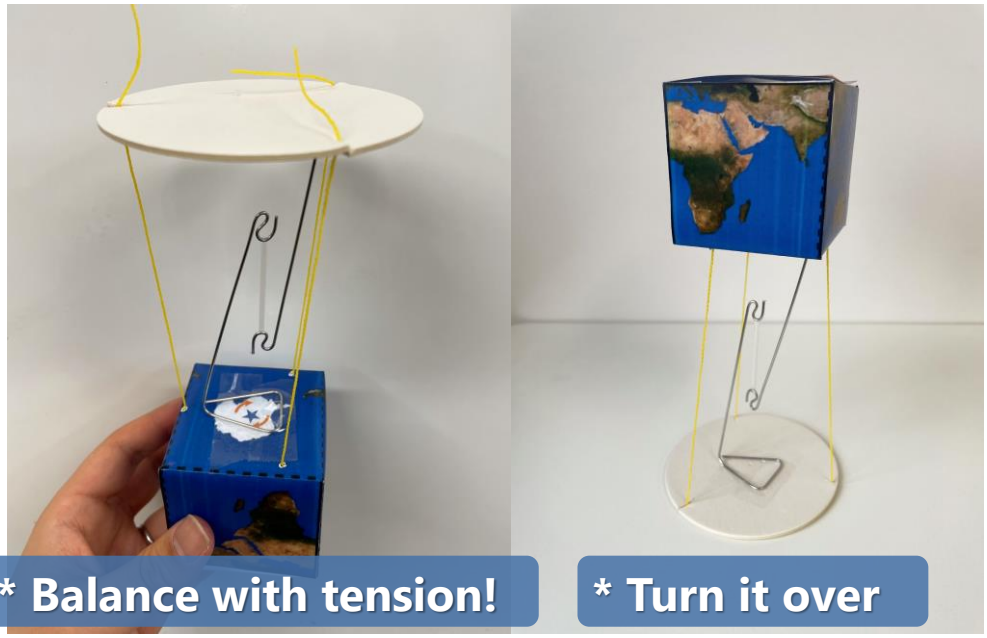


* Don’t pull too much

11　Connect the threads one by one.

15

10. Place a rubber band between two rods, like this.
11. Connect the threads from the bottom to the top, like this.



12 Set the threads with tape.

16

12. Pay attention to the tension created by the strings. Put tapes on the strings to stabilize the coaster.
13. Turn it over and see if it stands!

An example
with “beading cords”

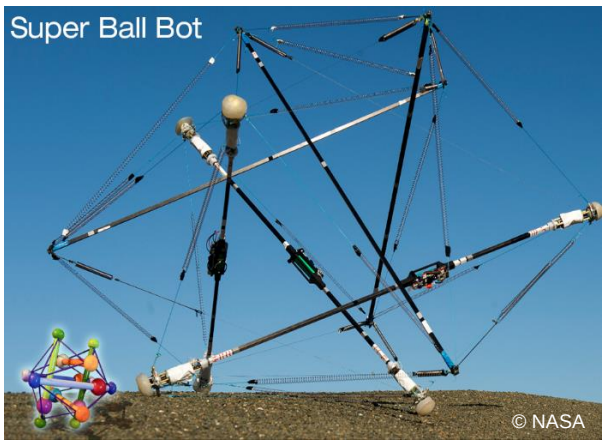
An example of
“Paper craft earth”

17

To the right, you see an example of a tensegrity structure, using the beading cords! And Paper craft Earth

Create your own tensegrity.

Conclusion



1 Small

2 Light-weight

3 Low-cost

4 Absorb shock

Tensegrity will make a change to space technology!

18

Let me conclude now with some remarks. Tensegrity is
1. Small, 2. Light-weight, 3. Low-cost, and 4. it absorbs shocks well.

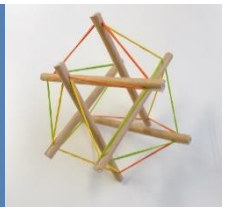
Tensegrity will make a great deal of change to space technology!!!

References and reference sites

1 Tom Flemons Archive
http://intensiondesigns.ca/archive/
2 The standard price for Falcon 9 launch services
https://www.spacex.com/media/Capabilities&Services.pdf
3 Super Ball Bot Drop and Roll
https://youtu.be/Hqn4AEfn_qg
4 Super Ball Bot
https://www.nasa.gov/spacetech/niac/2013phaseII_sunspiral.html
5 Super Ball Bot - Structures for Planetary Landing and Exploration
https://www.nasa.gov/sites/default/files/atoms/files/sunspiral_niac_feb2014_stanford_final2_tagged.pdf
6 Dagik Earth
https://www.dagik.net/english/hand-made-globe/
7 Reference for work made by Shigeki Noro 583～587
http://noroshigeki.web.fc2.com/mokuji10.html
8 Institute of space and Astronautical science Paper craft Earth
https://www.isas.jaxa.jp/en/gallery/papercrafts/earth.html

Let's Enjoy Tensegrity Structures!

Seiji Inoue
Hachinohe Technical High School **Inoue-seiji@m05.asn.ed.jp**



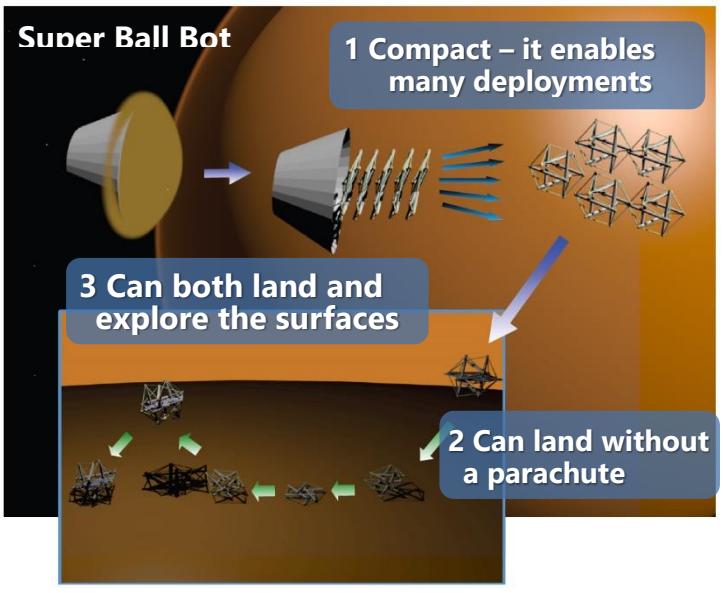
What is Tensegrity?

First explored by
Kenneth Snelson in the 1960's
Named by **Buckminster Fuller**
Tensegrity="**Tens**ion" + "Structural Int**egrity**"

Falcon 9
Payload to LEO 22,800kg
$ 62M / launch
About $ 2,700 / kg

Exploration goals

1. Small
2. Light-weight
3. Low-cost



This kind of robots would be able to land on the hazardous surfaces such as Titan.
It enables to create dramatically simpler mission profiles and reduces costs.

What is GREAT about Tensegrity?

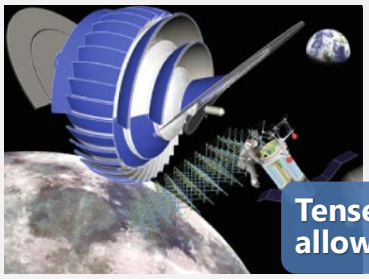
Two Main Points

1 Materials do not touch each other.
2 Sustained by a good balance.

Tensegrity's advantages

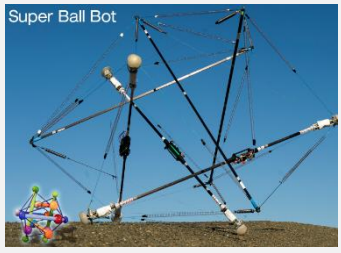
1. Small
2. Light-weight
3. Low-cost
4. Absorb shock

Would be a game changer!!



Tensegrity technology allows minimum mass

It would probably be useful if we were to build a large space structure in space.

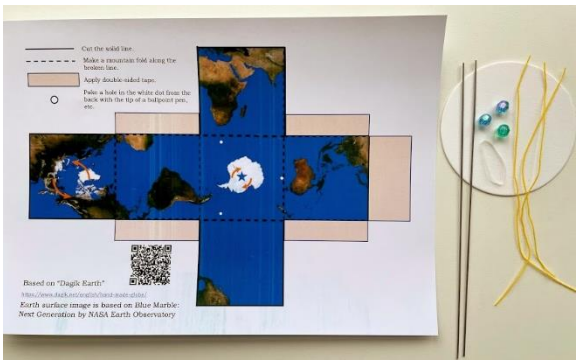


Let me conclude now with some remarks. Tensegrity is 1. Small, 2. Light-weight, 3. Low-cost, and 4. it absorbs shocks well.

Tensegrity will make a great deal of change to space technology!!

Today's Activities

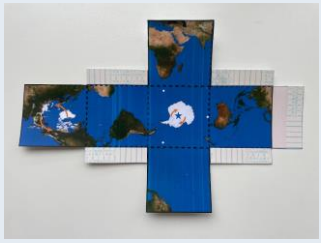
Let's build a Cubic Earth Tensegrity!



Materials list

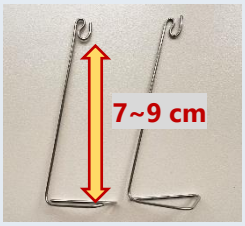
- Cubic Earth Paper Craft
- Leveling string (20cm)×3
- Stainless steel rod (20cm, Φ1.2mm) ×2
- Beads×3
- A paper coaster (Φ9cm,2mm)
- A rubber band (inner diameter 2.5 cm)

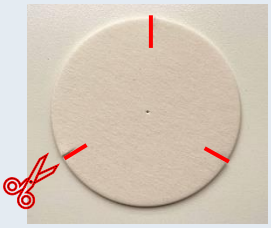
①



1) You have strings with beads.
2) You also have paper with double-sided tape.

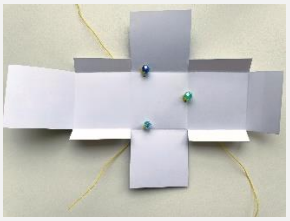
②





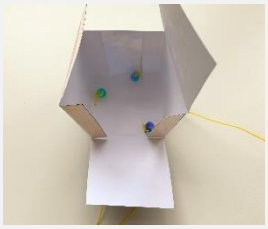
3) You have two stainless steel rods, with S-shaped heads.
4) You also have a coaster with three cuts (1cm cuts)

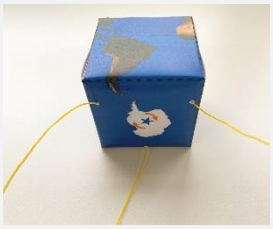
③



5) You see three holes on one side of the plane.
(The one with Antarctica!). Remove the vinyl backing.
6) Please flip it over. Put the thread through the 3 holes.

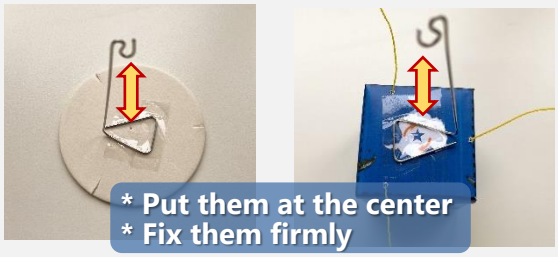
④





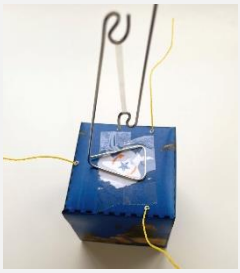
7) Stick the sides and make a cube.
8) A cube is completed.
Do you see 3 strings coming out from one side?

⑤



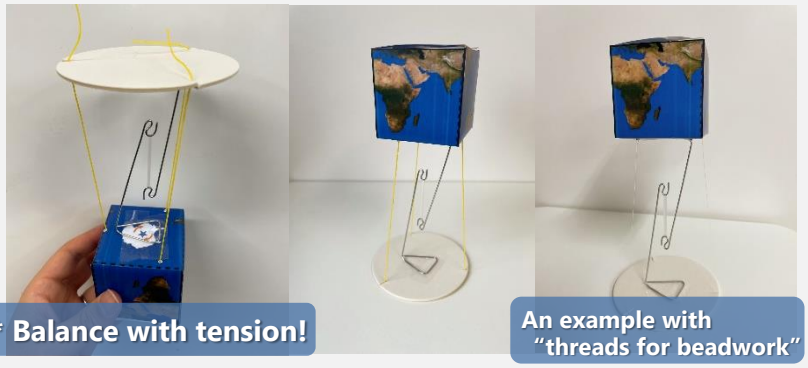
9) Put the rods on the cube with two pieces of tape as above so that the S-shaped heads will be at the center. See this example!

⑥



10) Place the rubber band between the two rods.
11) Connect the strings from the bottom to the top.

⑦



12) Pay attention to the tension created by the strings. Put tapes on the strings to stabilize the coaster.
13) Turn it over and see if it stands alone!

To the right, you see an example of a tensegrity structure using the threads for beadwork.

Cut the solid line.

Make a mountain fold along the broken line.

Apply double-sided tape.

Poke a hole in the white dot from the back with the tip of a ballpoint pen, etc.

Based on “Dagik Earth”

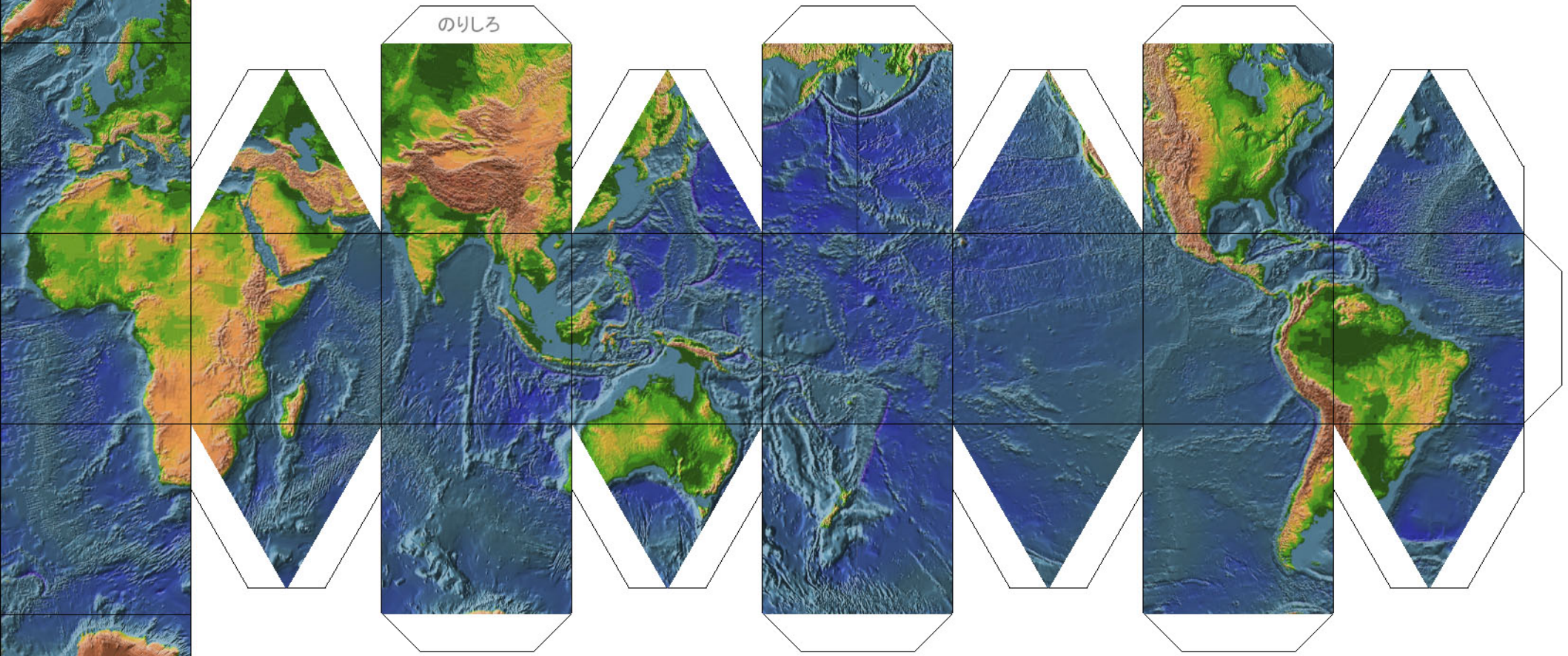
https://www.dagik.net/english/hand-made-globe/

Earth surface image is based on Blue Marble: Next Generation by NASA Earth Observatory

地球ペーパークラフト

高さごとに色分けして地球の地形が表されています。

画像提供：NASA/USGS
作成：宇宙研惑星画像センター（RPIF）
2002 年 7 月版



きれいにきりとり、両面テープなどで組み立ててください。