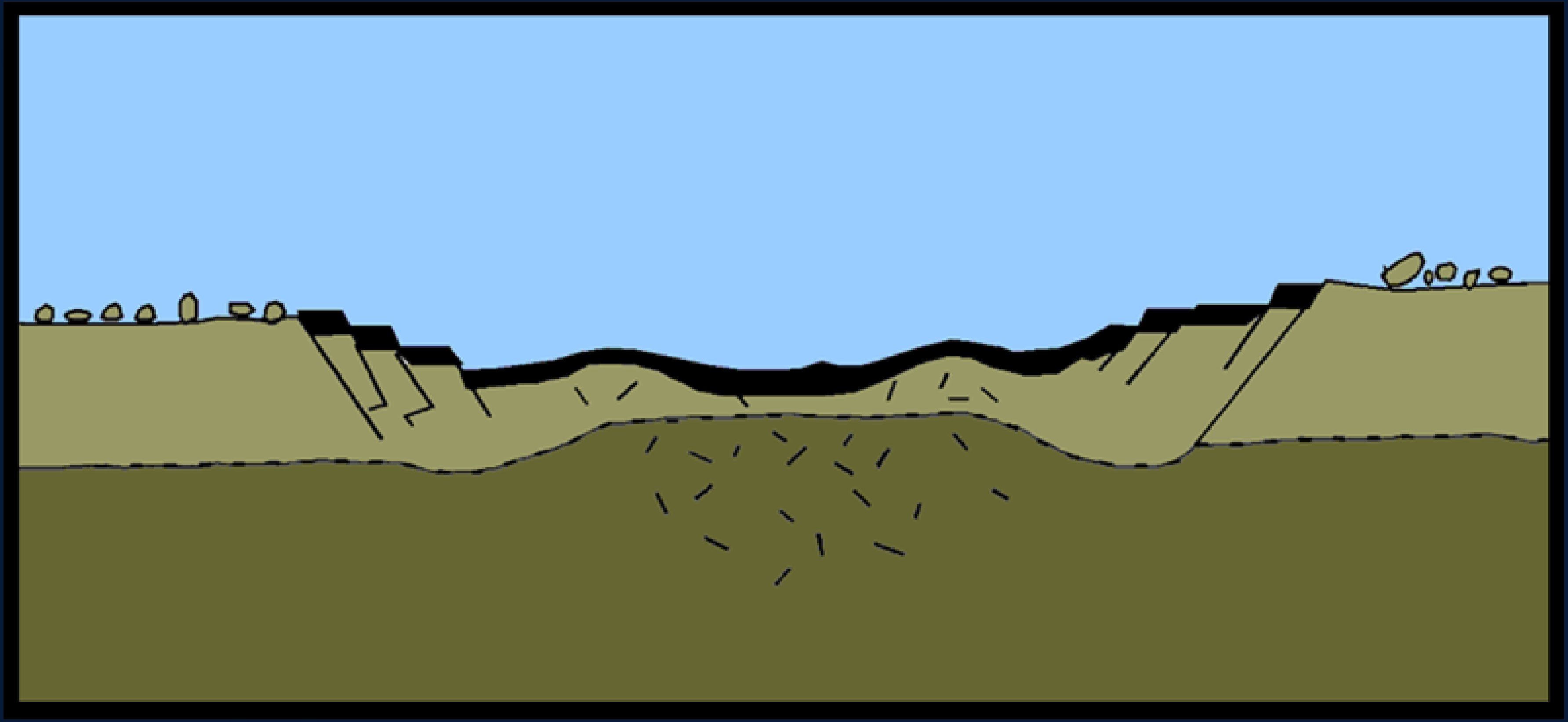
Crater formation

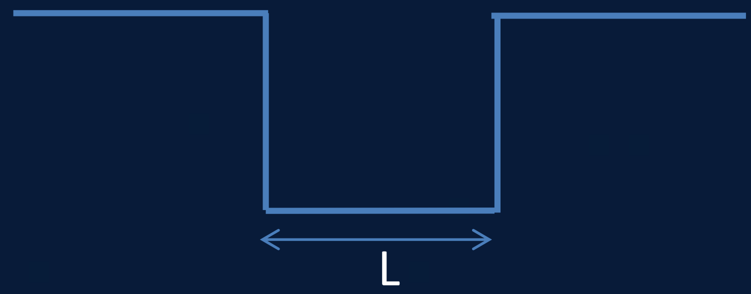
Craters form when meteorites strike the surface In the collision the kinetic energy of the meteorite is transferred to sound, heat, chemical, elastic and gravitational potential energy leaving a crater



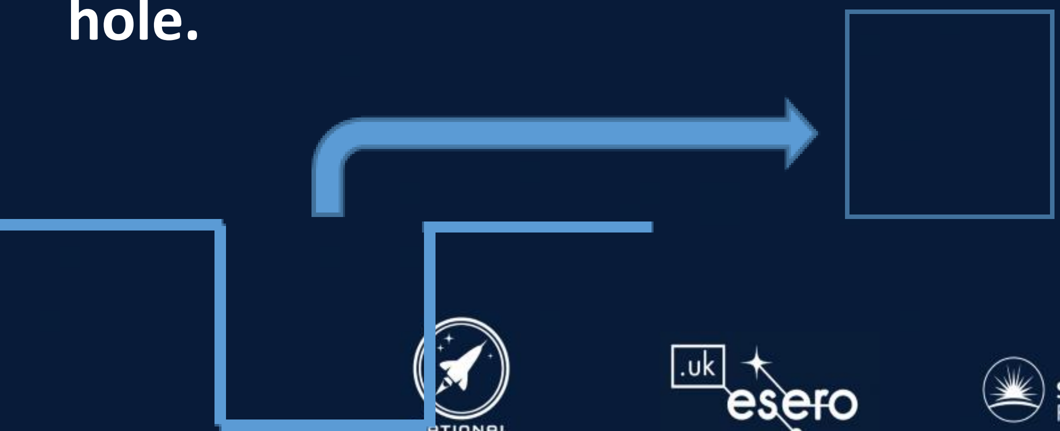
University of Arizona, Space Imagery Center

Simple Mathematical Modelling

A crater is modelled as a cubic hole, with sides of dimension L, dug into the flour (Byfleet, 2007; Florida State University).



Energy considerations would suggest that the energy required in digging this hole will be the same as the gain in potential energy in lifting a similar sized cube of material onto the ground next to the hole.

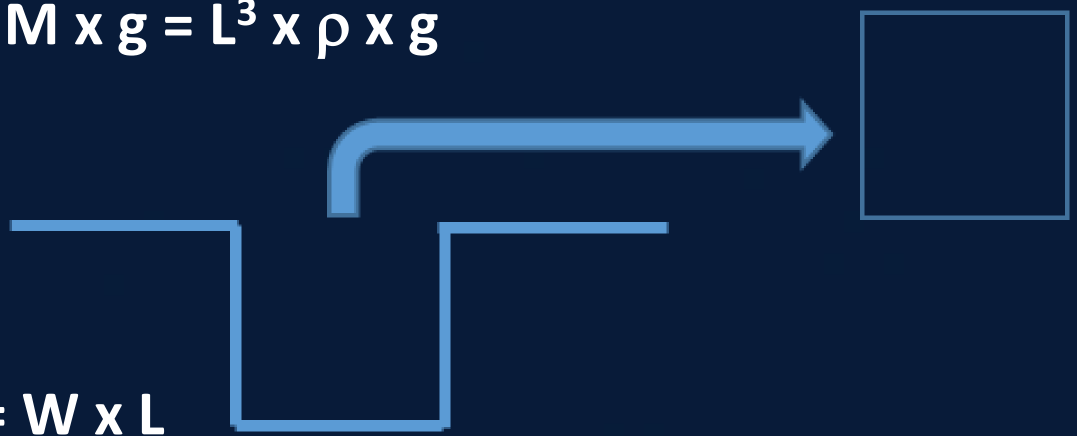


Simple Mathematical Modelling

The volume of the hole, $V = L^3$

Mass of material moved from hole, M = volume x density = $L^3 \times \rho$

Weight of this material, $W = M \times g = L^3 \times \rho \times g$



Gain in potential energy, $E_p = W \times L$

It is suggested that this analysis will be true for any shape of crater; we will just introduce a shaping factor to expand to any shape of crater.

$$E_p = W \times L \times f_c = L^3 \times \rho \times g \times L \times f_c = L^4 \times \rho \times g \times f_c$$

Simple Mathematical Modelling

The potential energy for digging the hole will come from the kinetic energy of the ball just before impact and the kinetic energy of the ball will equal the loss in potential energy of the ball during its fall (assuming no losses due to air resistance).

Kinetic energy of ball just before impact

E_k = loss of potential energy of falling ball = m x g x h

$m \times g \times h = L^4 \times \rho \times g \times f_c$

$$h \propto L^4 \text{ or } m \propto L^4$$

Theory therefore predicts that a graph of height of ball drop or mass of ball against (size of crater)^4 should yield a straight line since ρ and the craters' shape are all constant.

Advanced Mathematical Modelling

Experimental investigations have shown that there is a power law relationship between the kinetic energy of the impactor E and the resulting crater diameter D (Bunce, 2006; Leicester University).

Crater theory suggests that:

$D = kE^n$ where k and n are (non-integer) constants.

Taking natural logs of the above equation gives:

$\ln(D) = n\ln(E) + \ln(k)$

So a graph of ln(D) (along the y-axis) against ln(E) (along the x-axis) graph will produce a liner relationship with n as the gradient of the graph, and k as the intercept.

Imaging Techniques

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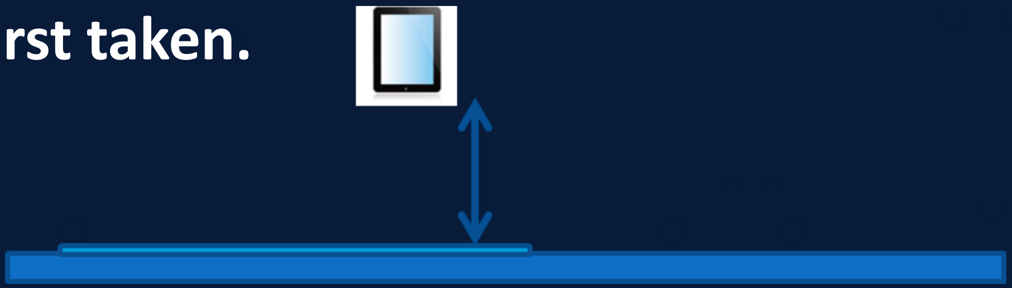
Develop an understanding of

- resolution
- image size

Use the same camera (iPad was used), from the same height each time a scaling image is first taken.



Which produces an image like this:

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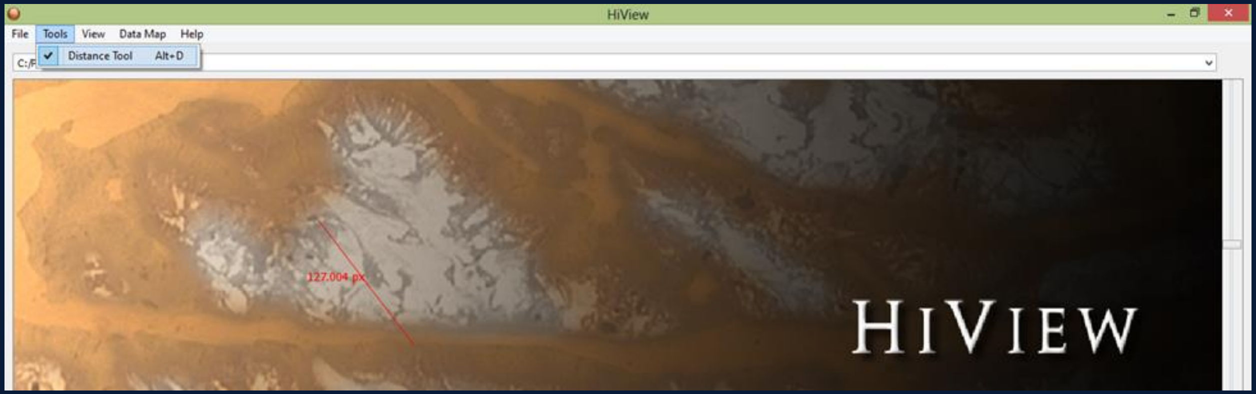
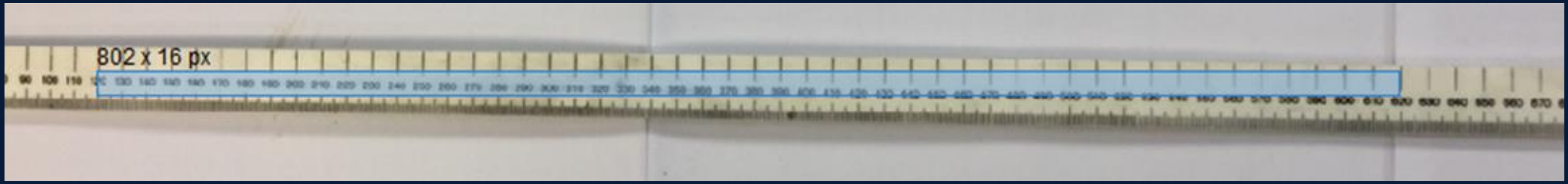
Imaging Techniques

This image is then uploaded into HiView and the measuring tool is used to count the number of pixels along a distance of the ruler.





So we have 802 pixels represents a distance of 500mm, so our resolution (with this camera and at this height) is

Resolution = 500/802 = 0.62 mm per pixel

Imaging Techniques

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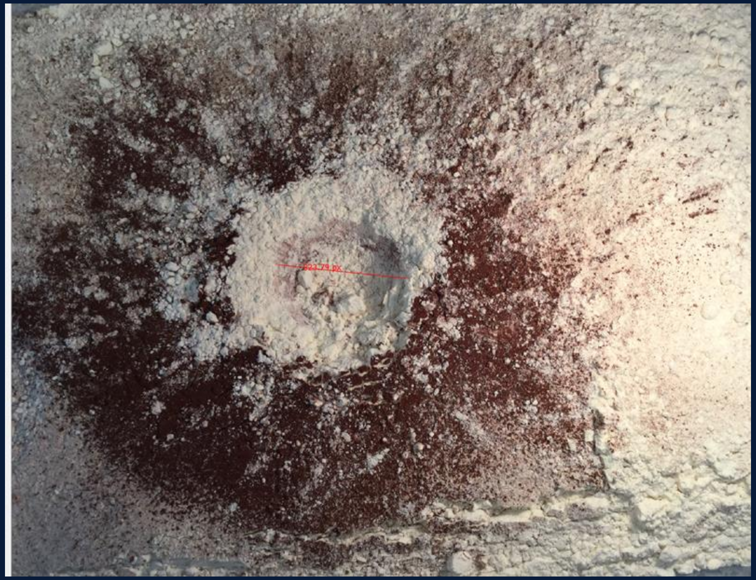
The crater image can be analysed in the same way using HiView



The image is 324 pixels in diameter and so the crater has a diameter of

Crater diameter = 324 x 0.62mm = 200 mm

Which can then be directly measured to validate the technique

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Imaging Techniques

The crater depth formula can also be used. Here a shadow from a lamp angled at 45^0 is used to create a shadow. The image is uploaded into HiView as before.

A shadow length of 114 pixels represents a distance of (114 x 0.62) = 71 mm.

$$d = \tan(90 - \theta) \times L$$

Where the incident angle is 45^0 gives crater depth as

$$d = \tan(45) \times 71 = 71 \text{ mm}$$

Imaging Techniques

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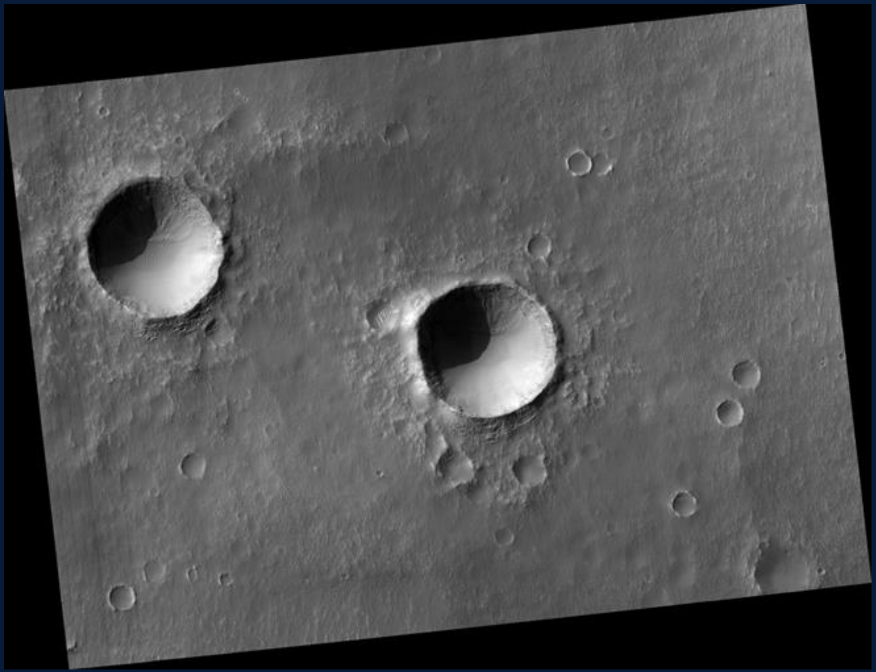
Download an image from HiRise database, in this example PSP_001750_1425



To complete the exercise any image will also need

1. Resolution (e.g. 25 cm per pixel)
2. Incidence angle (e.g. 72^0)
3. Emission angle (e.g. 6.2^0)

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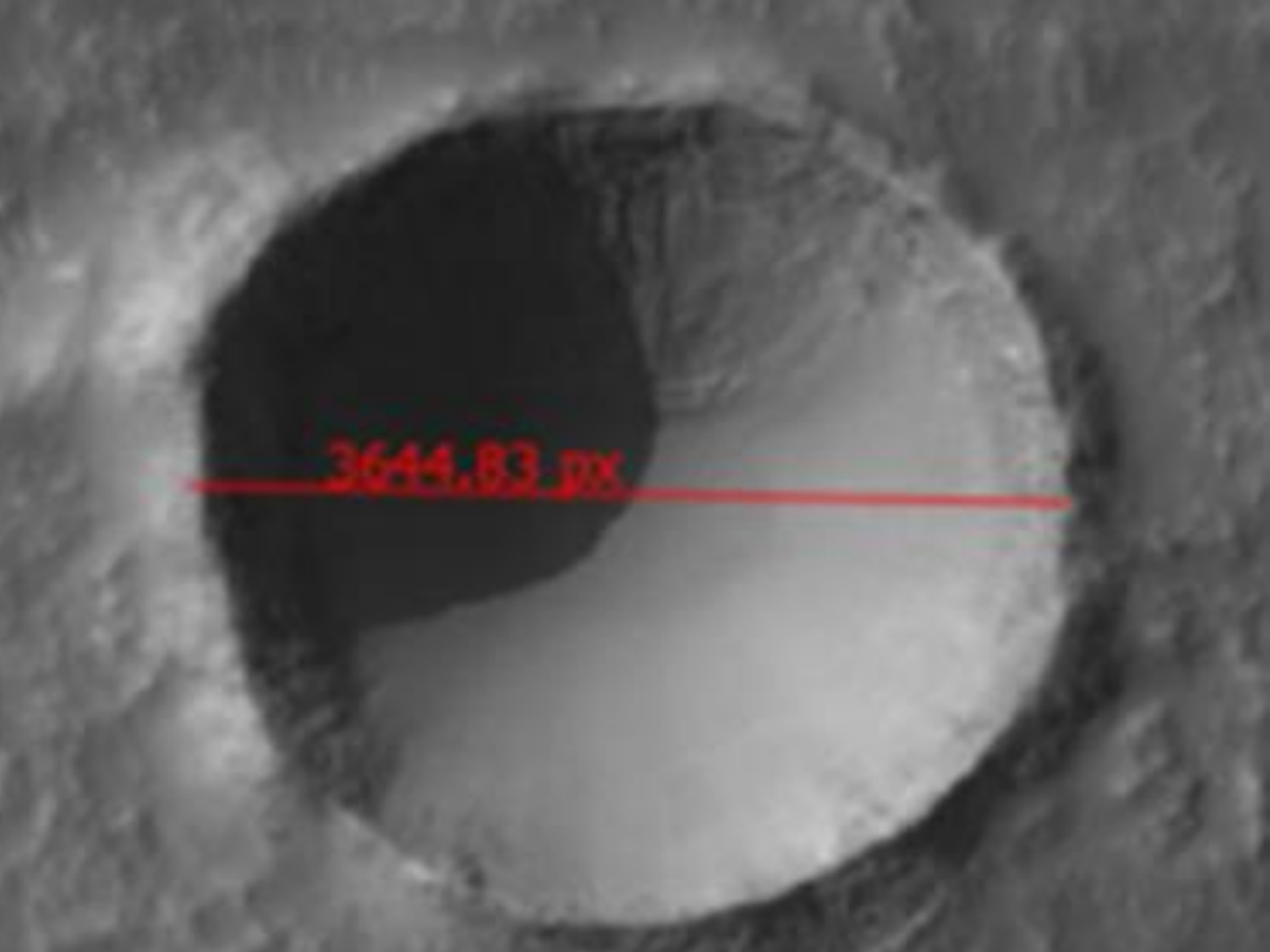
3644.83 px

Imaging Techniques

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Once the images have been selected and the impact craters identified it is time to take measurements using exactly the same techniques as for 'own' craters.

1. **Upload the image into HiView and use the measuring tool to count the pixels**

2. **Use the resolution (in this case 25cm per pixel) to calculate the diameter of the crater**

Diameter = 3645 x 25cm = 911.25 m

The published value for the craters is in the region of 900 m.

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Imaging Techniques

Crater depth can be calculated from the shadow length as before

1. **Upload the image into HiView and use the measuring tool to count the pixels**

2. **Use the shadow formula**

$$d = \tan(90-\theta) \times L$$

$$d = \tan(90 - 72) \times (1899 \times 25)\ \text{cm}$$

$$d = 15425\ \text{cm} = 154\ \text{m}$$

Imaging Techniques

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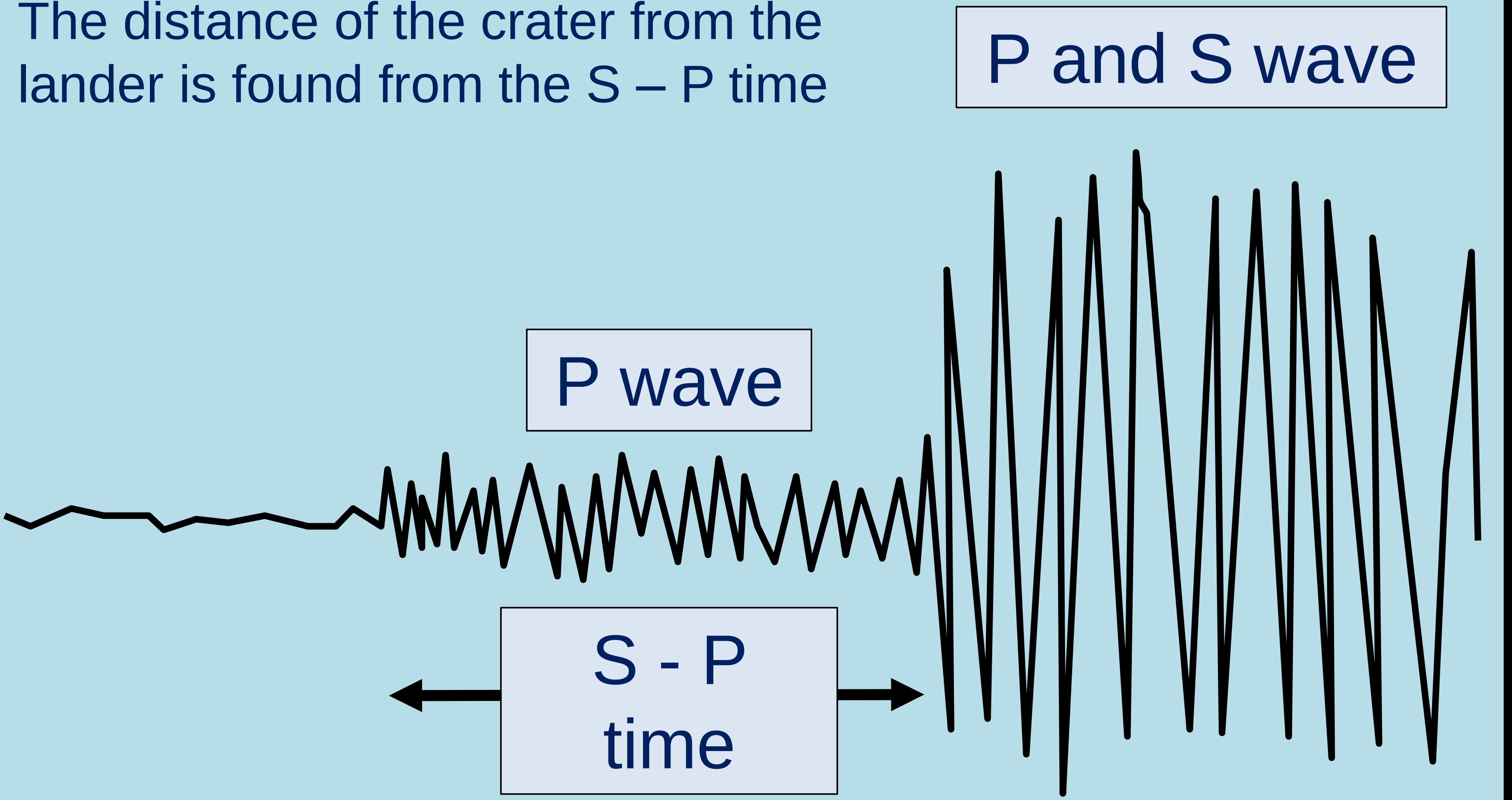
If you can't upload the image into HiView then use the map projected images

Seismometers record the waves from the impact

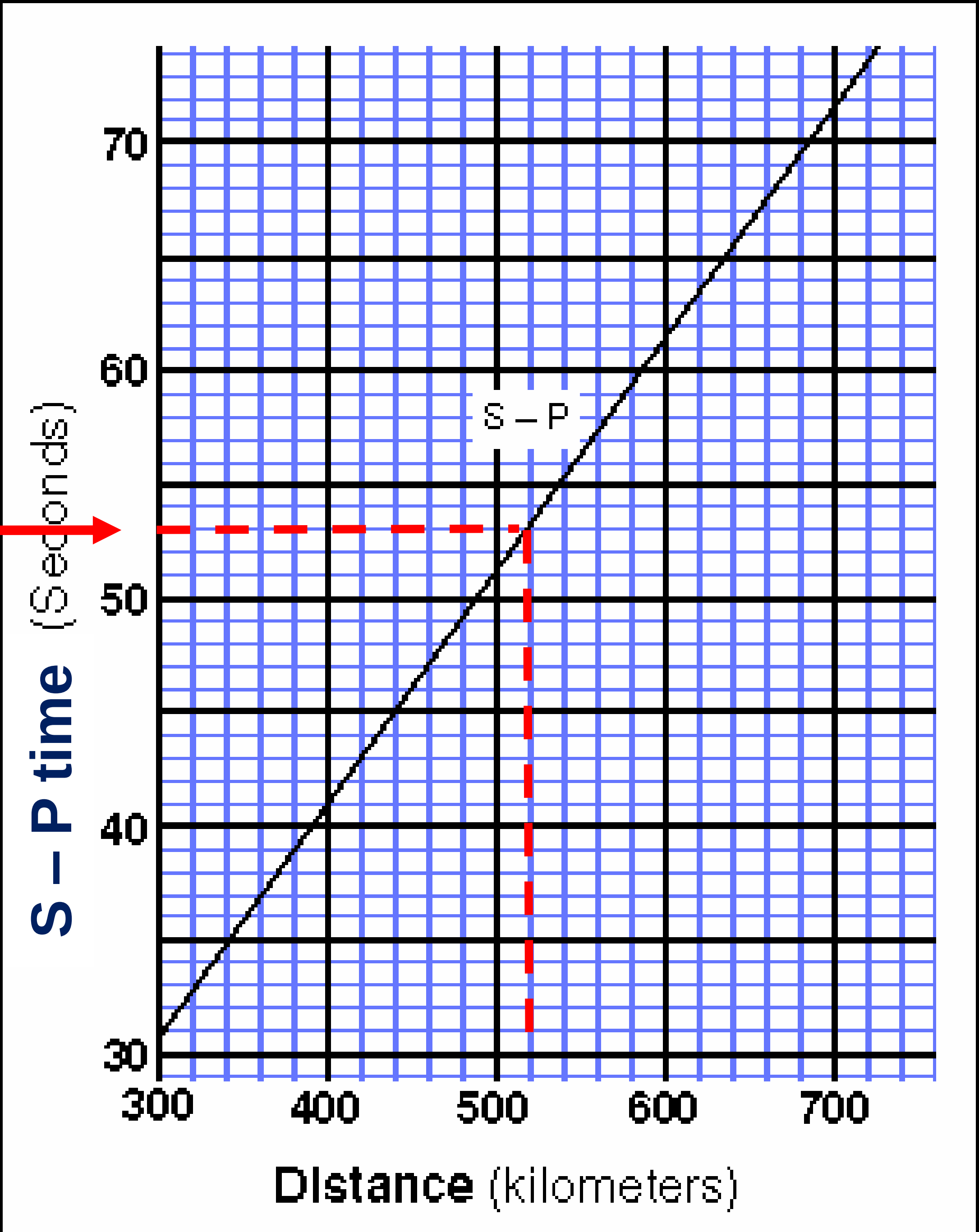
The distance of the crater from the lander is found from the S – P time



Graph of S – P time against distance

S – P time = 53 s

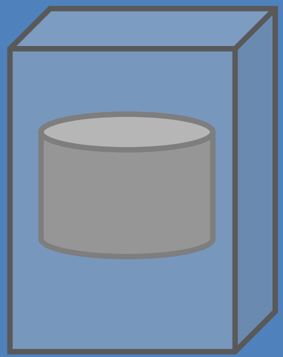
Distance = 520 km



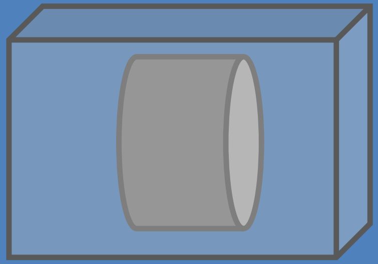
The amplitudes of the waves from the two seismometers is plotted
The graph gives the direction that the wave has come from

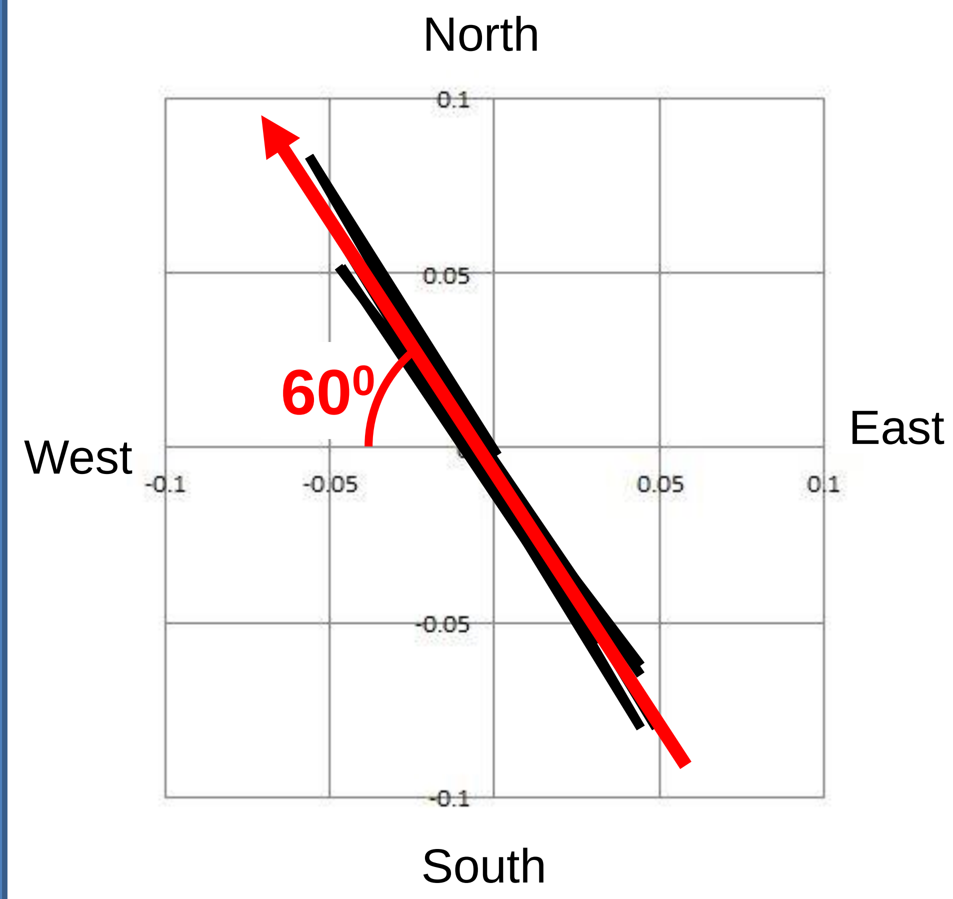
Seismometers

North - South

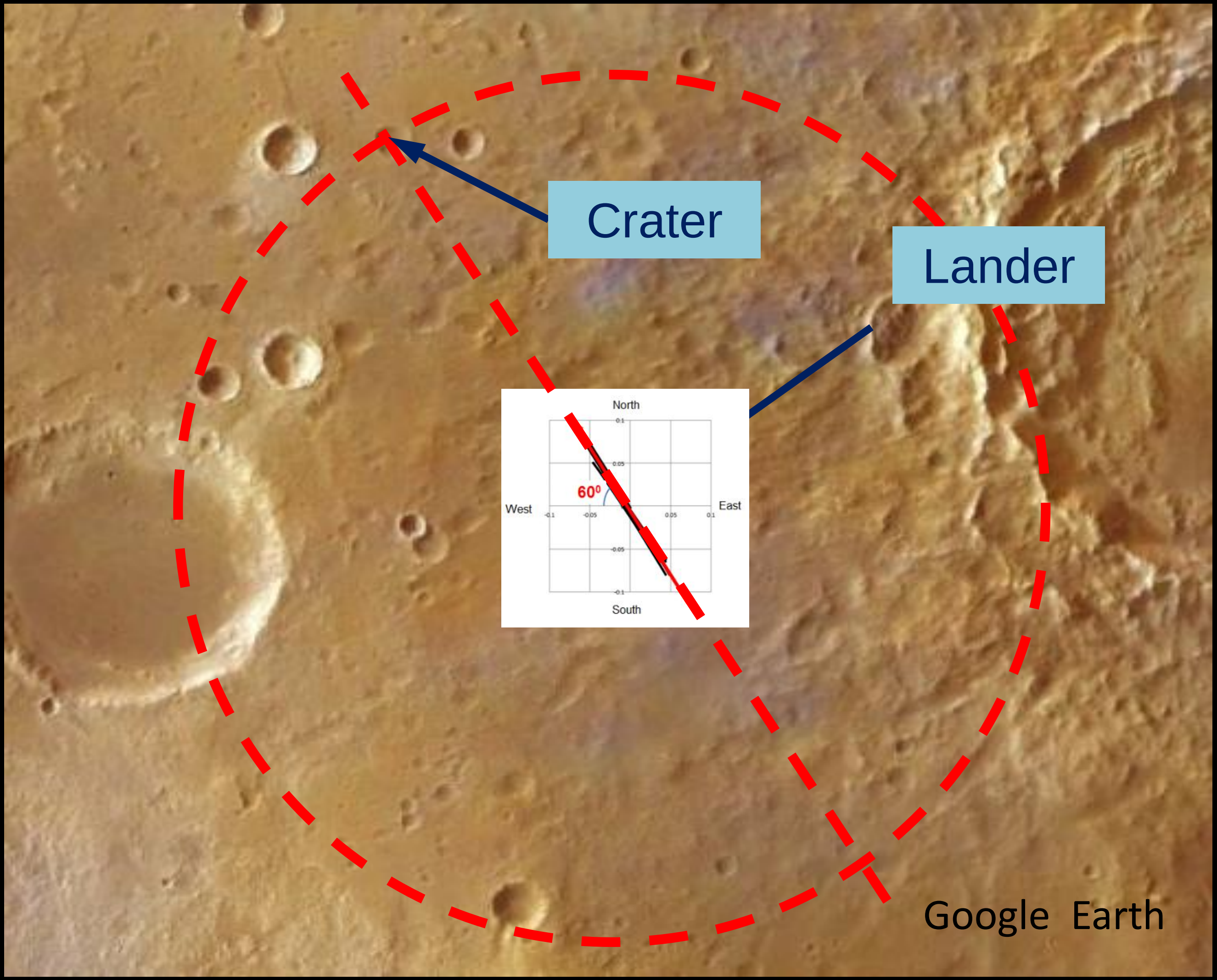


East - West



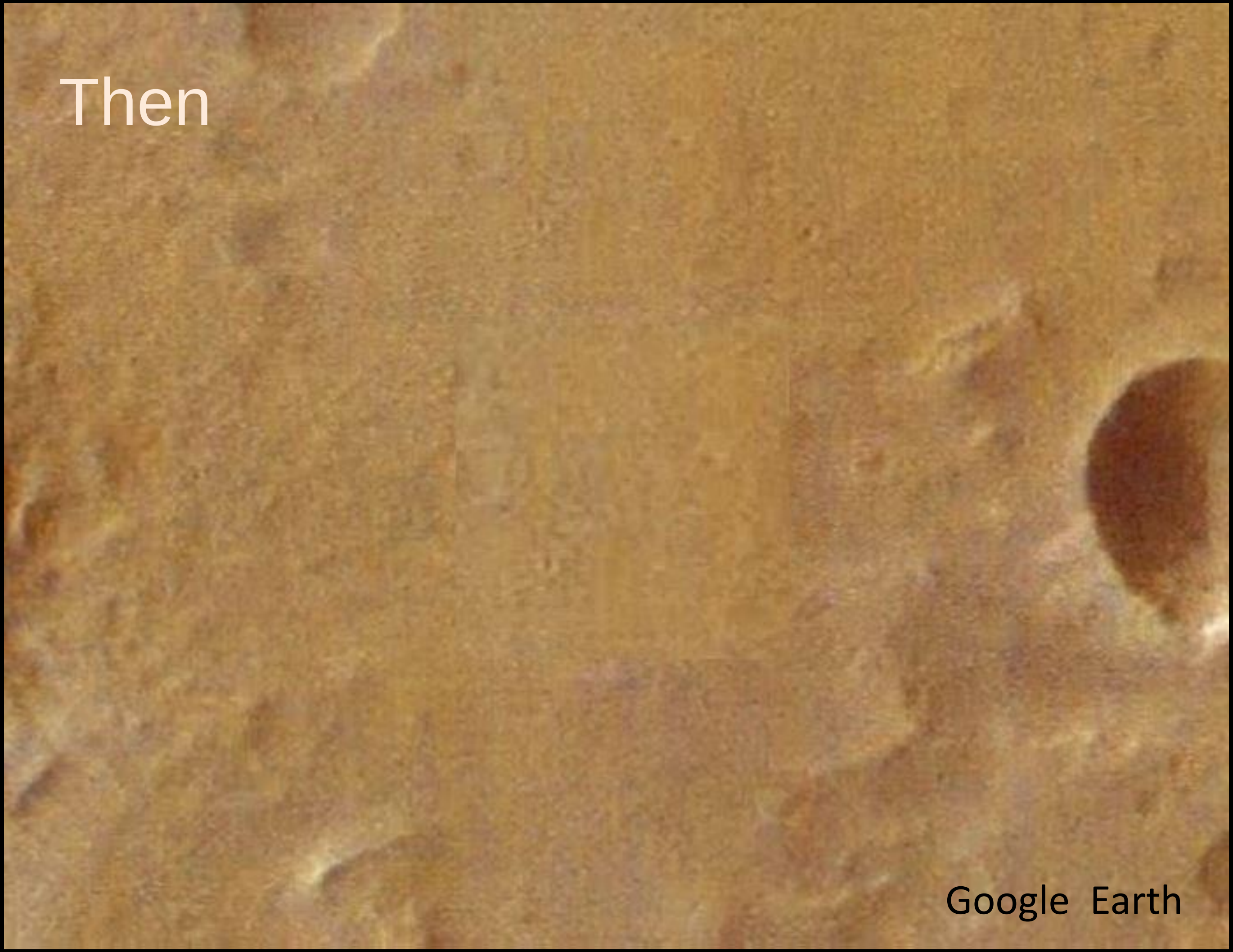


The information can but put on a map



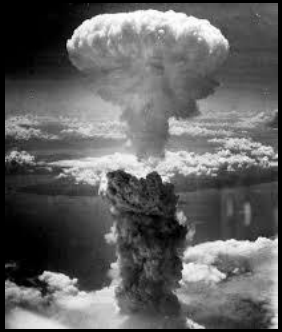
The distance from the S – P time

Old and new pictures can then be compared to look at the newly formed crater



How big was the impactor?

Crater events can be measured in kilotons (KT), much of the physics of craters was developed from nuclear testing.



Let's say a typical Meteor Crater event was 2.5 megatons (2500KT)

Use kinetic energy equation to work out MASS of the impactor

Use density equation to work out VOLUME of impactor

Assuming it's spherical, use volume of a sphere equation to work out RADIUS of impactor!

KE = 2500 KT

1kT = $4.2 * 10^{12}$ J

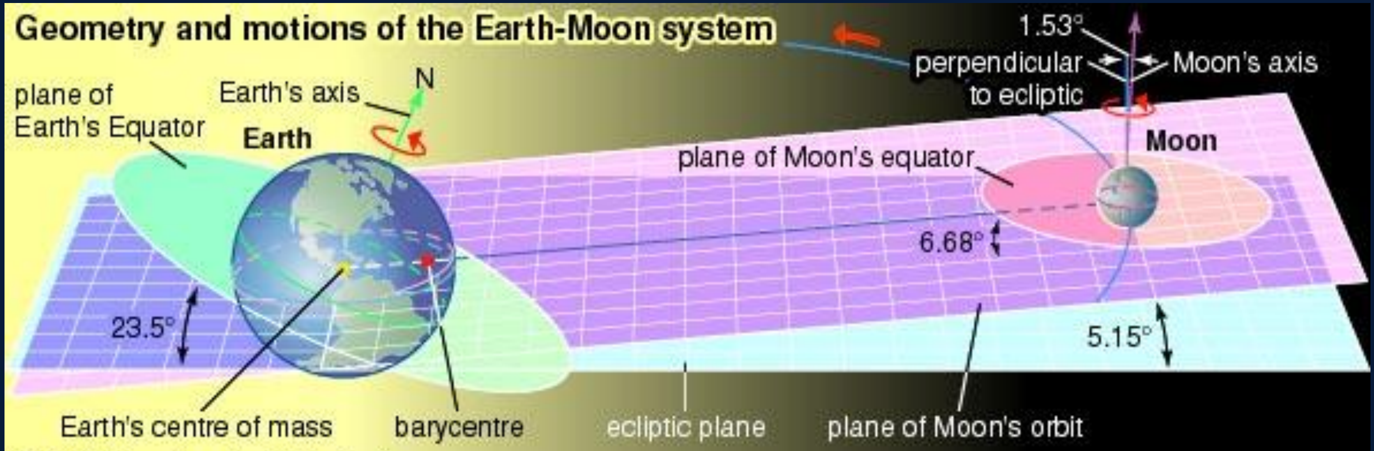
Entry velocity = 12.8km/s

Density of iron meteorite = $7 g/cm^3$ = $7000 kg/m^3$

What is 'wrong' on these two pictures?

http://wps.prenhall.com/wps/media/objects/679/695450/g_earth_moon.jpeg

- Earth diameter = 12 800 km
- Moon diameter = 3 460 km
- Earth-Moon distance = 384 000 km



Scale is the key

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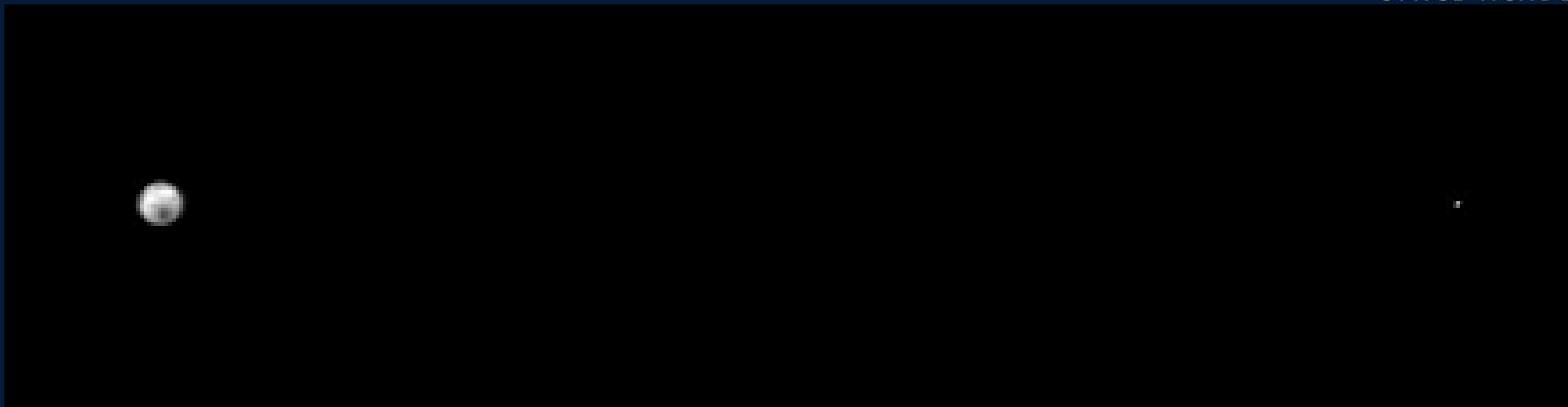

https://spacemath.gsfc.nasa.gov

Wrap string 10x around the Earth

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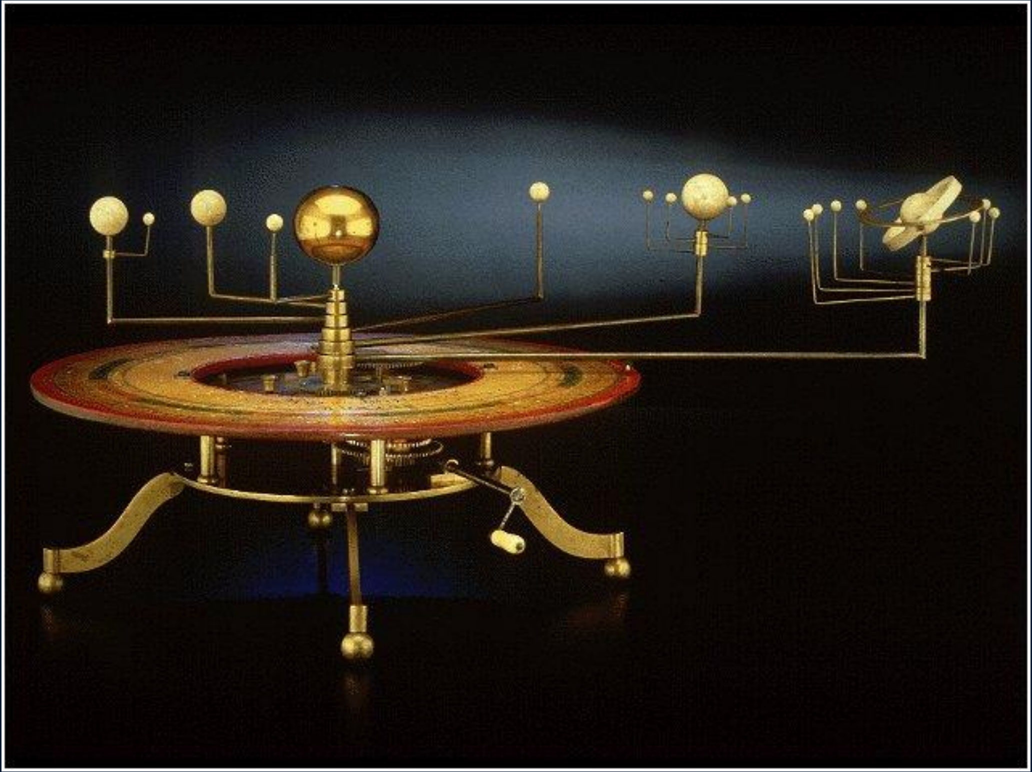
A proper scale model?



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Let’s meet the solar system…

- Sun – football
- Mercury – pinhead
- Venus – peppercorn
- Earth – peppercorn
- Moon - pinhead
- Mars – pinhead
- Jupiter – conker
- Saturn – cherry tomato
- Uranus – raisin
- Neptune – raisin

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Where shall we put them?

Distances from the Sun to:

- Mercury – 6m
- Venus – 11m
- Earth – 15 m
- Mars – 23 m
- Jupiter – 78 m
- Saturn – 142 m
- Uranus – 287 m
- Neptune – 450 m

Use Google Earth

Where are the stars?

Our nearest neighbour, Proxima Centauri, is about 4.24 LY (light years) away.

This equates to about 6 700 km in our scale model!

Hovercraft Challenge

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Can you make your hovercraft travel the furthest?

Things to think about:

- Balloon dragging on the floor
- How much air to use
- How hard to push the hovercraft

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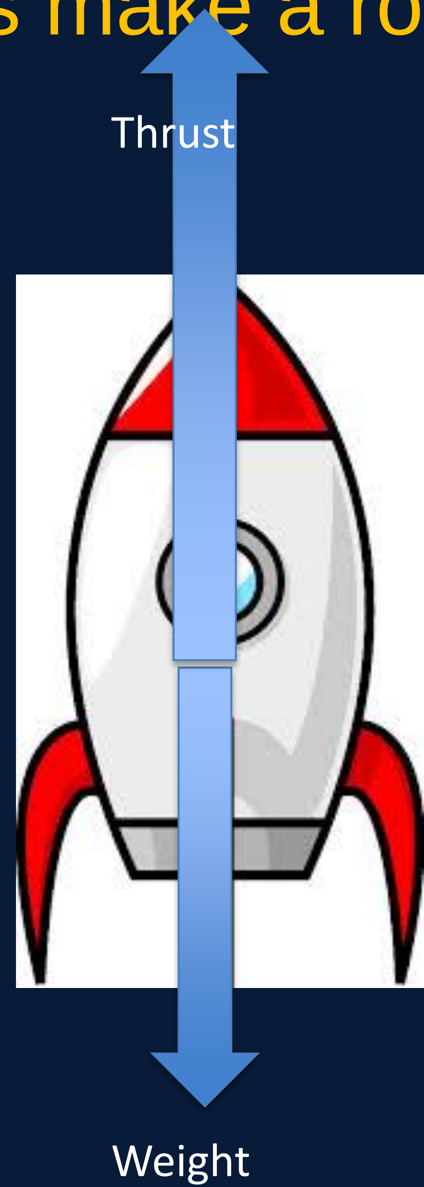
And how does this make a rocket launch?

Initially at rest…

Newton's 1st law states that in order to start moving, an overall, or resultant force must act on the rocket…



How can we produce this thrust force?

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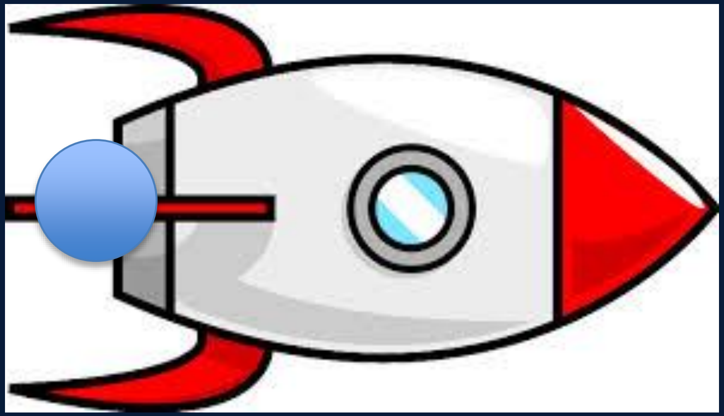

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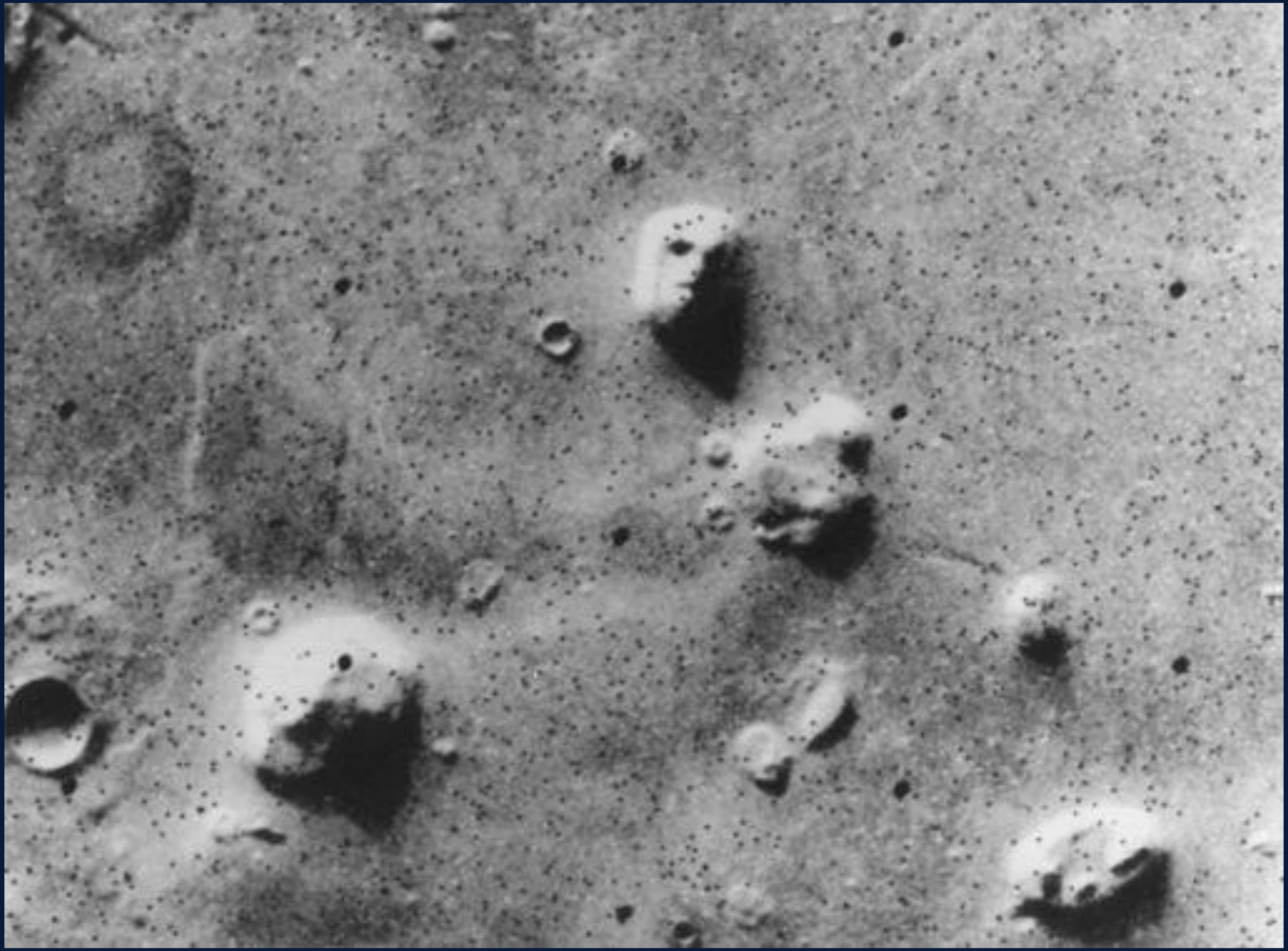
Cydonia – Viking Orbiter (1976)



https://en.wikipedia.org/wiki/Cydonia_(region_of_Mars)

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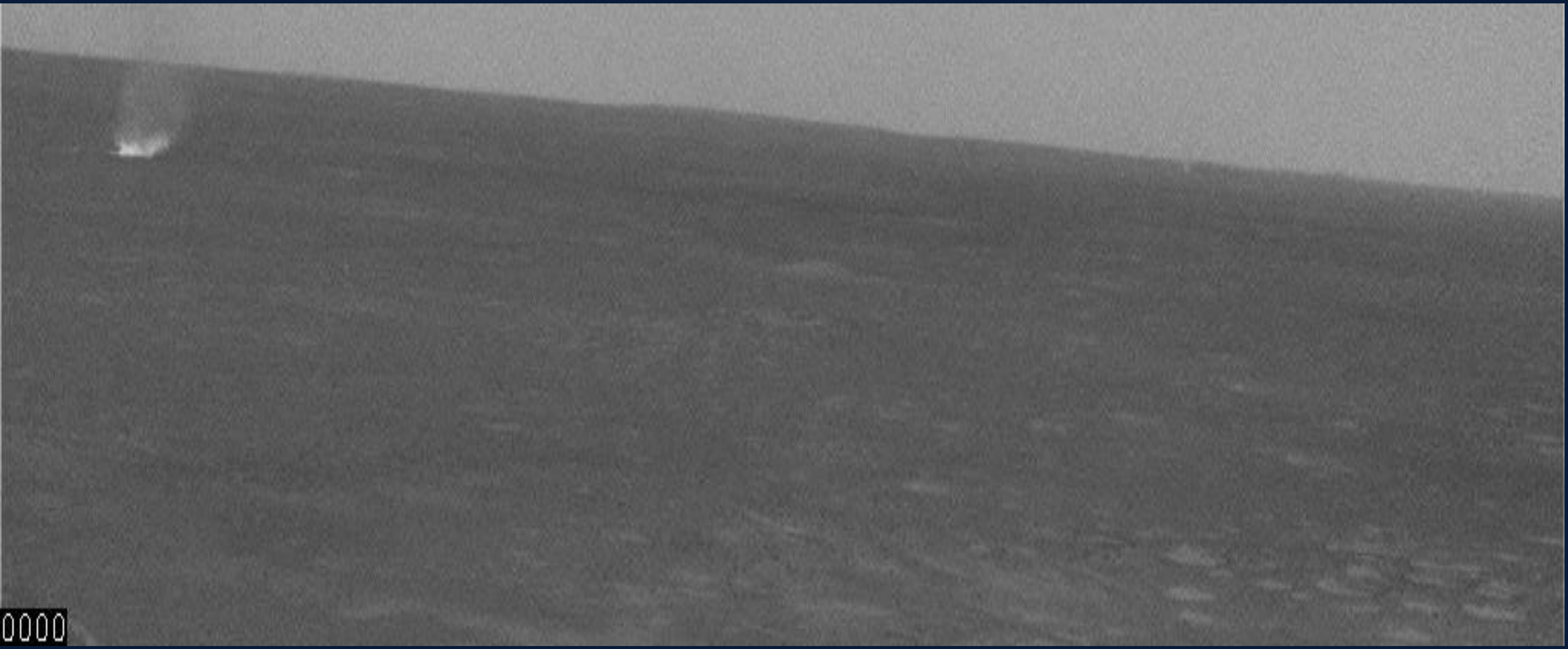
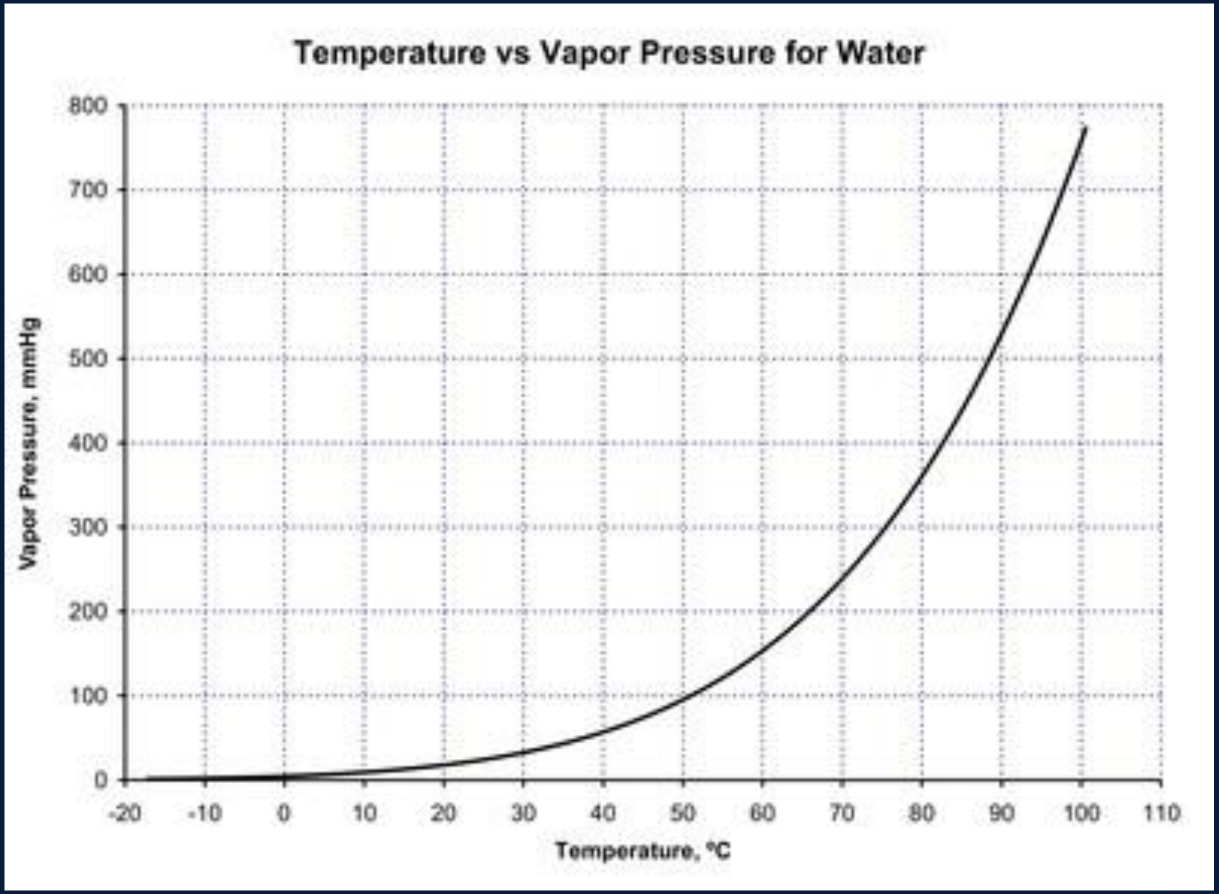
Martian Dust-Devils



How atmospheric pressure affects the boiling point of water



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Mars surface pressure comparable to earth at 39km altitude

www.flickr.com

www.redbull.com

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This is an image of a small part of space (1mm by 1mm held at 1m arm length) in the centre of the Hubble Ultra Deep Field.
Hubble Ultra-Deep Field observed 10,000 galaxies

How many Galaxies in the Universe?

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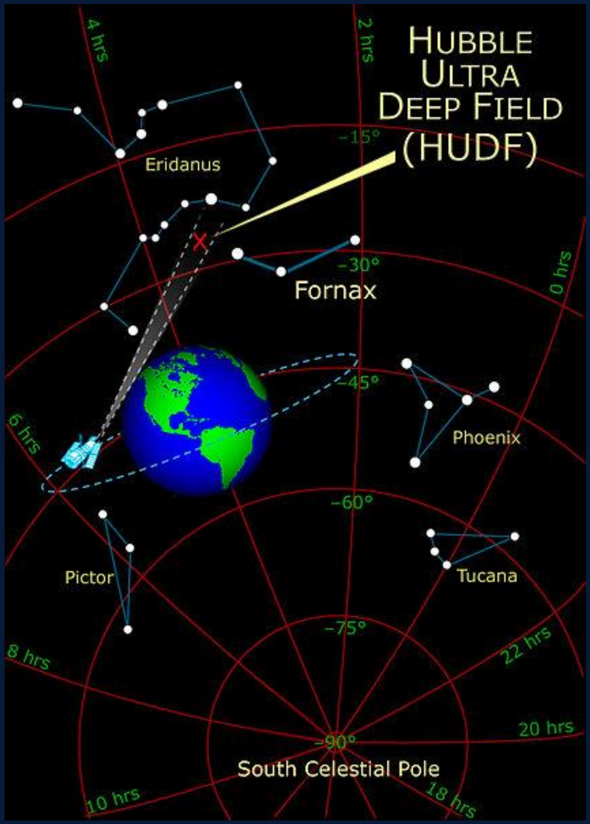
Compiled over a number of months exposure time.

The faintest galaxies are one ten-billionth of the brightness that the human eye can see.



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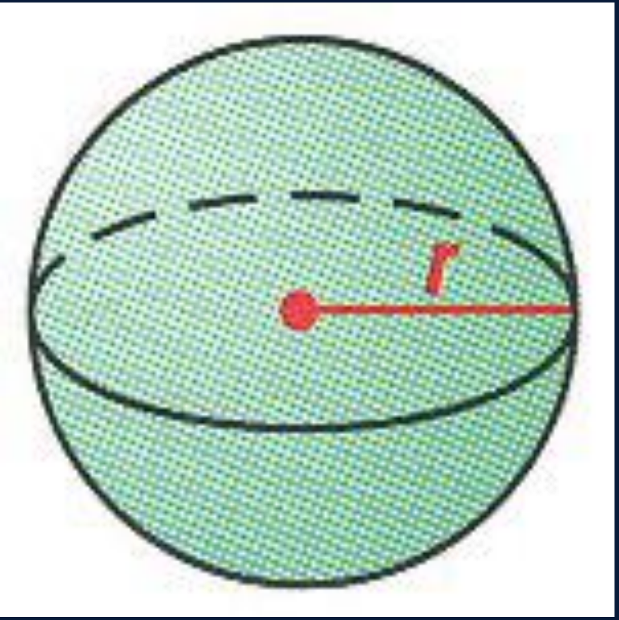
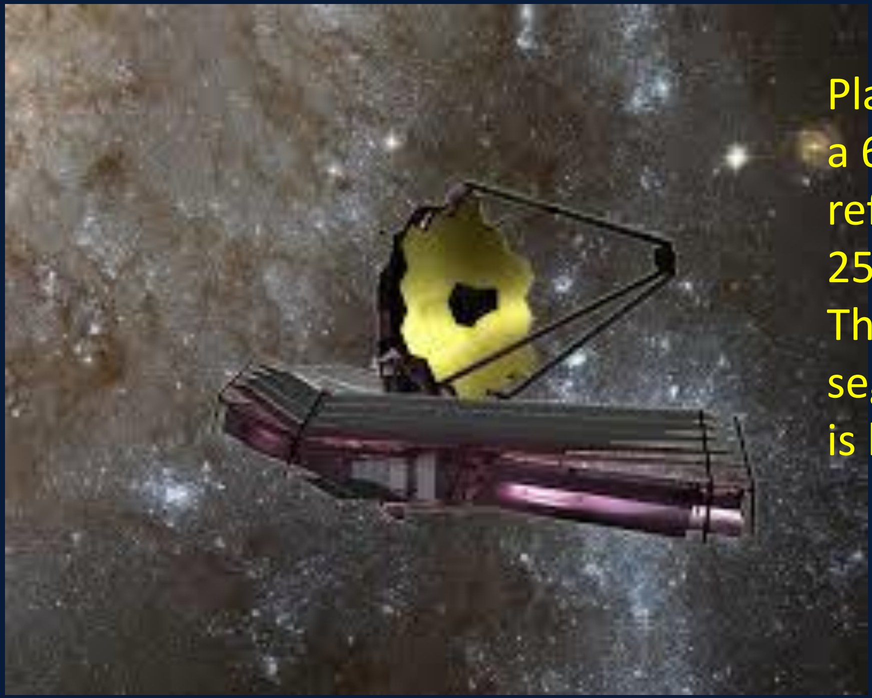
So, how many galaxies are there in the Universe?



James Webb Space Telescope



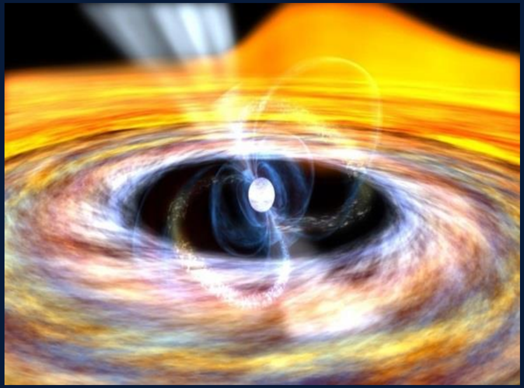
Credit: NASA/ESA

Planned launch in 2018, JWST's primary mirror is a 6.5-meter-diameter gold-coated beryllium reflector with a collecting area of 25 m^2.

The mirror is composed of 18 hexagonal segments, which will unfold after the telescope is launched.

The JWST will have an elliptical orbit around the second Lagrange point, or L2 which is around 4 times farther than the distance between the Earth to the Moon.

Really Big Numbers



The core of a massive star can be compressed during a supernova and collapses into a neutron star. A neutron star has a mass comparable to that of the Sun, but as it is only about 10 km in radius.

Neutron stars can spin and the surface is rotating at thousands of Kms^{-1}.

Magnetic fields over ten million times stronger than on Earth.
Surface temperature of a neutron can be around a million Kelvin.

The gravity is around two hundred billion times that on the surface of the earth.

Wish Upon a Neutron Star

Rutherford showed that an atom is mainly empty space and nearly all the mass is concentrated in the nucleus.

The mean density of this nuclear material is roughly 2 x 10^{17} Kgm^{-3}, which is the density of a neutron star.

From this data calculate the true volume of space that the human race occupies.