Physics update
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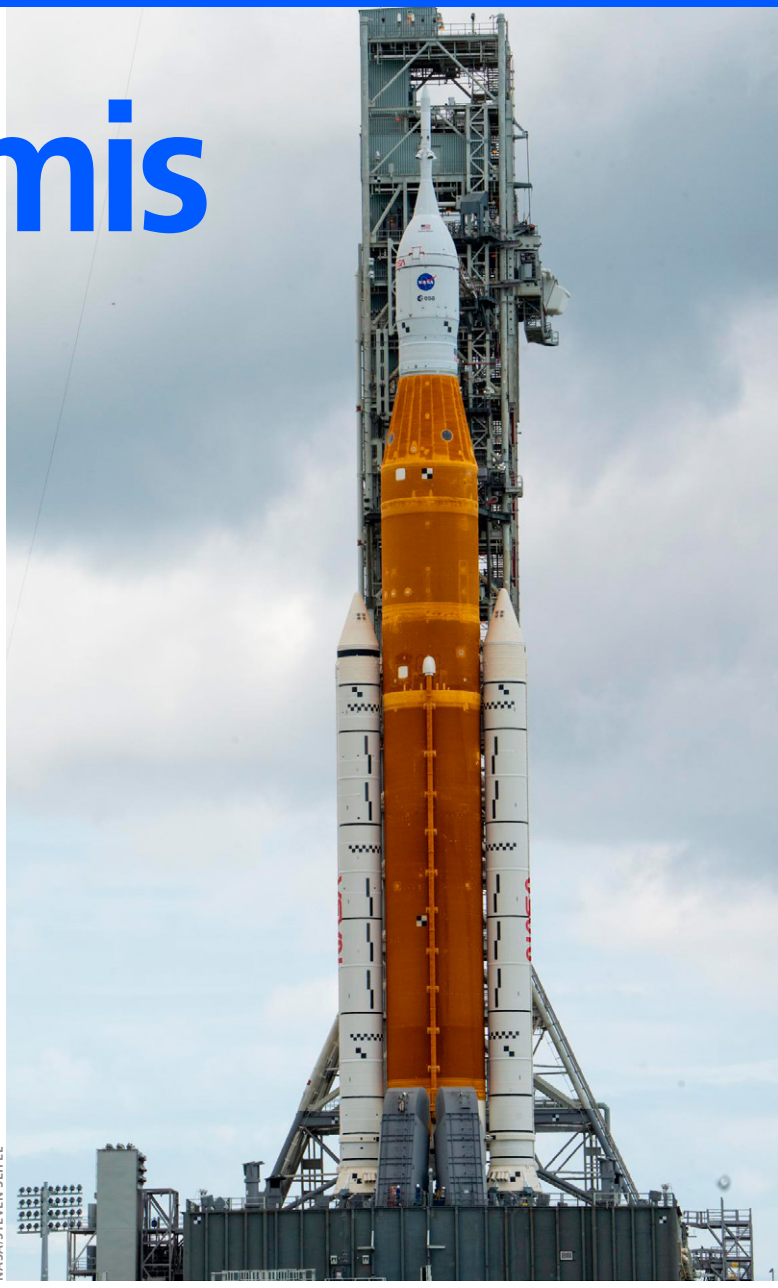
The Artemis missions

The NASA Artemis missions aim to return astronauts to the Moon. Next month we are midway between the launch of the Artemis I mission in November 2022 and the projected launch date for the Artemis II mission in November 2024. **Carol Tear** looks at the aims of the programme and progress so far


NASA/STEVEN SEIPEL

Artemis I on the launch pad

The Artemis programme formally began in 2017, although many of its parts were developed for previous projects. There are three aims for the programme: inspiration for a new generation of explorers, scientific discovery and economic benefits. The short-term goal is to land the first woman and first person of colour on the Moon. In the medium term the aim is to explore more of the lunar surface, in collaboration with commercial and international partners, and to establish the first Moon base. A Moon base will be part of the long-term preparations for sending the first astronauts to Mars and extracting lunar resources.

The name Artemis comes from Greek mythology. The goddess Artemis was the twin sister of Apollo. The NASA Apollo programme ran from 1961 to 1975 and during that time 12 men landed on the Moon.

The Artemis I mission

Artemis I was an uncrewed test flight of the space launch system (SLS) and the *Orion* spacecraft. The SLS is a super heavy-lift rocket capable of launching the *Orion* spacecraft with four astronauts and cargo directly to the Moon. It has about 40 MN of thrust, which is 15% more than the *Saturn V* rocket used for the Apollo missions. For comparison, the two engines of an Airbus A320–200 aircraft together can provide about 240 kN of thrust. The SLS has a top speed of 39 500 km/h, whereas *Saturn V* had a top speed of 28 000 km/h.

Launched by the SLS on 16 November 2022, *Orion* took a figure-of-eight flight path, orbiting the

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Earth and then the Moon. When *Orion* reached the Moon, it descended to about 130 km from the lunar surface where the gravitational force 'kicked' it into a retrograde orbit. Retrograde means travelling in the opposite direction to the spin of the Moon. This took it 429 700 km from Earth, further away than any of the Apollo missions. After 6 days it left the Moon's orbit and returned to Earth. *Orion* travelled 2.3 million kilometres in about 25.5 days and landed in the Pacific Ocean on 11 December 2022.

On future missions, *Orion* will take a crew to a lunar orbit. It is made of three main sections: the service module, the crew module and the launch abort system (LAS), which detaches after *Orion* reaches orbit. If the launch goes wrong the LAS will pull the crew module away and land it safely. The service module provides life support and power to the crew module.

The Artemis II mission

Artemis II will be the first crewed flight of the *Orion*. The crew will be testing systems during the 10-day mission, which will complete two Earth orbits and one Moon orbit before returning to Earth. The mission is similar to the Apollo 8 mission, when three astronauts first orbited the Moon. They circled it 10 times on 24 December 1968.

Artemis II has a crew of four: Commander Reid Wiseman, Pilot Victor Glover and Mission Specialists Christina Hammock Koch and Jeremy Hanson. They are currently in training. The *Orion* spacecraft they will travel on is being tested. After testing it will be integrated with its service module.

During this mission the crew will test separation and docking equipment because this will be needed for the *Lander* — on the future Artemis III mission the *Lander* will take astronauts to the Moon's surface. The crew are preparing for these tasks.

You can check mission progress on the NASA website. Although the launch is planned for November 2024, we expect that this may change because a lot of the equipment is of a new design. There are often unexpected issues during development and safety comes first. The crew cannot get out and walk if there is a fault.

Question

1 Artemis I had a mass of 2.61×10^6 kg. After 8 minutes of flight the speed was 27 200 km/h. Show that this is consistent with a thrust of 40 MN.

Answer

1 First convert the speed and time into SI units:

$$27\,200\,\text{km/h} = \frac{(27\,200 \times 1000\,\text{m})}{(60 \times 60\,\text{s})} = 7556\,\text{m/s}$$

$$8\ \text{minutes} = 8 \times 60\,\text{s} = 480\,\text{s}$$

Next, calculate the average acceleration of Artemis I:

$$a = \Delta v/\Delta t = \frac{(7556\,\text{m/s})}{480\,\text{s}} = 15.74\,\text{m/s}^2$$

Finally, using Newton's second law, the force needed to give Artemis I this acceleration is:

$$F = ma = 2.61 \times 10^6\text{kg} \times 15.7\,\text{m/s}^2 = 4.10 \times 10^7\text{N} = 41.0\,\text{MN}$$

Resources

The Artemis Program, NASA:
www.nasa.gov/specials/artemis/

Artemis I launch:
https://tinyurl.com/artemisIlaunch

Artemis II flight path:
https://tinyurl.com/artemisIIpath