Physics update
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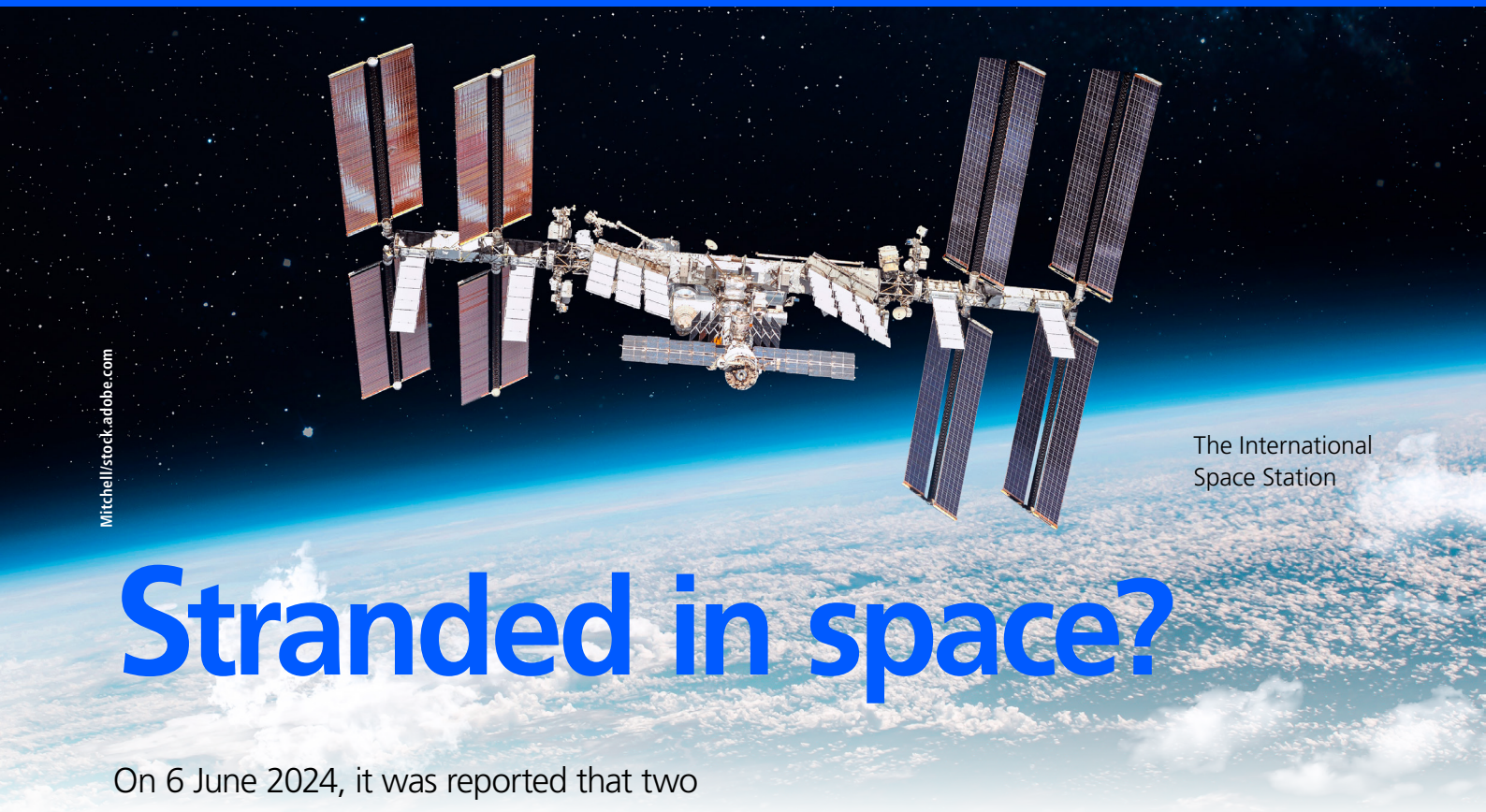

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The International Space Station

Stranded in space?

On 6 June 2024, it was reported that two NASA astronauts, Butch Wilmore and Suni Williams, were 'stranded in space'. Were they really stranded? What happened? **Carol Tear** explains

This mission was the first crew-test of the Boeing Starliner. It was intended to transport the astronauts to the International Space Station (ISS) for a week and return them safely to Earth. After a successful launch using an Atlas V rocket, the Starliner, which comprises the crew capsule and the service module (see the weblink to NASA's diagram of the Boeing Starliner), travelled to the ISS and docked.

The International Space Station

The ISS has been crewed continuously by astronauts and cosmonauts since 2000, usually by a crew of seven. Since 2020, the Soyuz and the SpaceX Dragon have been transporting crew to and from the ISS. During a crew handover there may be more people aboard, sometimes as many as 13.

When Butch and Suni arrived, there were seven others on board. The two cosmonauts that had been on the ISS the longest, since September 2023, usedd the Soyuz craftThey returned to Earth in September 2024, with a third cosmonaut, having spent over a year in space. Four astronauts, the SpaceX Crew-8, arrived on a SpaceX Dragon in March 2024.

With the Starliner unusable, Butch and Suni did not have a ride home, but the ISS receives regular supplies of cargo and has facilities to support life – being stranded on a space station is not as serious as being stranded in space. NASA had some time to consider the best course of action.

Thruster malfunction

The problem was first noticed when the Starliner began docking with the ISS. Helium leaks were detected and 5 of the 28 reaction control system (RCS) thrusters malfunctioned. The mission team managed to get four back online and it docked at the next attempt. The Starliner has a very large number of engines (see the weblink to the Starliner diagram). These are used to manoeuvre the Starliner, tilting and

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rotating it, as well as providing thrust to accelerate and to slow the speed.

Newton's third law tells us that forces come in interaction pairs. An interaction pair of forces are equal in magnitude and opposite in direction. They also act on different objects. The pair for your weight, for example, is the force of gravitational attraction you exert on the Earth, which acts upwards towards your centre of gravity.

Once the Starliner reaches space, there is no friction, no air resistance – nothing to provide an interaction pair force. In order to change its speed or direction, a rocket engine, or thruster, is required. These engines typically generate thrust by using a liquid propellant in a chamber. The propellant undergoes a decomposition process that releases a large amount of energy. The hot decomposition gases are ejected at high speed through a nozzle, and as a result of the force from the engine on the gases, there will be an equal force in the opposite direction on the rocket. This accelerates the rocket forwards.

There is nothing to slow the Starliner down, so thrusters must be in pairs – one in each direction. Turning the Starliner, or changing its orientation, will also require pairs of thrusters. It is so important to have control of movement that there are two sets of at least some of the thrusters, in case of failure.

Problem solving

NASA's first step was to collect and review data and possible return outcomes. It consulted with Boeing, and with other engineers, as to whether the problem was too serious to use the Starliner. It was decided that it did not reach the safety and performance requirements for human spaceflight. On 24 August, NASA announced that Butch and Suni would stay on the ISS and join the current expedition.

At the time of writing, the SpaceX Crew-9 is scheduled to arrive on 25 September (Crew-8 will leave on 1 October). If all goes to plan, the SpaceX Dragon will carry two astronauts to the ISS instead of four and bring space suits for Butch and Suni, as these are different to the Boeing Starliner suits. Butch and Suni will return on the SpaceX Dragon.

Return to Earth

Starliner returned under remote control, undocking from the ISS on 6 September. When preparing for de-orbit, Starliner tested 12 thrusters on its service module. One of the thrusters did not fire when commanded, but NASA and Boeing decided that this would be fine because only six thrusters are needed – the other six are back-ups.

Docking clips were undone and thrusters fired to separate from the ISS. Later, thrusters were fired to leave orbit, turn the space craft and jettison the service module. For re-entry, the thrusters are used, if necessary, to angle the Starliner so that the heat shield protects it. The heat shield is 'ablative', meaning it burns off in a controlled way, reducing the heat from 3000°F to 300°F – even though it is only between 5–10 cm thick. The outer surface is heated to a gas that carries away the heat by convection and the burning resins create a boundary layer between the hot and cooler surfaces.

Inside the Starliner, it is at about room temperature. The Starliner is slowed by the friction forces, eventually reaching a lower speed that results in a cooler temperature. The thrusters are used to jettison the heat shield and parachutes and airbags slow the descent for landing. The Starliner completed the landing safely under remote control from the command centre.

As members of Crew-9, Butch and Suni will return to Earth in February or March 2025. Instead of 1 week, they will have spent 9–10 months on the ISS, both unexpectedly celebrating their birthdays in orbit around the Earth.

Weblink

NASA's diagram of the Boeing CST-100 Starliner:
https://tinyurl.com/bufr23u9