SCIENCE FICTION BECOMES SCIENCE FACT – *ALMOST*

By: Henry Holden

SOME MAY remember a 1998 Steven Spielberg film called *"Deep Impact"* an American science fiction disaster film. The film depicts the attempt to prepare for, and destroy, a seven-mile-wide comet on a collision course with the Earth which would cause mass extinction of all life.

To accomplish this, a crew of notable Hollywood stars land on the comet, plants nuclear bombs below the surface, sets the timers, and then launches off the comet. The only good thing that could be said about this film was scientists said it was "more scientifically accurate" than another film, *"Armageddon"* (same story line using an asteroid).

On November 12, 2014, science fiction met science fact, sort of. After sailing through space for more than 10 years, the European Space Agency's (ESA) Rosetta spacecraft landed Philae (fee-LAY), a robotic probe on a comet. Rosetta was launched into space in 2004, on a four-billion-mile (6,4 billion kilometres) journey to the comet. The spacecraft arrived at Comet 67P Churyumov-Gerasimenko on August 6, 2014.

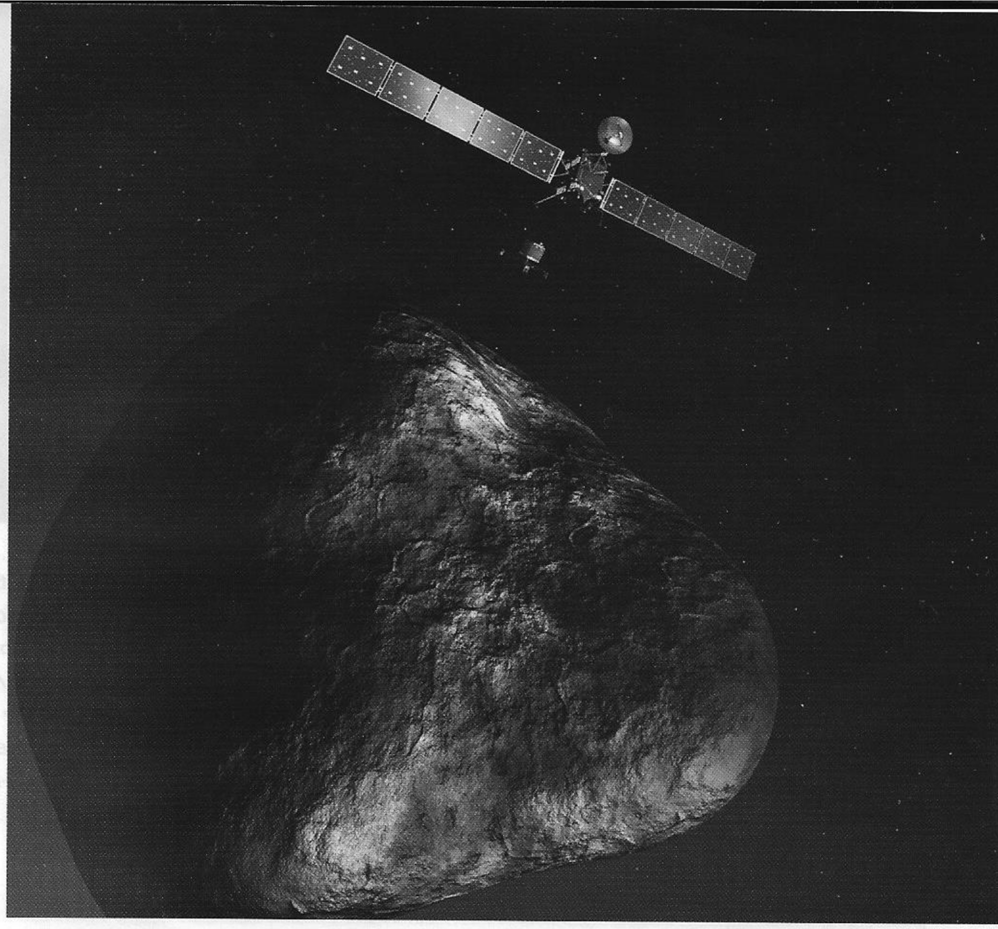
Rosetta's mission was not to destroy the comet, but, led by the ESA's consortium of partners from Europe and NASA, the primary aim of the mission was to shed light on the origin and evolution of the solar system.

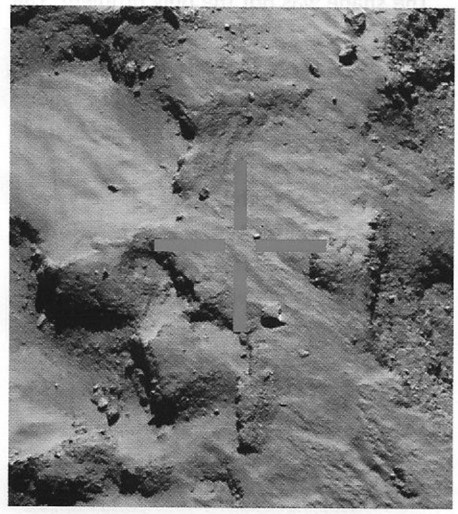
One question is: Did comets form within our solar system or in interstellar space?

"Rosetta is trying to answer the very big questions about the history of our solar

Above: *At the moment of touchdown on Comet 67P/Churyumov-Gerasimenko, Philae's landing gear should have absorbed the forces of landing while ice screws in each of the probe's feet and a harpoon system locked Philae to the surface. At the same time, a thruster on top of the lander should have pushed it down to counteract the impulse of the harpoon imparted in the opposite direction. None of this happened. The lander bounced twice before settling. (Image: ESA/ATG Medialab).*

Left: *Rosetta orbiter is a large aluminium box with dimensions 2,8 x 2,1 x 2,0 metres. The scientific instruments are mounted on the top of the box (payload support module) while the subsystems are on the base (bus support module). (Image: ESA/ATG Medialab).*





Above: *An artist's illustration of the European Space Agency's comet-chasing Rosetta spacecraft as it approached the comet.* Image: ESA - C. Carreau

Right: *This image, showing a narrow-angle image taken from a distance of 30 km on September 14, 2014 (prior to landing), marks the first touchdown point of the Philae lander.* Image: ESA/Rosetta/NAVCAM

system," said Matt Taylor, ESA Rosetta project scientist. "What were conditions like at its infancy and how did it evolve? What role did comets play in this evolution? How do comets work?"

Rosetta is named for the Rosetta Stone, a block of black basalt that was inscribed with a royal decree in three languages — Egyptian hieroglyphics, Egyptian Demotic and Greek. The spacecraft's robotic lander is called Philae, named after a similarly inscribed obelisk found on an island in the Nile River.

Both the stone and the obelisk were keys to deciphering ancient Egyptian hieroglyphs. Scientists hope the Rosetta mission will provide a key to many questions about the origins of the solar system.

LAUNCH

The launch itself was not a textbook launch. Rosetta launched on March 2, 2004, aboard an Ariane 5 rocket. Rosetta was set to launch in 2003, to rendezvous with Comet 46P/Wirtanen. However, due to rocket failure, the mission was postponed, and the target was changed to Comet 67P/Churyumov-Gerasimenko.

To achieve the required velocity to rendezvous with 67P/C-G, Rosetta used gravity assist manoeuvres to accelerate throughout the inner solar system. The comet's orbit was known before Rosetta's launch, from ground-based measurements, to an accuracy of approximately 100 km (62 miles).

Information gathered by the onboard cameras beginning at a distance of 24-million km (15-million miles) were processed at ESA's Operation Centre to refine the position of the comet in its orbit to a few kilometres.

Rosetta made four slingshot flybys to boost its speed — one around Mars, and three around Earth. On its journey, it studied other comets, photographed asteroids, and gathered information about the atmospheres of Venus and Mars.

The spacecraft also performed two asteroid flyby missions. The craft completed its fly-by of asteroid 2867 Šteins, in September 2008, and of 21 Lutetia, in July 2010.

Scientists at the European Space Agency put Rosetta into a hibernation mode in June 2011, (to conserve resources) for its 373-million-mile (600-million km) journey. After "awakening" in January 2014, the spacecraft still had four months to journey until it reached its 2,5-mile-wide target travelling at 84 000 mph, just inside Jupiter's orbit.

PHILAE LANDING

The night before the landing, a thruster on the lander failed to respond to commands sent from Earth. Engineers were unable to correct the fault. The malfunction threatened to abort the mission, but at 0235 GMT on Wednesday mission, controllers decided to go ahead with the landing.

First, a series of commands had to be precisely executed to ensure that Rosetta orbited about 14 miles above the surface and did not crash to the surface of the comet, and that Philae arrived at its landing site safely.

Rosetta was gliding alongside the comet at a "walking pace." Philae got a gentle nudge to descend at a similar rate of around one metre per second, carried to the comet surface by the weak gravitational pull.

"The impact was a bit like walking into a wall. It doesn't particularly hurt or damage you, but you know you've done it," said Philae project manager, Stephan Ulamec.

Separation of the lander was planned for about 09:03 GMT and touch down followed about seven hours later.

Matt Taylor, the project scientist on the Rosetta mission, said he was expecting an "exponential increase in stress" as the lander made its slow descent. "Where the Mars Curiosity rover had its seven minutes of terror as it touched down on Mars," he said, "this was seven hours of terror."

Descending at a speed of about two miles per hour (3,2 kph) Philae lander touched down on the comet on Wednesday, November. 12. A signal confirming the safe landing came in 16:02 GMT.

THREE TOUCHDOWNS

Once Philae touched the surface, the lander should have deployed three harpoons into the comet, designed to tether the probe to the dusty cosmic body, but there were problems.

Partially due to anchoring harpoons not firing, and the comet's low gravity (a hundred-thousand times less than that of Earth), Philae bounced off the surface and flew up to about six-tenths of a mile both above the comet's surface as well as downrange. →

Almost two hours after first contact, Philae again touched down. A second, shorter bounce resulted, again sending it airborne.

With its third and final touchdown, the Rosetta mission's Philae became the first soft landing of a robotic spacecraft on a comet.

However, the bounced landings put Philae partially in the shadow of a rock outcropping preventing the primary battery enabling the core science goals of the lander from charging.

Philae lander completed its last transmission on Friday (November 14) at 0036 GMT, before settling into a hibernation state as its batteries ran out.

The probe had been studying the surface of the comet for 57 hours when it went to sleep, possibly for good.

Above: *Rosetta's lander Philae has returned the first panoramic image from the surface of a comet. The view, unprocessed, as it had been captured, shows a 360° view around the point of final touchdown. The three feet of Philae's landing gear can be seen in some of the frames.*

(Both images: ESA/Rosetta/Philae/CIVA)

Below: *Rosetta's lander Philae is safely on the surface of Comet 67P/Churyumov-Gerasimenko, as this mosaiced CIVA image confirms. One of the lander's three feet can be seen in the foreground. The image above is a two-image mosaic.* ESA/Rosetta/Philae/CIVA.

NEVER EASY

Landing Philae on the comet's surface was never going to be easy. When ESA managers received their first close-up images of the comet in July, its unusual rubber duck shape left some doubting a safe touchdown was possible.

The shape was not the only problem. The comet's surface was hostile: hills and spectacular jutting cliffs gave way to cratered plains strewn with boulders. If Philae landed on anything other than even ground it could topple over, leaving it stranded.

"The surface of this comet is very, very rough," said Andrea Accomazzo, ESA Rosetta flight director. "It's not the ideal place to land on, but this is what we had, and this is what we were trying to do.

"We were a bit lucky, as well. If the lander had hit the surface of the comet in the proximity of a boulder or something like that, then there's nothing we could do. We can't actively steer the trajectory of the lander on descent. That's the part that worried me most."

Once the lander touched down, and its thousands of Twitter fans breathed a communal sigh of relief, the science was just beginning. "Once we touched down we did the panoramic view to see if Bruce Willis was standing there with his team. Then we started doing the real sniffing measurements," Taylor said.

Touchdown for the lander played out 510-million kilometres from Earth, between the orbits of Mars and Jupiter, on a comet hurtling through space at more than 18 km/second or some 40 265 miles per hour. At such a distance, even radio signals travelling at the speed of light take nearly half an hour to travel from Earth to the spacecraft, making real-time control of the landing impossible.

Rosetta is expected to stay with Comet 67P/C-G as it makes its closest approach with the Sun in August 2015, observing how a frozen comet changes as it approaches the heat of the Sun.

Between now and then, conditions that are preventing Philae from charging its batteries could change. It is not implausible that as the comet moves in closer to the Sun, the amount of light made available to Philae will increase, in amount and in intensity.

Structural changes on the comet, could also be a factor. As the comet draws closer to the Sun, obstructions preventing its batteries from charging could crumble or melt as the comet warms and becomes more active.

There is also a longshot that jets of gas and dust that are generated as the comet's internal ices are heated, could jar Philae in such a way that it moves to a more favourable lighting position.

Should this occur and the batteries recharge, the spacecraft could beam back scientific data to Earth that could help scientists understand more about comets and the early solar system (when the balls of ice and dust first formed), among other things. Instruments on Rosetta have already revealed that the comet smells like rotten eggs.

Philae for now will remain silent, but the assessment of the thermal status of the probe is encouraging. There is hope that it can survive and share some of the secrets of our solar system. ✈