Pearson

E.1: The Metric Mix-up: A $125 Million Unit Error

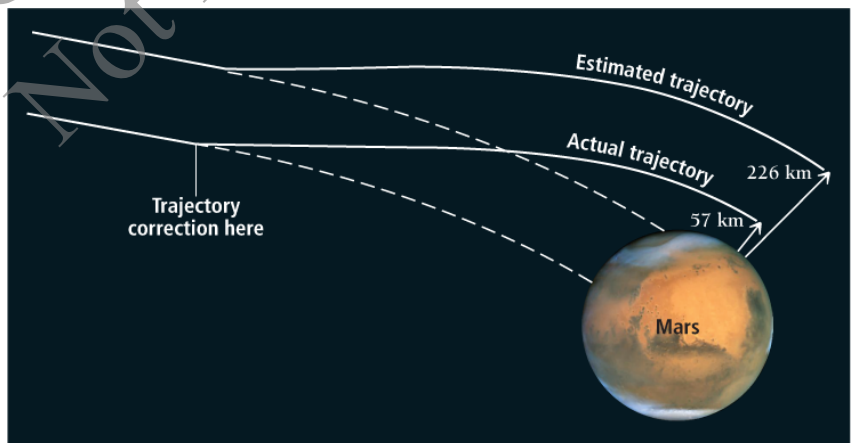
On December 11, 1998, NASA launched the Mars Climate Orbiter, which was to become the first weather satellite for a planet other than Earth. The Orbiter's mission was to monitor the Martian atmosphere and to serve as a communications relay for the Mars Polar Lander, a probe that was to follow the Orbiter and land on the planet's surface three weeks later. Unfortunately, the mission ended in disaster. A unit mix-up caused the Orbiter to enter the Martian atmosphere at an altitude that was too low. Instead of settling into a stable orbit, the Orbiter likely disintegrated. The cost of the failed mission was estimated at $125 million.

There were hints of trouble several times during the Orbiter's nine-month cruise from Earth to Mars. Several adjustments made to its trajectory seemed to alter the course of the Orbiter less than expected. As the Orbiter neared the planet on September 8, 1999, discrepancies emerged about its trajectory. Some of the data indicated that the satellite was approaching Mars on a path that would place it too low in the Martian atmosphere. On September 15, engineers made the final adjustments that were supposed to put the Orbiter 226 km above the planet's surface. About a week later, as the Orbiter entered the atmosphere, communications were lost. The Orbiter had disappeared.

Later investigations showed that the Orbiter had come within 57 km of the planet surface (Figure E.1), an altitude that was too low. If a spacecraft enters a planet's atmosphere too close to the planet's surface, friction can cause the spacecraft to burn up. The on-board computers that controlled the trajectory corrections were programmed in metric units (newton · second), but the ground engineers entered the trajectory corrections in English units (pound · second). The English and the metric units are not equivalent (1 pound · second = 4.45 newton · second). The corrections that the ground engineers entered were 4.45 times too small and did not alter the trajectory enough to keep the Orbiter at a sufficiently high altitude. In chemistry as in space exploration, **units** are critical. If we get them wrong, the consequences can be disastrous.

Figure E.1 The Metric Mix-up

The top trajectory represents the expected Mars Climate Orbiter trajectory; the bottom trajectory represents the actual one.



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