

The Patriot Missile Failure



On February 25, 1991, during the Gulf War, an American Patriot Missile battery in Dharran, Saudi Arabia, failed to intercept an incoming Iraqi Scud missile. The Scud struck an American Army barracks and killed 28 soldiers.

The Explosion of the Ariane 5



On June 4, 1996 an unmanned Ariane 5 rocket launched by the European Space Agency exploded just forty seconds after lift-off. The rocket was on its first voyage, after a decade of development costing US \$7 billion (the most expensive disaster, so far.)

Reason for Patriot failing to fire

Software Problem Led to System Failure.

The cause was an inaccurate calculation of the time since boot due to computer arithmetic errors.

A little details:

The time in tenths of second as measured by the system's internal clock was multiplied by $1/10$ to produce the time in seconds.

This calculation was performed using a *24 bit fixed point register*.

The value $1/10$, which has a non-terminating binary expansion, was chopped at 24 bits after the radix point. The small chopping error, when multiplied by the large number giving the time in tenths of a second, lead to a significant error.

Reason for Patriot failing to fire

The Patriot battery had been up around 100 hours, and an easy calculation shows that the resulting time error due to the magnified chopping error was about 0.34 seconds.

Indeed,

$$1/10 = (0.0001100110011001100110011001100....)_2$$

Now the 24 bit register in the Patriot stored

$$0.000110011001100110011001100$$

introducing an error

$$(0.0000000000000000000000000011001100....)_2$$

or about 0.000000095 decimal.

Reason for Patriot failing to fire

Multiplying by the number of tenths of a second in 100 hours gives

$$0.000000095 \times 100 \times 60 \times 60 \times 10 = 0.34.$$

A Scud travels at about 1,676 meters per second, and so travels more than half a kilometer in this time.

This was far enough that the incoming Scud was outside the "range gate" that the Patriot tracked.

Ironically, the fact that the bad time calculation had been improved in some parts of the code, but not all, contributed to the problem, since it meant that the inaccuracies did not cancel.

The Ariane 5 disaster

The cause of the failure was a software error in the inertial reference system.

More specifically, a 64 bit floating point number relating to the horizontal velocity of the rocket with respect to the platform was converted to a 16 bit signed integer.

The number was larger than 32,768, the largest integer storeable in a 16 bit signed integer, and thus the conversion failed.