WATCH YOUR UNITS & PRECISION!

COLUMBUS DID NOT KNOW HIS UNITS!

WATCH YOUR CONVERSIONS

CONTROL GOES BAD IN 8-BITS

http://mentalfloss.com/article/25845/quick-6-six-unit-conversion-disasters

4. In 1999, the Institute for Safe Medication Practices reported an instance where a patient had received 0.5 grams of Phenobarbital (a sedative) instead of 0.5 grains when the recommendation was misread. A grain is a unit of measure equal to about 0.065 grams... yikes. The Institute emphasized that only the metric system should be used for prescribing drugs.

5. An aircraft more than 30,000 pounds overweight is certainly no laughing matter. In 1994, the FAA received an anonymous tip that an American International Airways (now Kalitta Air, a cargo airline) flight had landed 15 tons heavier than it should have. The FAA investigated and discovered that the problem was in a kilogram-to-pounds conversion (or lack thereof).

6. Even Columbus had conversion problems. He miscalculated the circumference of the earth when he used Roman miles instead of nautical miles, which is part of the reason he unexpectedly ended up in the Bahamas on October 12, 1492, and assumed he had hit Asia. Whoops.

Do any more unit conversion disasters spring to mind? Ever had one yourself? Tell us all about it in the comments.

DATA MIXUP

Avoiding Catastrophe From Unit Confusion

On September 23, 1999, the Mars Climate Orbiter disintegrated in the atmosphere of the planet and was never heard from again – a preventable disaster, given the right tools for the job.

After 10 long months of space travel, a team of exhausted NASA engineers and scientists eagerly awaited the opportunity to celebrate the successful insertion of the Mars Climate Orbiter spacecraft into Martian orbit. However, the mission soon became known as the mission that failed due to confusion between units of measurement and cost US taxpayers more than $125 million USD.

In a joint effort to better understand Mars, NASA and subcontractors designed the Orbiter program as one in a series of missions. The unmanned spacecraft was to collect data on the planet's climate and serve as a communication relay between mission control and future spacecraft in the program.

On its journey, the Orbiter approached the planet following a precisely calculated flight path. The spacecraft was to enter Martian orbit at a specific altitude that would prevent it from breaching the upper atmosphere and encountering catastrophic atmospheric stresses. As NASA engineers stood by, communication with the Orbiter was suddenly lost and never established again. The Orbiter never successfully transmitted data from the red planet, except for a single grainy picture of Mars taken at a distance of about 4.5 million km. The mission was a total failure.

A Completely Avoidable Root Cause

The intended trajectory of the spacecraft would have resulted in an orbiting altitude of 226 km above the surface of the planet, far above the dangerous conditions of Mars' upper atmosphere. However, a NASA investigation found that the actual Orbiter approach trajectory brought the spacecraft within 57 km of the planet's surface – even though the Orbiter was thought to be able to survive only at altitudes greater than 80 km. The extreme environmental conditions of Mars' upper atmosphere destroyed the spacecraft within seconds.

Further analysis concluded that human error caused the discrepancy in trajectories: the flight system software onboard the Orbiter was written to calculate thruster performance in metric Newtons (N), but mission control on Earth was inputting course corrections using the Imperial measure, pound-force (lbf).

"People sometimes make errors," said Dr. Edward Weiler, NASA associate administrator for space science. "The problem here was not the error, it was the failure of NASAs systems engineering, and the checks and balances in our processes to detect the error. That's why we lost the spacecraft."[1]

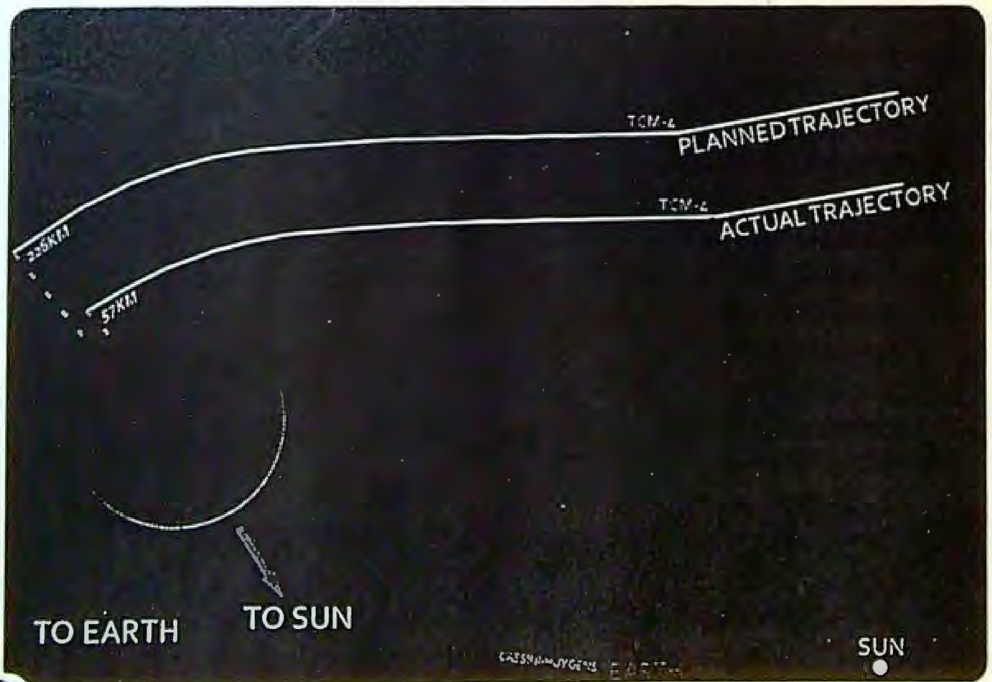

Figure 1. *Due to confusion between measurement units for a vital spacecraft operation, the actual trajectory taken was far closer to the planet than intended.*

Industry Trends Demand Smarter Tools

With the advances of communication technology in the last decade, global development teams can work together like never before. Multinational corporations often design products in one geographical location, send prototypes for validation testing to another location, and perform end-of-line tests at manufacturing sites located in completely different countries. Furthermore, today's complex designs often include components from globally diverse suppliers, and entire aspects of a project may be delegated to subcontractors.

For teams that collaborate across borders, the difference in measurement unit standards (International System of Units (SI) versus Imperial) is only part of the challenge. Given any quantity, there are multiple ways to represent the same measurement.

[1] "NASA's Metric Confusion Caused Mars Orbiter Loss," last modified September 30, 1999, http://articles.cnn.com/1999-09-30/tech/9909_30_mars.metric_1_mars-orbiter-climate-orbiter-spacecraft-team?_s=PM:TECH.

Unit Conversion Tips

Unit Conversion Errors Can be Costly (and deadly)

- A passenger plane ran out of fuel and had to dead stick land because of a unit conversion error. Check out the story of the Gimli Glider at links below:
  1. http://www.silhouet.com/motorsport/tracks/gimli.html
  2. http://archives.cbc.ca/IDC-1-69-240-1155-20/that_was_then/life_society/gimli_glider
  3. http://www.answers.com/topic/gimli-glider
- A NASA spacecraft was lost because engineers used the incorrect unit. Check out the story of the Mars Orbiter lost.

How To Avoid Unit Conversion Errors

1. Proper conversion occurs by **multiplying by one**, since this does not change the physical magnitude of an item. Do not take short cuts, write out each step as follows, where each fraction in parentheses is equal to a physical value of one:

$$7\text{ miles}\times\left(\frac{1.6\text{ km}}{1\text{ mile}}\right)\times\left(\frac{1000\text{ meters}}{1\text{ km}}\right)=11{,}200\text{ meters}$$

$$\frac{4\text{ miles}}{\text{hour}}\times\left(\frac{1.6\text{ km}}{1\text{ mile}}\right)\times\left(\frac{1000\text{ meters}}{1\text{ km}}\right)\times\left(\frac{1\text{ hour}}{60\text{ minutes}}\right)\times\left(\frac{1\text{ minute}}{60\text{seconds}}\right)=\frac{1.79\text{ meters}}{\text{second}}$$

2. **Memorize common values**. This will give you a quick method of developing real world smarts! Always ask yourself if you expect the numerical values in new units to be larger or smaller than the starting units. Also check the intermediate values of unit conversions, such as the distance conversion in the speed example above, to better find errors. Guess the conversion factors for the items below then check them using the computer tools listed below. Pay attention to values in work you are doing and reports you read; it will develop your intuitive sense of values and save your neck sooner or later!

   a. A mile is larger than a km.
   b. A radian is much larger than a degree.
   c. A Kg force is larger than a pound (yes I know one is mass and the other is force; see discussion below).
   d. A Newton is smaller than a Kg weight on earth. Tip an apple on earth weighs about one Newton (remember the apple that hit Sir Isaac Newton on his head!).
   e. A Slug is much larger than a pound (see below)

3. Some special cases:

   a. Angles: Degrees and Radians

HANDOUT

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With phase-lag compensation numerical problems may occur in the realization of the filter coefficients. To illustrate this point, suppose that a microprocessor is used to implement the digital controller. Suppose, in addition, that filter coefficients are realized by a binary word that employs 8 bits to the right of the binary point. Then the fractional part of the coefficient can be represented as [4]

$$\text{fraction} = b_7 * \frac{1}{2} + b_6 * \frac{1}{4} + b_5 * \frac{1}{8} + \cdots + b_0 * \frac{1}{2^8}$$

where b_i is the ith bit, and has a value of either zero or 1. For example, the binary number

$$11000001_2 = 2^7 + 2^6 + 1$$

$$(0.11000001)_2 = \left(\frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^8}\right)_{10} = (0.75390625)_{10}$$

$$\frac{128+64+1}{256}$$

The maximum value that the fraction can assume is $[1 - 1/(2)^8]$, or 0.99609375. Note, in Example 8.1, that a denominator coefficient of 0.999300 is required, but a value of 0.99609375 will be implemented (b_7 to b_0 are all equal to 1). The numerator coefficients, when converted by standard decimal-to-binary conversion algorithms [4], become

$$(0.3891)_{10} \Rightarrow (0.01100011)_2 = 0.38671875$$

$$(0.38840)_{10} \Rightarrow (0.01100011)_2 = 0.38671875$$

! IN 8-bits

Thus the compensator zero has been shifted to $z = 1$, and the digital filter that is implemented has the transfer function

$$D(z) = \frac{0.38671875z - 0.38671875}{z - 0.99609375}$$

$D(1) = 0$!

Shown in Figure 8-9 are the frequency responses of the designed filter and the implemented filter, and the effects of coefficient quantization are evident. The resultant system stability margins, when the implemented filter is used, are: phase margin 70° (designed value 55°), and gain margin 18 dB (designed value 16 dB). However, the implemented filter has a dc gain of zero; thus the system will not respond correctly to a constant input. Hence more bits must be used to represent the filter coefficients. Coefficient quantization effects are investigated in detail in Chapter 14.

$z=1$

We can view the coefficient quantization problem as one that results from the choice of the sample period T. We place digital filters in a physical system in order

$\Delta_{real} = \varepsilon$

$\Delta_{binary} = 0$

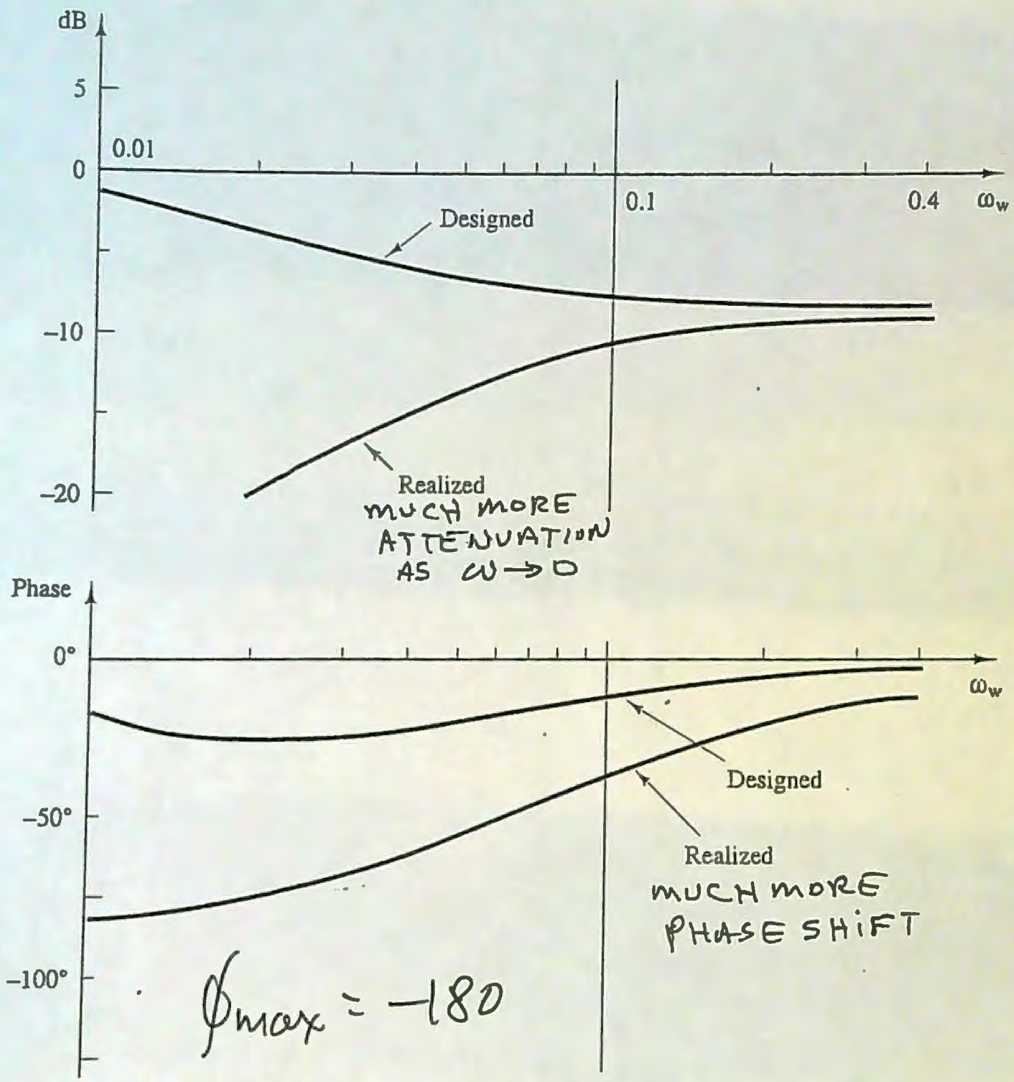

Figure 8-9 Frequency responses of designed and of realized digital controllers.

to change its real (s-plane) frequency response, and we want this change to occur over a certain real frequency (ω) range. The choice of T places this frequency range on a certain part of the unit circle in the z-plane, since $z = \epsilon^{j\omega T} = 1\angle\omega T$. Thus since phase-lag filtering occurs for ω small, the choice of T small requires that the filtering occur in the vicinity of the $z = 1$ point. Thus the phase-lag pole and zero will occur close to $z = 1$, and thus close to each other. If T can be chosen to be a larger value, the phase-lag pole and zero will move away from the $z = 1$ point (and each other), and the numerical accuracy required for the filter coefficients will not be as great.