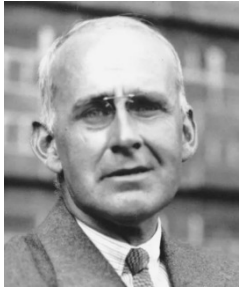


Reliability of Numerical Simulator



Never believe an experimental result until it has been confirmed by theory

Sir Arthur Stanley Eddington

01



Model Reliability

Mathematical model and its data describe the real physics with sufficient accuracy

02



Algorithm Reliability

Underlying numerical algorithms should be stable, consistent, and convergent

03



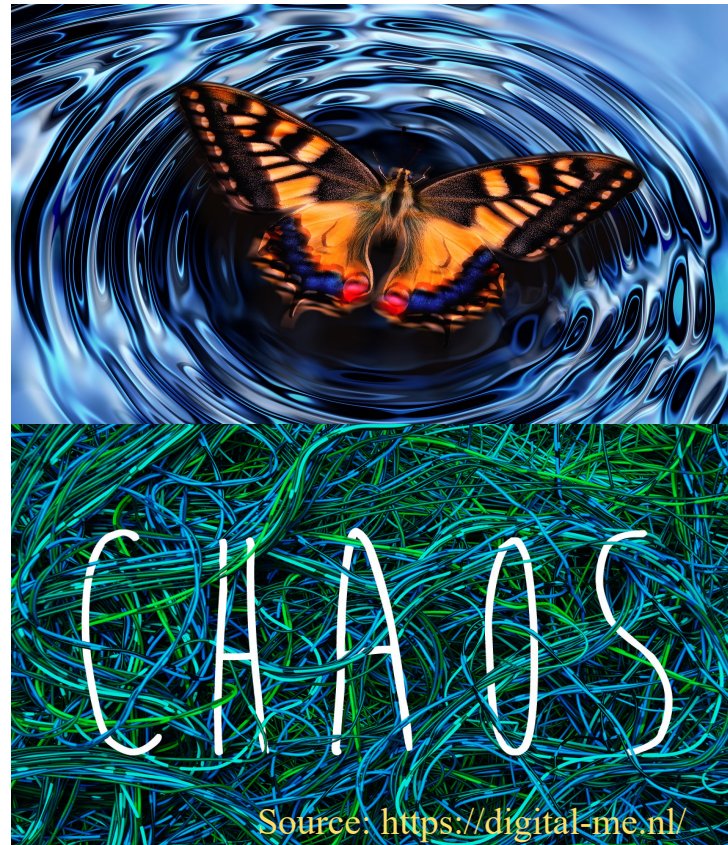
Software Reliability

The ability to perform its required functions under static conditions for a specific period

Why Results Are Not As Expected



Edward N. Lorenz



Margaret Hamilton

In 1961, E. Lorenz was using a Royal McBee LGP-30 computer with 6-digit precision to predict weather. The printout rounded variables off to a 3-digit number, so a value like 0.506127 printed as 0.506. So he tried to input a rounded number, but ...

The Patriot Missile Failure



- On the news:

During the 1991 Gulf War, a U.S. Patriot Missile battery at Dhahran (达兰), Saudi Arabia failed to intercept an incoming Iraqi Scud missile on February 25, resulting in 28 deaths and 100+ injuries.

- Failure Reasons: **0.343-second time discrepancy**

- To track time, the PM system performed a floating-point multiplication by 0.1, which has no exact binary representation (using 24 bits).
- After 100 hours of operation, the integer time value was approximately 3,600,000 tenths-of-seconds.
- The accumulated error from repeatedly multiplying this large integer by the inexact floating-point representation of 0.1 resulted in the 0.343-second time discrepancy that caused the tracking failure.



The Loss of the Sleipner A Platform

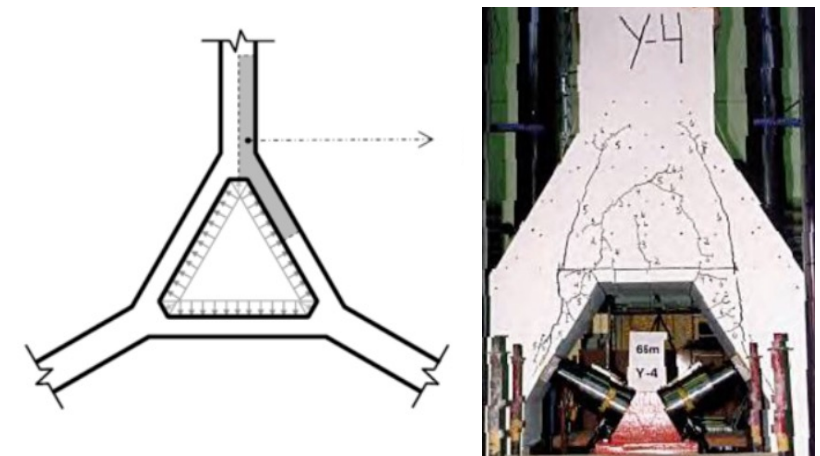


- On the news:

On August 23, 1991, the Sleipner A platform suddenly sank near Stavanger, resulting in approximately \$700M in losses.

- Failure Reasons: **45% underestimation of shear forces**

- Engineers used NASA's NASTRAN software, but the model contained distorted elements with skewed faces.
- When analyzing stress results, engineers fitted a second-order polynomial curve to their data and used extrapolation to determine edge stresses (over-fitting).
- The analysis relied on the 1977 Norwegian concrete code, which predicted failure at nearly twice the actual pressure.



The Legendary “Nine Calculations”

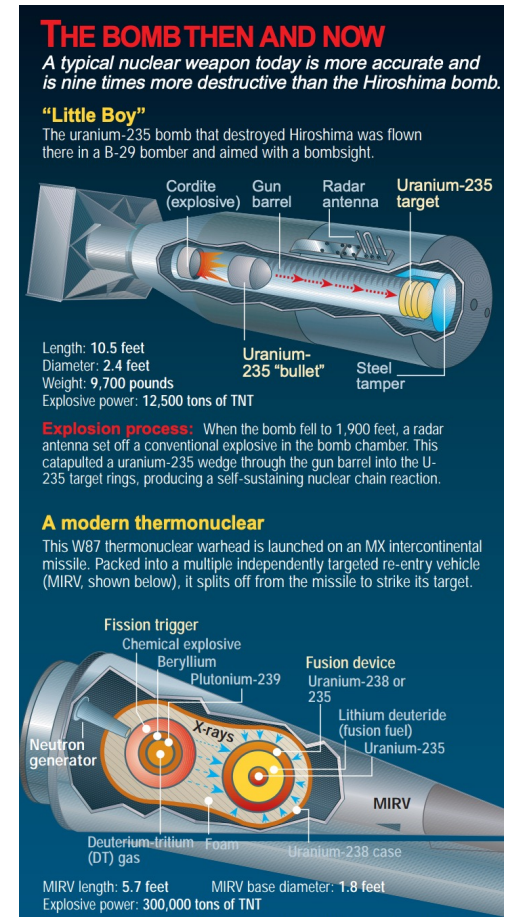


- Chinese scientists attempted to replicate calculations from a Soviet teaching model. But the calculation of pressure values during explosive implosion consistently fell short of the Soviet figures.
- Over **nine intense rounds** of recalculations and cross-disciplinary debates involving physicists, mechanics experts, and mathematicians, the discrepancy persisted, stalling the entire atomic bomb project.

九次计算：原子弹原理突破

- 一天三班倒不间断计算
- 九次计算肯定流体假定
- 最大功原理放倒拦路虎

Theoretical Breakthrough: Zhou Guangzhao constructed an ideal model and proved that the maximum achievable pressure **could never reach** the Soviet expert's claimed value.



W87两级内爆式氢弹弹头

Cox Report, 1999

Mean Time To Failure



MTTF (MTBF):

measures the average time a non-repairable asset operates before it fails

2 days

Ancient but stable

The mean time to failure of ENIAC (**1946**) [[Alexander Randall 2006](#)]

26.1

CPU failures per week

ASCI Q at LANL has 26.1 CPU failures per week [[Michalak et al. 2005](#)]

4-6 hours

Soft error in L1 cache

BlueGene/L has one soft error in L1 cache every 4 to 6 hours [[Bronevetsky, Supinski 2008](#)]

4.2 hours

Requires repair actions

Lessons learned from the analysis of system failures at petascale; see [DSN 2014](#)

30 mins

Run without problems

Researchers have predicted that large jobs may fail once every 30 minutes on **exascale** platforms

Modern Implementation



- **Main Issues:** reliability, user-friendliness, and efficiency

- **LAPACK** is a highly optimized library of linear algebra routines written in Fortran 90. These routines include matrix multiplication, factorization (LU, Cholesky, QR, etc.), least squares solutions of linear systems, eigenvalue problems, and many others.

- **ScaLAPACK** is a parallel-distributed version of LAPACK (MPI-parallel)