

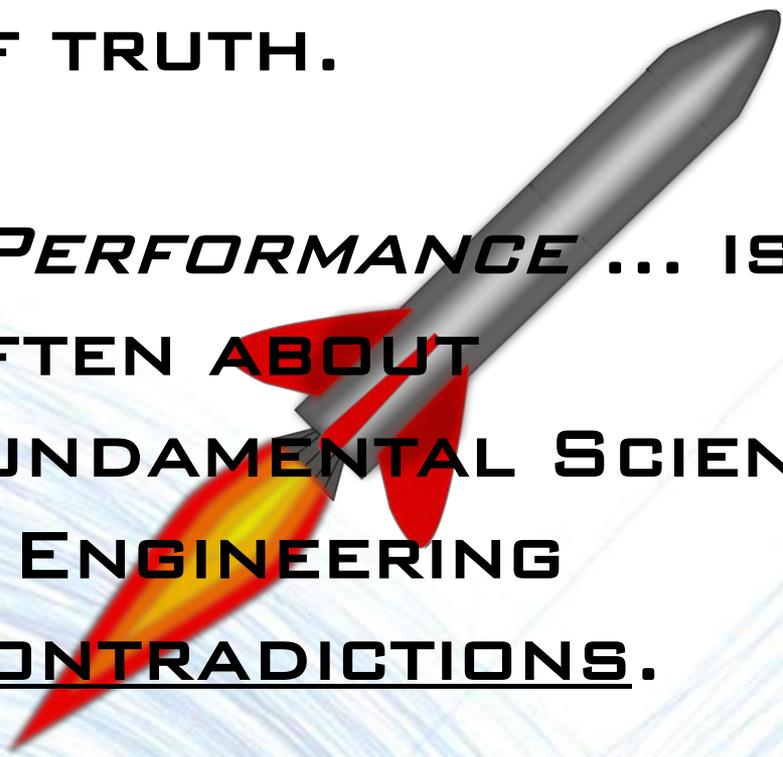
# WHY THE 'ROCKET SCIENCE' FOR SUCH EVERYDAY PRODUCTS?



- PRODUCTS MUST *PERFORM ...2<sup>ND</sup> MOMENT OF TRUTH.*



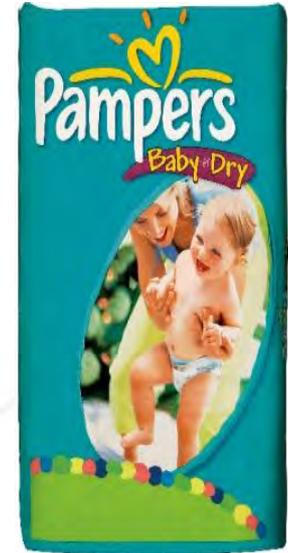
- *PERFORMANCE ... IS OFTEN ABOUT FUNDAMENTAL SCIENCE & ENGINEERING CONTRADICTIONS.*





## MATERIALS ...

- STRONG BUT SOFT,
- STRETCH NOT BREAK,
- BREATH BUT CONTAIN,
- BREAK...NOT TEAR.



## PACKAGES ...

- CREATIVE DESIGN IS KEY,
- STRONG BUT LIGHT,
- NEVER LEAK...BUT OPEN EASILY.



## MORE CONTRADICTIONS...

### FORMULATIONS ...

- PROTECT FABRICS ... BUT REMOVE STAINS,
- BE COMPACT, BUT USED EASILY.



### LIQUIDS ...

- MIXTURES CAN'T SEPARATE,
- MUST DISPENSE EASILY... BUT STAY WHERE APPLIED.



# THE CLEANING CONTRADICTION...

- REMOVE OR MAKE UNNOTICEABLE:  
‘SOIL’, ‘STAINS’ & ‘ODORS’



- LEAVE THE REST  
UNALTERED: FIBERS, DYES,  
SURFACES, HAIR, SKIN,  
PETS

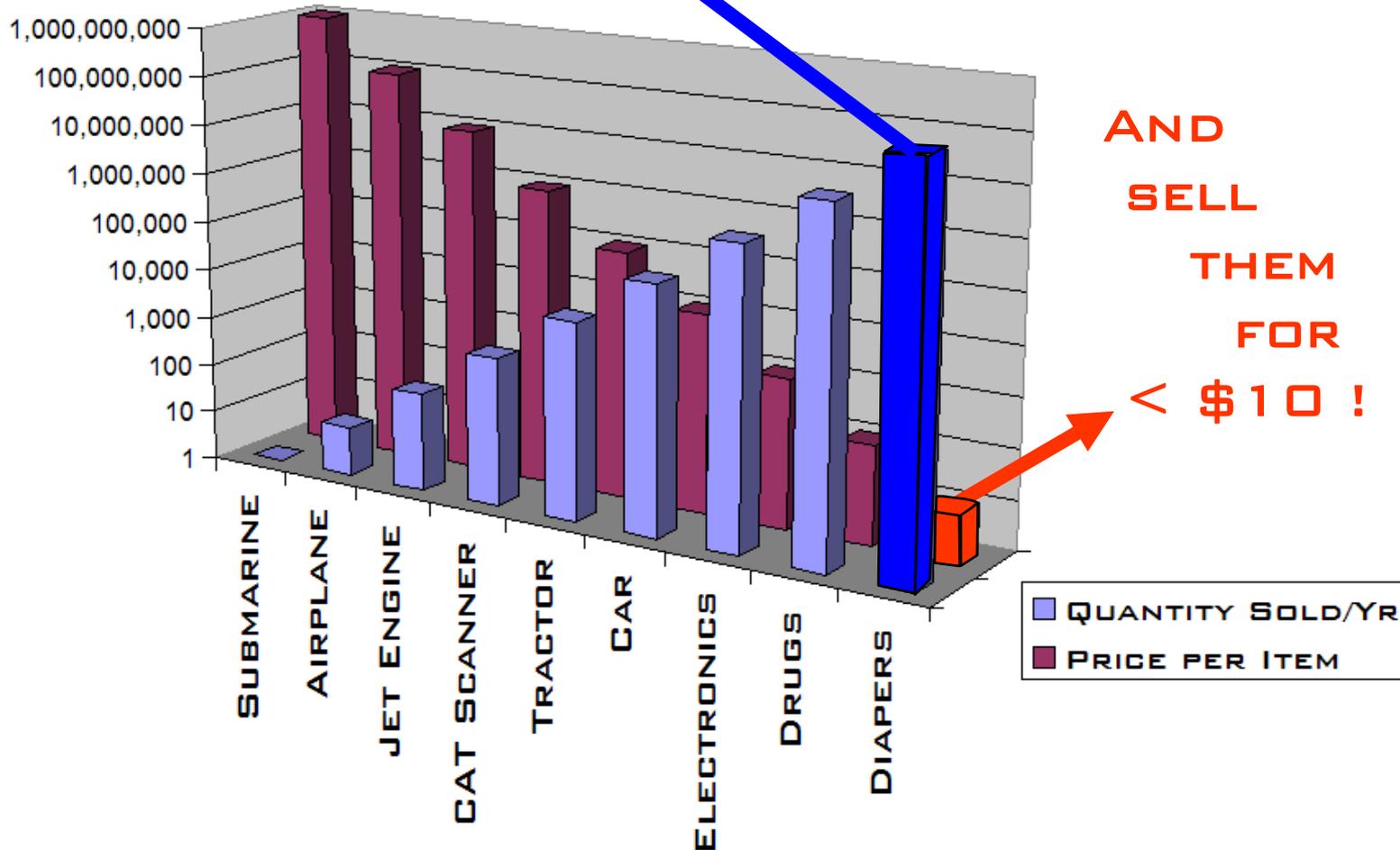
EXCEPT...

‘WHAT IT SMELLS LIKE...’



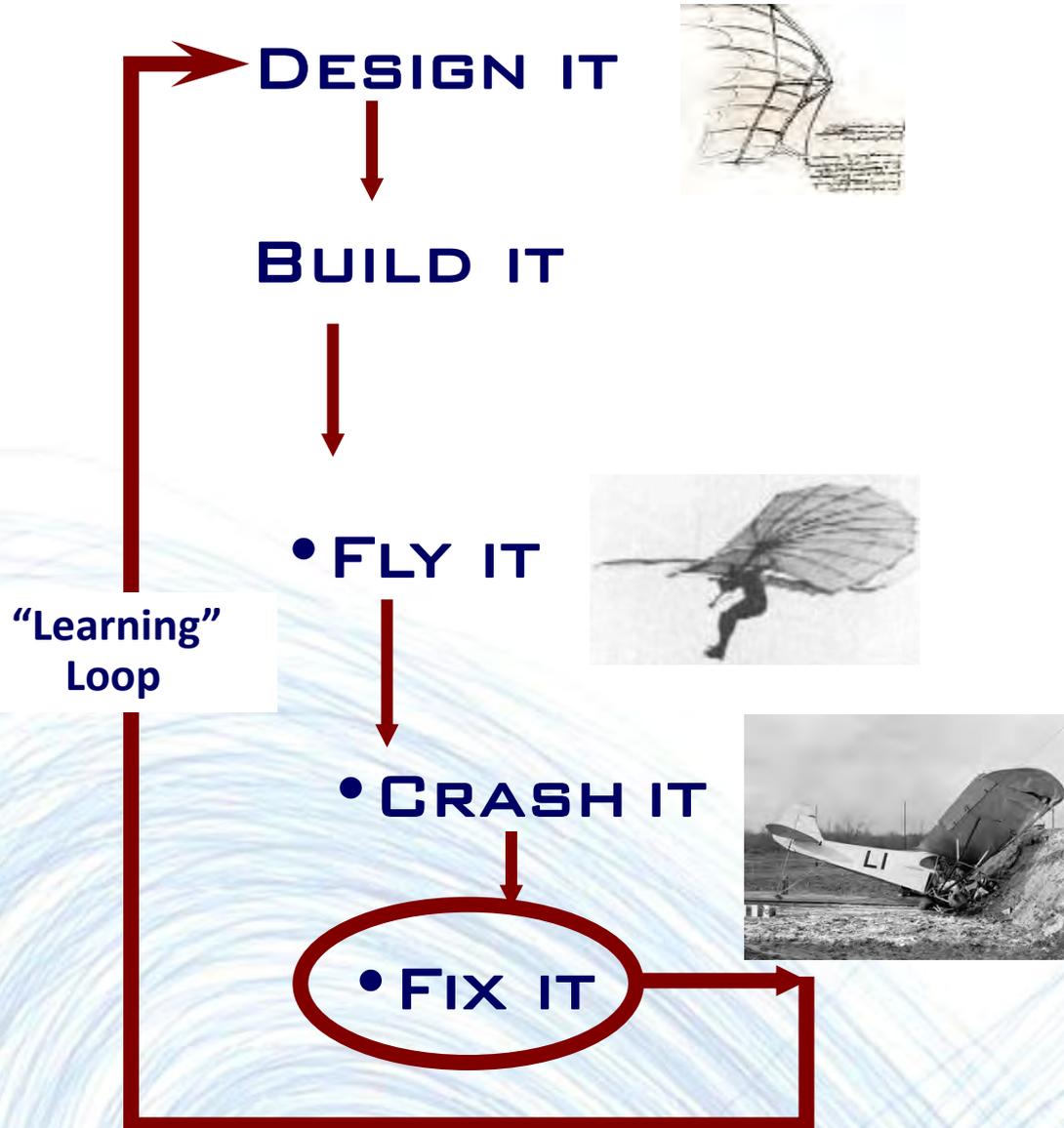
# SCALE: SELL A BILLION \$

WE MAKE BILLIONS OF PRODUCTS A YEAR...



AND  
SELL  
THEM  
FOR  
FOR  
< \$10 !

# INNOVATION LEARNING CYCLE



## Outcomes

- **Costs too much:**
  - One-time-use Equipment
  - Testing Infrastructure
- **Takes too long:**
  - Cycles of Prototypes
  - Development is Sequential



**Products are not innovative:**



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# MODELING & SIMULATION HAS 'TRANSFORMED' INDUSTRIES?

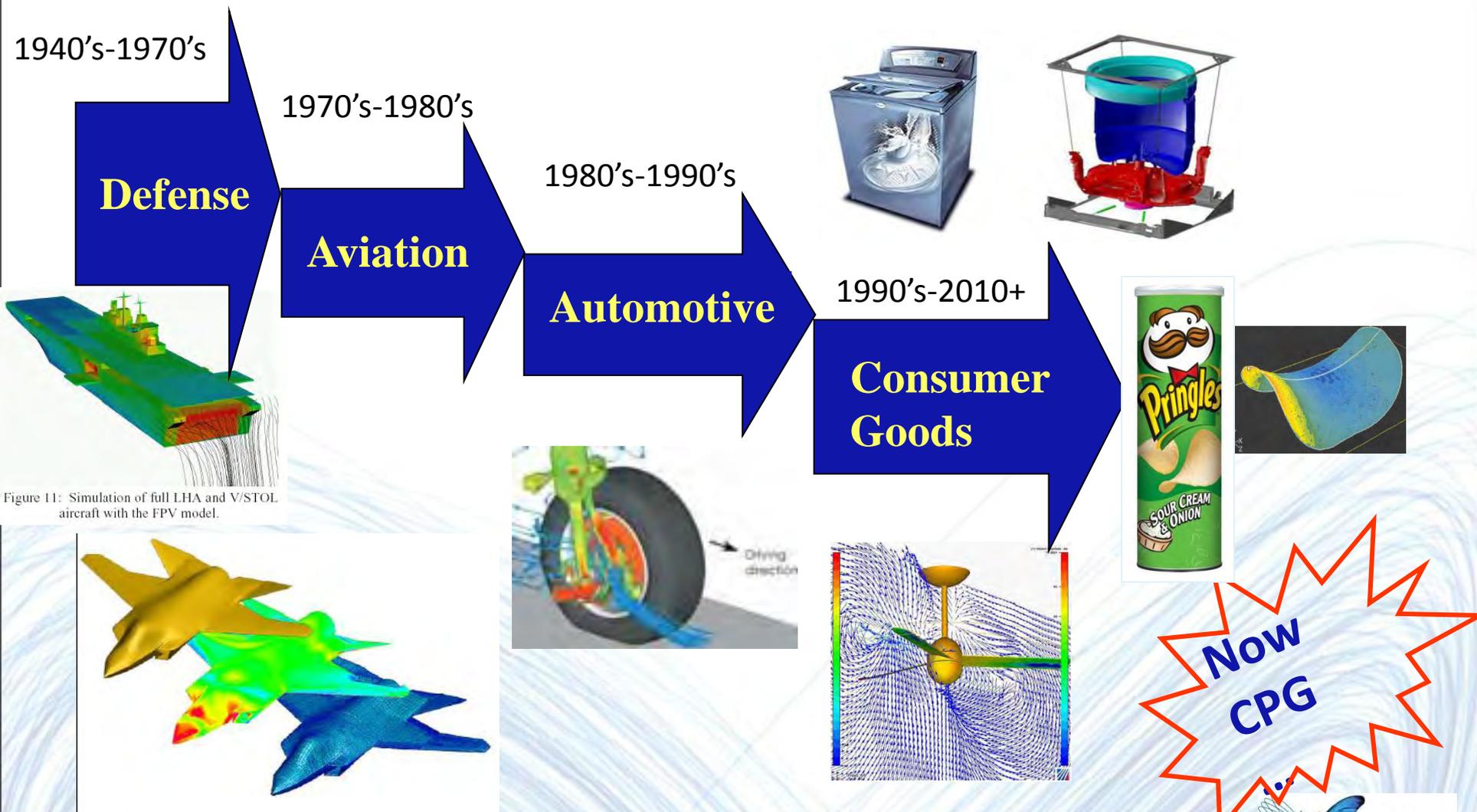


Figure 11: Simulation of full LHA and V/STOL aircraft with the FPV model.

**NOW CPG**

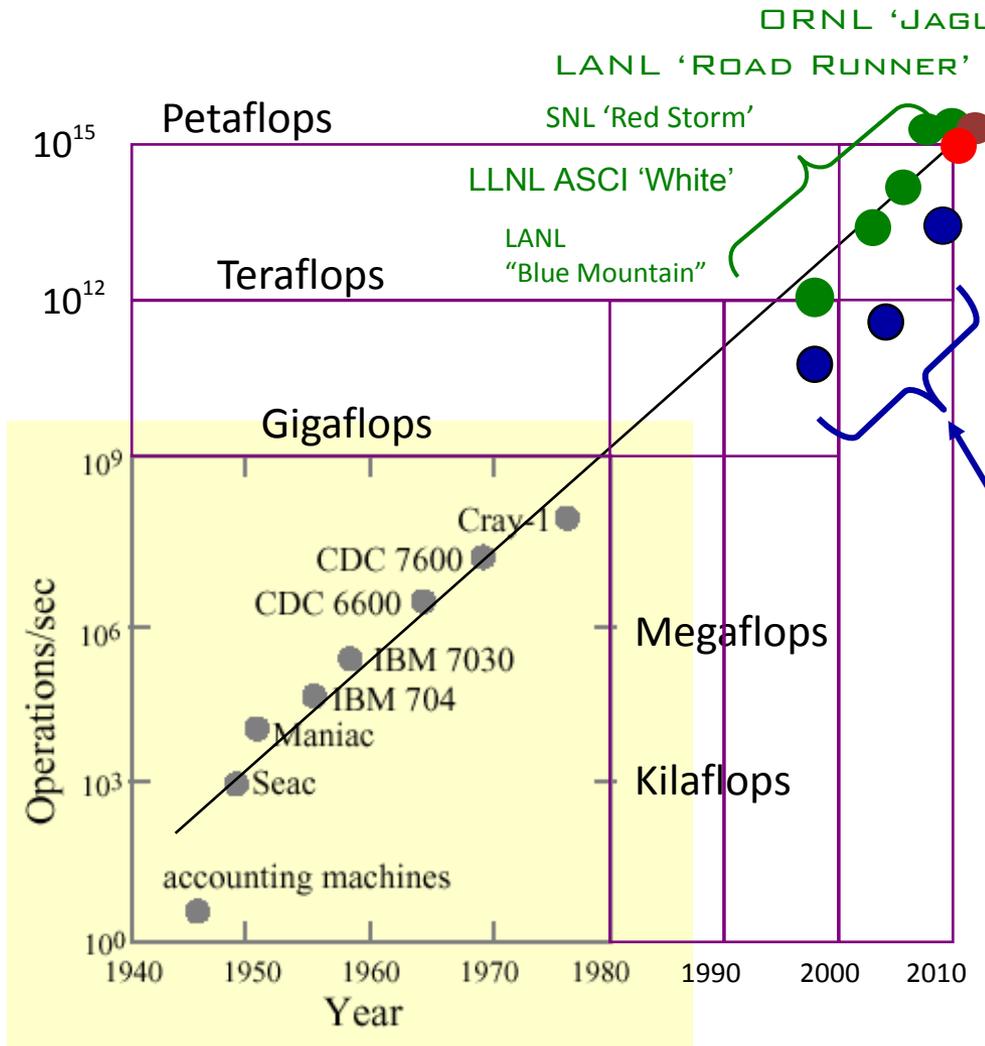
**Modeling & Simulation**

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# A TREND I BET ON... 'MOORE'S LAW'

## COMPUTING HARDWARE PERFORMANCE



U.S. Dept. of Energy  
'Leadership' Class  
Machines

U.S. NSF 'Tier 1'  
Blue Waters

Chinese Gov't

P&G's  
1<sup>st</sup>, 2<sup>nd</sup>, & 3<sup>rd</sup>  
Generation  
Super Computers



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# COMPUTING COSTS \$/CPU-HR

- IN 2001...COMPUTING (HARDWARE ONLY) COST P&G ~\$1.50 PER CPU-HR
- IN 2008...P&G COMPUTING COSTS (HDWR, SUPPORT, FACILITIES...) ARE ~ \$0.15 PER CORE-HR.
- 2012 COMPUTING (HARDWARE ONLY) PROJECTING TO COST ~ \$0.01-0.03 PER CORE-HR.



***WHAT ARE WE GOING TO  
DO WITH ALL THAT  
POWER?***

REPLACE:

SLOW AND EXPENSIVE  
LEARNING CYCLES

WITH:

FASTER, SMALLER  
EXPERIMENTS; VIRTUAL  
MODELS & SIMULATIONS



REPLACE 'PHYSICAL' WITH 'VIRTUAL'?

---

THE PURSUIT OF

...

REALISM



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# REALISM REQUIRES...

- TACKLING ‘FULL COMPLEXITY’ PROBLEMS
- SOLVING LARGER EQUATION SETS...
  - (BILLION ELEMENTS, BILLION ATOMS/MOLECULES...ETC.)
- PARAMETRIC STUDIES VS. POINT ESTIMATES
  - (STOCHASTIC PARAMETER INPUTS)
- NON-EXPERTS DO ANALYSIS...
  - AUTOMATE FOR PRACTITIONERS, WHAT REQUIRES AN EXPERT TODAY



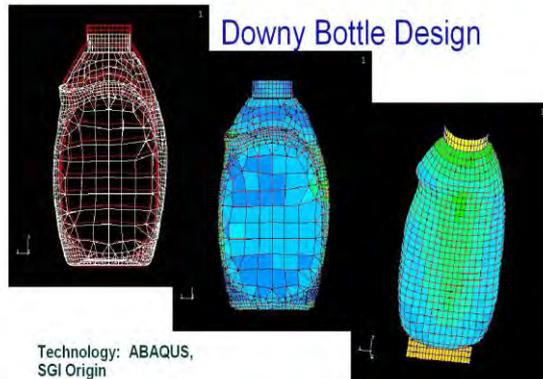
# OUR M&S APPROACH...

WE BUILD AND  
TEST THE **FIRST**  
PROTOTYPES...

**'VIRTUAL'** ONES  
THAT...

- **FIT**
- **WORK**
- **MAKE FINANCIAL SENSE**

 Package Design Examples

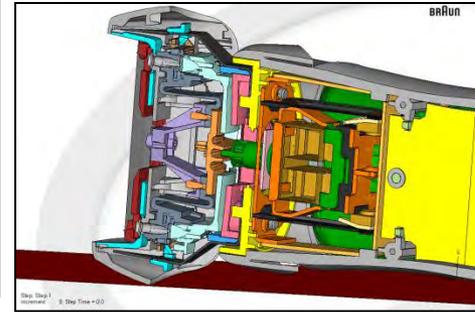
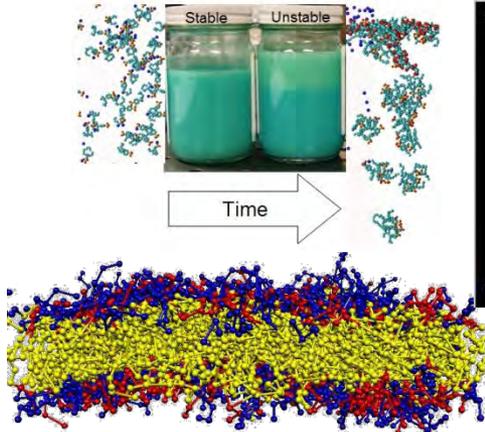


...**BEFORE**  
THEY EXIST IN  
THE REAL  
WORLD.

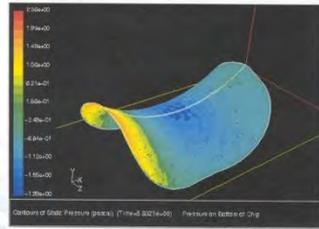
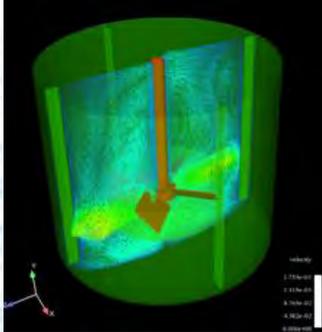


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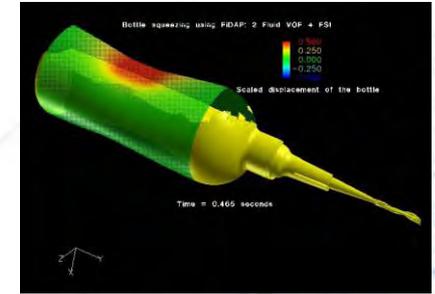
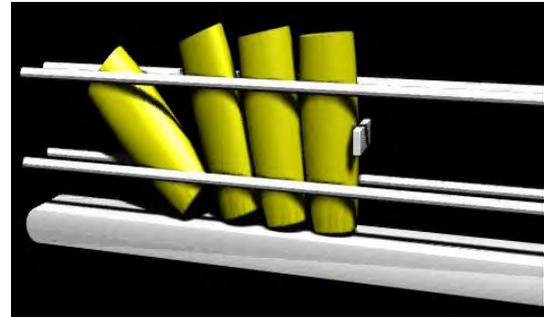
## Product/ Device/ Package



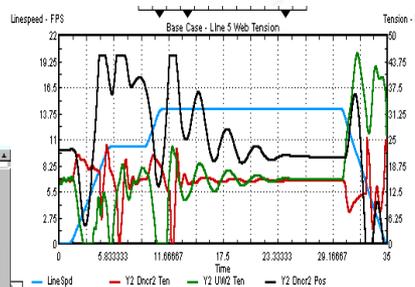
## Process



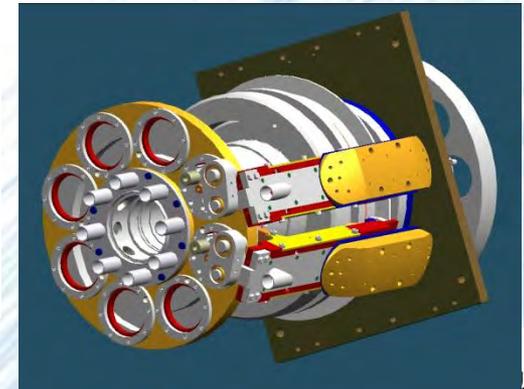
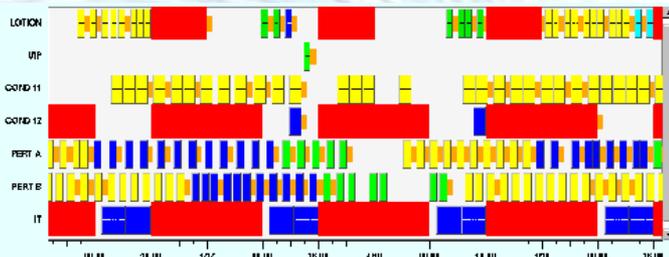
Pressure on the Bottom of the Chip



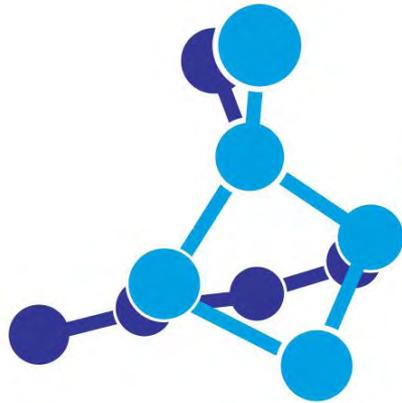
## Mechanical & Converting



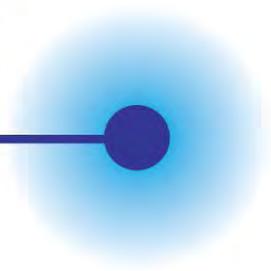
## Supply Chain, Through- put, & Reliability



# Examples



# Computational Chemistry



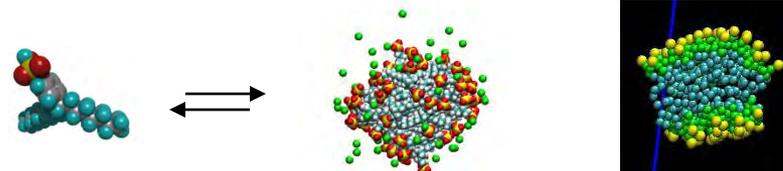
computer aided engineering



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- MICELLIZATION:

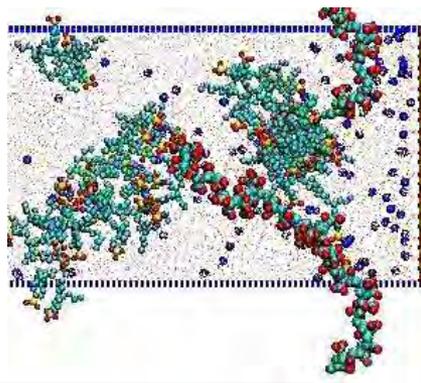
- CALCIUM EFFECTS, SIZE, CMC
- POLYMER EFFECTS, SIZE, CAC



*Spherical or lamellar (bilayer)*

- INTERFACIAL EFFECTS:

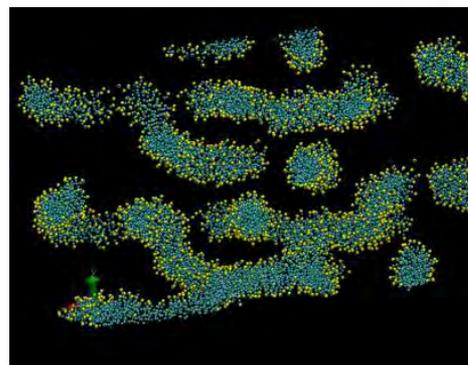
- CALCIUM EFFECTS
- POLYMER EFFECTS
- SURFACTANT EFFECTS
- HYDRODYNAMIC EFFECTS



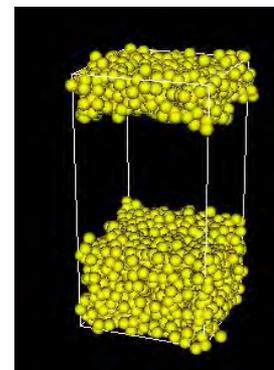
*Surfactant at a clay surface*

- 'SOIL' REMOVAL

- EMULSIFICATION
- SOLUBILIZATION



*cylindrical micelles*



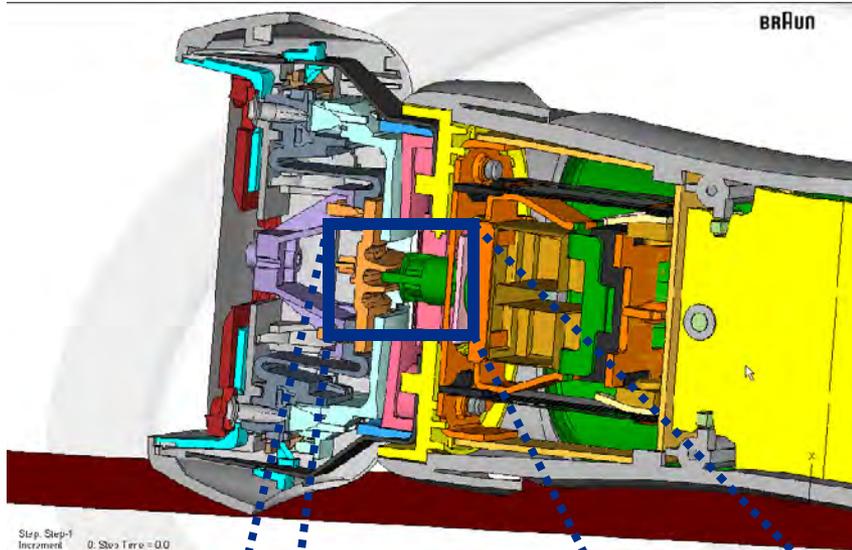
*oil-water interfaces*



- **Rigid Body Kinematics**
  - **Finite Element Analysis (FEA):**
    - Implicit
    - Explicit
    - Linear
    - Non-linear
    - Massive Contact
    - Complex non-metal
- Material Models:** High Strain Rates 1/500 Seconds, Elastic-plastic, Hysteresis: Visco-Elastic, Visco-Plastic



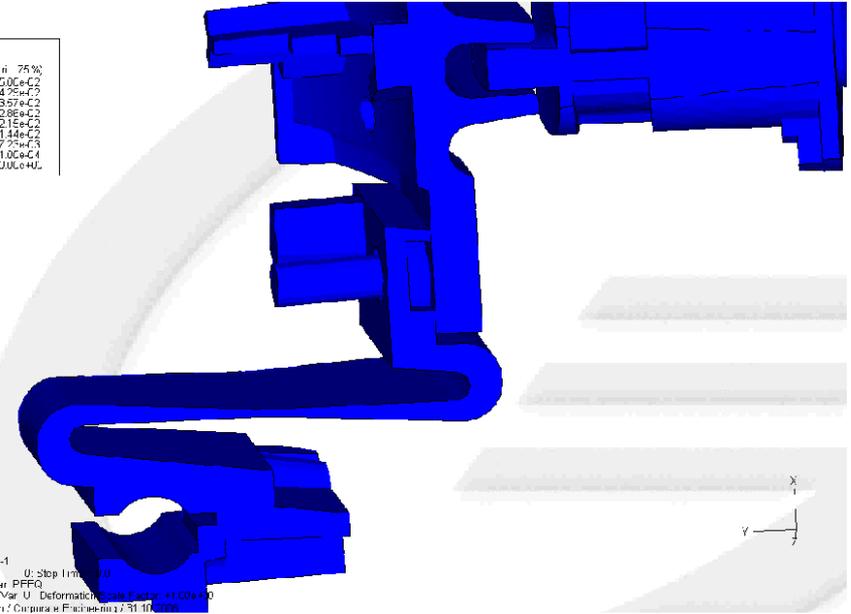
# BATHROOM FLOOR DROP



PEEQ  
(Max: 2.175%)

Red	+2.00e-2
Orange	+4.25e-2
Yellow	+3.57e-2
Light Green	+2.98e-2
Green	+2.15e-2
Dark Green	+1.34e-2
Blue	+7.75e-3
Light Blue	+1.00e-2
Dark Blue	+3.00e-3

Step: Step-1  
Increment: 0; Step Time: 0.0



Step: Step-1  
Increment: 0; Step Time: 0.0  
Primary Var: PEEQ  
Deformed Var: U; Deformation Scale Factor: +1.00e+00  
R: Plasser / Corporate Engineering / 2/11/2008



LOTS OF SMALL  
PARTS...  
...EVERYONE MUST  
WORK!



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- **Computational Fluid Dynamics (CFD):**
  - Free Surface Flow
  - Contained Turbulent Flow
  - Multi-Phase Flows
  - Creeping & Low Reynold's Number Flows
  - Non-Newtonian & Visco-Elastic Material Properties
  - Flow in Porous Media



# MAKING A $10^9$ PRINGLES?

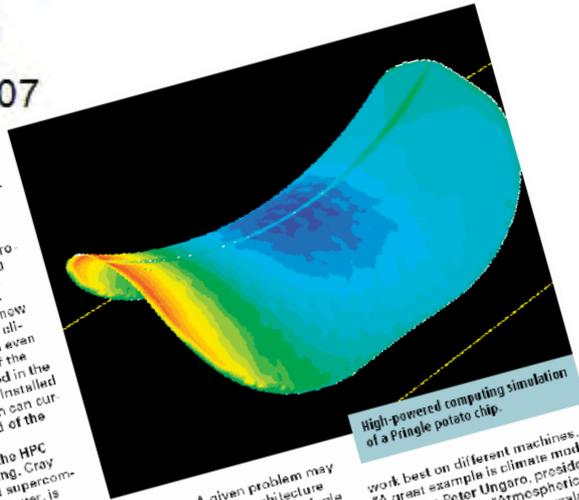
## FORTUNE

August 20, 2007



tricity, you can use it to charge the batteries." In Spain, the Barcelona Supercomputing Center is home to a 94-teraflop machine called MareNostrum ("our sea"). The fastest in Europe (and the ninth-fastest in the world), MareNostrum has provided support to more than 200 research projects; it has aided in the design of new planes, studied the impact of climate change in Europe, and even saved the hull design of the new ship that competed in the America's Cup race. Installed in a chapel, MareNostrum can currently handle only a third of the requests it receives.

Access is one issue the HPC community is addressing. Cray Inc., the Seattle-based supercomputer giant that built Jaguar, is working to solve another problem: flexibility. Today's machines typically use one of four processor architectures: in technical terms, they're known as scalar, vector, multithreading, and attached po-



High-powered computing simulation of a Pringle potato chip.

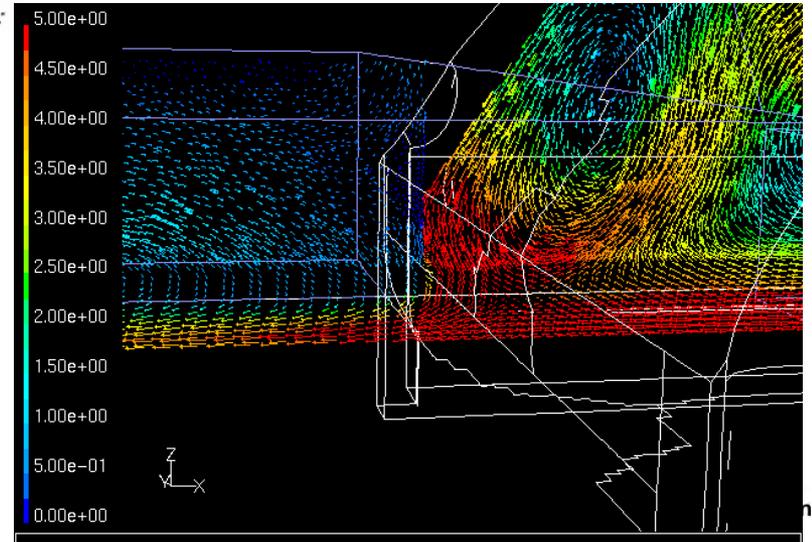
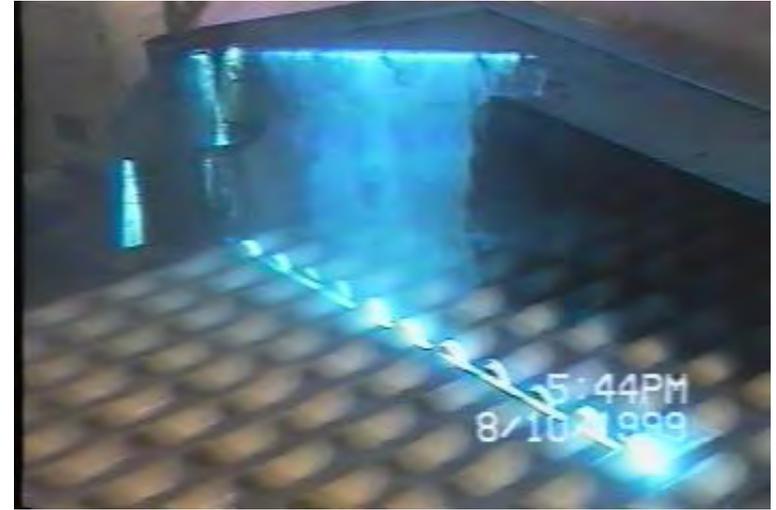
processors. A given problem may work better on one architecture than another. Even within a single area of research, different tasks

work best on different machines. "A great example is climate modeling," says Peter Ungaro, president and CEO of Cray. "Atmospheric modeling works well on a scalar computer, while ocean modeling works well on a vector machine. Users are looking for a single computer that can efficiently run a complex variety of applications."

### WHY HPC MATTERS

In the Study of U.S. Industrial HPC Users commissioned by the Council on Competitiveness, IDC asked 33 aerospace, automotive, fire, petroleum, electronics, pharmaceutical, life sciences, software, financial services, transportation logistics, and entertainment companies in the U.S. where they'd be if they didn't have access to high-performance computing. Their replies:

HOW LONG DOES IT TAKE TO MAKE A **BILLION** PRINGLES?



Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=1.8410e+01) Mar 16, 2000 FLUENT 5.3 (3d, segregated, mgke, unsteady)

# What are the areas of Challenge & Research?

Multi\_Physics...



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# MULTI-SCALE CHALLENGES

**HIGH PERFORMANCE COMPUTING USING  
 $10^3$  -  $10^4$  PROCESSORS ENABLES:**

- **SPATIAL DOMAIN DE-COMPOSITION OF  
LARGE COMPLEX PROBLEMS**

**MULTI-SCALE PROBLEMS ALSO REQUIRE:**

- **TEMPORAL DOMAIN COMPRESSION OR  
DE-COMPOSITION TO ENABLE LARGE  
NUMBERS OF PROCESSORS TO SOLVE.**



# MULTI-PHYSICS CHALLENGES

## CHEMICAL SYSTEMS MULTI-PHYSICS :

- CRYSTALLIZATION, AGGLOMERATION, CHEMICAL RX
- REACTOR DESIGNS



## STRUCTURE / FLUID COUPLING:

- FREE SURFACE FLOW ON AND THROUGH COMPRESSIBLE
- PARTIALLY SATURATED POROUS MEDIA



## FLUIDS / STRUCTURE INTERACTION FSI:

- FLEXIBLE FILMS IN FLUIDS E.G. 'FLAG WAVING'
- SQUEEZING TO DISPENSE FROM BOTTLES
- CONTAINER SLOSHING, BOTTLE DROP



# ...HOW DO WE USE THE POWER!

The Evolution  
Of M&S Application  
And Business  
Value

“Analysis Led”  
Discovery

Defines the  
option space  
‘where’ designs  
work...or don’t work

“Virtual”  
Trial & Error

Predicts ‘why’ designs  
work...or don’t work  
(in systems that don’t exist yet)

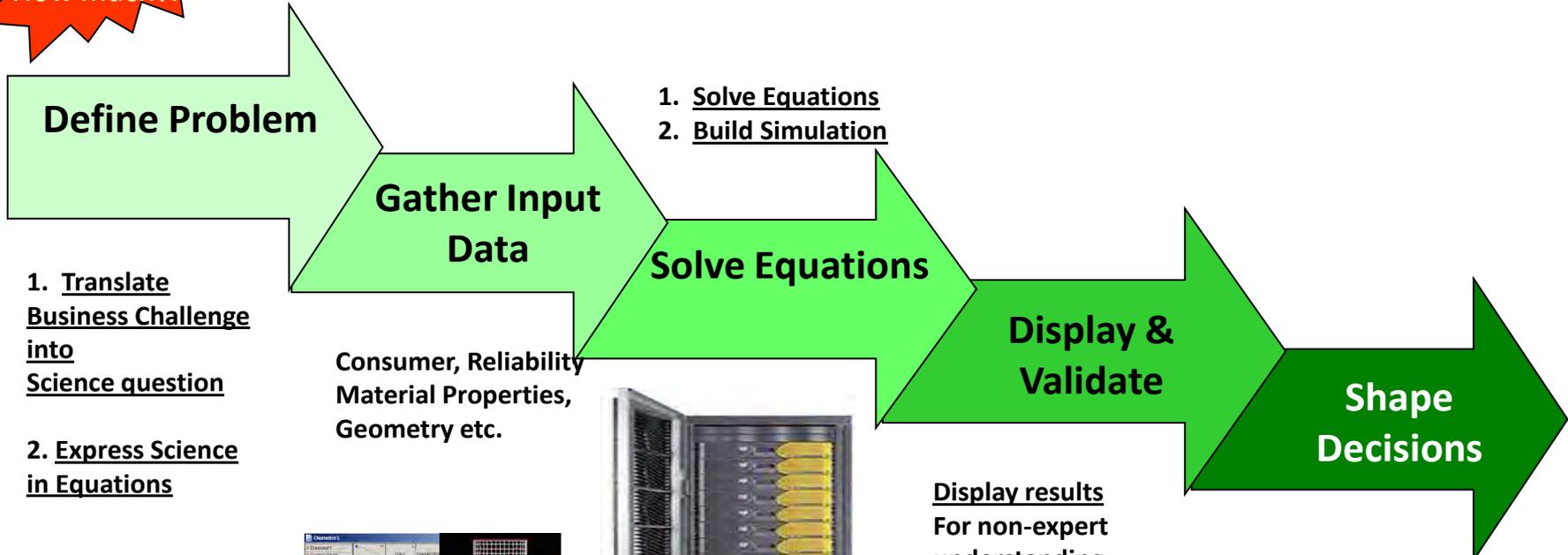
Pathology

Explains ‘why’ existing  
products & systems  
work...or don’t work



# M&S WORK PROCESS

What if ?,  
Why not ?,  
How much?.



**Define Problem**

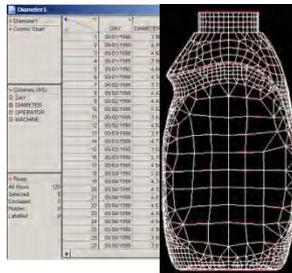
1. Translate Business Challenge into Science question

2. Express Science in Equations

$$\left( \sqrt{1 + 4 \frac{\beta \rho}{\alpha^2 \mu^2} \frac{\Delta p}{\Delta L}} \right)$$

**Gather Input Data**

Consumer, Reliability  
Material Properties,  
Geometry etc.



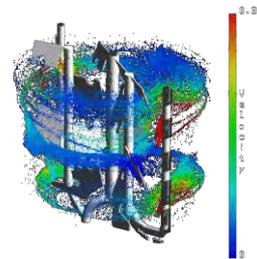
1. Solve Equations  
2. Build Simulation

**Solve Equations**



**Display & Validate**

Display results  
For non-expert understanding



**Shape Decisions**

Apply & Deploy:

- reframe the question
- guide the choices
- confirm the situation
- stop the project



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# THEMES FOR THE FUTURE

- MOORE'S LAW...BUT PARALLEL
- APPLICATION SOFTWARE...THE CURRENT 'ISSUE'
- 'DEMOCRATIZATION' OF ANALYSIS
- BUSINESS VALUE...REPLACING SLOW & EXPENSIVE LEARNING WITH VIRTUAL
- COMPUTING SKILLS & COMPUTATIONAL AWARENESS THE MOST IMPORTANT TREND FOR PRACTICING ENGINEERS

