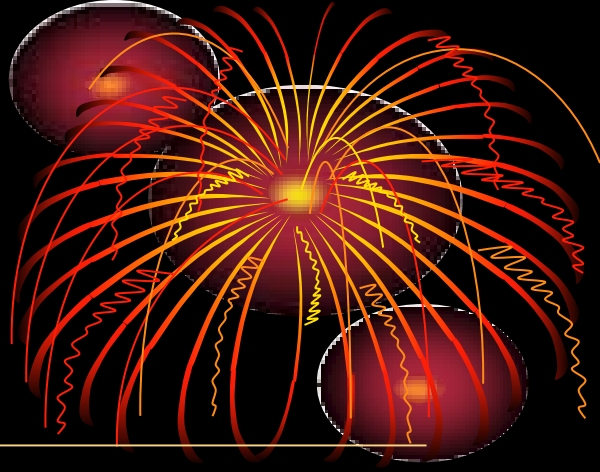
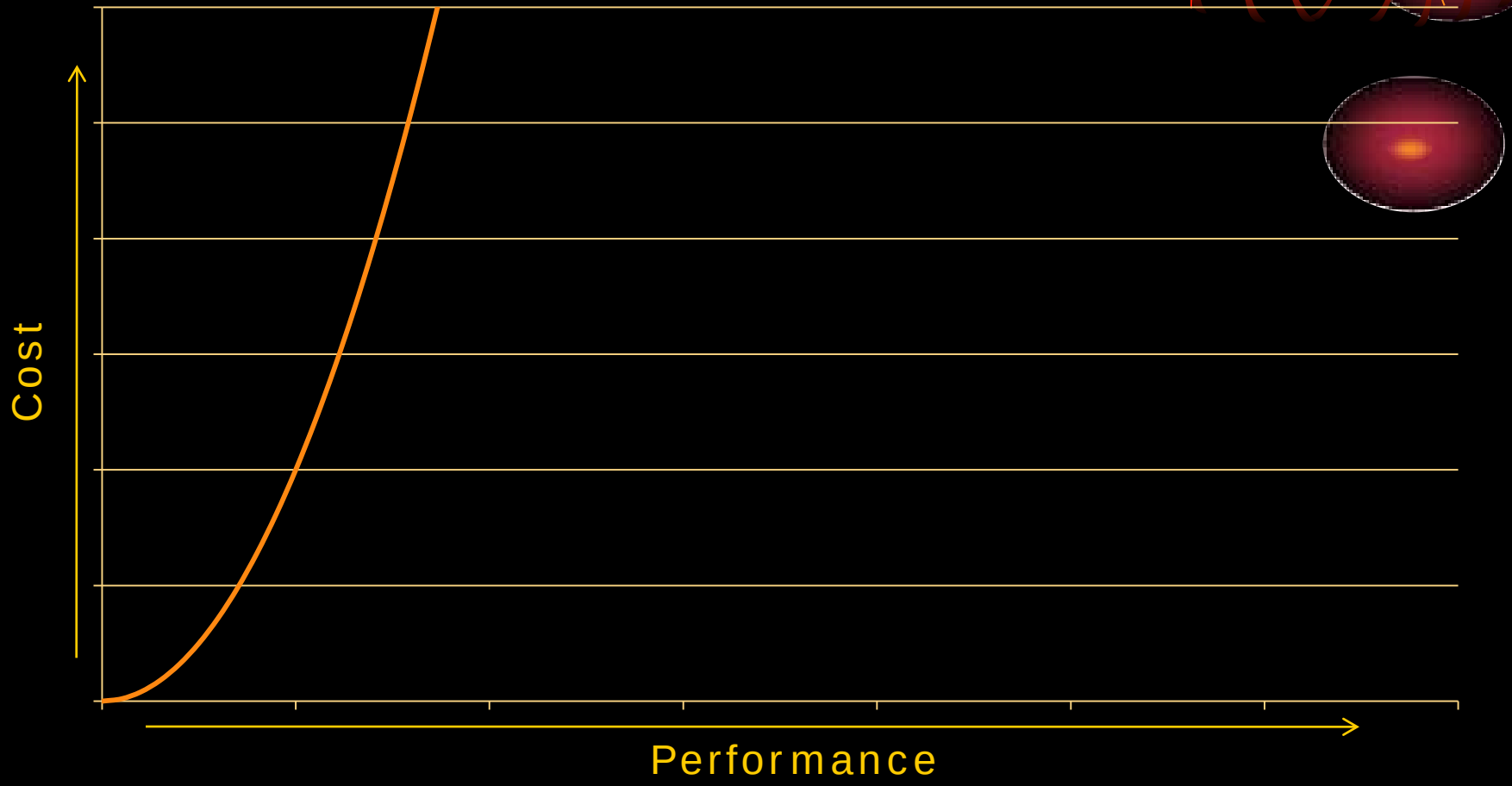
Counter-Intuitive Systems Engineering

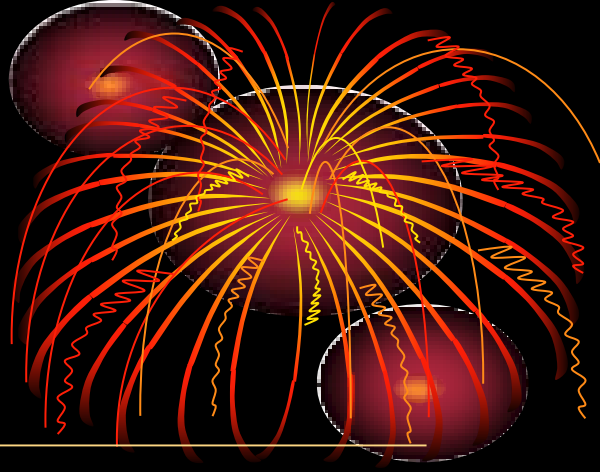
Tunneling Through The Cost Barrier

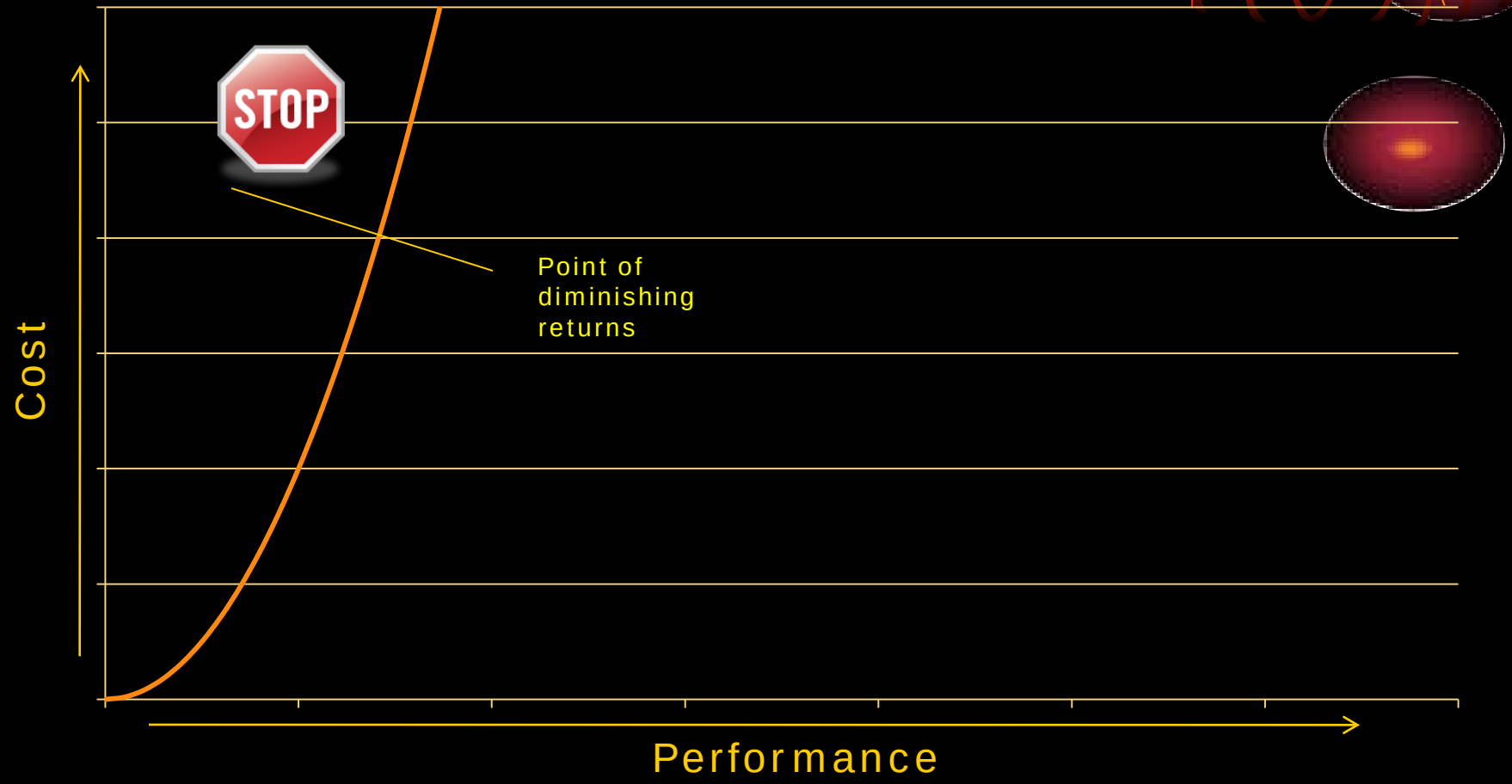
We are taught...





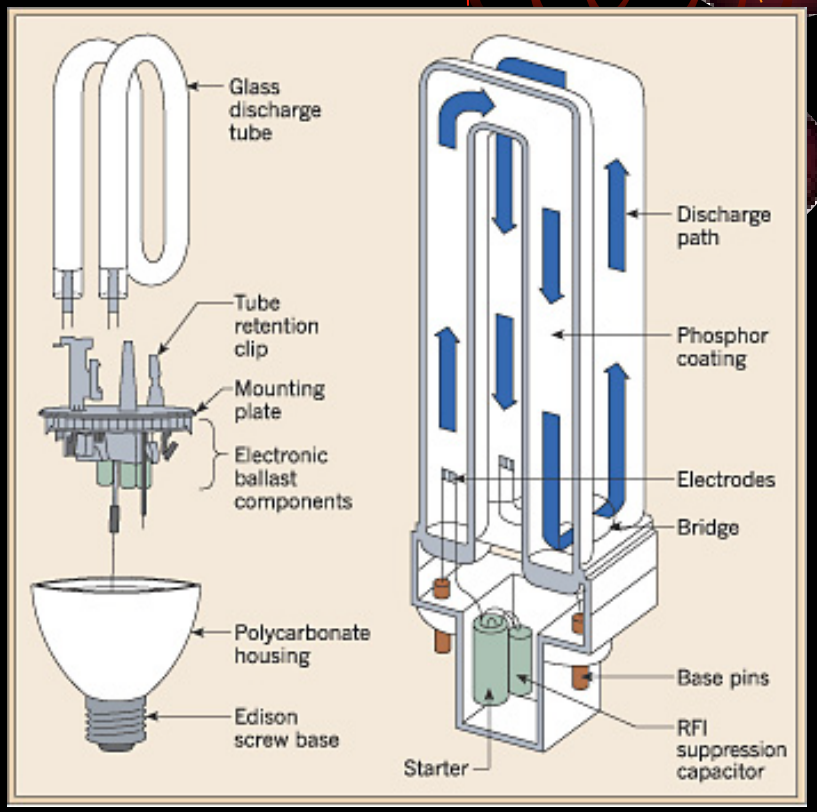
We are taught...



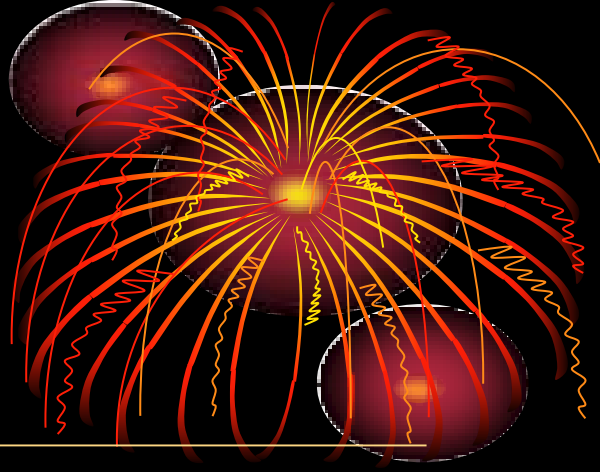


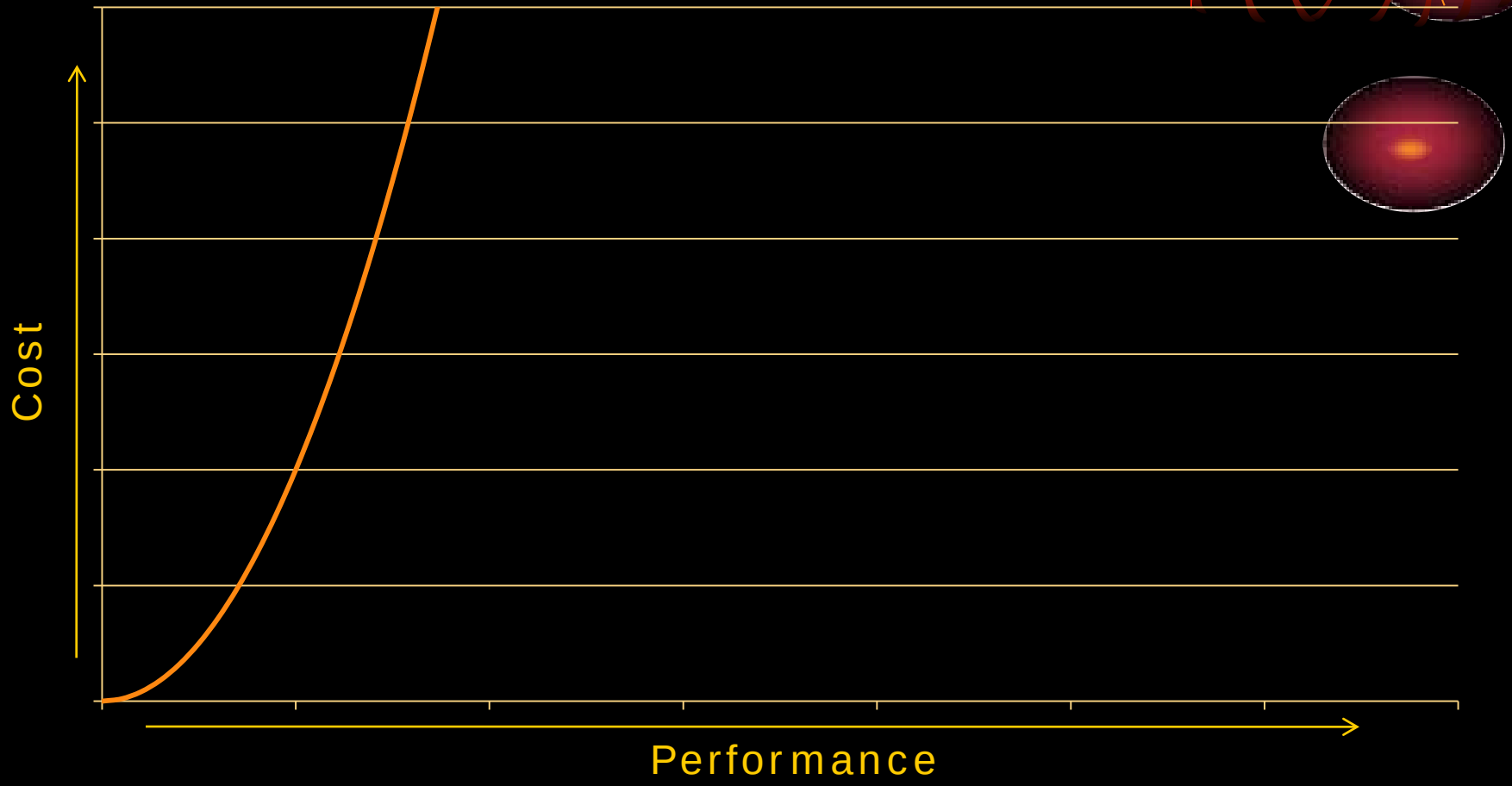
Example: Change the light bulbs to CFL

- Save: 75W each
- Cost: $10 each
- Net: $133 / kW saved
- Life: 1000 h
- Savings: 75 kWh
- Cost of savings: $0.075 / kWh

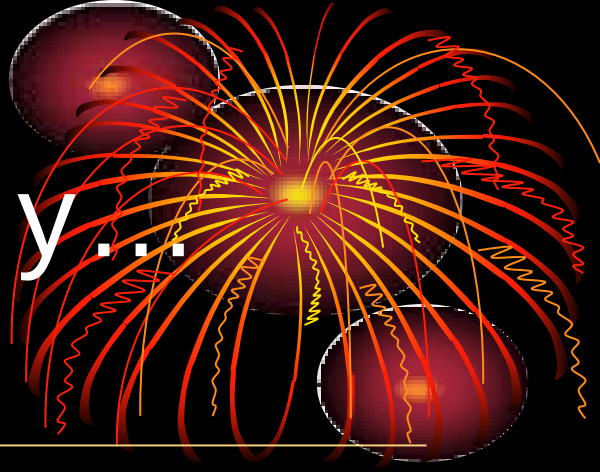


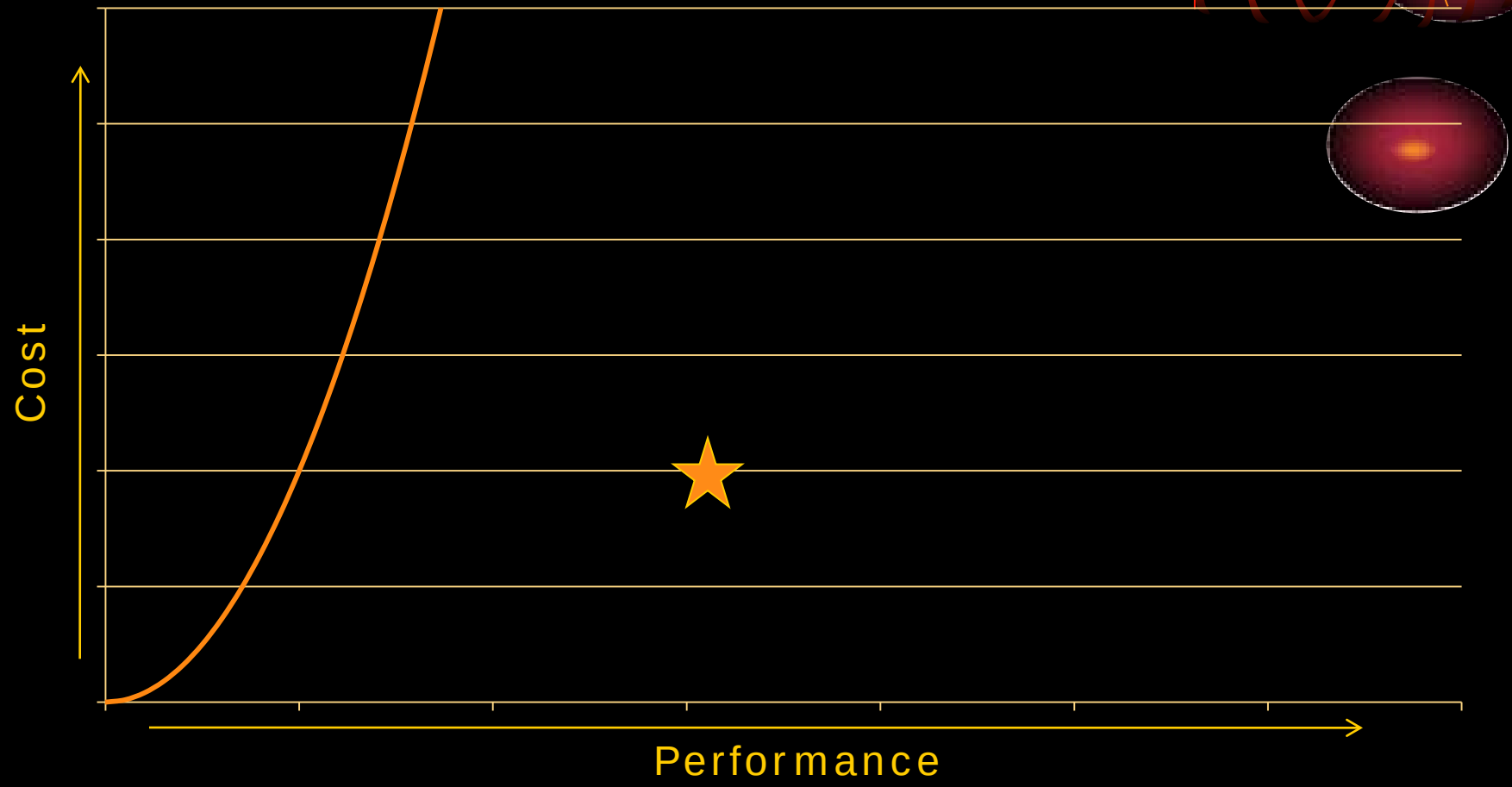
We are taught...



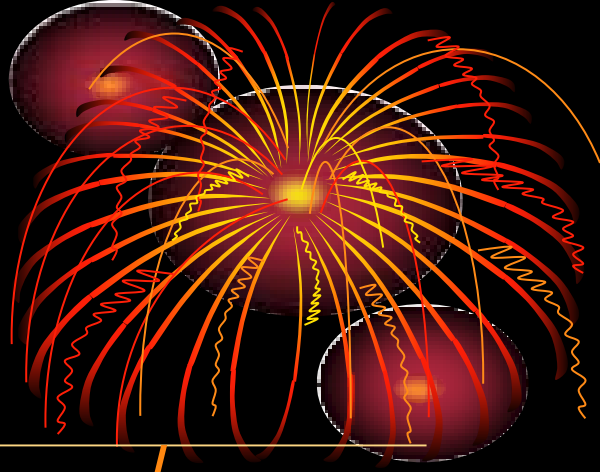


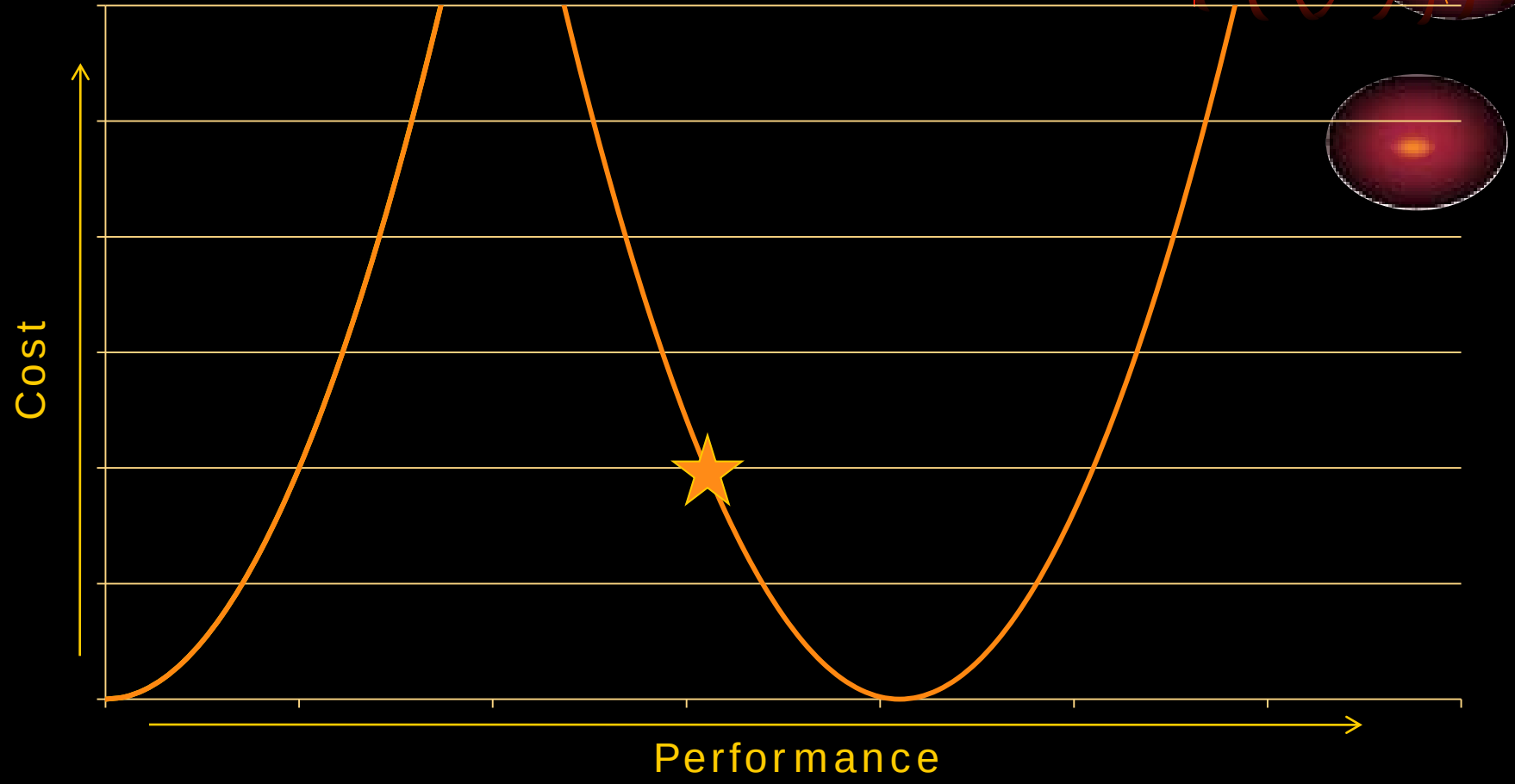
But then somebody...



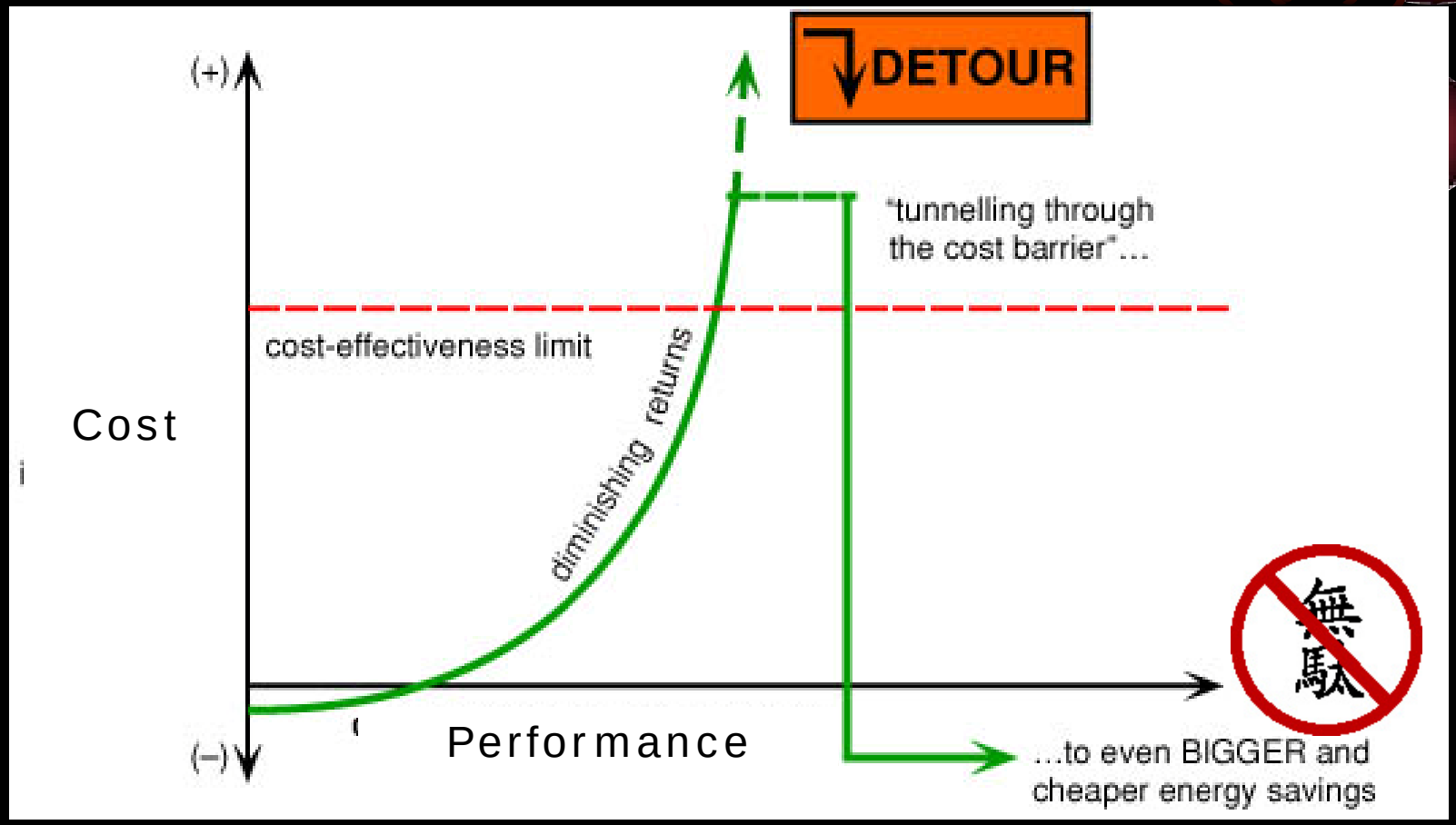


Perhaps...





New reality: “tunneling through the cost barrier”



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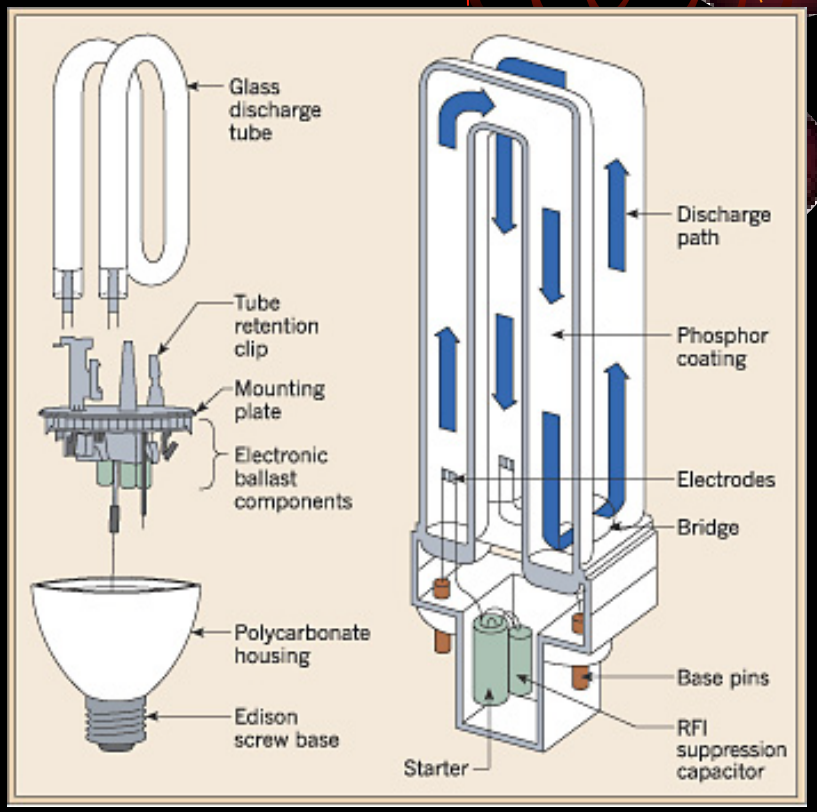


But what if I own the Power Plant?

But what if I own the Power Plant?

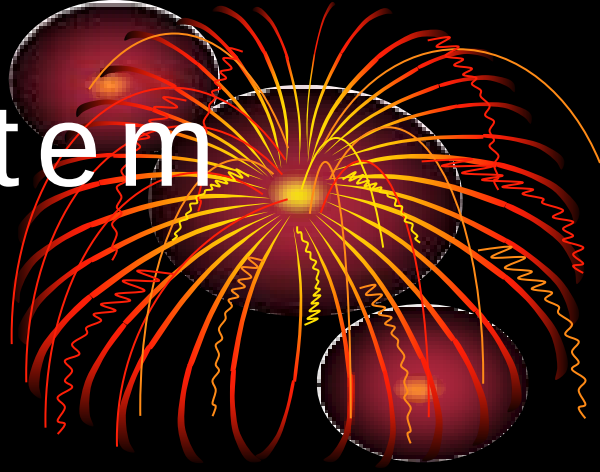
- A dozen light bulbs = 1 kW

Honda eu3000is = $2000

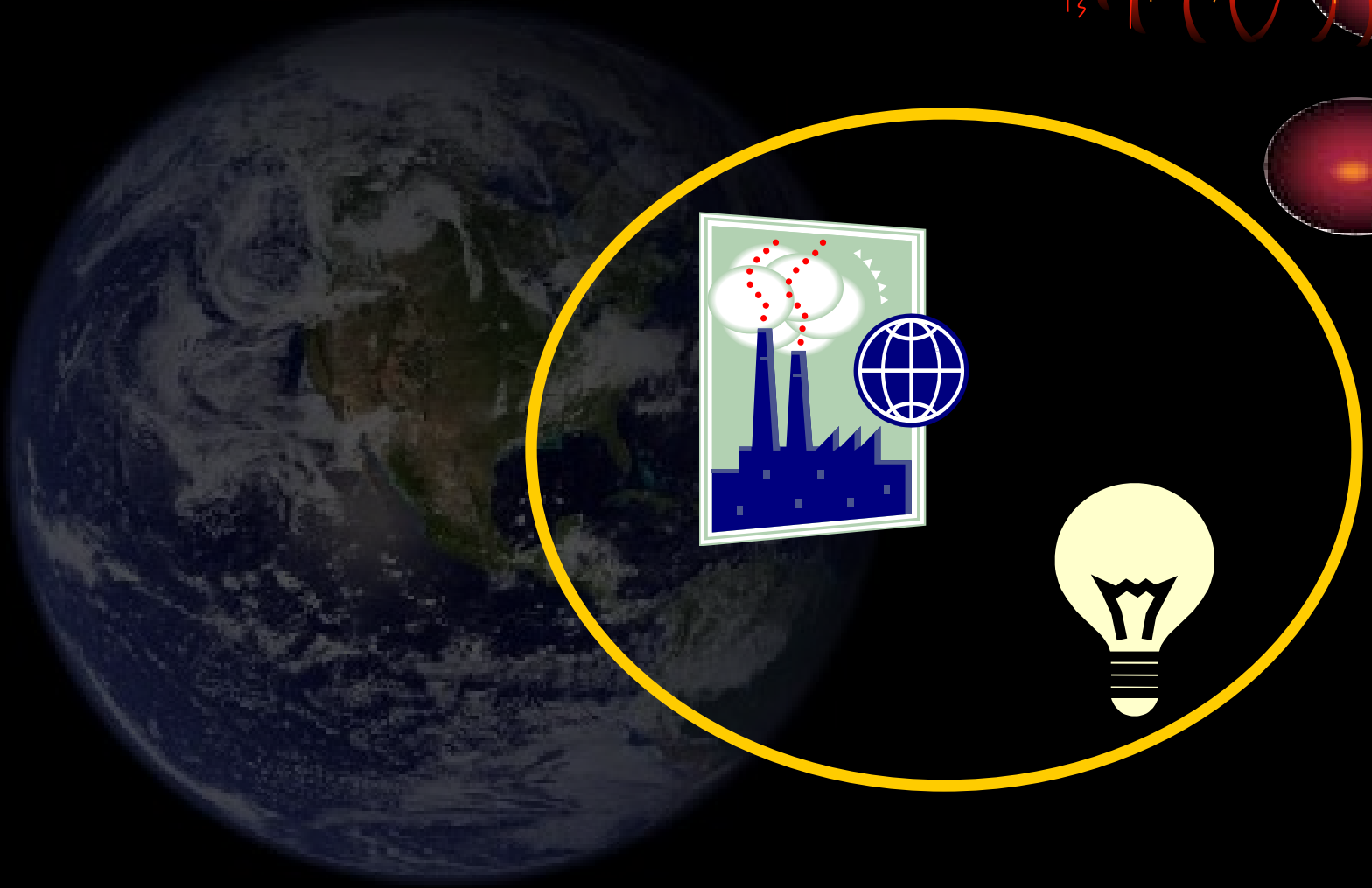
- $100 / light bulb

Honda eu2000 = $800

Re-Define the System Boundary

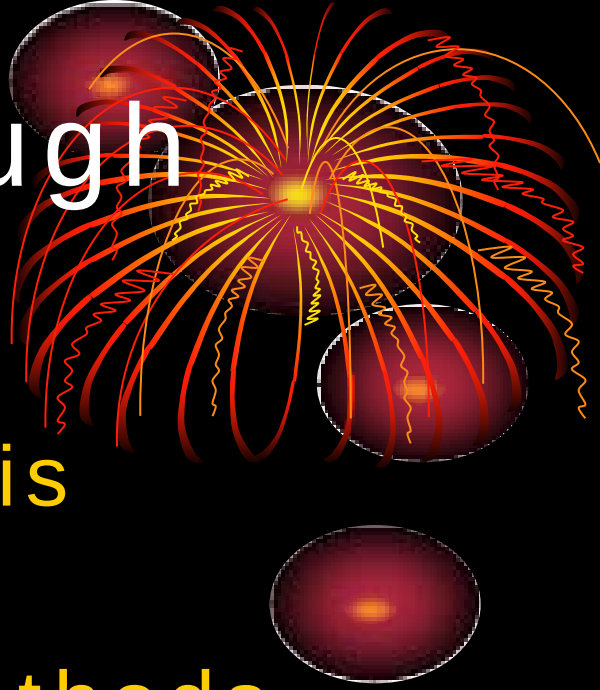


Re-Define the System Boundary



Re-Define the System Boundary

How is Breakthrough Possible?



- The cost/benefit curve is discontinuous
- Continuous-process methods (i.e. incremental improvement) won't find breakthroughs
- You have to "jump the track"

How is Breakthrough Possible?

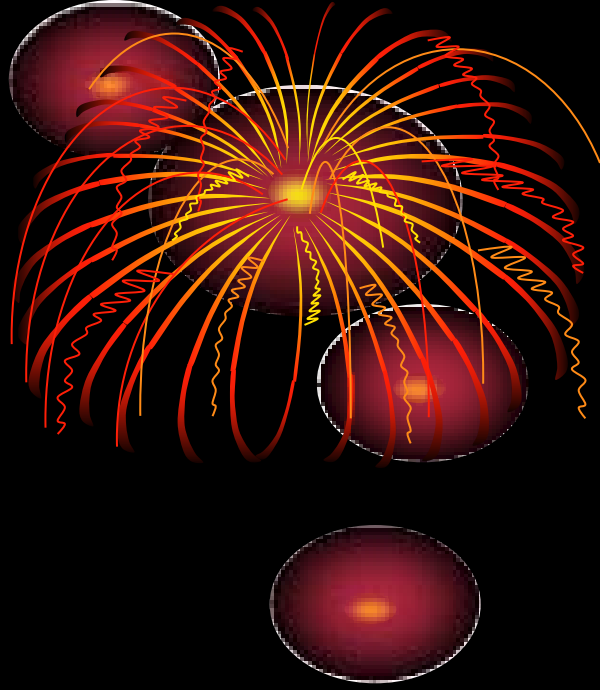
- Techniques for jumping the track:
  - Multitasking
  - Muda-Elimination
  - Teleology

How is Breakthrough Possible?

- Techniques for finding it:
  - Multitasking
  - Muda-Elimination
  - Teleology

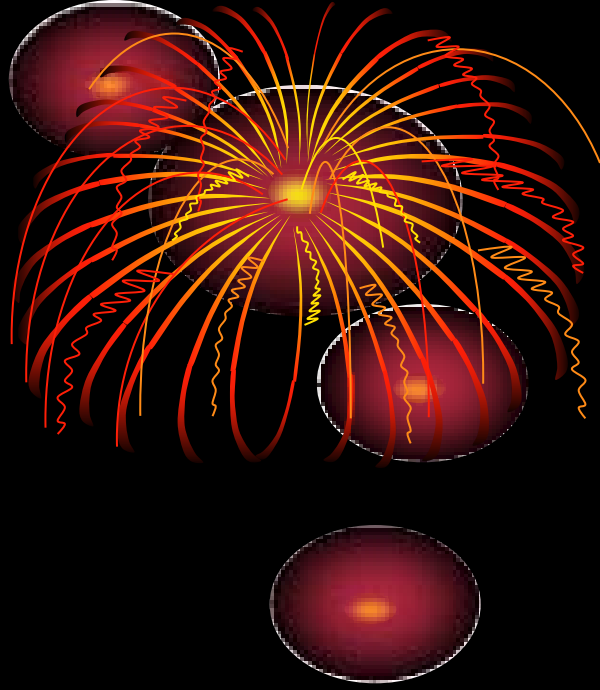
Multitasking

- Container steel

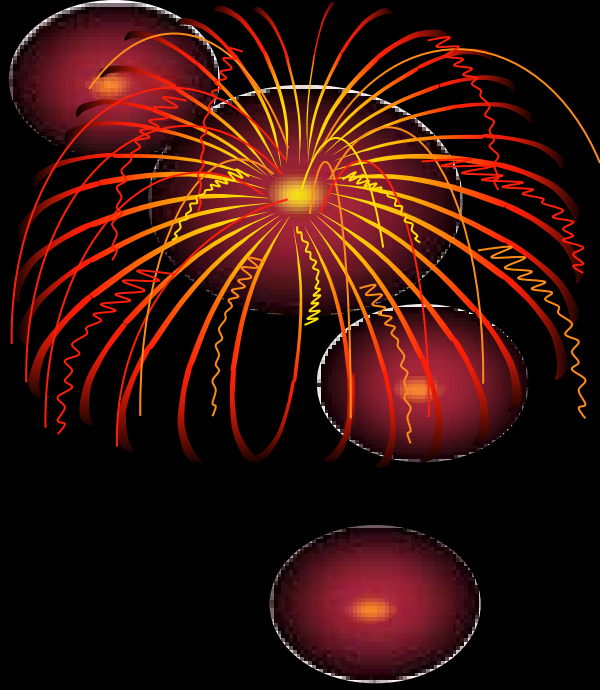


Multitasking

- Container steel
- Structural pipes?

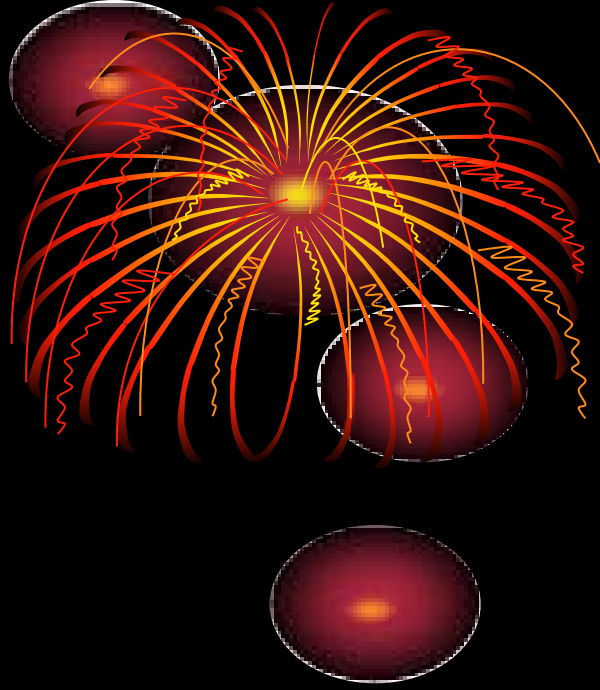


Multitasking



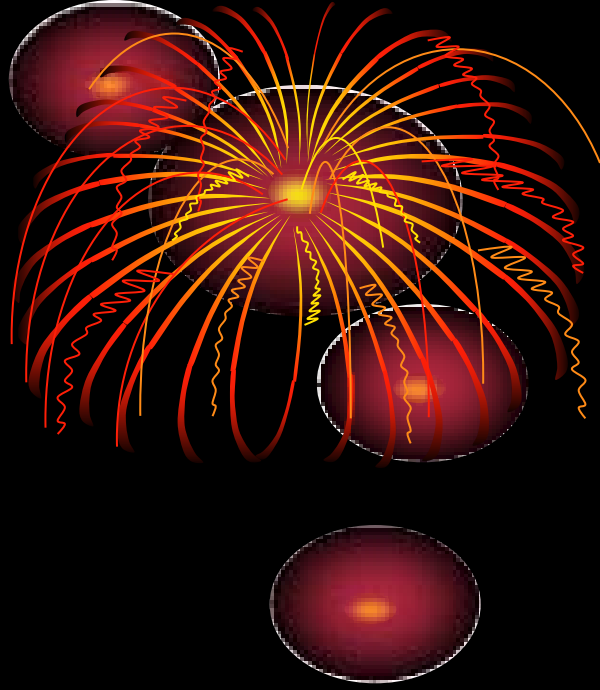
- Container steel
- Structural pipes?
- Conductive Structure?

Multitasking



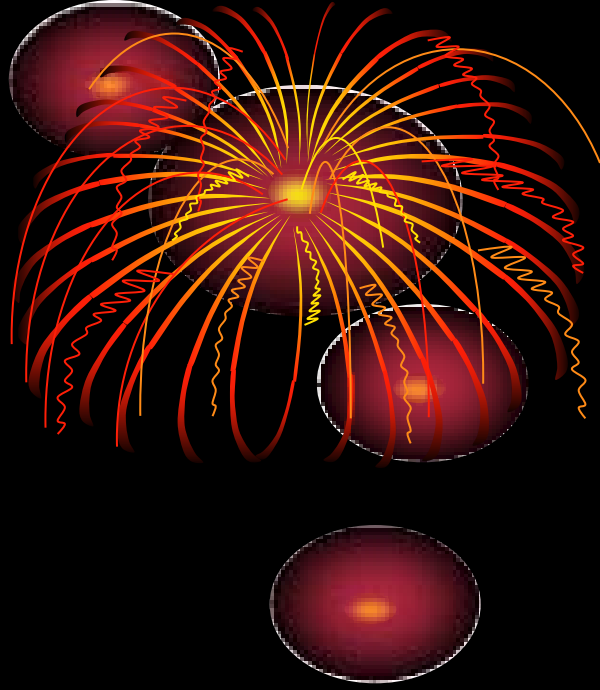
- Container steel
- Structural pipes?
- Conductive Structure?
  - It’s done in cars!

Multitasking



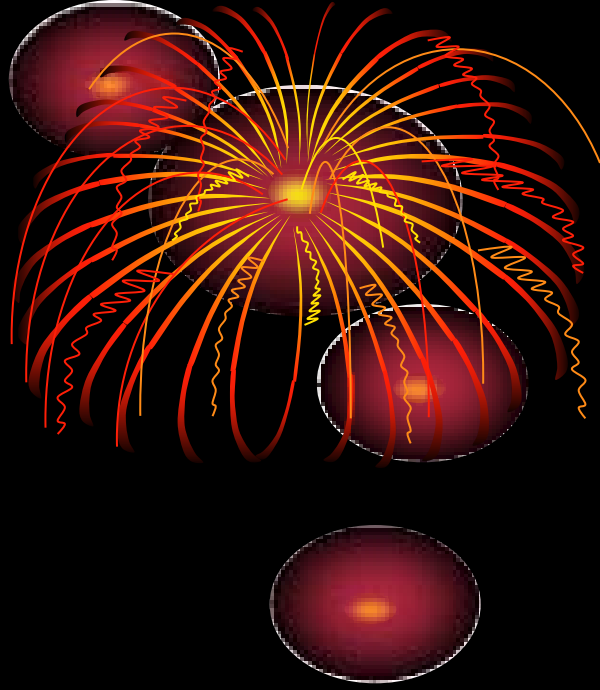
- Container steel
- Structural pipes?
- Conductive Structure?
- SKJOLD’s Insulation

Multitasking



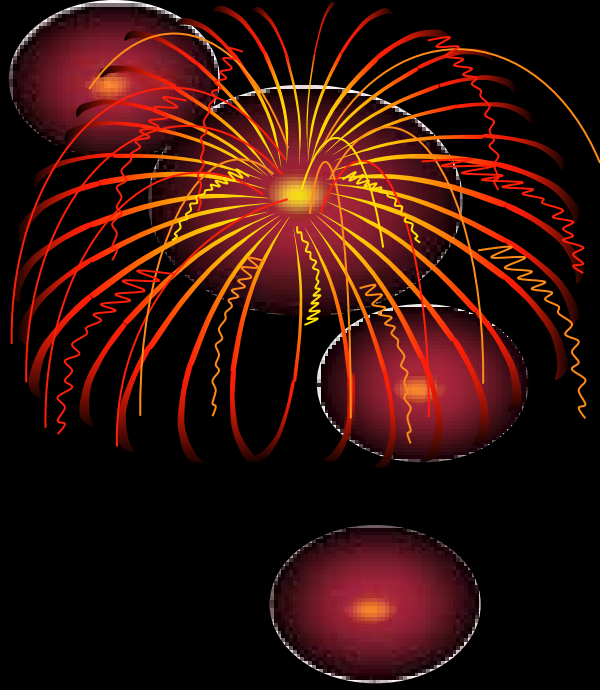
- Container steel
- Structural pipes?
- Conductive Structure?
- SKJOLD’s Insulation
  - Air conditioning in winter in Norway!

Multitasking



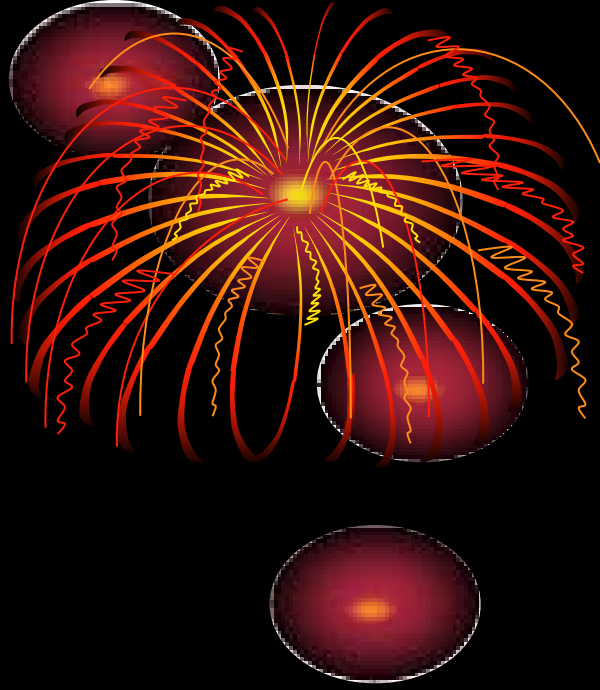
- Container steel
- Structural pipes?
- Conductive Structure?
- SKJOLD's Insulation
  - Air conditioning in winter in Norway!
  - (Maybe they went too far?)

Multitasking



- Container steel
- Structural pipes?
- Conductive Structure?
- SKJOLD’s Insulation
- Amory Lovins’ house

Multitasking

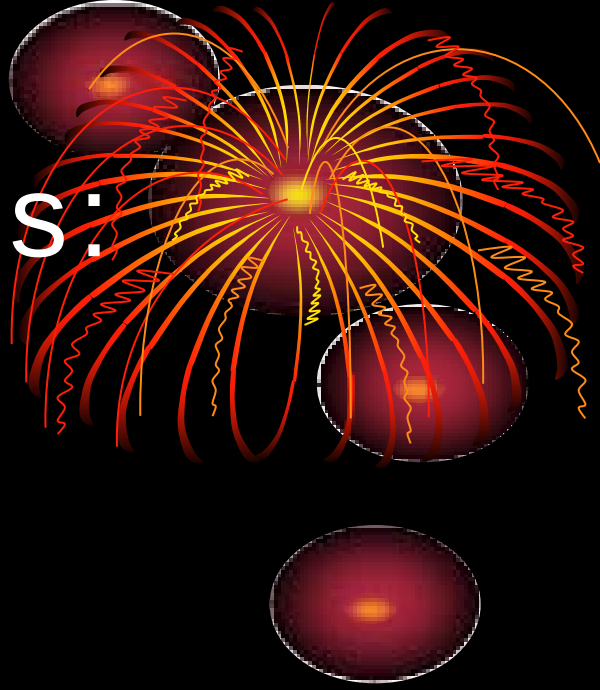


- Container steel
- Structural pipes?
- Conductive Structure?
- SKJOLD's Insulation
- Amory Lovins' house
  - The second root is a Colorado home with no furnace

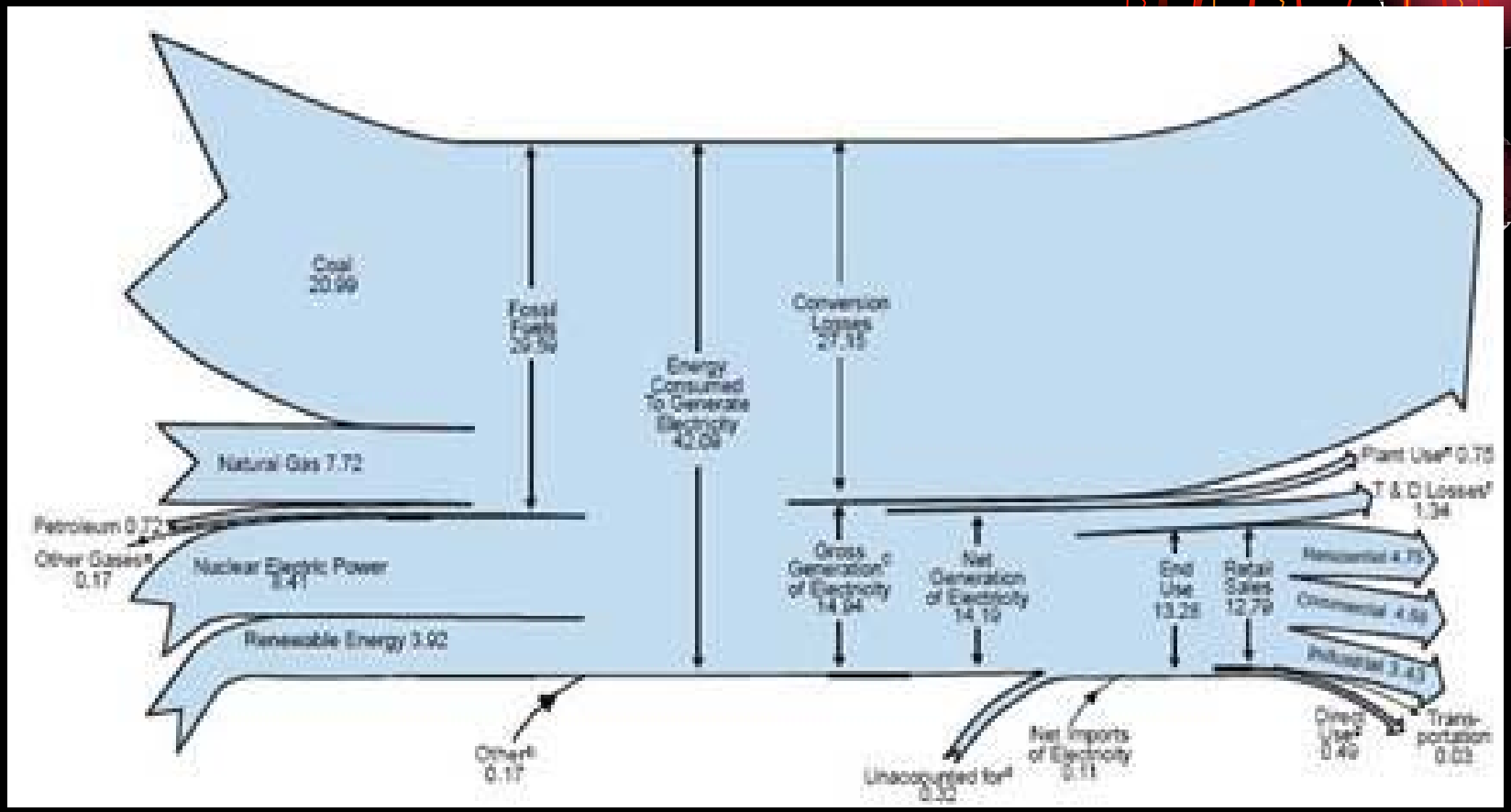
How is Breakthrough Possible?

- Techniques for finding it:
  - Multitasking
  - Muda-Elimination
  - Teleology

Real life is like this:

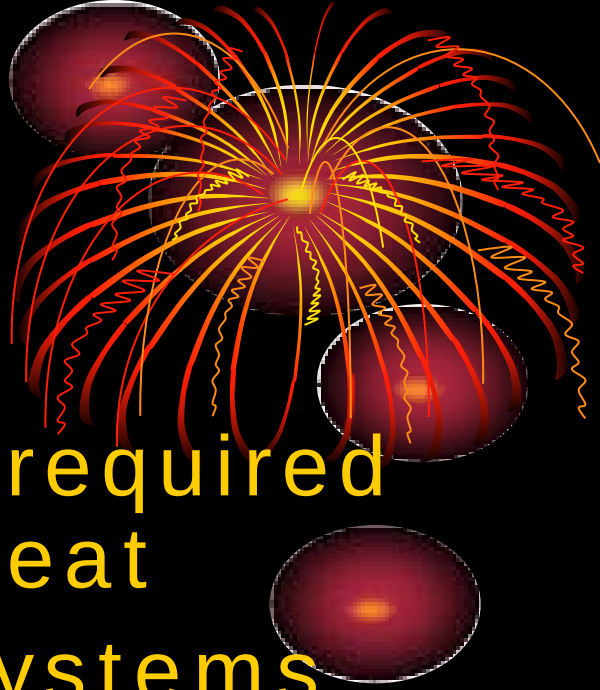


To get One out requires Three in



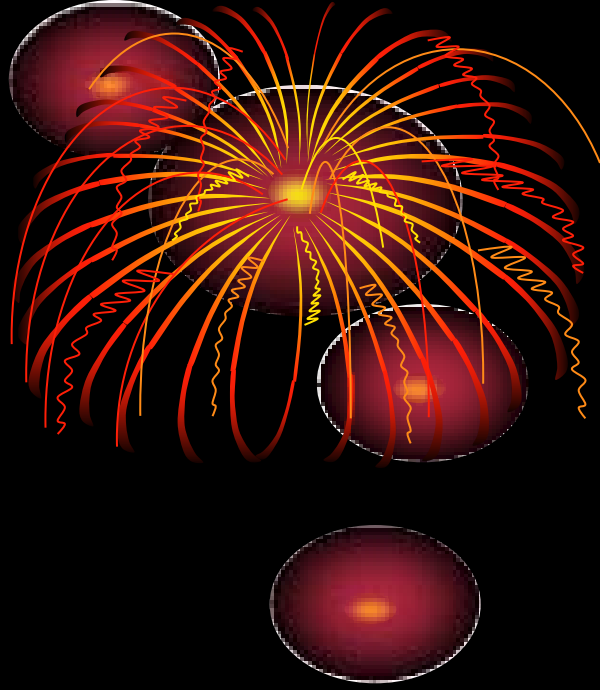
Source: EIA 2009

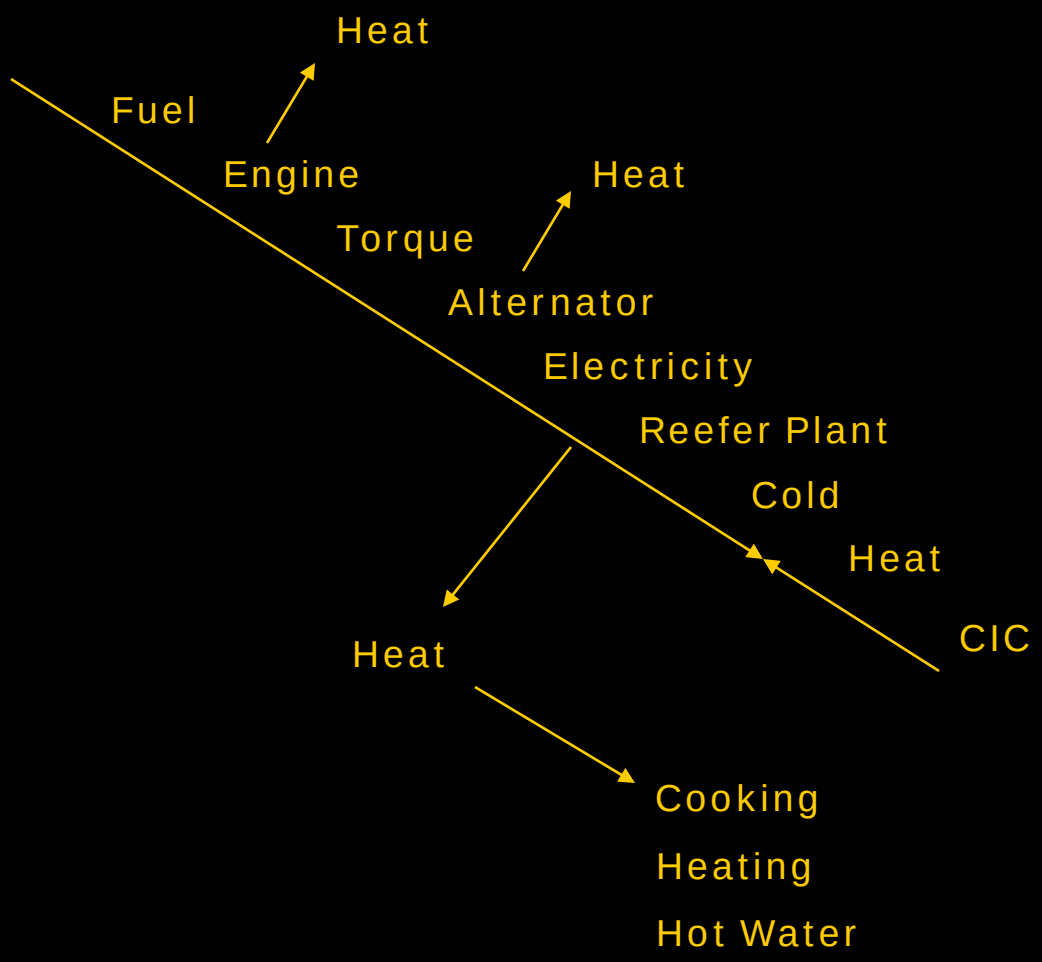
Another example: The Heating Plant



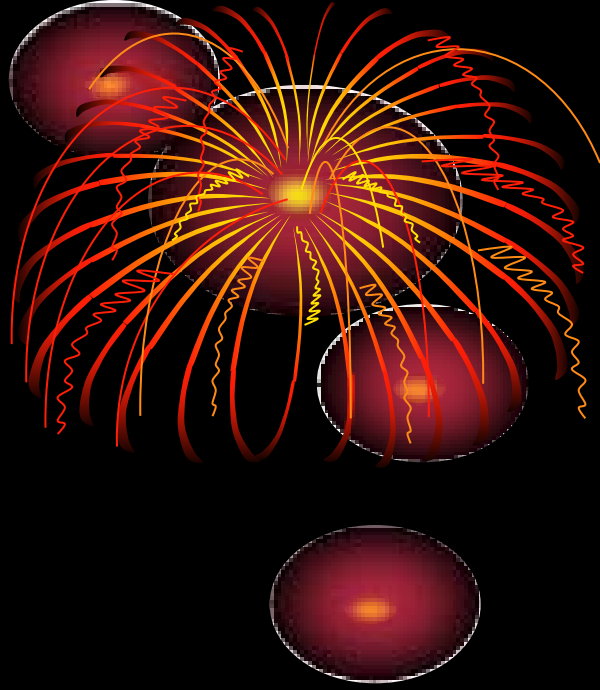
- Large complex system required to generate domestic heat
- Simultaneously other systems are cooling components to minimize heat
- Can I reduce the heat NEED far enough to ELIMINATE the heating plant?

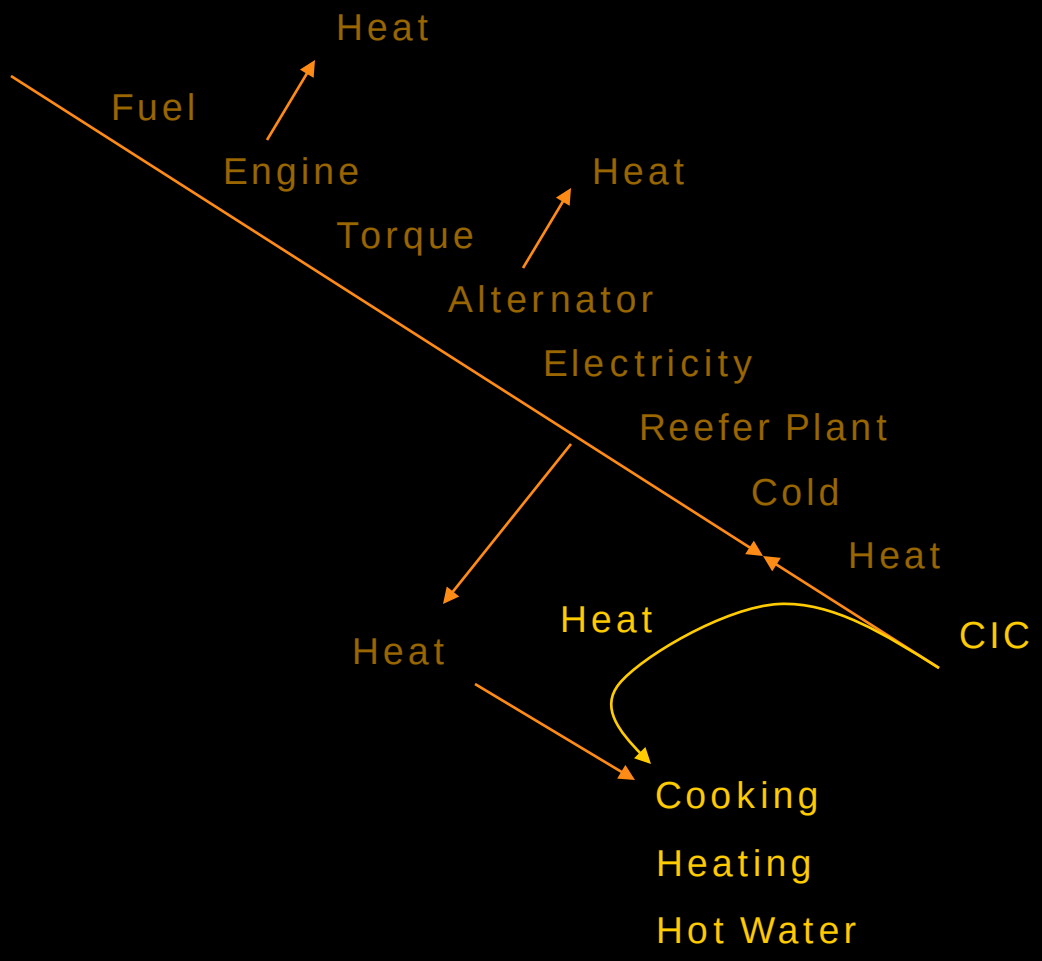
Heating & Cooling





Heating & Cooling





Amory's House

Snowmass CO. (Near Aspen) 7,000 feet above sea level

Amory’s house

This room is the "furnace" for the building. This 900-square-foot space, plus the heat gain from the other windows, lights, appliances, and people, provides all the heat that's needed for the entire building most of the year. The heat is stored in the masonry, the floor, the water, and the earth under the house. Because of the building's huge thermal capacity, heat is stored for months, not just hours. Heat captured in September may be used in December. Two wood stoves are available for additional heating duty, but they are generally used only on very cold winter mornings.

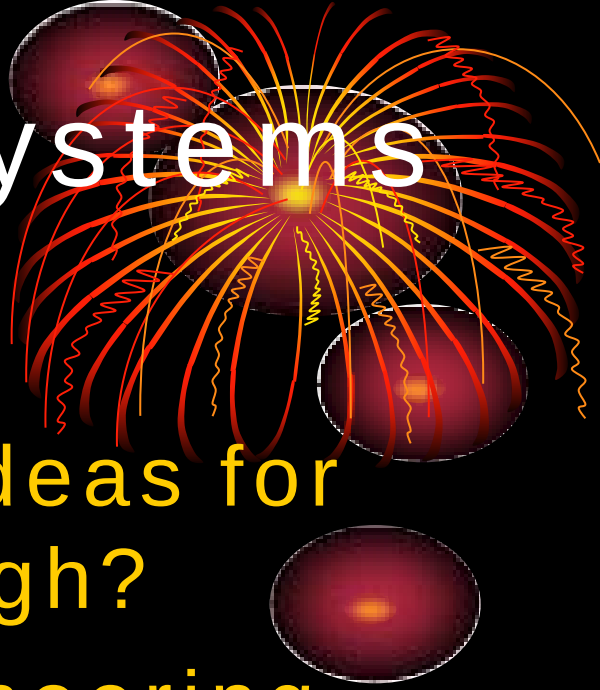
Amory's house

- By reducing the DEMAND
- And MINIMIZING THE WASTE
- Dr. Lovins ELIMINATED THE HEATING PLANT

Amory's House

- Most the impact of being super-green was to leave things out, not add things.
- The cost of the alternative energy systems was, in 1984, $6100.
- The cost of energy to heat the house would have been $7000.
- Payback in ten months.

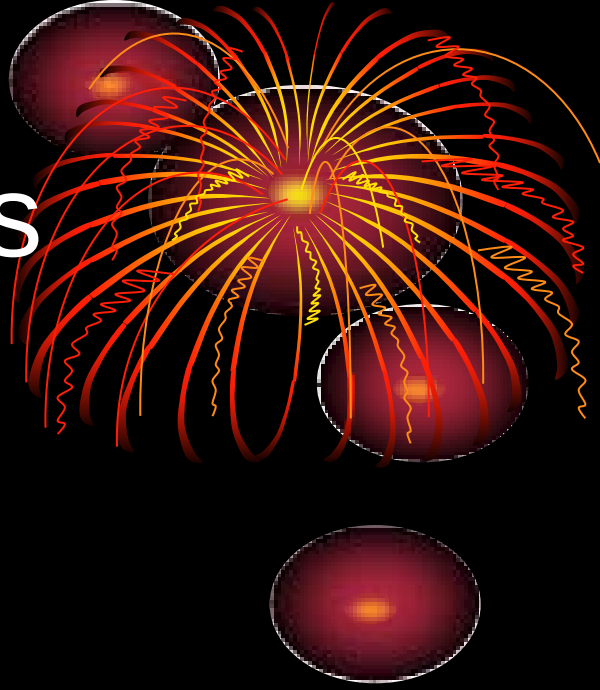
Unconventional Systems Engineering



- Where do you get the ideas for this type of breakthrough?
- How do you apply engineering methods to this?

Where to get ideas

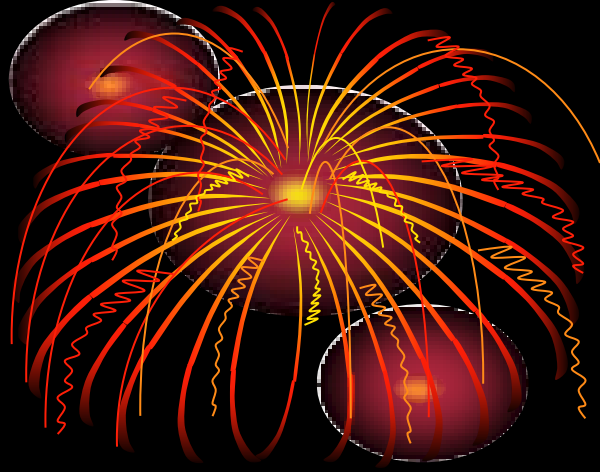
- One tool: Teleology



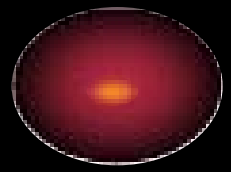
How is Breakthrough Possible?

- Techniques for finding it:
  - Multitasking
  - Muda-Elimination
  - Teleology

Normally

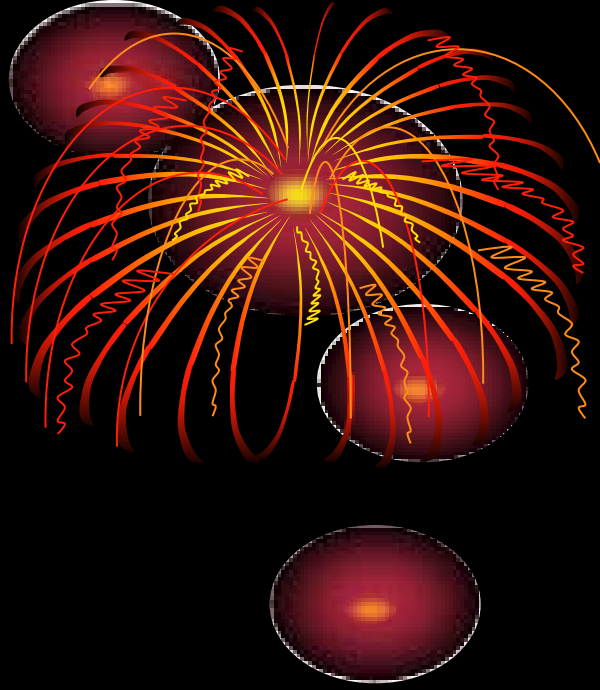


- Prior Art:
  - “What does a ship rudder look like?”

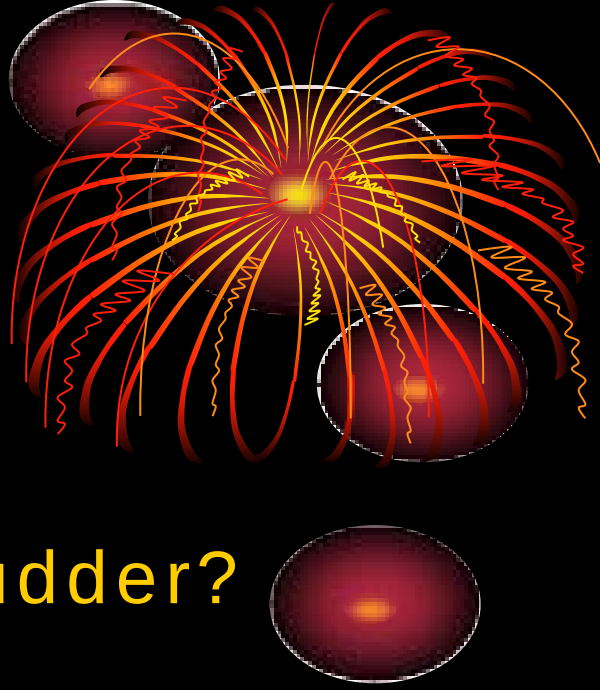


Teleology

- The study of purpose

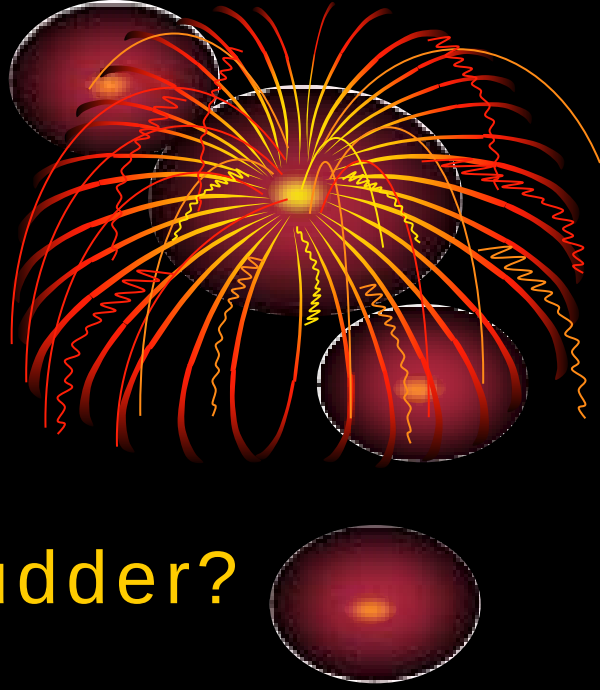


Teleology



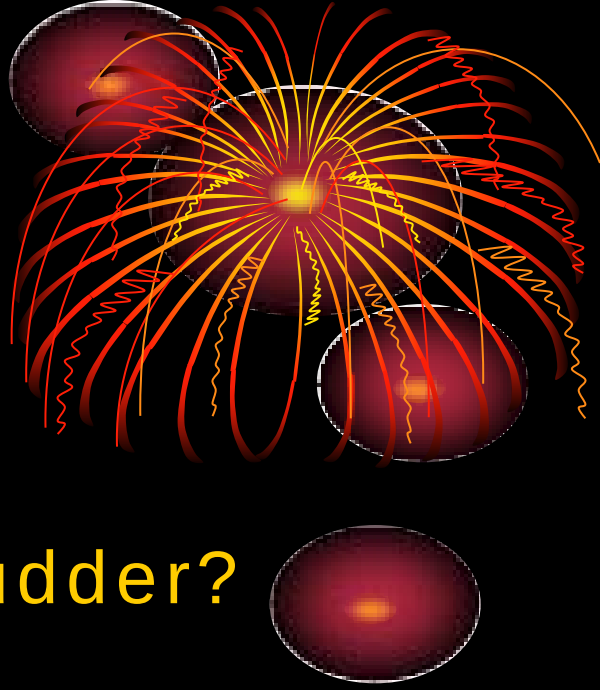
- The study of purpose
- What is the purpose of a rudder?

Teleology



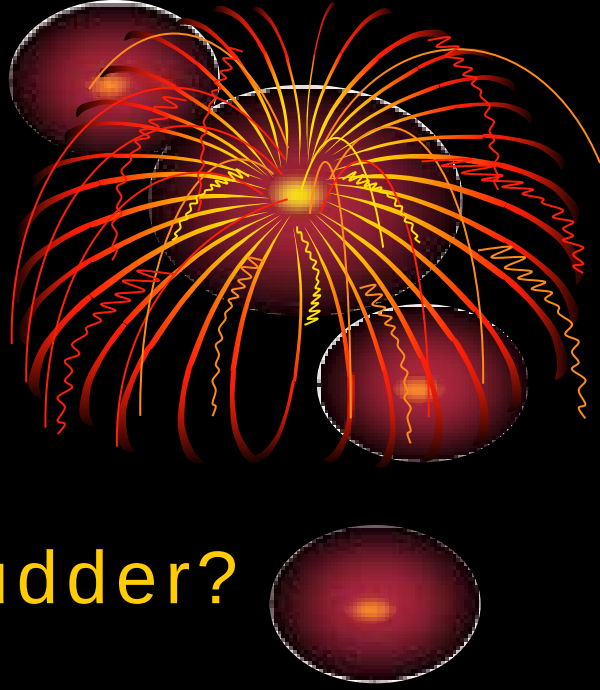
- The study of purpose
- What is the purpose of a rudder?
  - Direction

Teleology



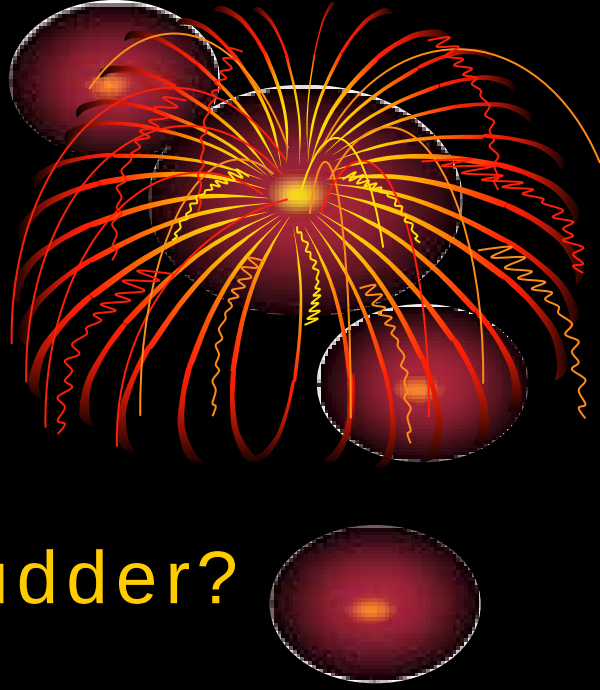
- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?

Teleology



- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?
  - Rudders

Teleology

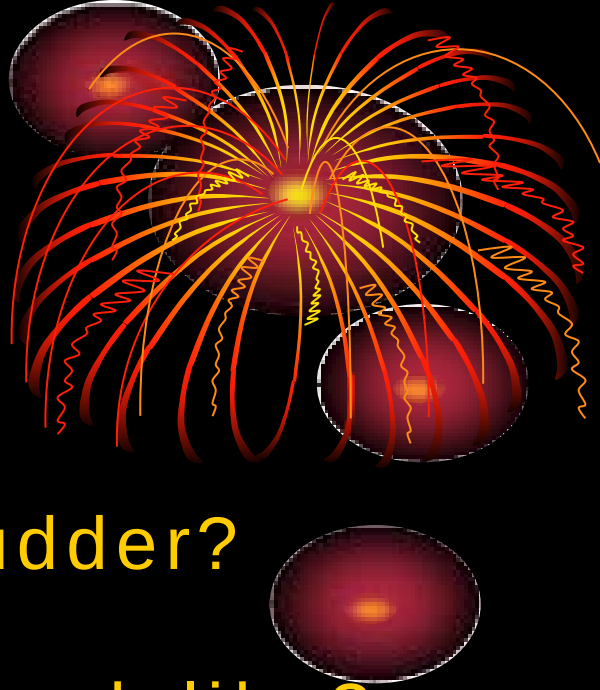


- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?
  - Rudders
  - Combined rudder propellers

Teleology

- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?
  - Rudders
  - Combined rudder propellers
  - Horizontal rudders

Teleology

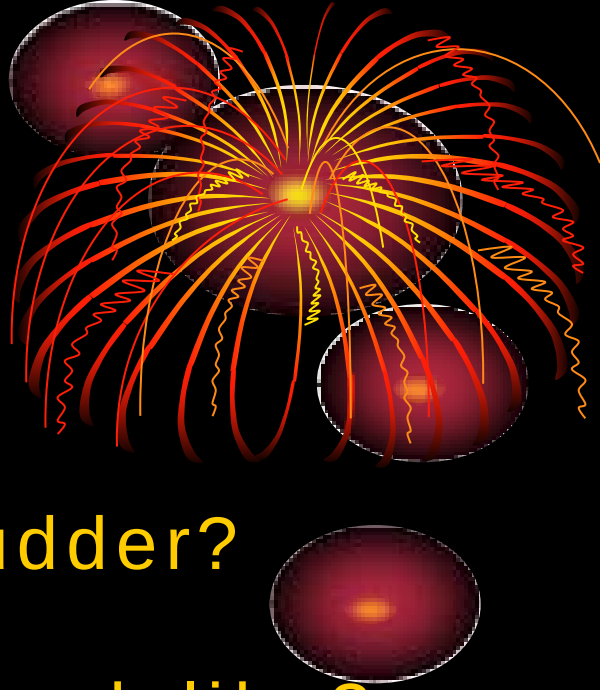


- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?
  - Rudders
  - Combined rudder propellers
  - Horizontal rudders
  - Differential thrust

Teleology

- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?
  - Rudders
  - Combined rudder propellers
  - Horizontal rudders
  - Differential thrust
  - Lateral forces

Teleology



- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other “directors” look like?
  - Rudders
  - Combined rudder propellers
  - Horizontal rudders
  - Differential thrust
  - Lateral forces
  - Ballistics

Teleology

- The study of purpose
- What is the purpose of a rudder?
  - Direction
- What do other directors look like?
  - Rudders
  - Canned rudder propellers
  - Horizontal rudders
  - Differential thrust
  - Lateral force
  - Ballistics

"Teleology" is defining the system boundary around the Problem

Teleology

- “TRIZ” (Theory of Inventive Problem Solving) is a Teleology tool
- “ARI” – Accelerated Radical Innovation

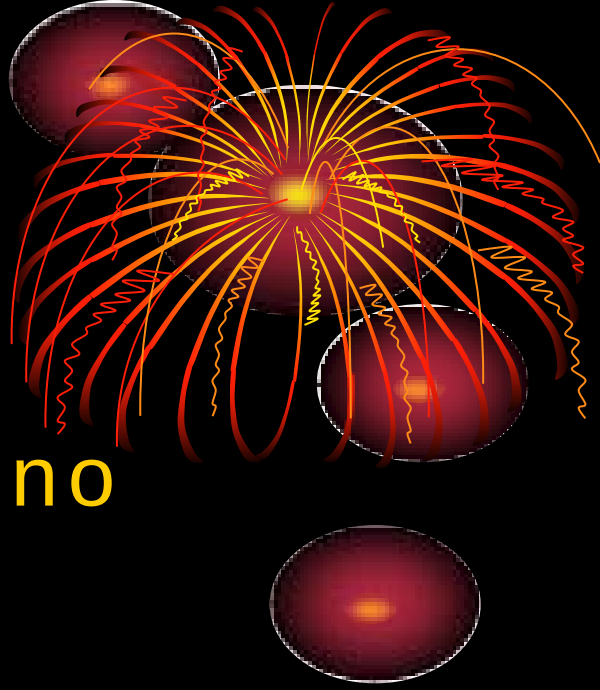
Where to get ideas

- One tool: Teleology
- Second tool: Eliminate Muda

Eliminate Muda

Muda

- That for which there is no customer



How do you eliminate Muda?

- 1: Get rid of it
- 2: Find a customer for it

A Cooling system

- Teleology: Remove unwanted heat
- Teleological Solutions:
  - Radiate it
  - Convect it
  - Insulate from it
  - Etc.

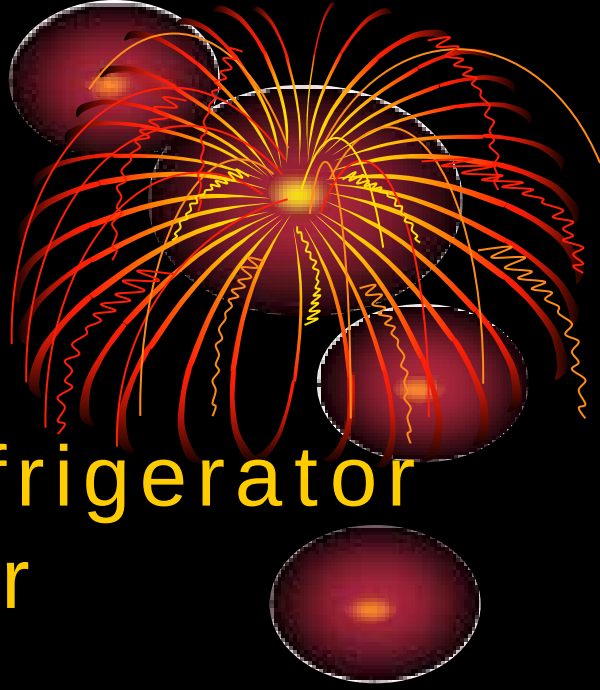
A Cooling system

- Teleology: Remove unwanted heat
- Muda Solution:
  - Don’t make unwanted heat

A Cooling system

- Teleology: Remove unwanted heat
- Muda Solution:
  - Don’t make unwanted heat
  - Change it from “unwanted” to “wanted”

Maybe...

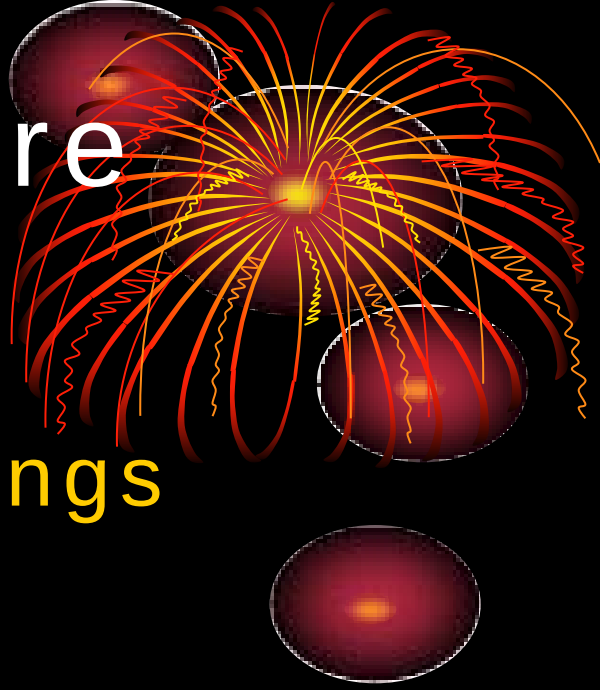


- The best dorm room refrigerator is a taste for warm beer

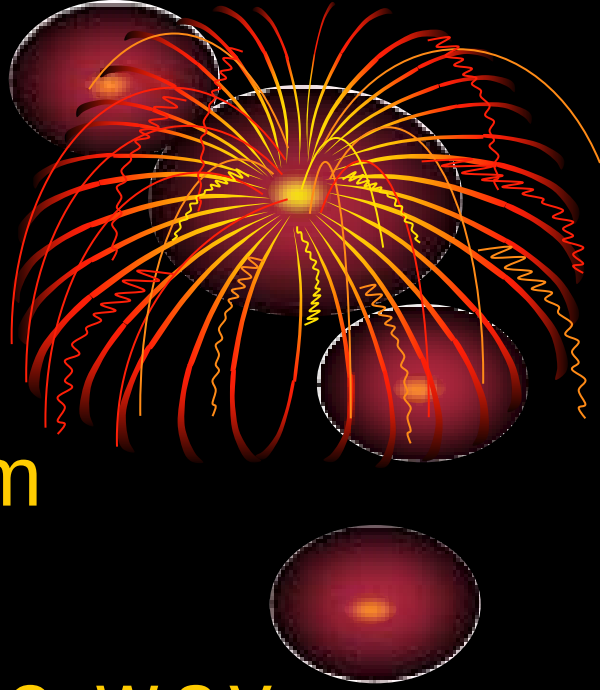
Dear ONR:

- You want a breakthrough in reducing the weight of shipboard cooling systems?
- Invest in systems that don't need to be cooled
  - ceramic engines
  - electronics that like to run hot

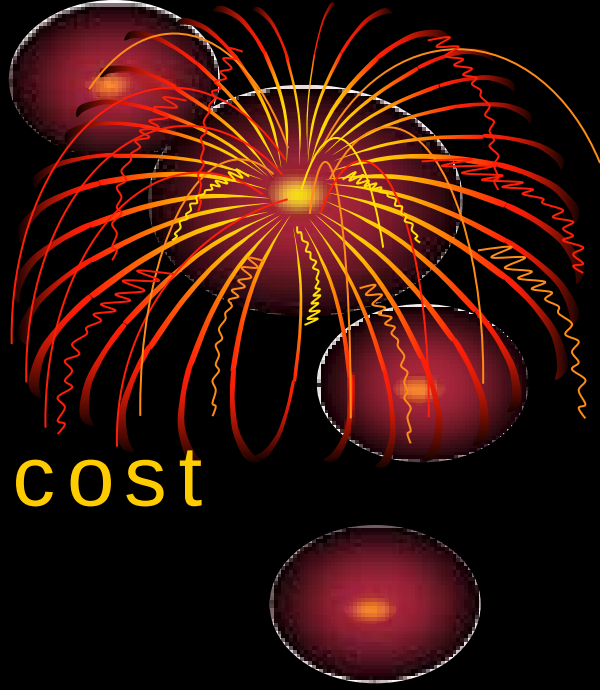
Too exotic? A more prosaic example:



- Double resilient mountings



- Decompose the problem Teleogically
- Take the benefits all the way upstream
- Look far afield for Teleos
- Be creative in eliminating Muda



- Very large savings can cost LESS than small ones

The Truth

- The Cost/Benefit relationship is not necessarily monotonic

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- It may not even be Continuous

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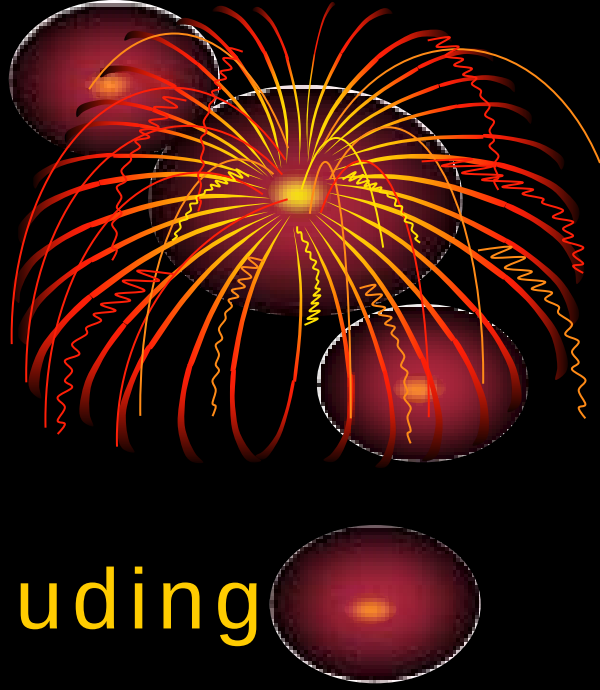
The Truth

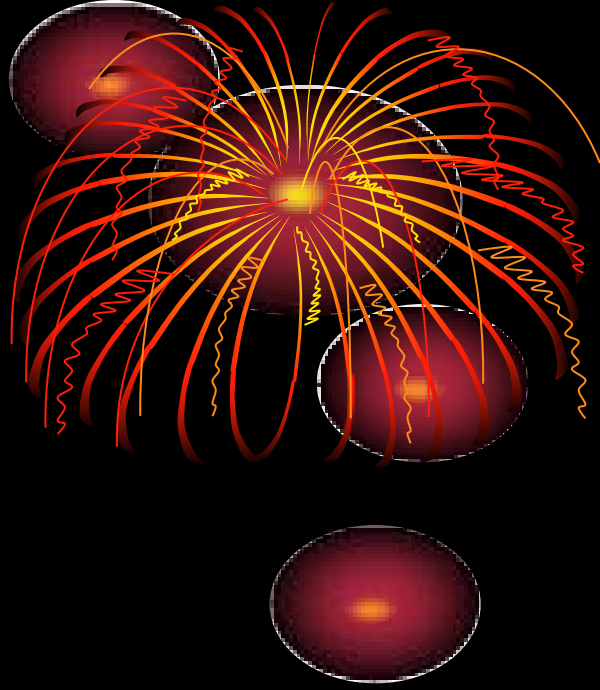
- The Cost/Benefit relationship is not necessarily monotonic
- It may not even be Continuous
- Incremental solutions CAN NOT find the ‘second root.’
- Practical tools exist

Practical Tools



- Multitasking
- Teleological Study, including TRIZ
- Muda elimination

EXAMPLES
(if time permits)



Muda?

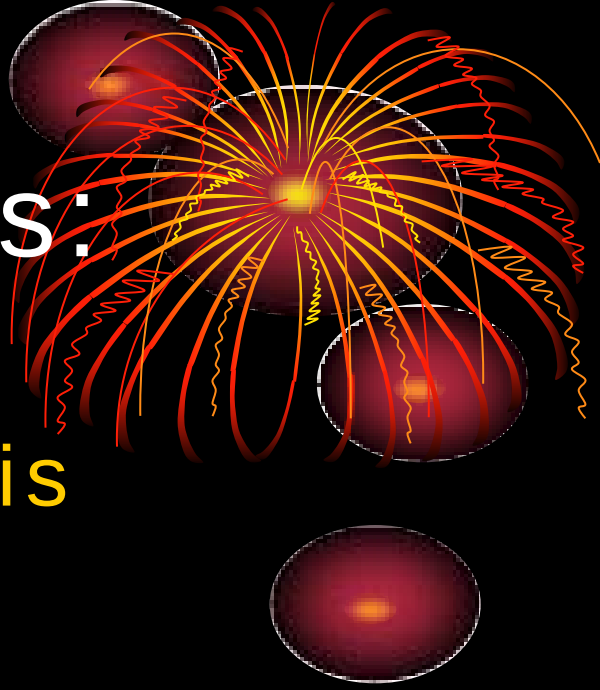
Teleology

Teleology

Teleology in My Home:

- How do you mount a Christmas tree on a sailboat?

Innovative process:



- Find out what the goal is

Innovative process:

- Find out what the goal is
  - How to fix the base to the tree?

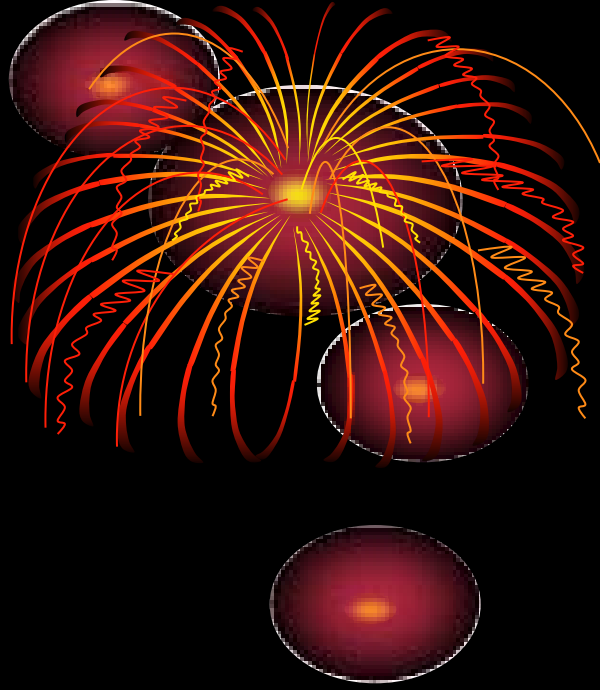
Innovative process:

- Find out what the goal is
  - ~~How to fix the base to the tree?~~
  - How to fix the tree to the floor or table?

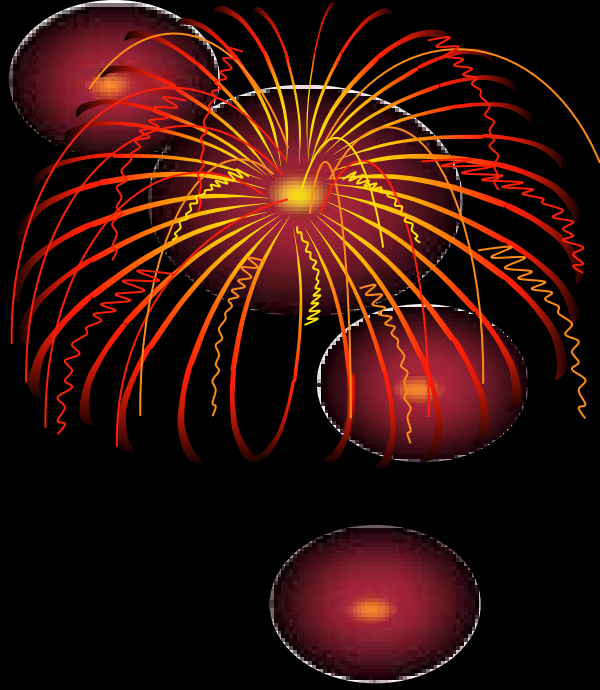
Innovative process:

- Find out what the goal is
  - ~~How to fix the base to the tree?~~
  - ~~How to fix the tree to the floor or table?~~
  - How to maintain the tree in a vertical orientation

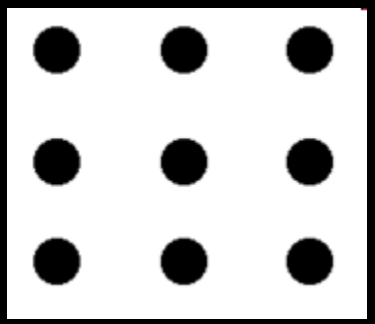
Back-Up



Outside the Box



Outside the Box



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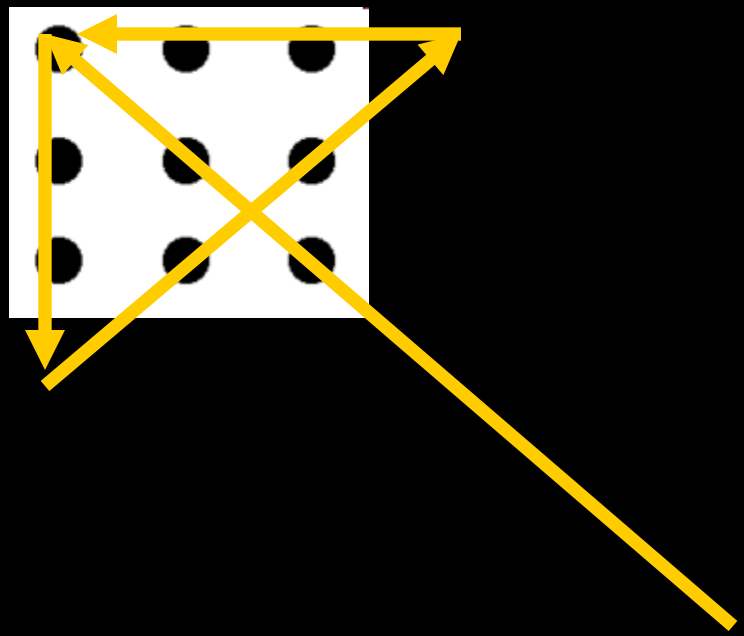
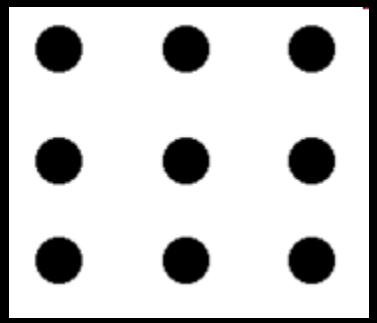


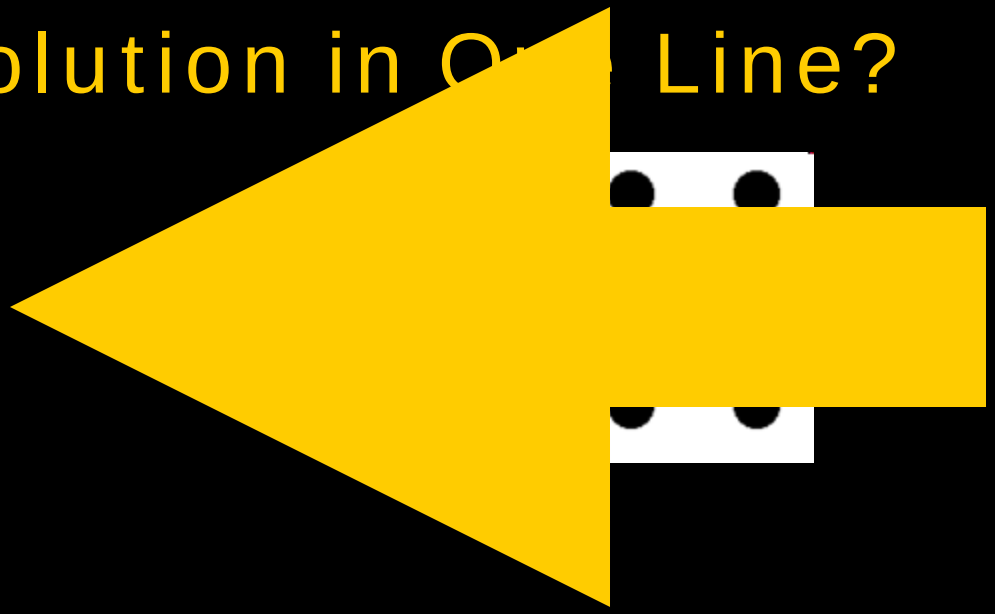
Outside the Box

- Solution in One Line?



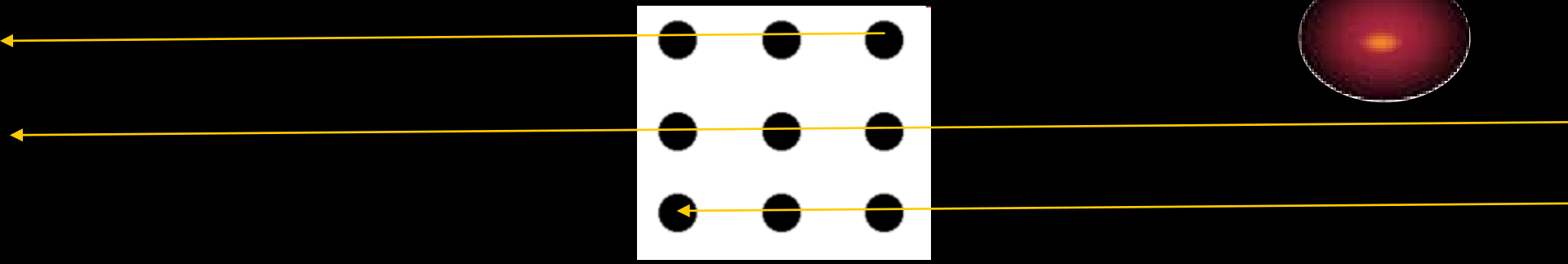
Outside the Box

- Solution in O[illegible] Line?

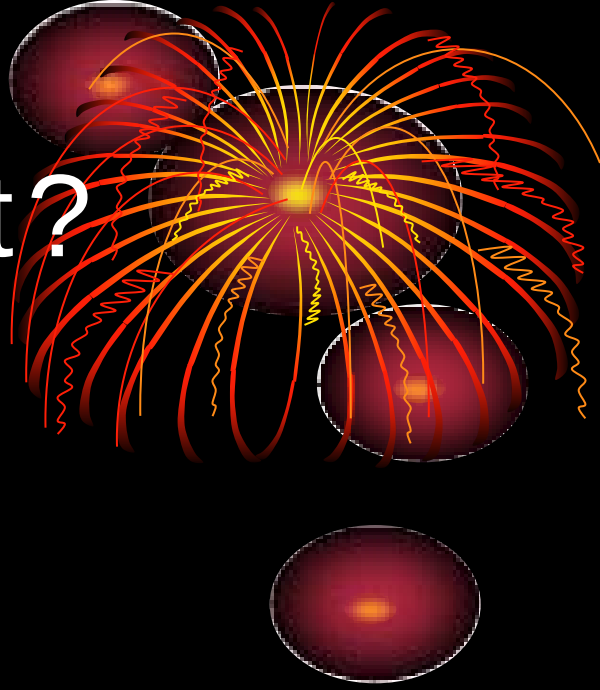


Outside the Box

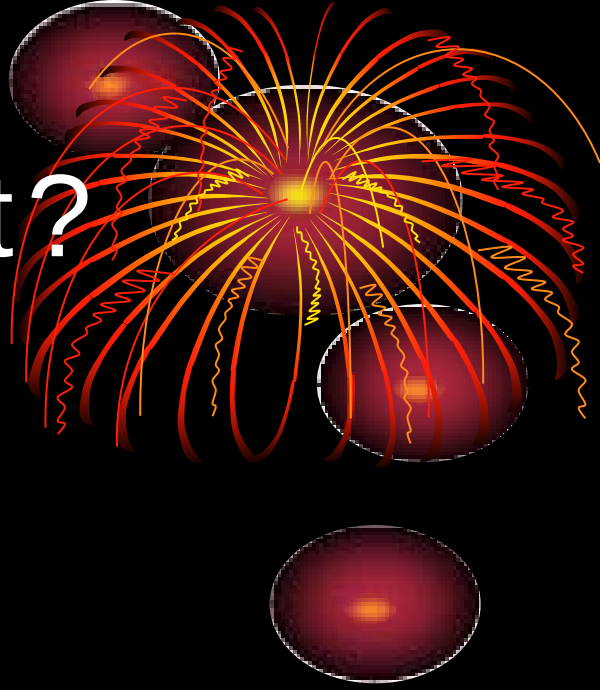
- Solution in One Line?



Can Anybody Do It?



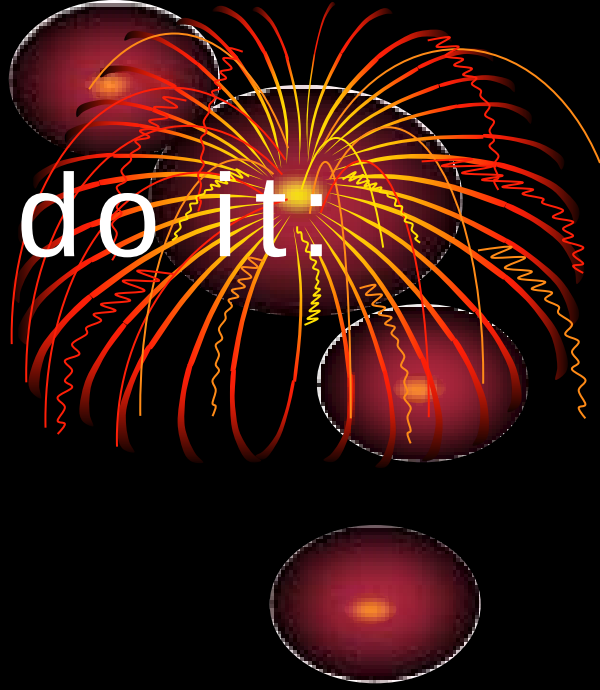
Can Anybody Do It?



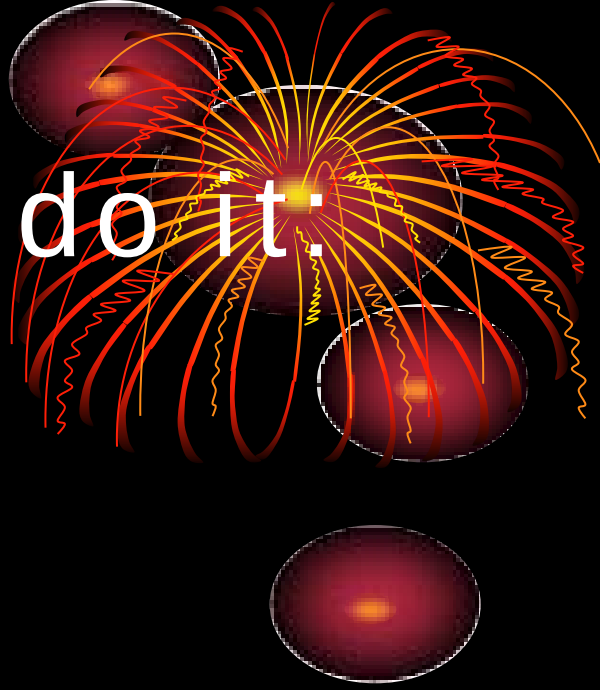
- No.

Not everyone can do it:

- Math

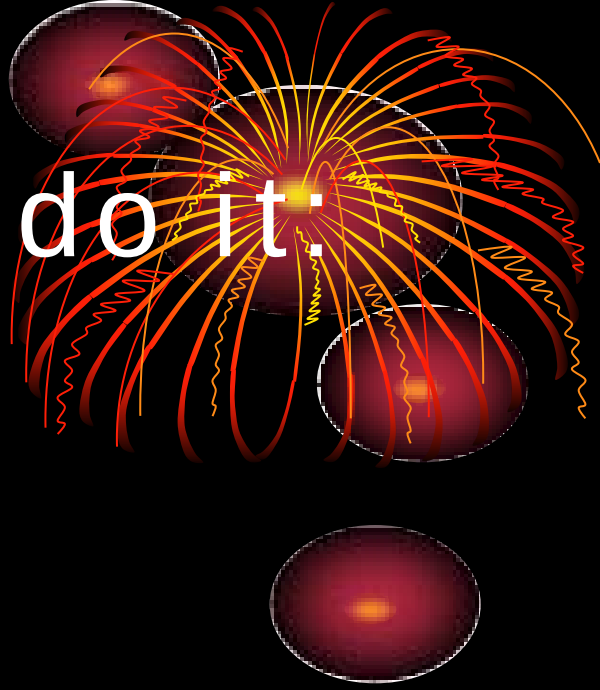


Not everyone can do it:



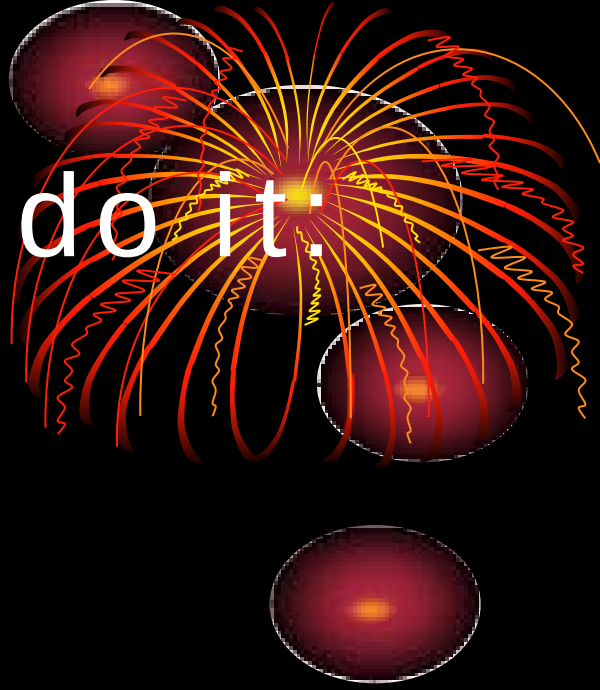
- Math
- Engineering Analysis

Not everyone can do it:



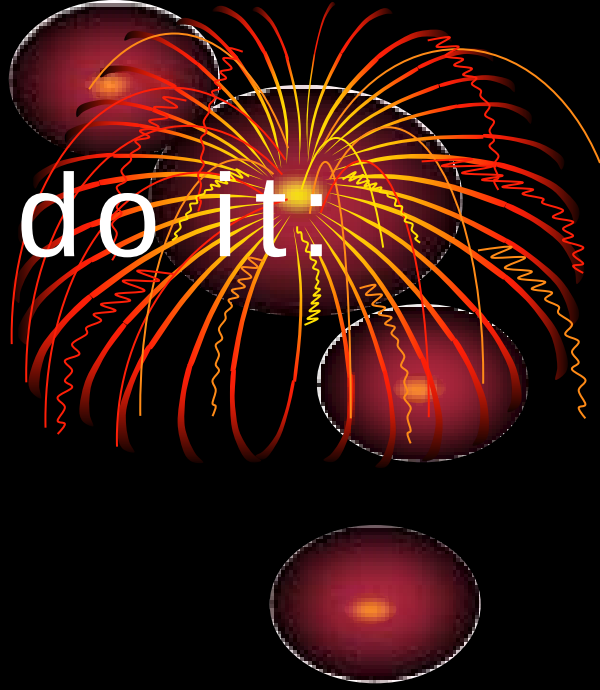
- Math
- Engineering Analysis
- Engineering Synthesis

Not everyone can do it:



- Math
- Engineering Analysis
- Engineering Synthesis
- Engineering Innovation

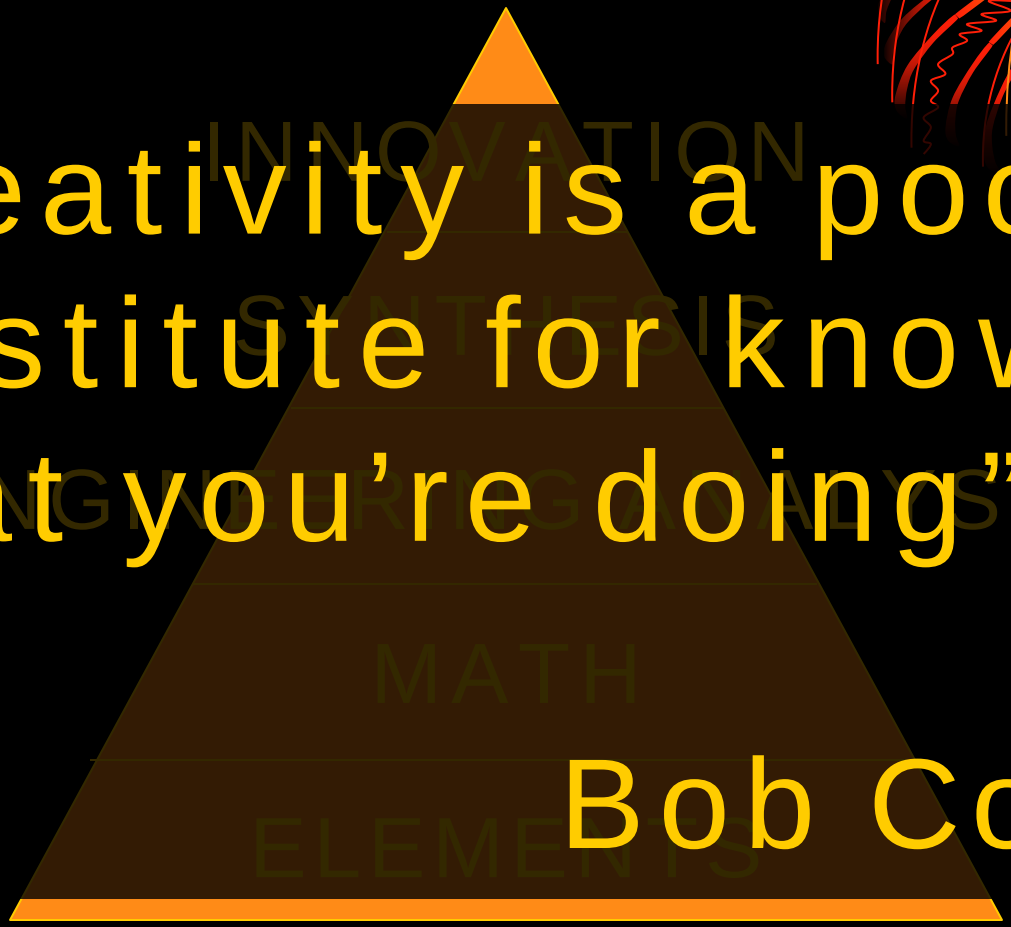
Not everyone can do it:



- Math
- Engineering Analysis
- Engineering Synthesis
- Engineering Innovation

Not a value – just a fact

Caveat:



"Creativity is a poor substitute for knowing what you're doing"

Bob Colwell