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Counter-Intuitive Systems Engineering

McKesson, Chris

Monterey, California: Naval Postgraduate School

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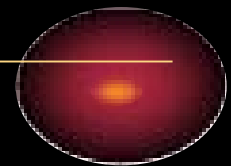
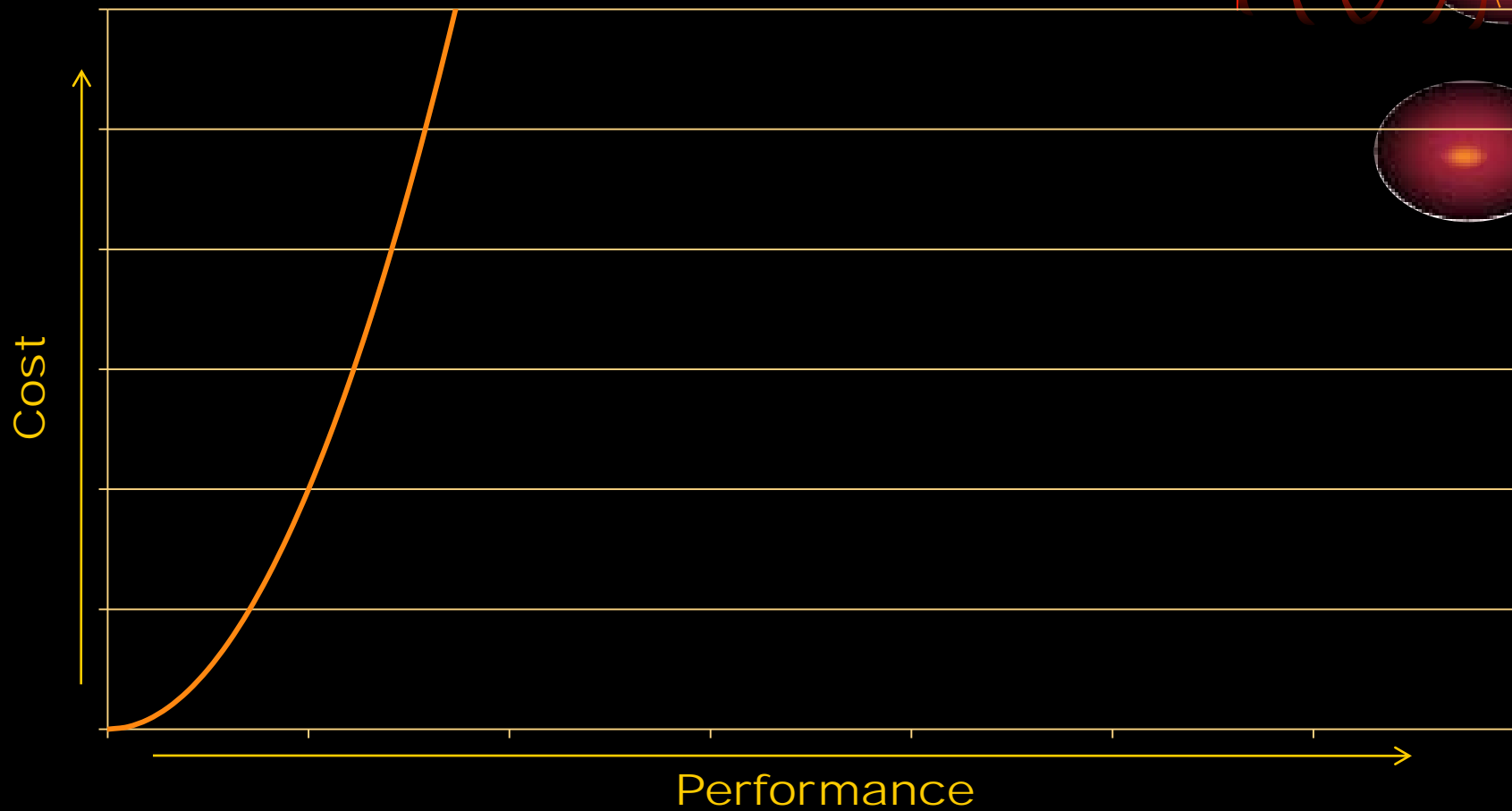
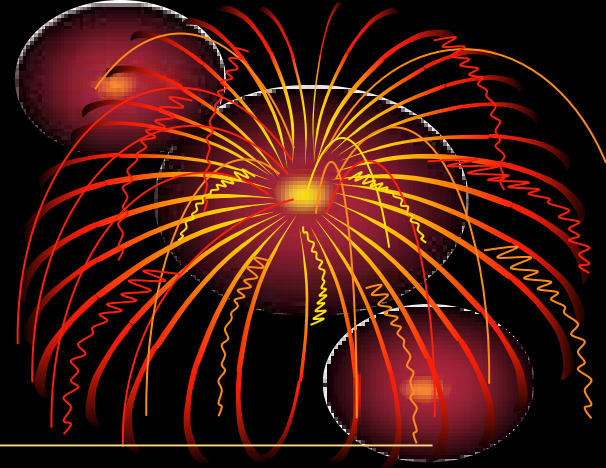


Counter-Intuitive Systems Engineering

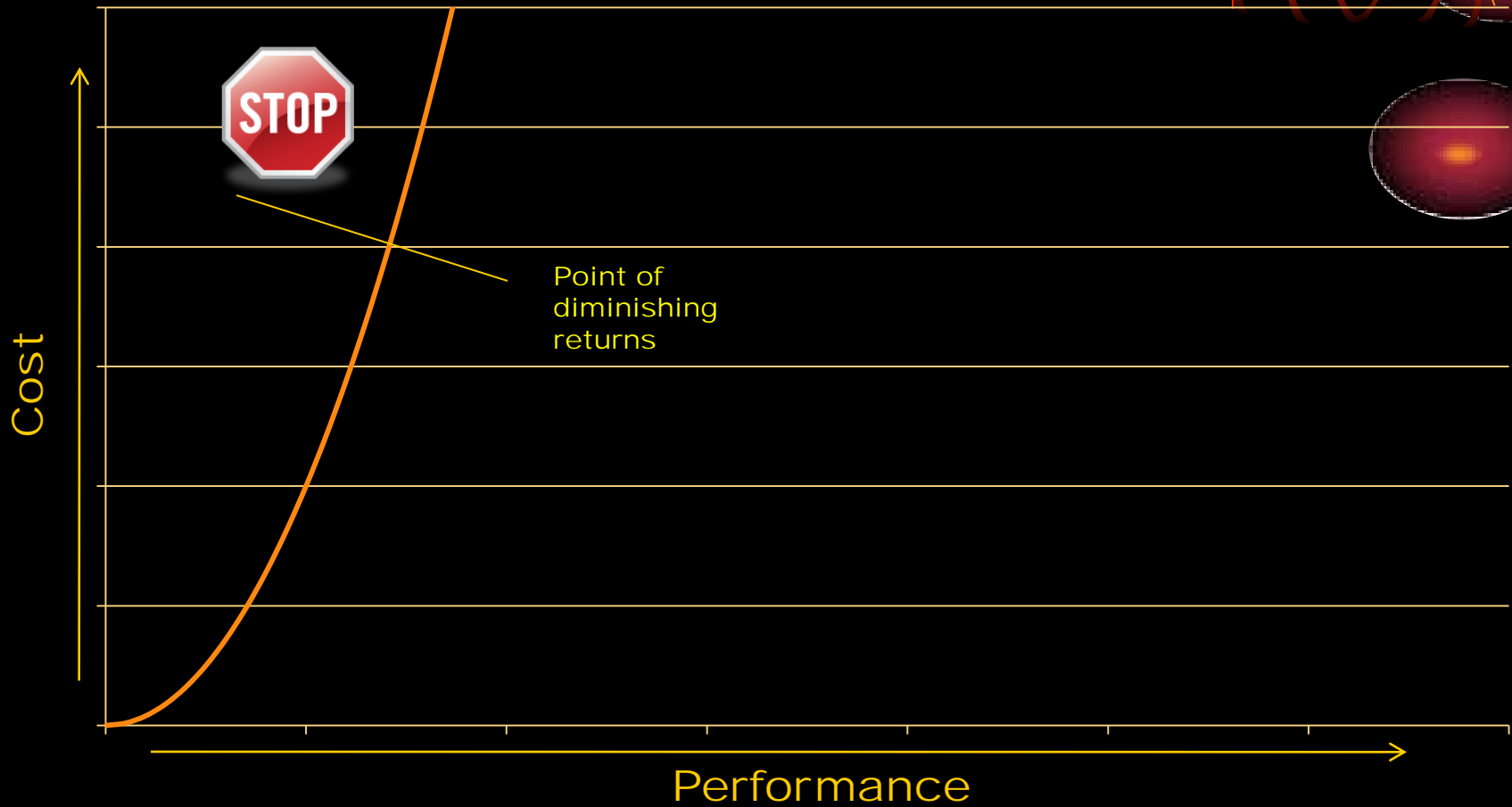
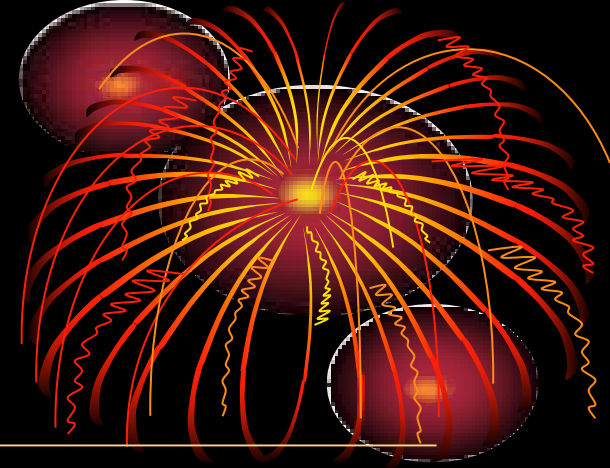
Tunneling Through The
Cost Barrier



We are taught...



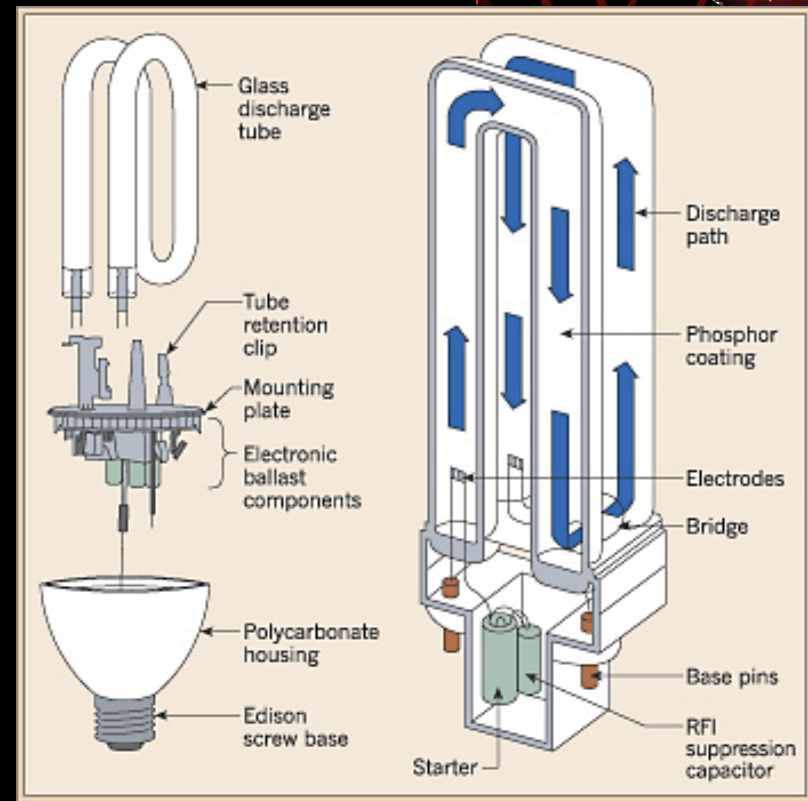
We are taught...



Example: Change the light bulbs to CFL

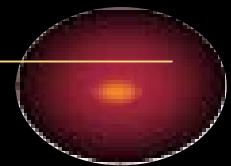
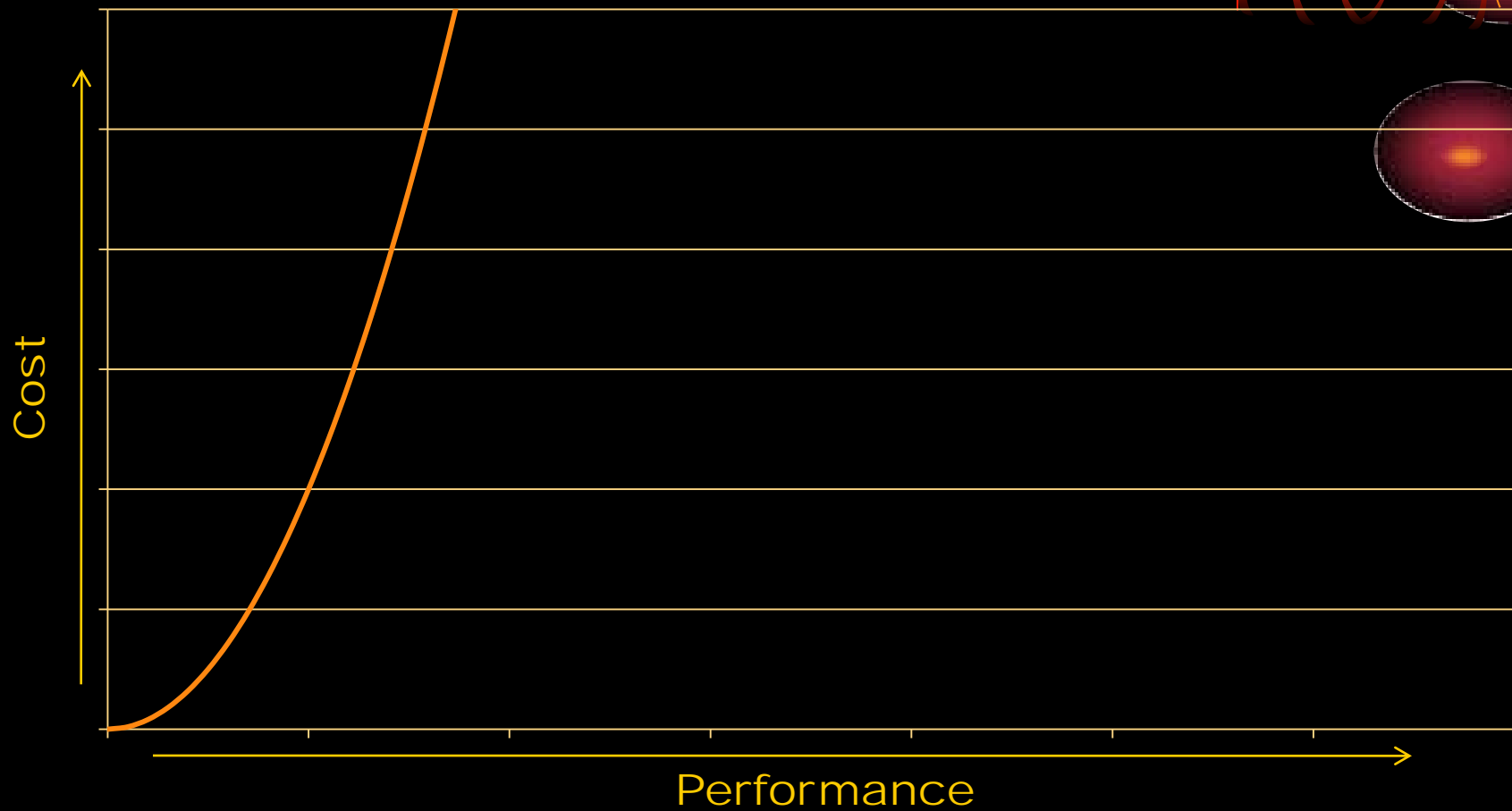
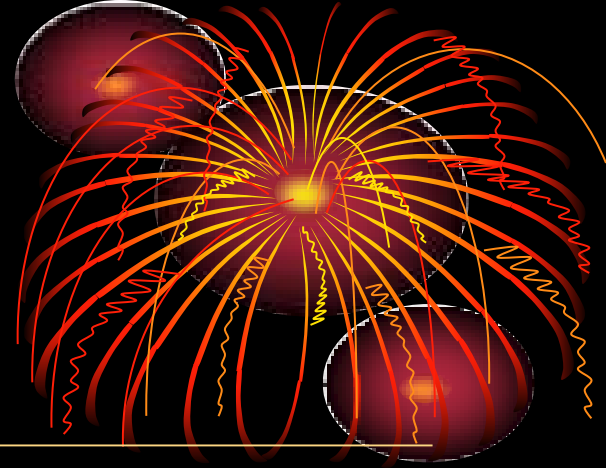


- Save: 75W each
- Cost: \$10 each
- Net: \$133 / kW saved
- Life: 1000 h
- Savings: 75 kWh
- Cost of savings: \$0.075 / kWh

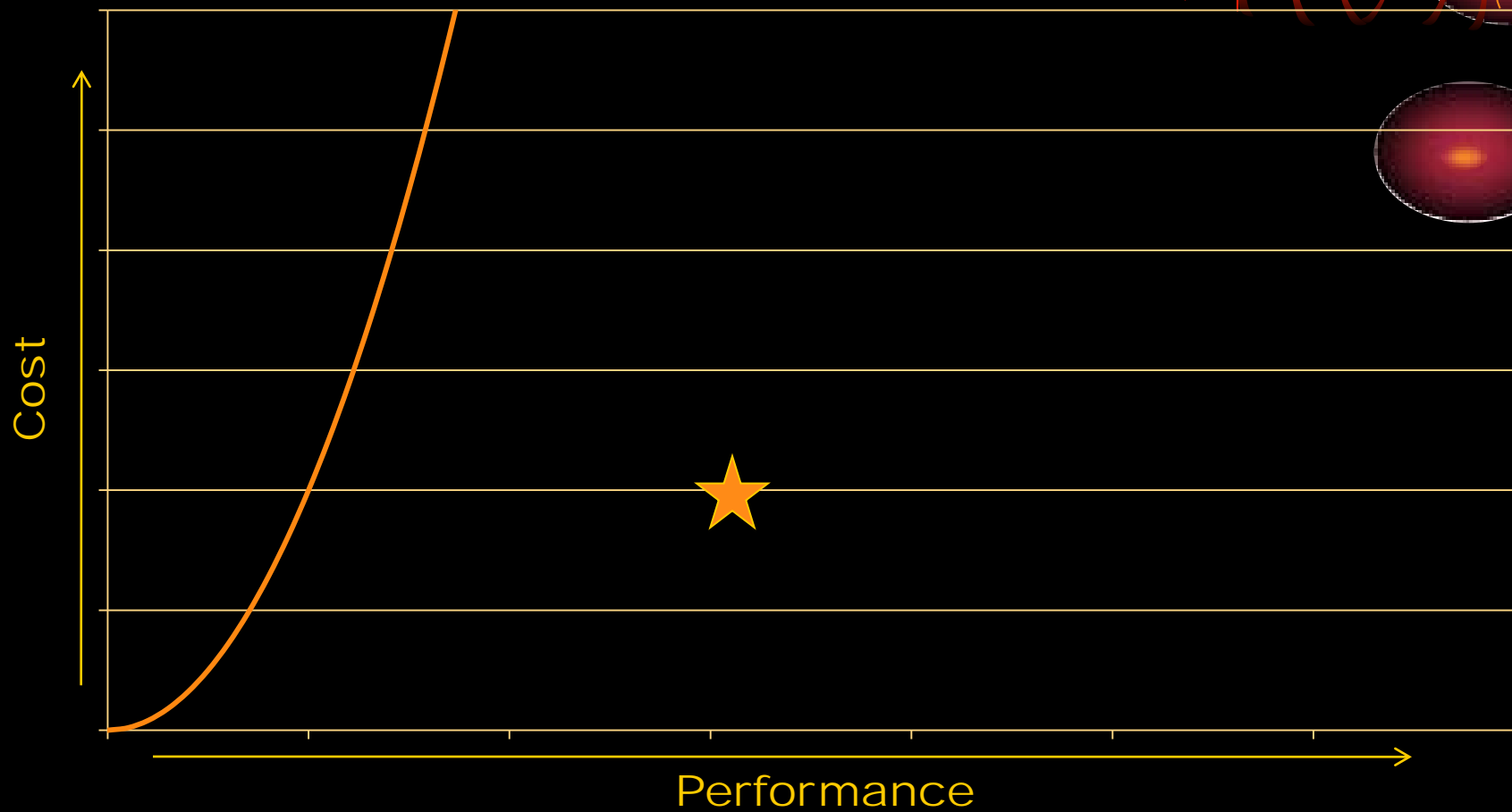
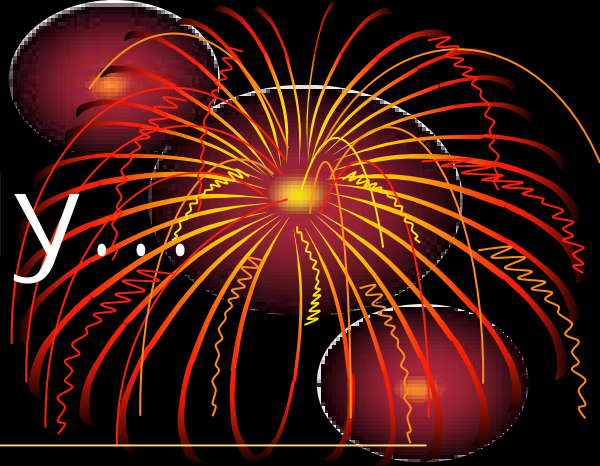




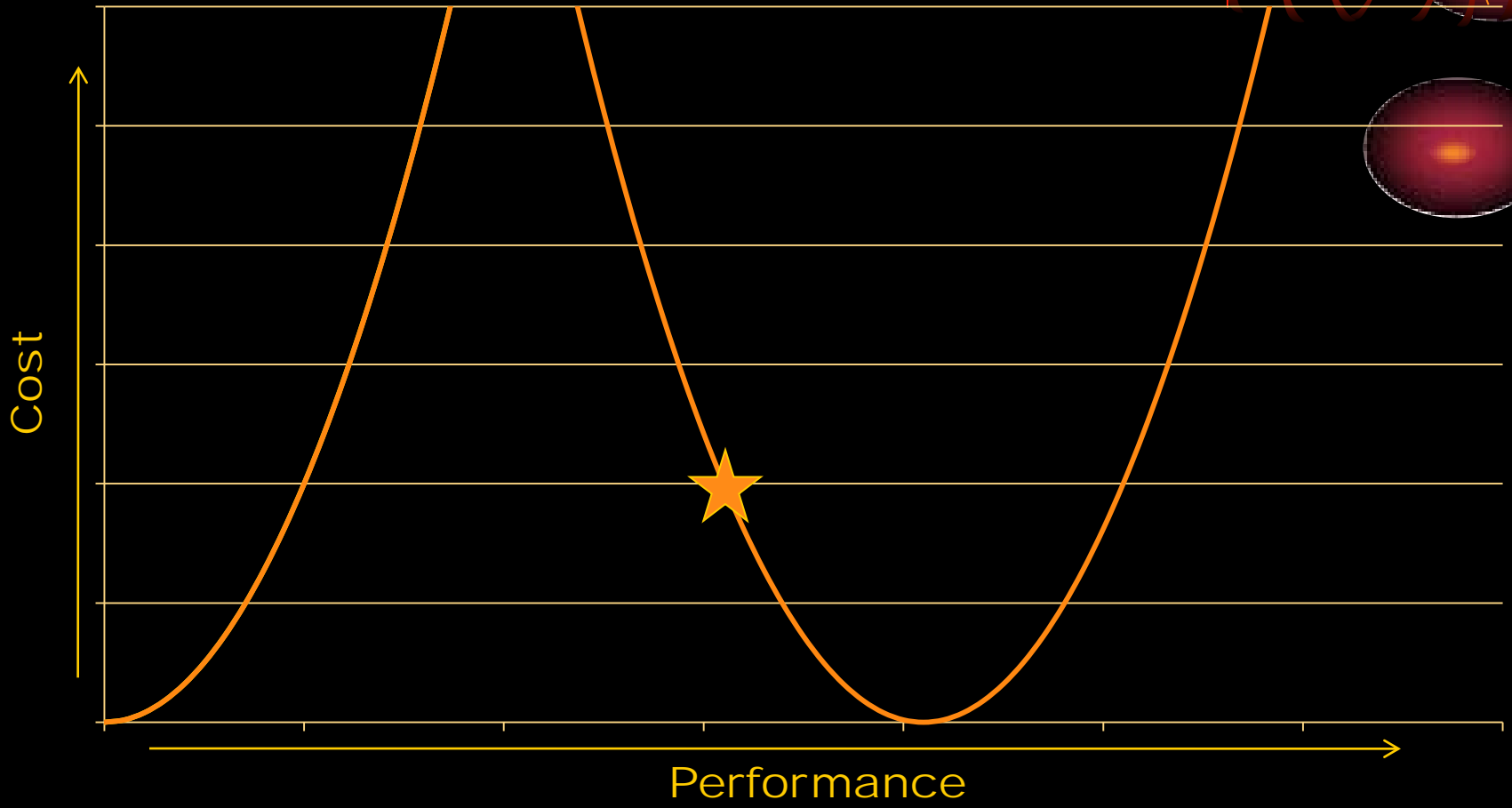
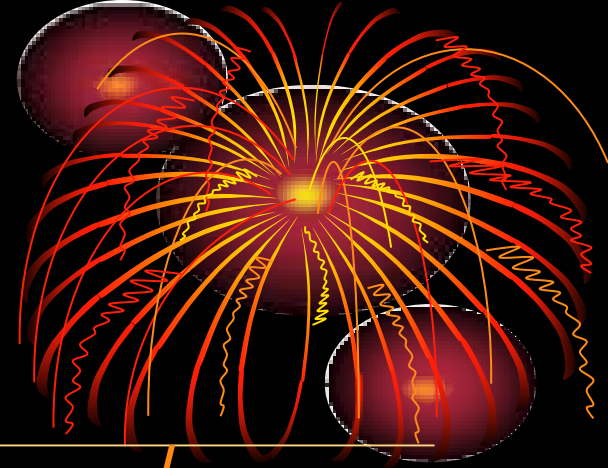
We are taught...



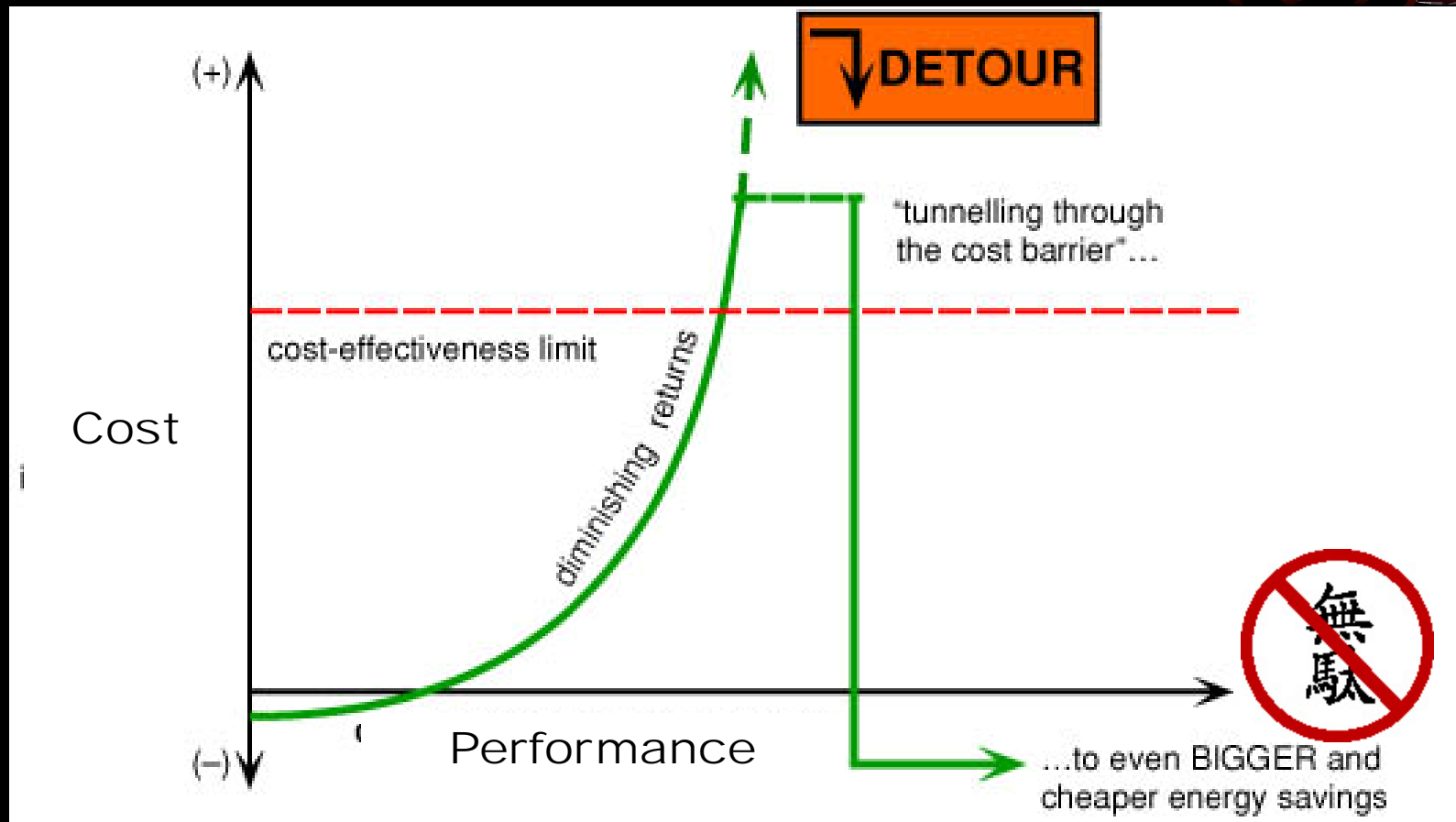
But then somebody...



Perhaps...

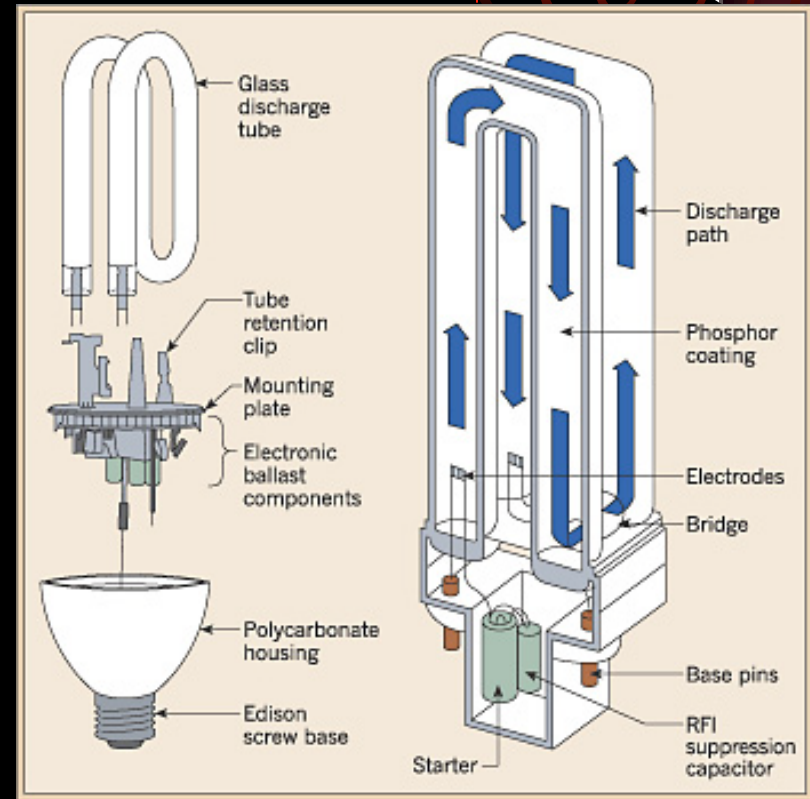


New reality: "tunneling through the cost barrier"



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





But what if I own the
Power Plant?



But what if I own the Power Plant?

- A dozen light bulbs = 1 kW
- \$100 / light bulb



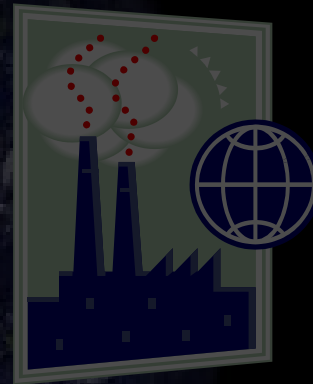
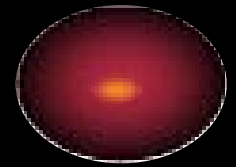
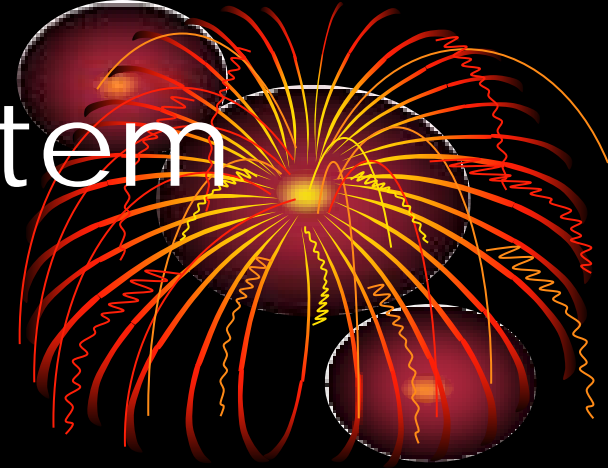
Honda
eu3000is
= \$2000



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?

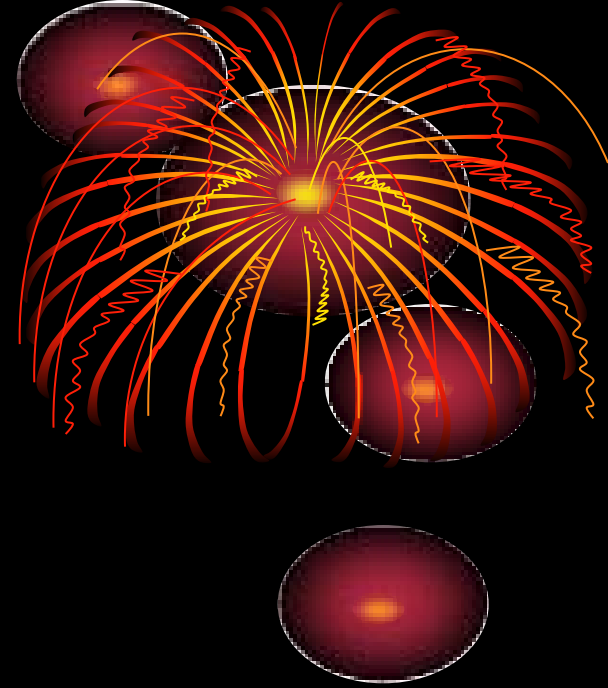
- Techniques for finding it:
 - Multitasking
 - Muda-Elimination
 - Teleology





Multitasking

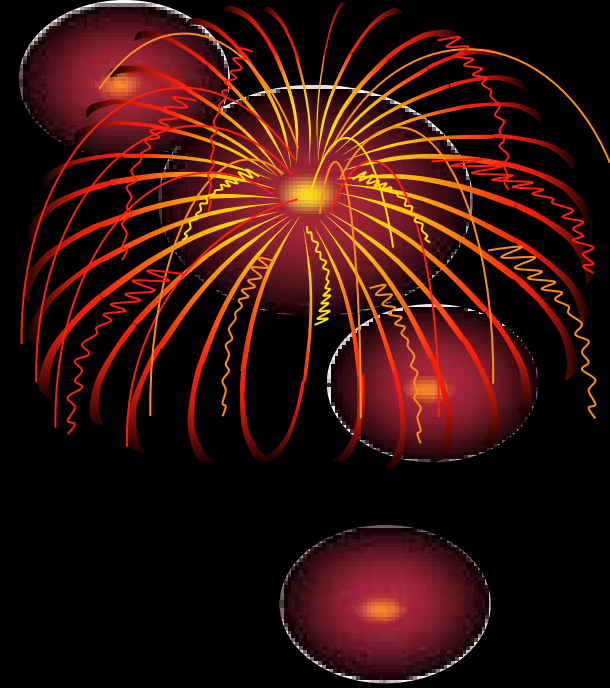
- Container steel





Multitasking

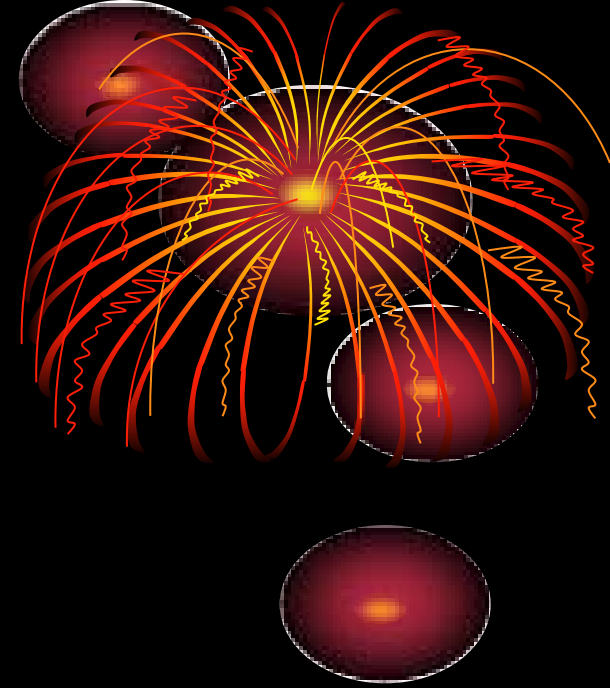
- Container steel
- Structural pipes?





Multitasking

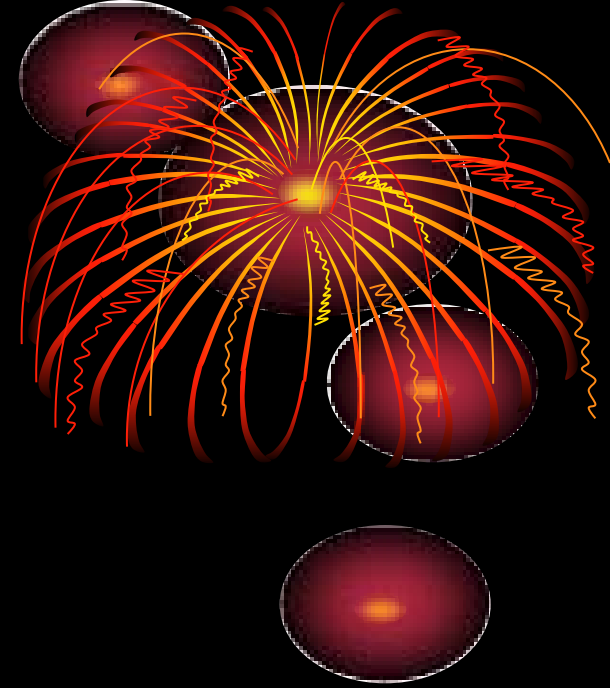
- Container steel
- Structural pipes?
- Conductive Structure?





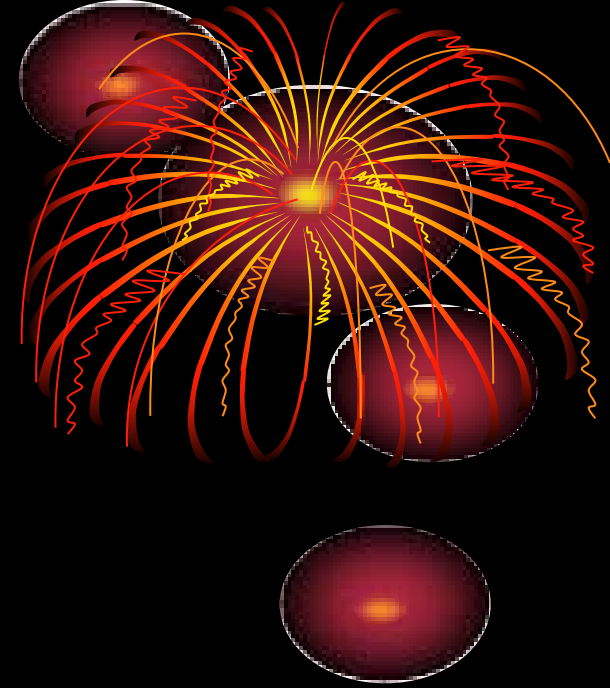
Multitasking

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



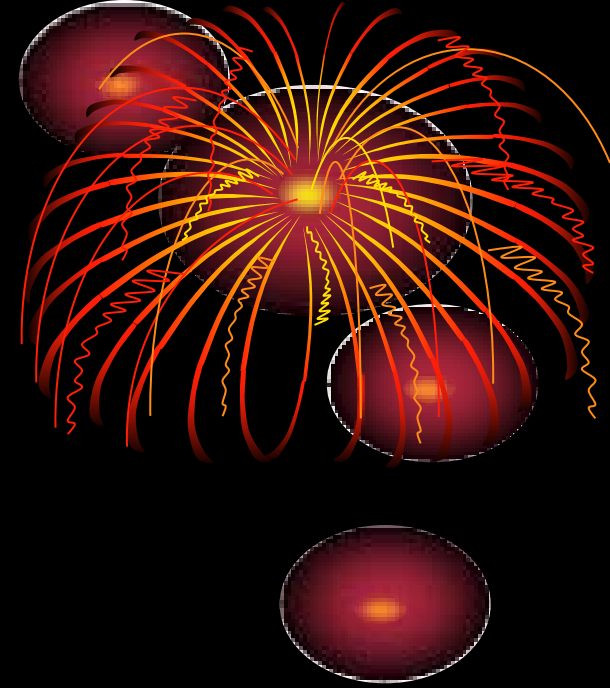
Multitasking

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



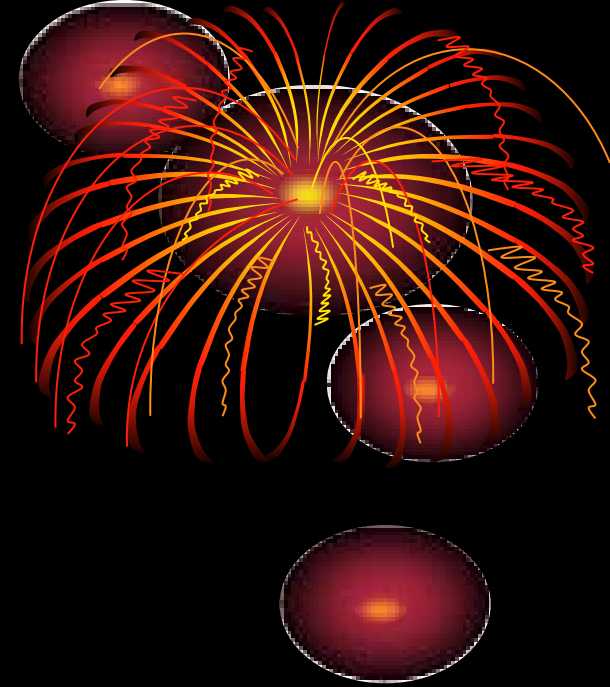
Multitasking

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



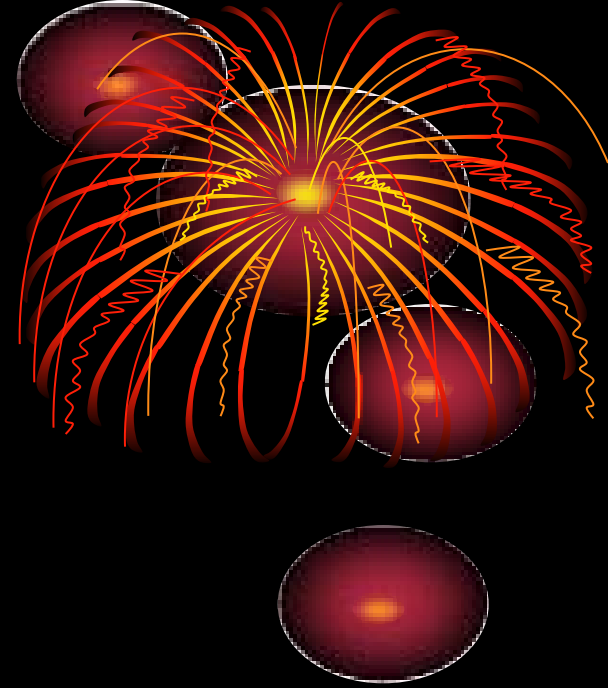
Multitasking

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



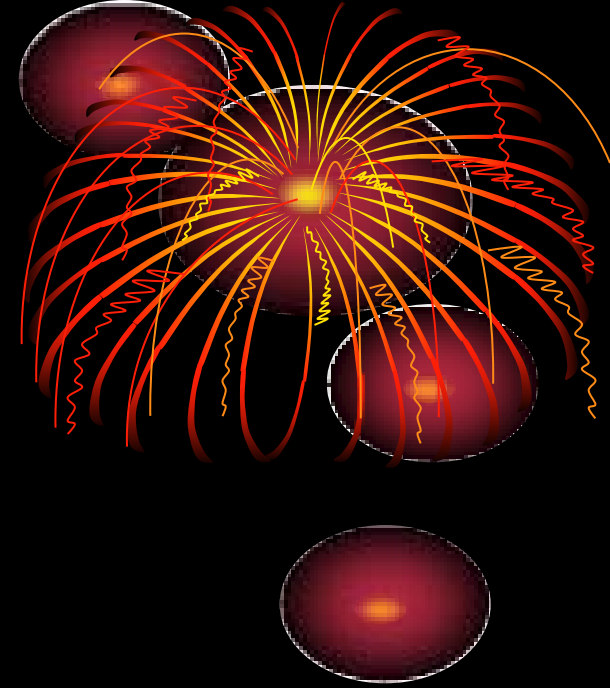
Multitasking

- 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



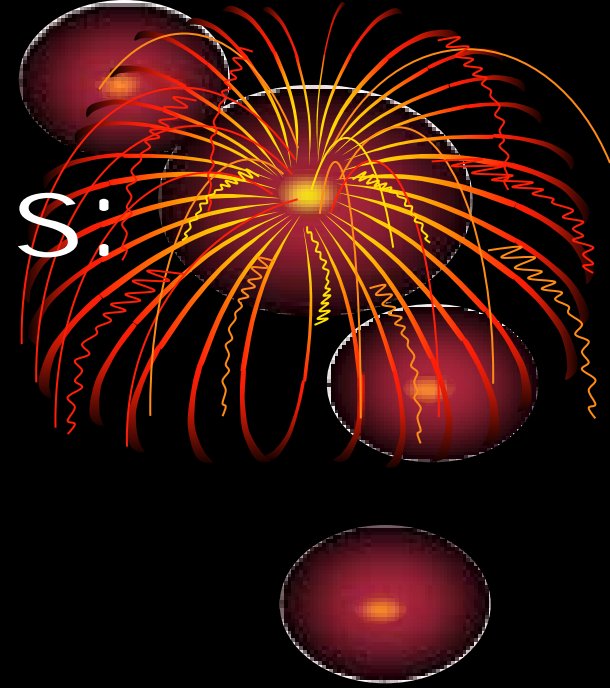
How is Breakthrough Possible?

- Techniques for finding it:
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 - Teleology

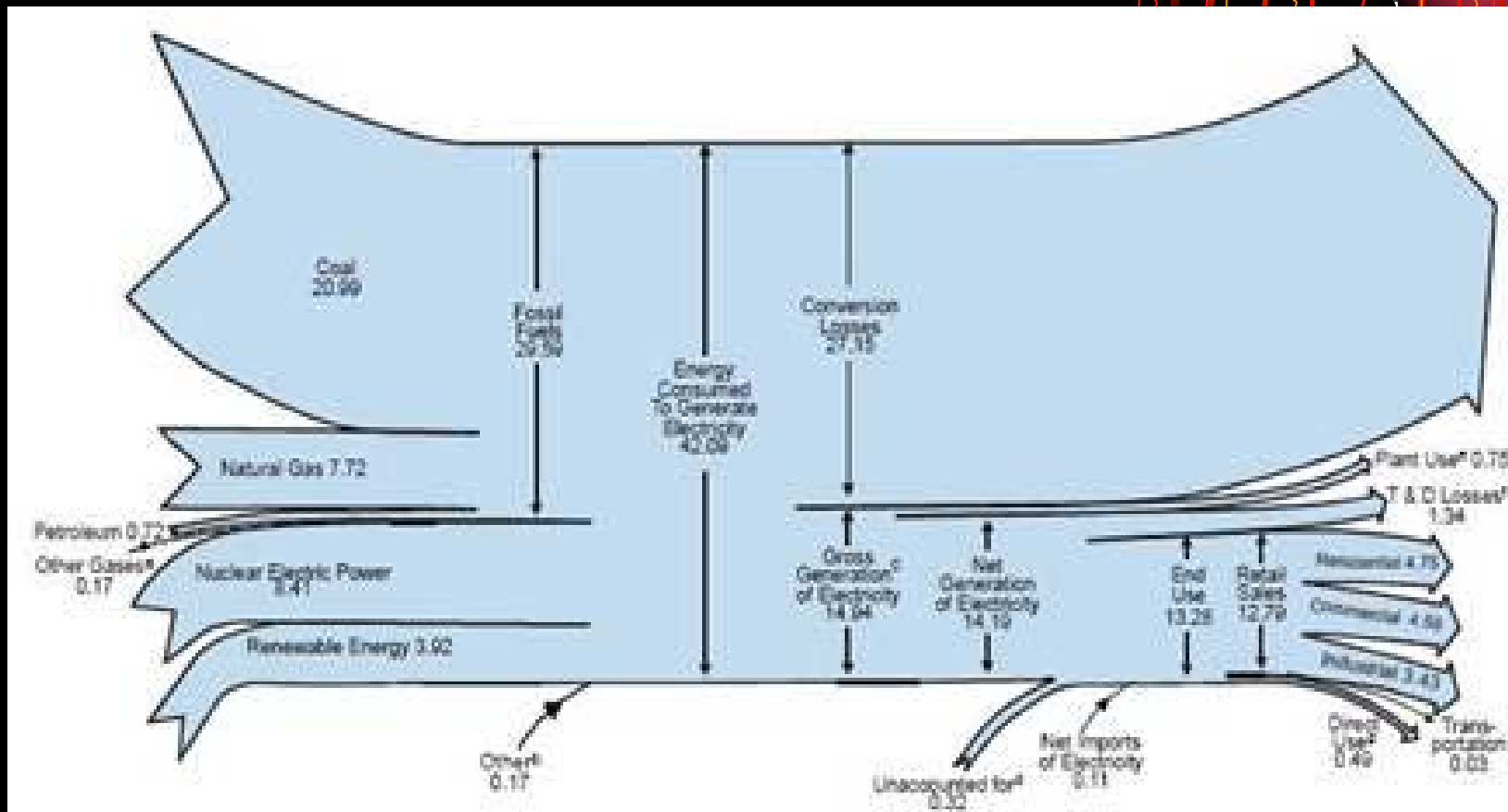




Real life is like this:



To get One out requires Three in



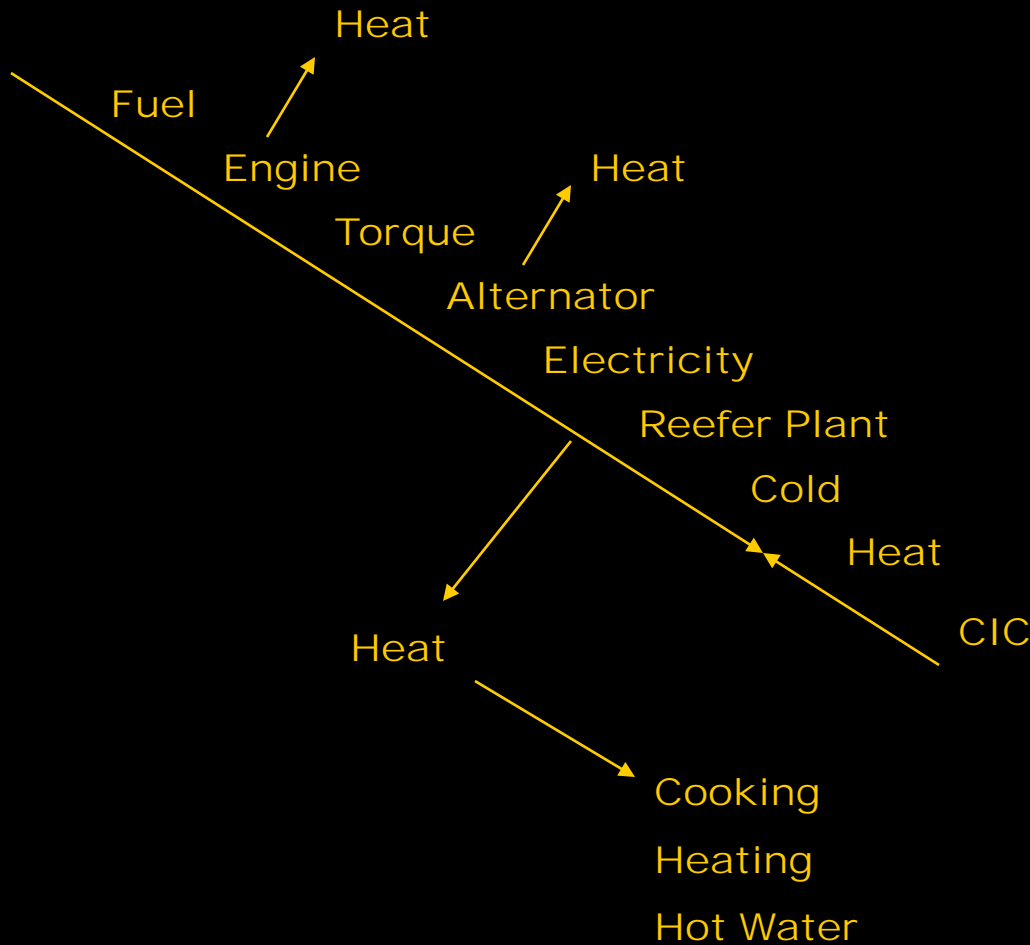
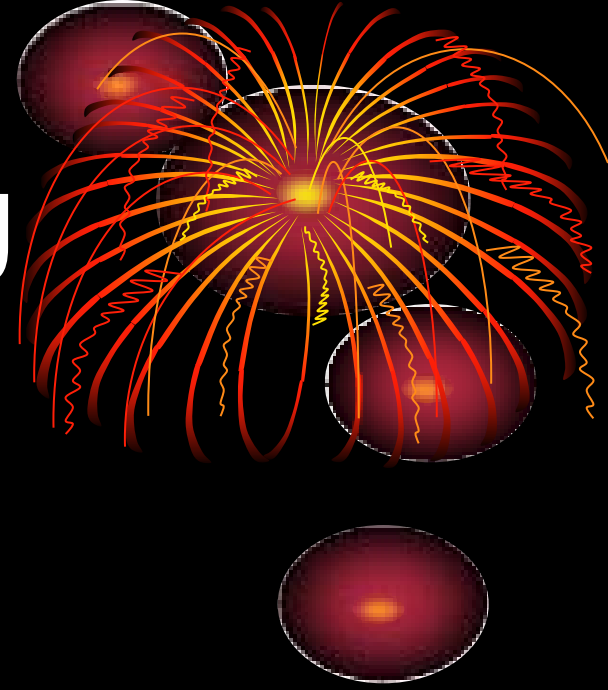
Source: EIA 2009

Another example: The Heating Plant

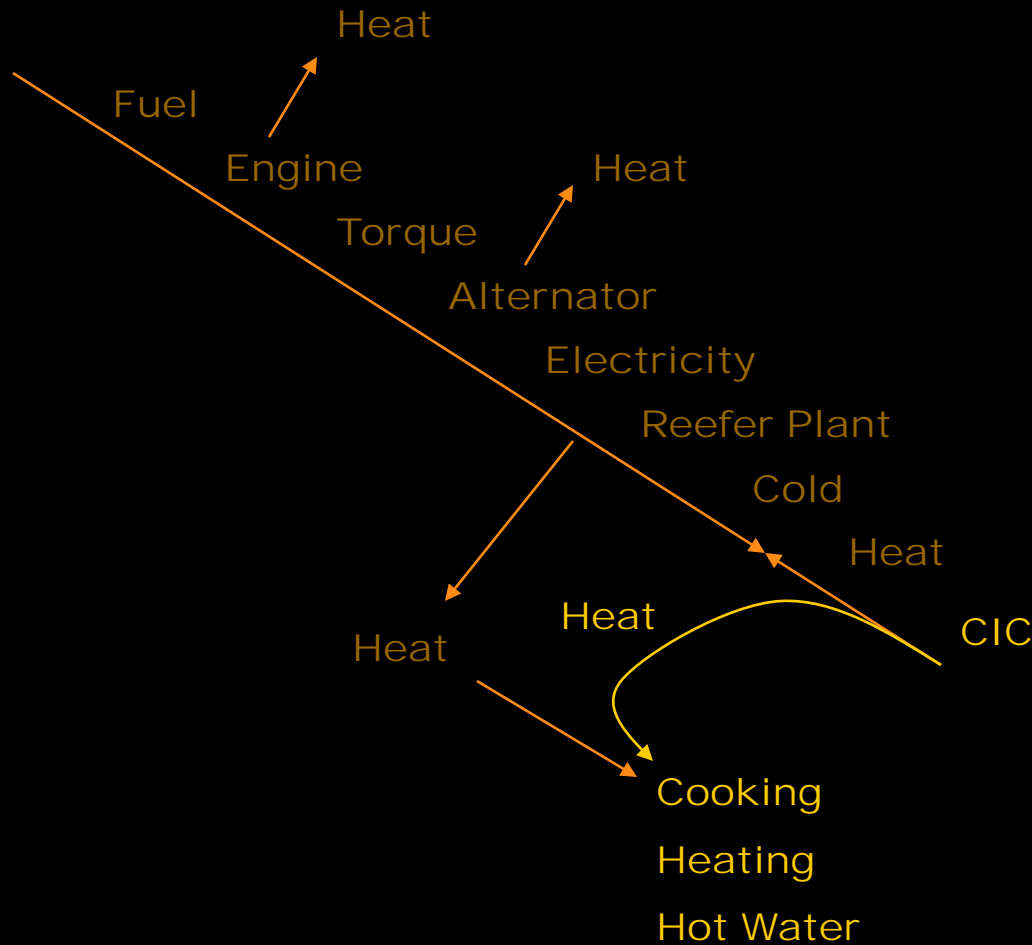
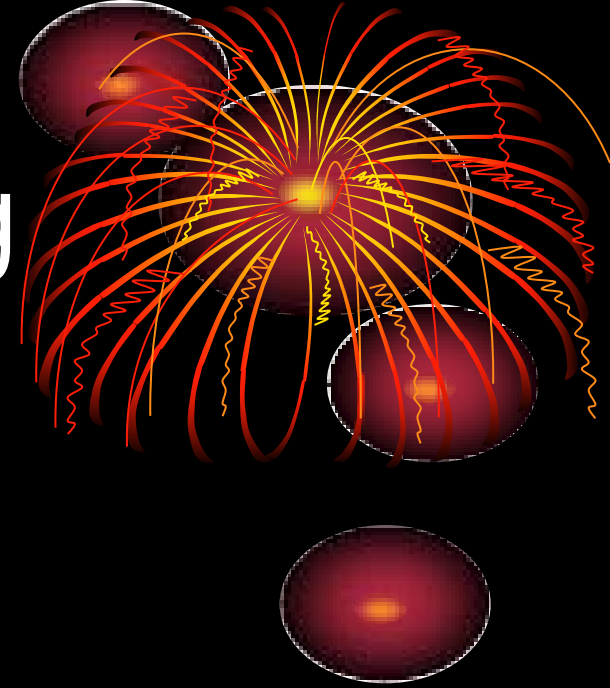


- Large complex system required to generate domestic heat
- Simultaneously other systems are cooling components to minimize heat
- Can I reduce the heat NEED far enough to ELIMINATE the heating plant?

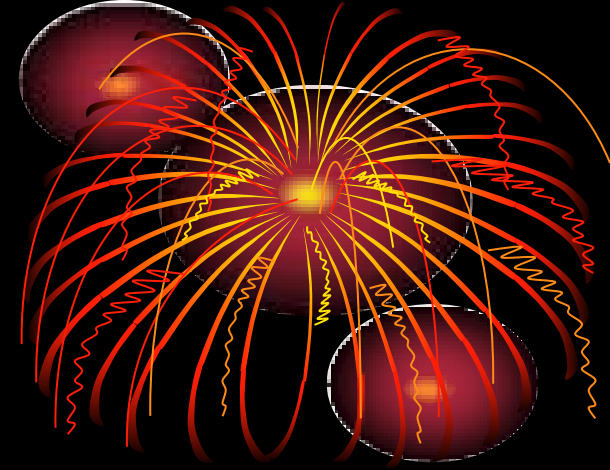
Heating & Cooling



Heating & Cooling

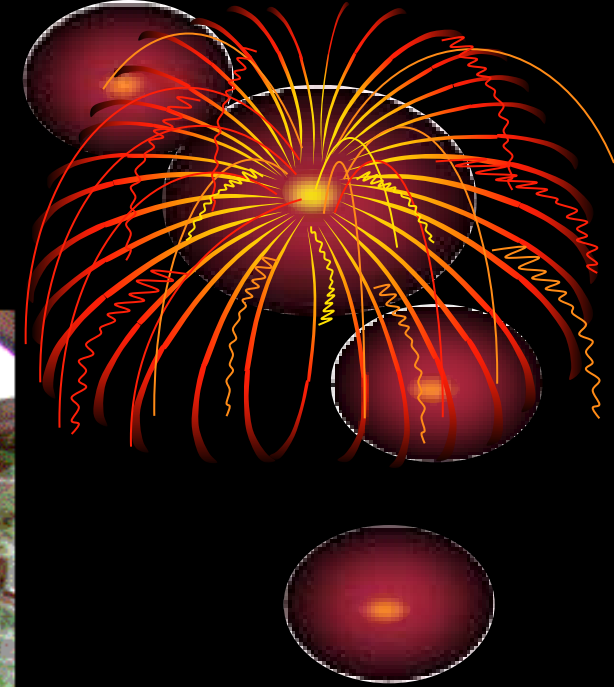


Amory's House



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

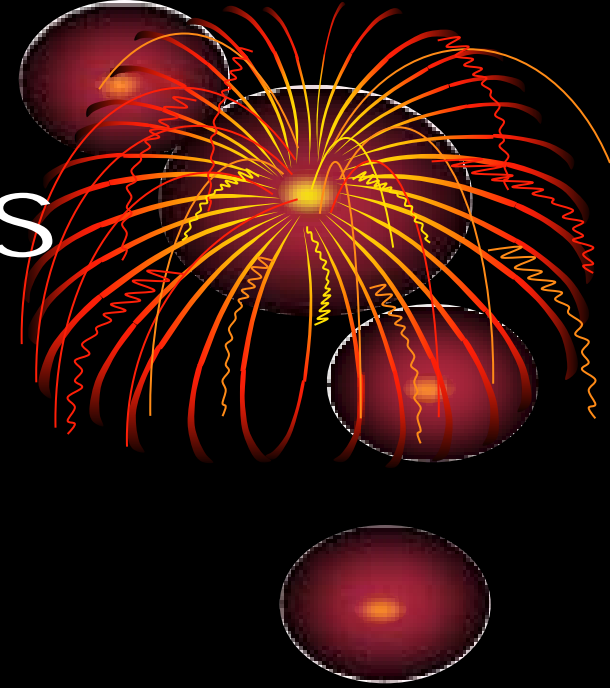


- Where do you get the ideas for this type of breakthrough?
- How do you apply engineering methods to this?



Where to get ideas

- One tool: Teleology



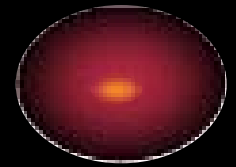
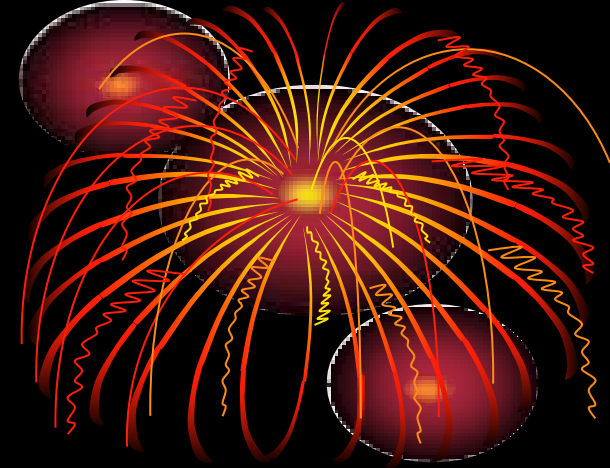
How is Breakthrough Possible?

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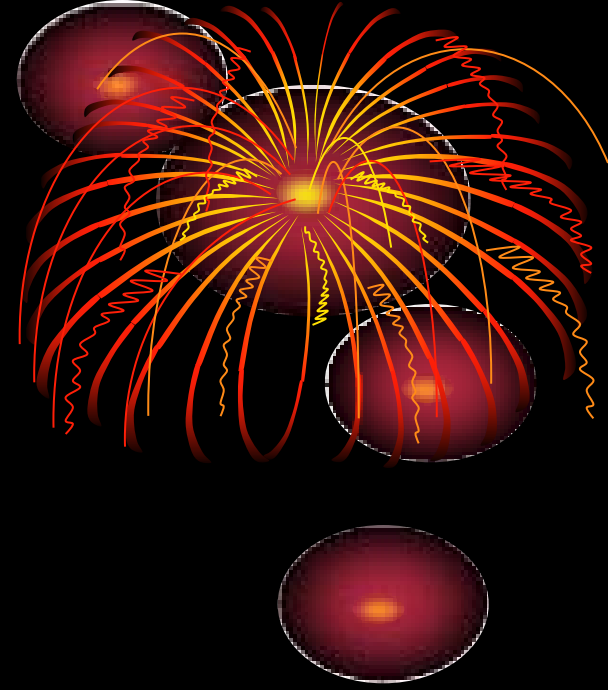
Normally

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



Teleology

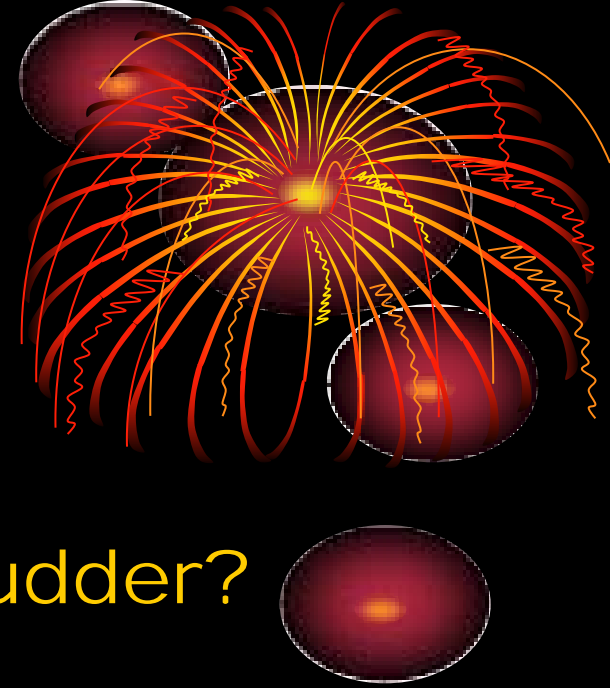
- The study of purpose





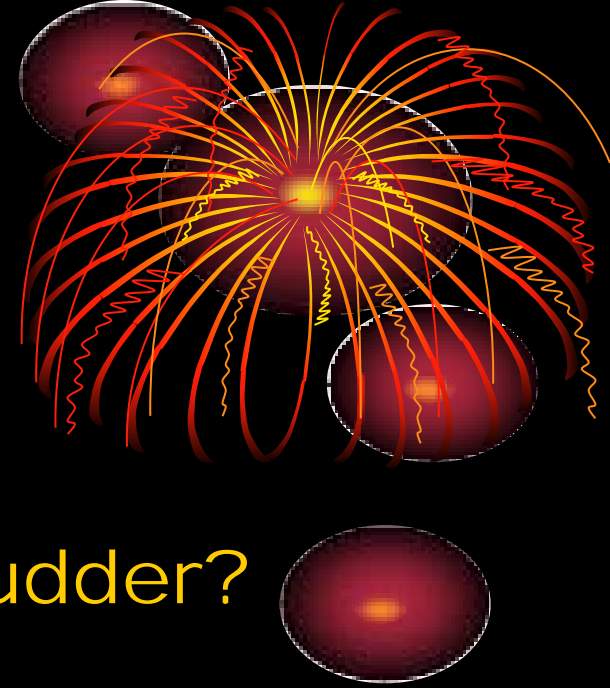
Teleology

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



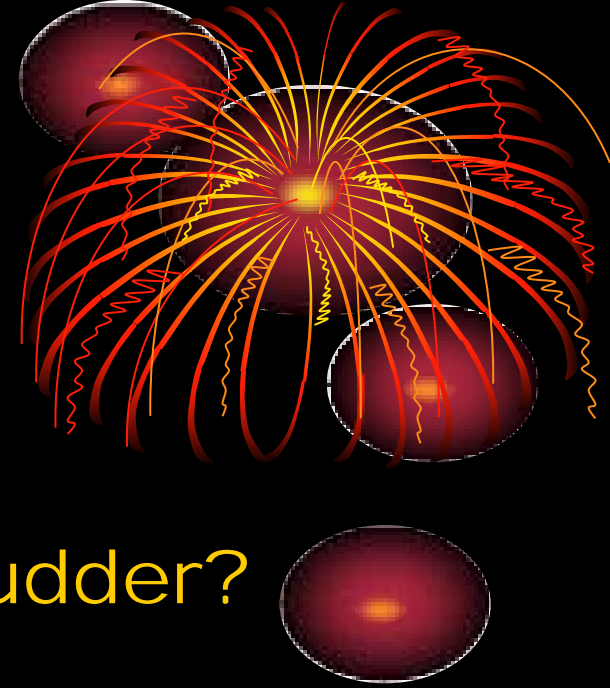
Teleology

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



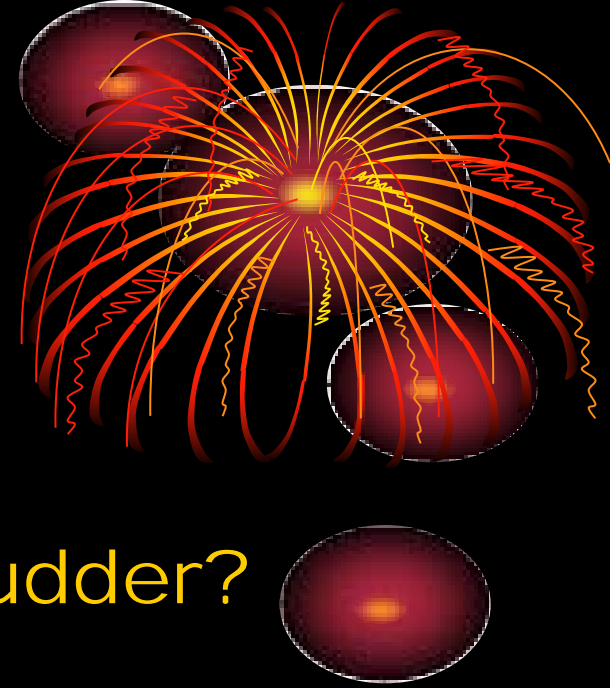
Teleology

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



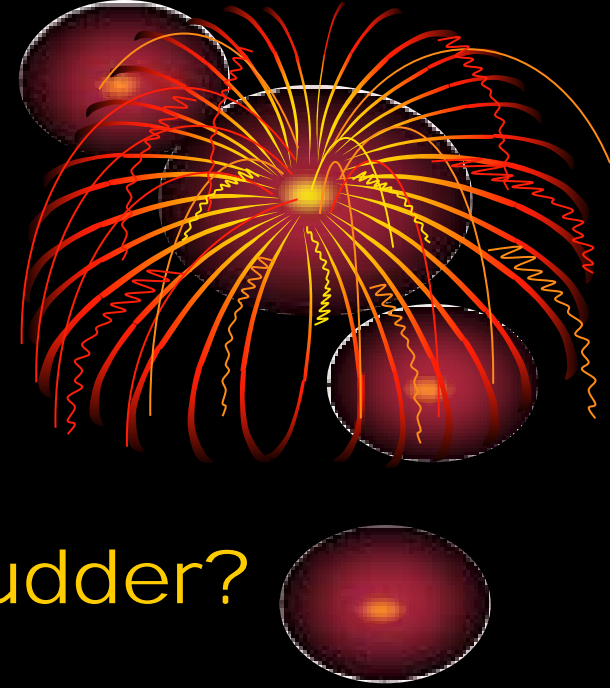
Teleology

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



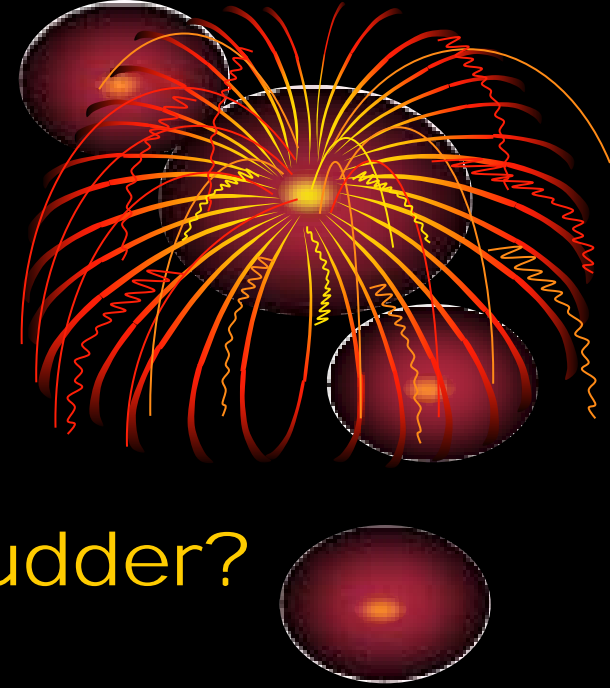
Teleology

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



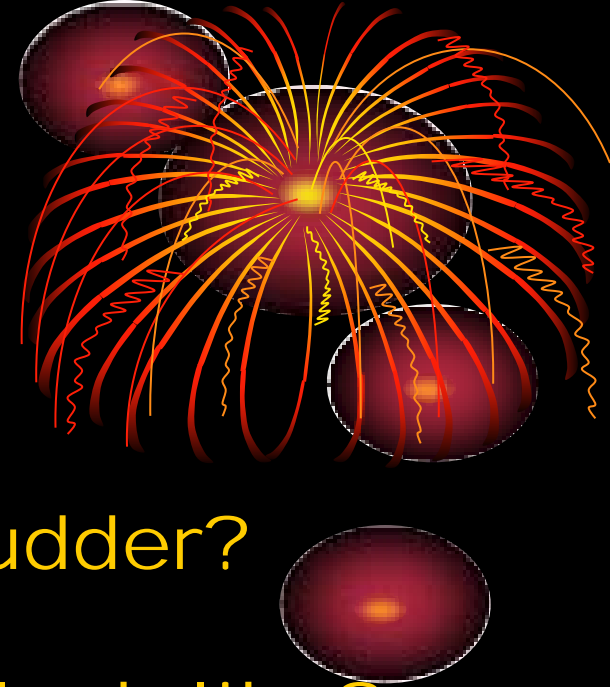
Teleology

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



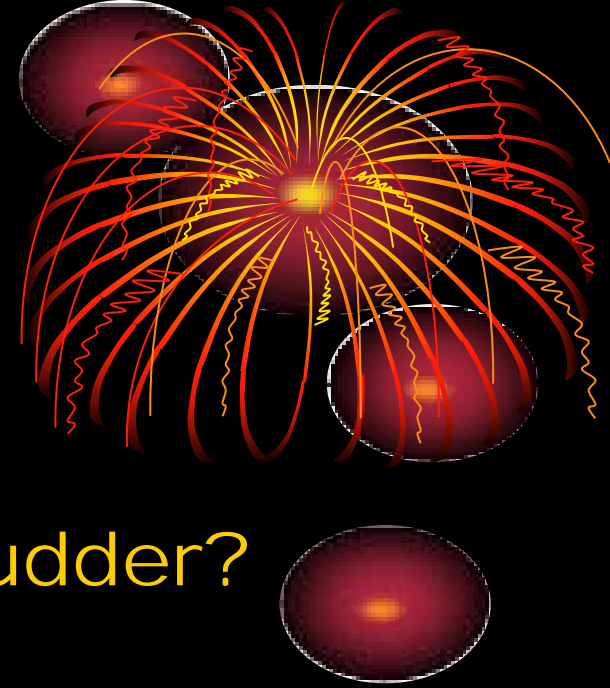
Teleology

- 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



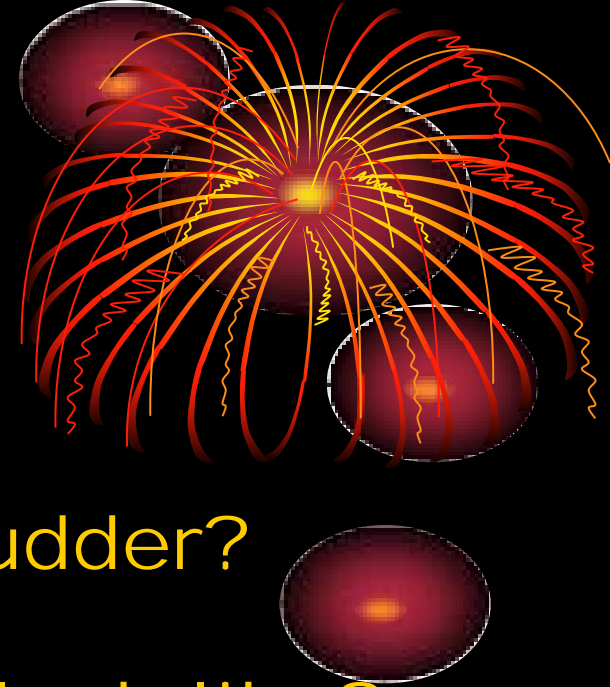
Teleology

- 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

“Teleology” is defining the system boundary around the Problem

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



Teleology

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

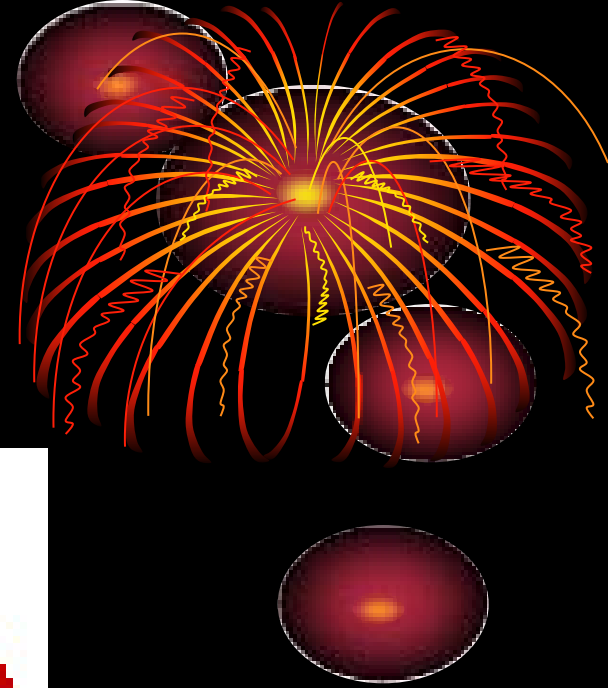


Where to get ideas

- One tool: Teleology
- Second tool: Eliminate Muda



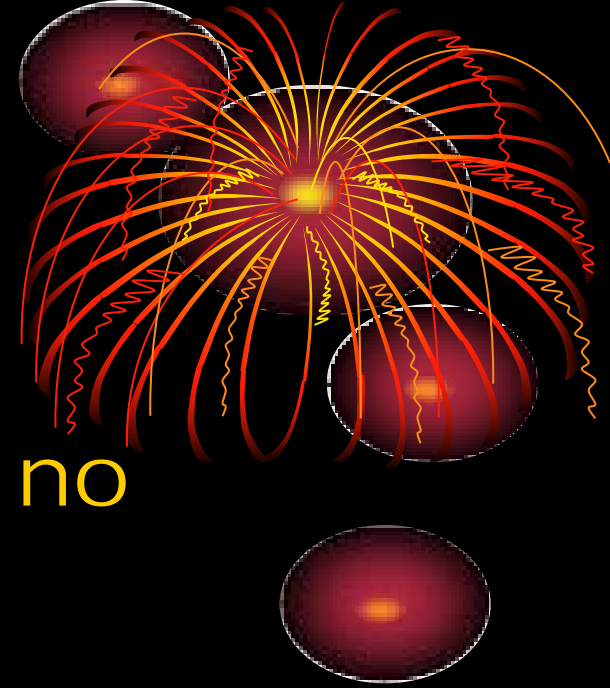
Eliminate Muda





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

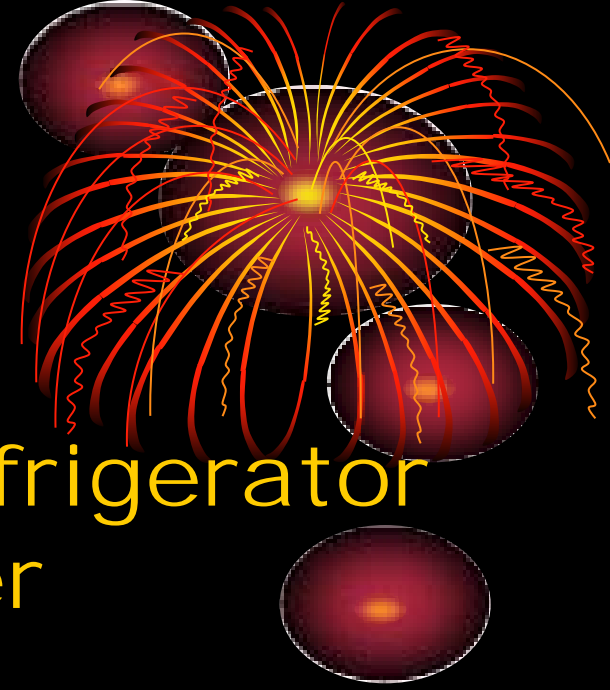


- Teleology: Remove unwanted heat
- Muda Solution:
 - Don't make unwanted heat
 - Change it from "unwanted" to "wanted"



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

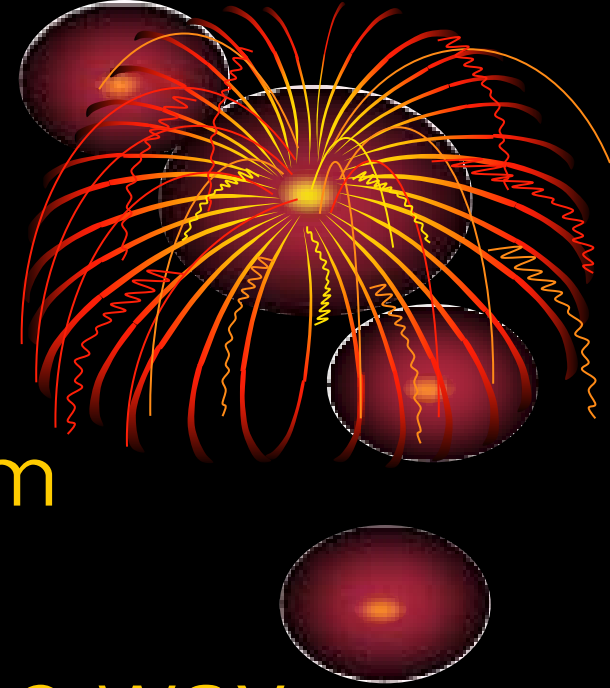




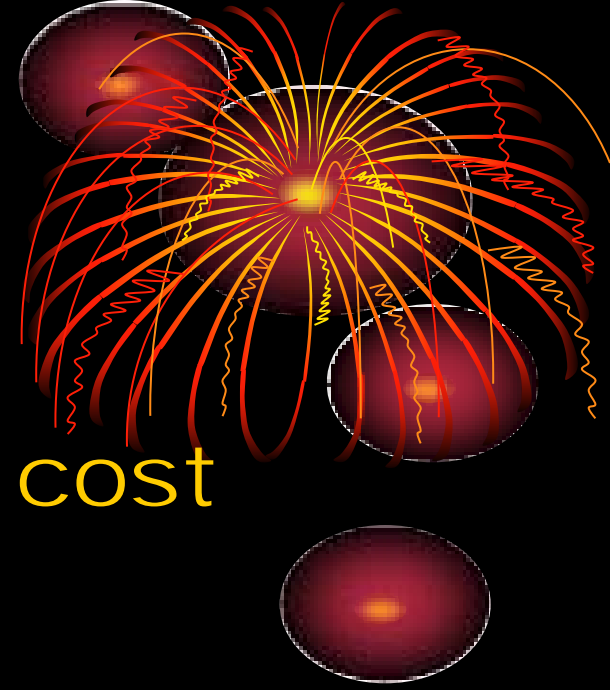
Too exotic? A more
prosaic example:

- Double resilient mountings





- Decompose the problem
Teleologically
- 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





The Truth

- The Cost/Benefit relationship is not necessarily monotonic
- It may not even be Continuous



The Truth

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



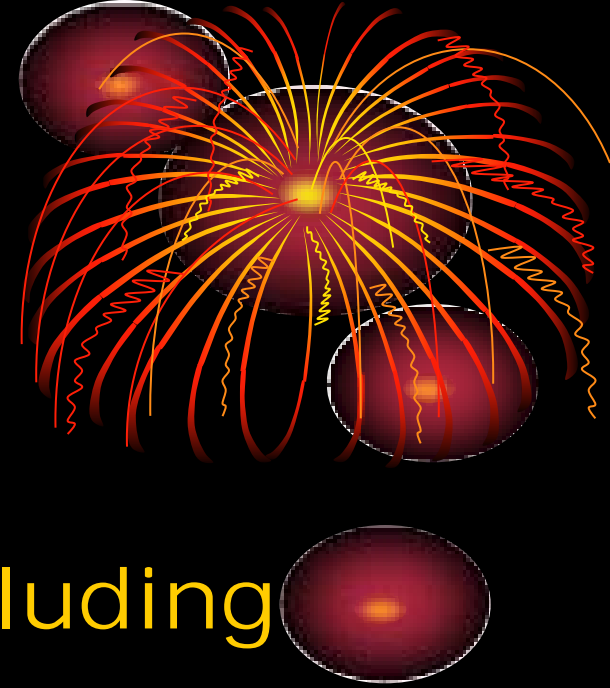
The Truth

- 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



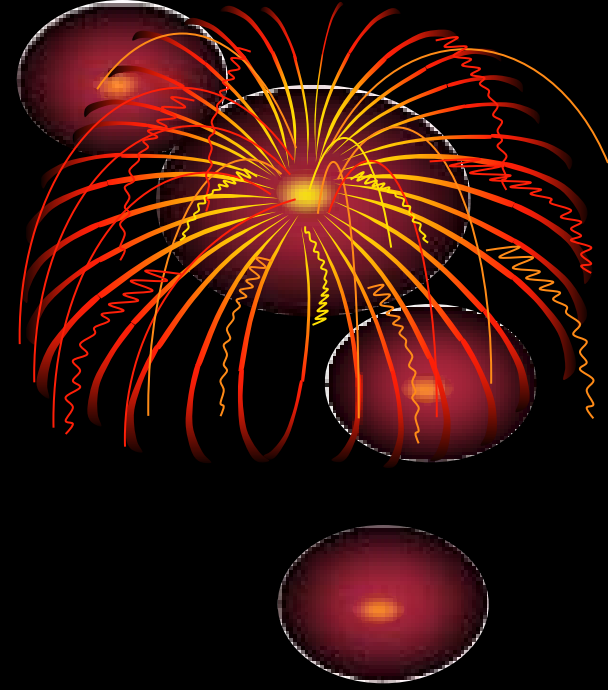
Practical Tools

- Multitasking
- Teleological Study, including TRIZ
- Muda elimination



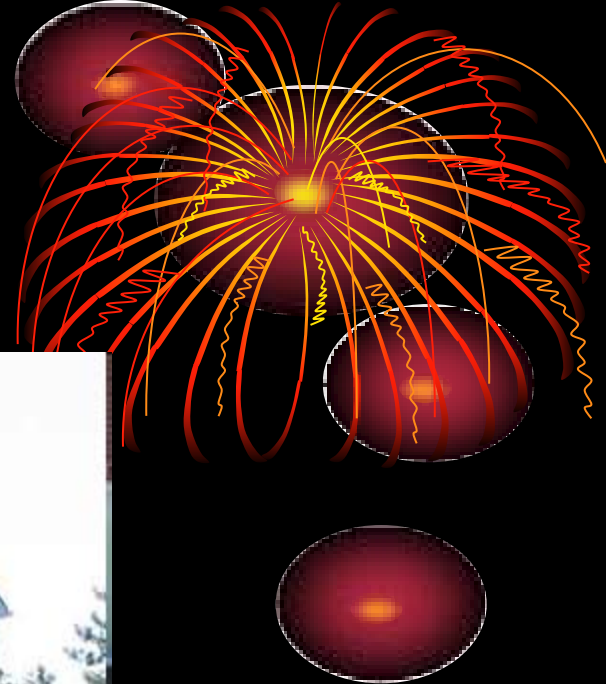
EXAMPLES

(if time permits)

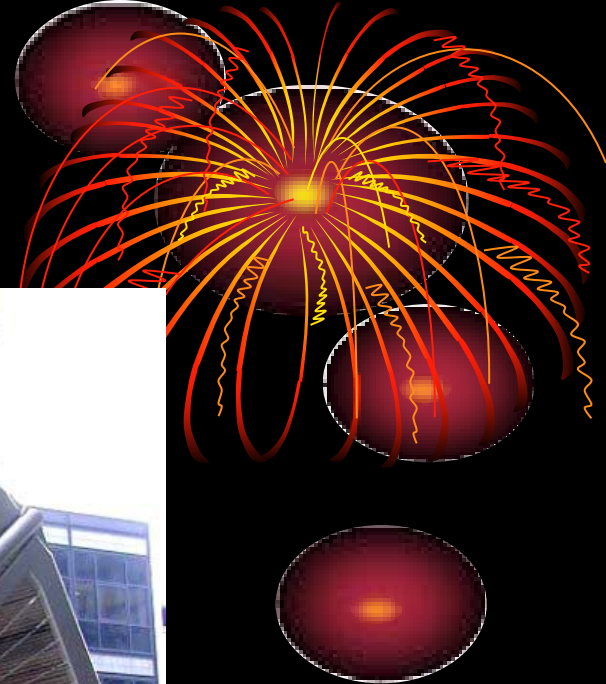




Muda?



Teleology



Teleology



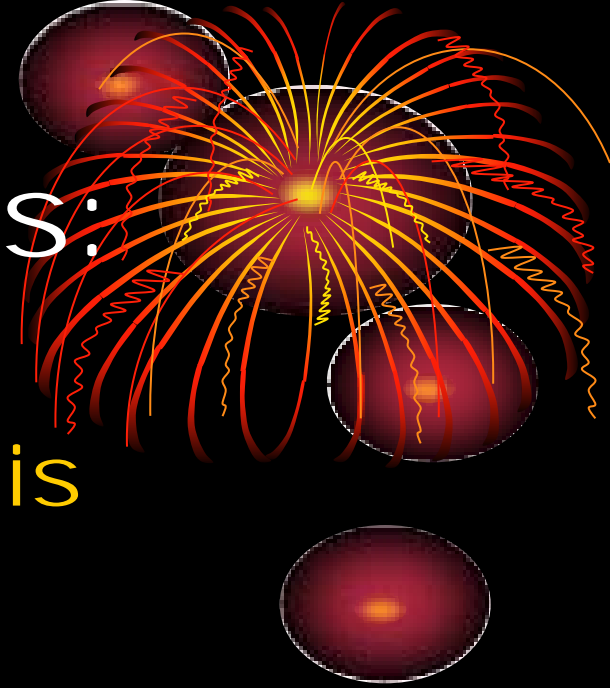
Teleology in My Home:

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



Innovative process:

- Find out what the goal is



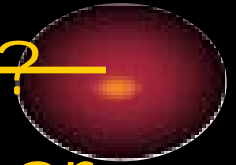
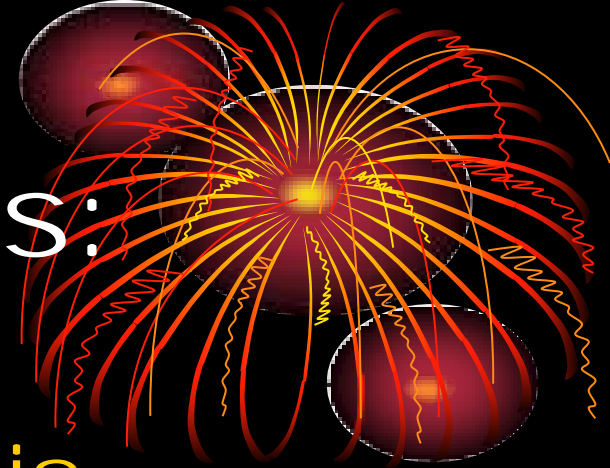
Innovative process:

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

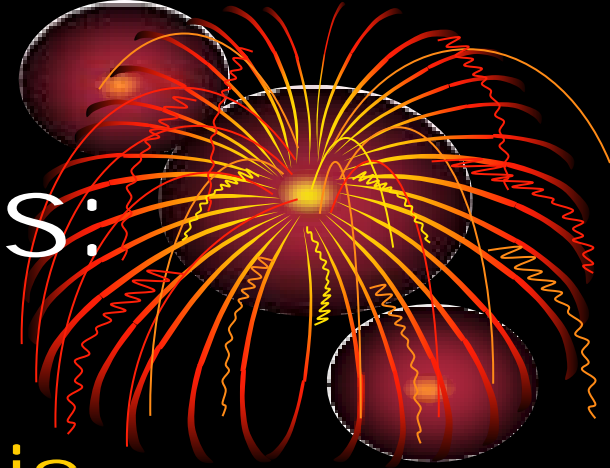


Innovative process:

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



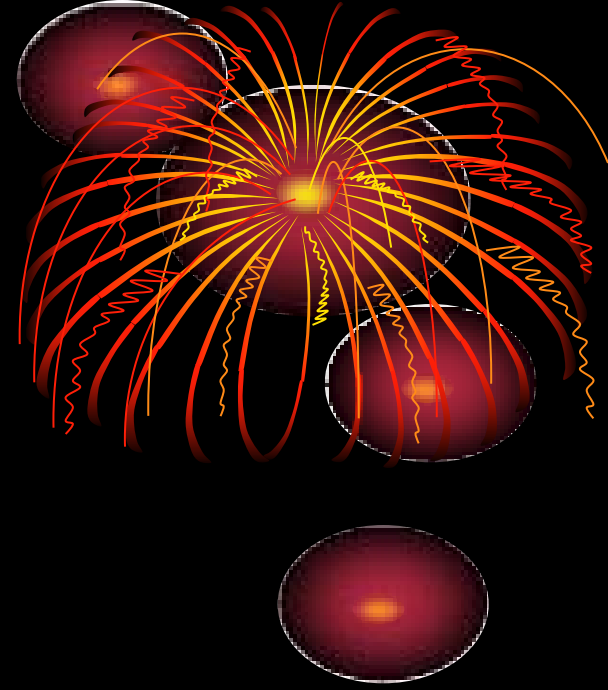
Innovative process:



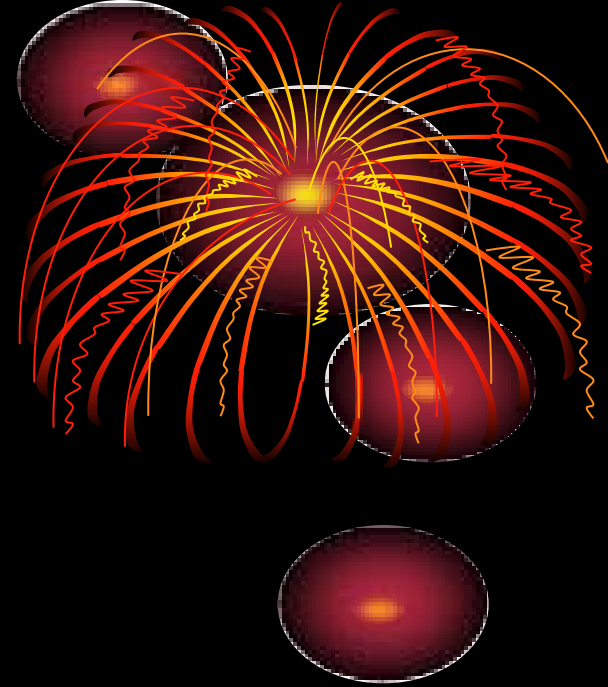
- Find out what the goal is
 - ~~• How to fix the base to the tree?~~
 - ~~• How to fix the tree to the floor or table?~~
 - How to maintain the tree in a vertical orientation



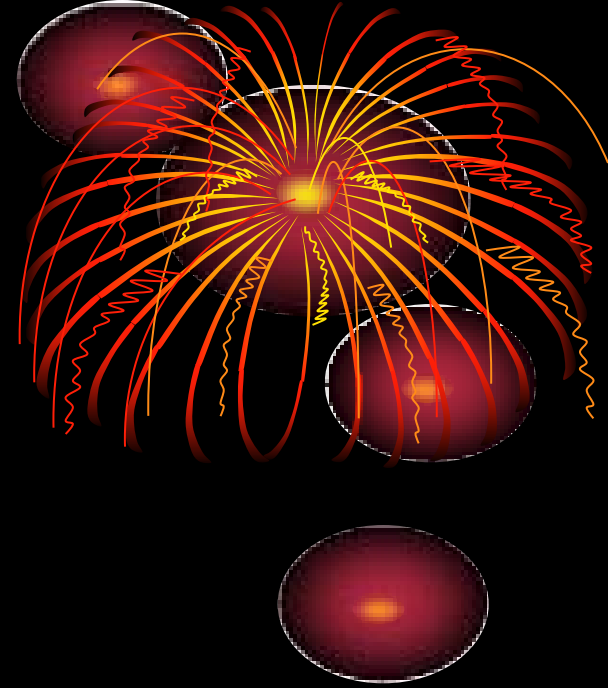
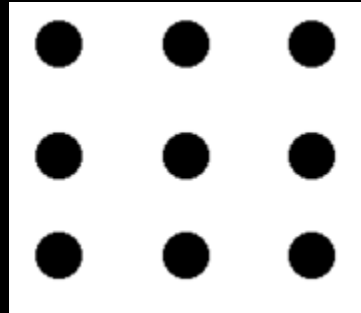
Back-Up



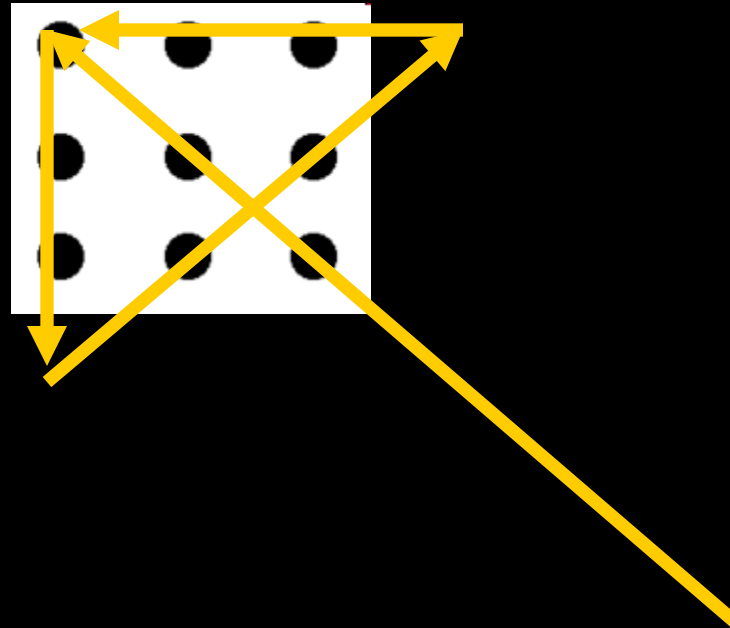
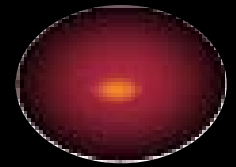
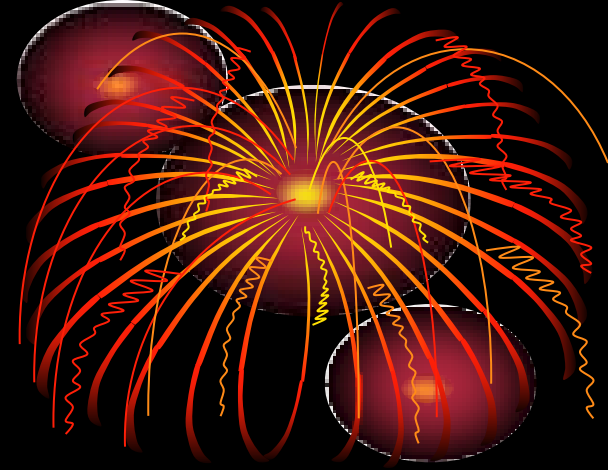
Outside the Box



Outside the Box

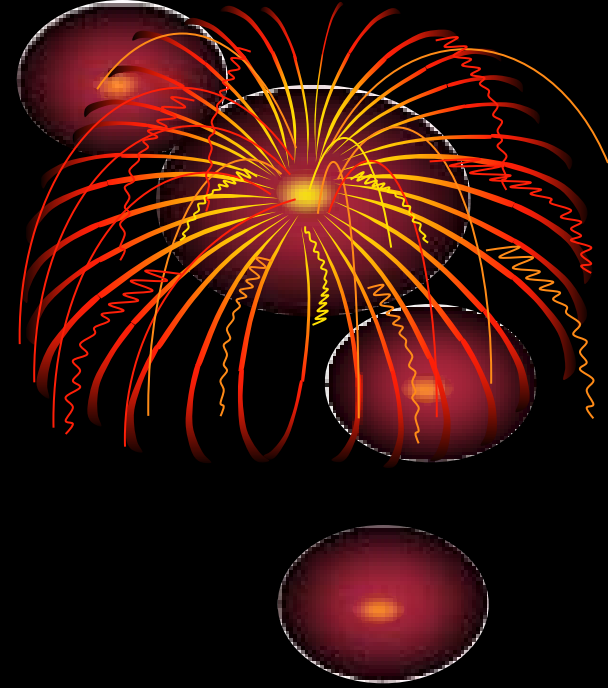
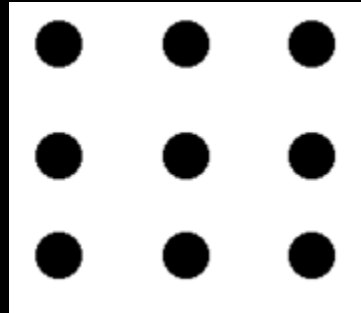


Outside the Box



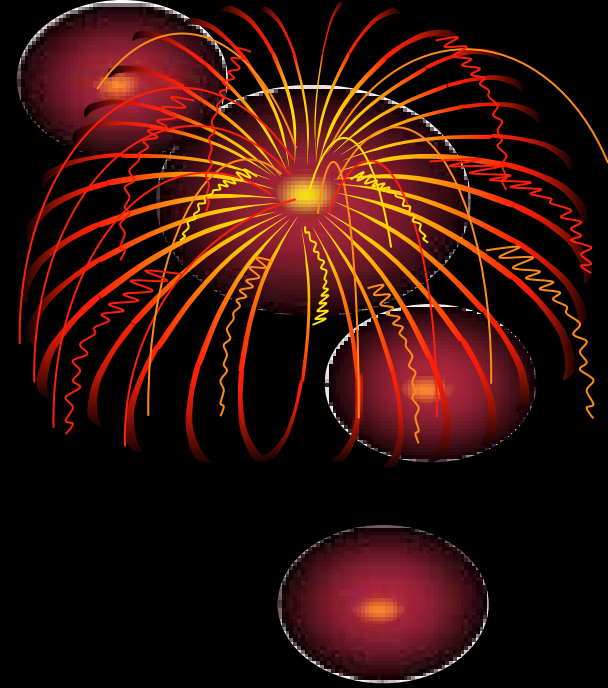
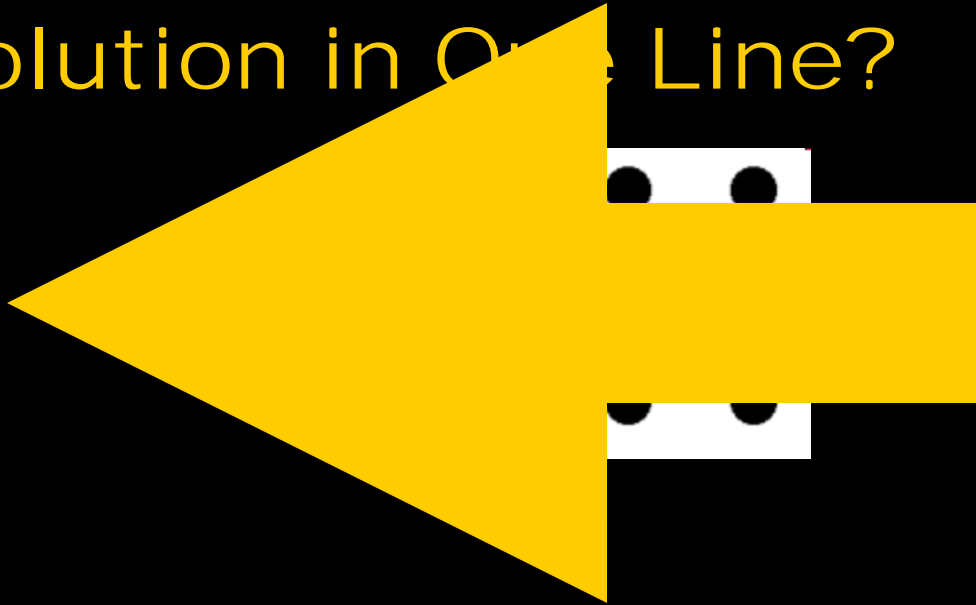
Outside the Box

- Solution in One Line?



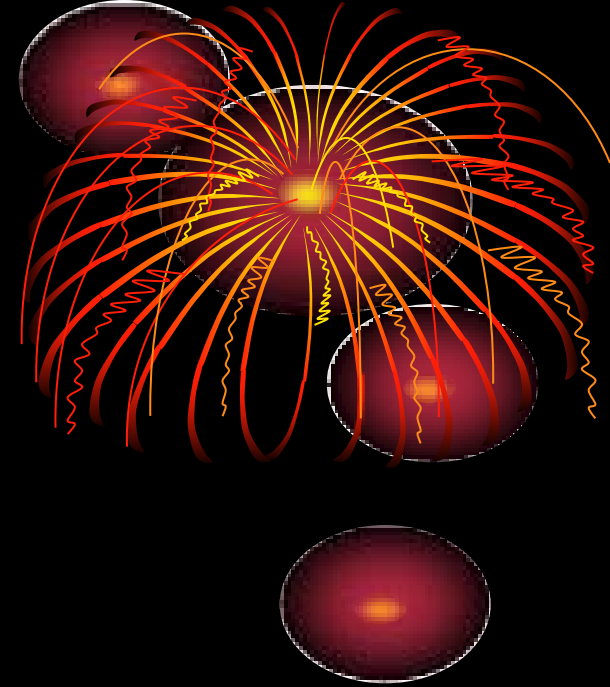
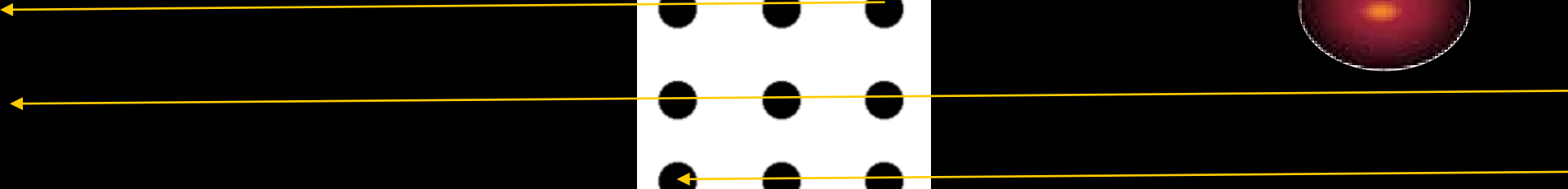
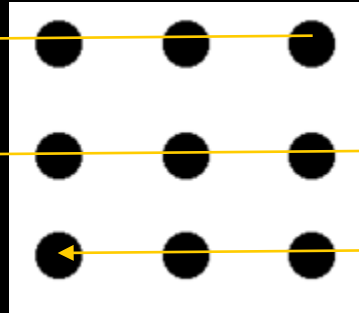
Outside the Box

- Solution in One Line?



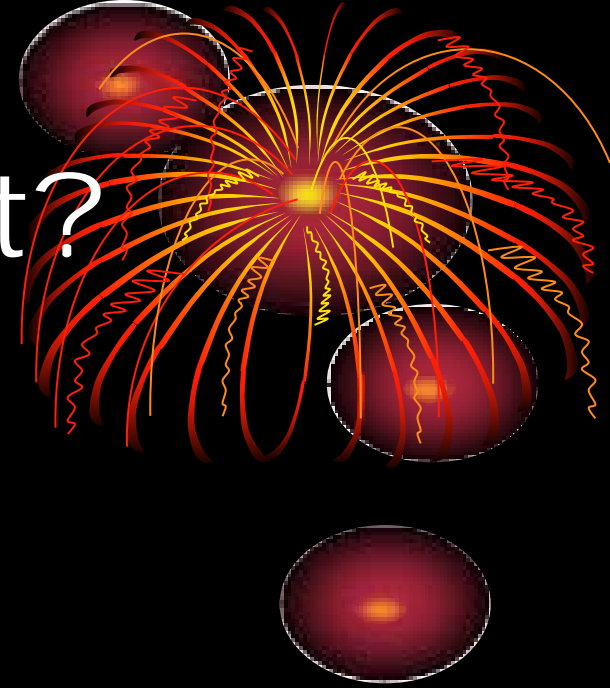
Outside the Box

- Solution in One Line?





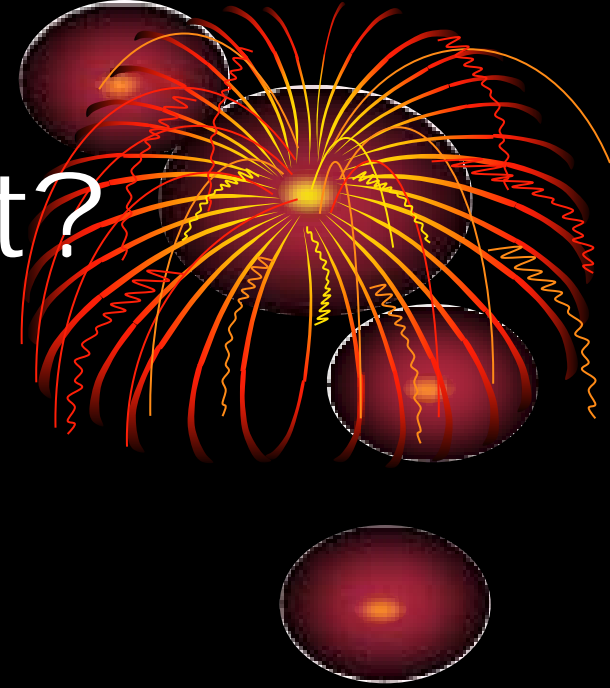
Can Anybody Do It?





Can Anybody Do It?

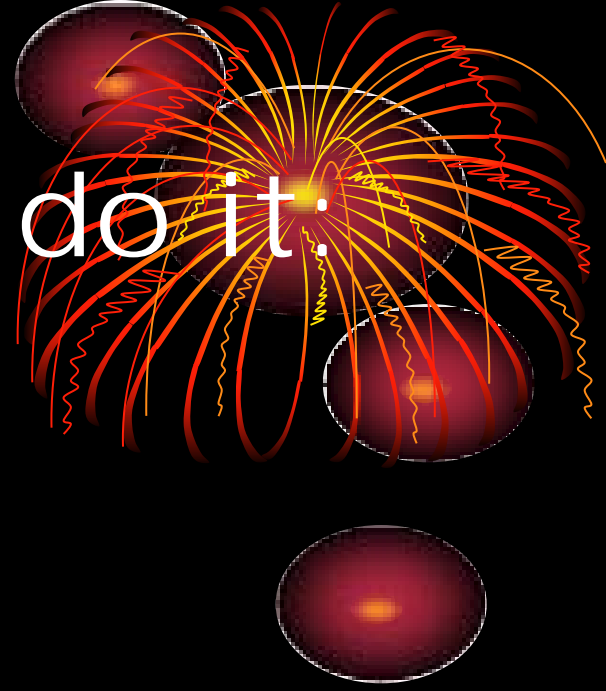
- No.





Not everyone can do it:

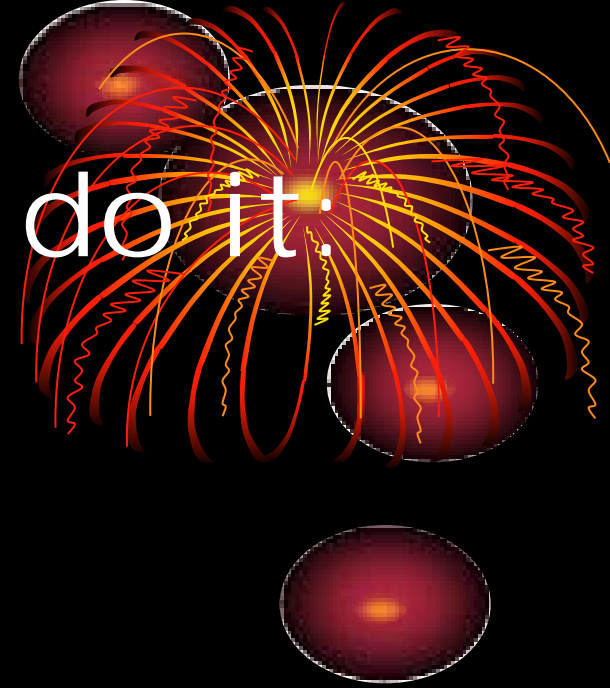
- Math





Not everyone can do it:

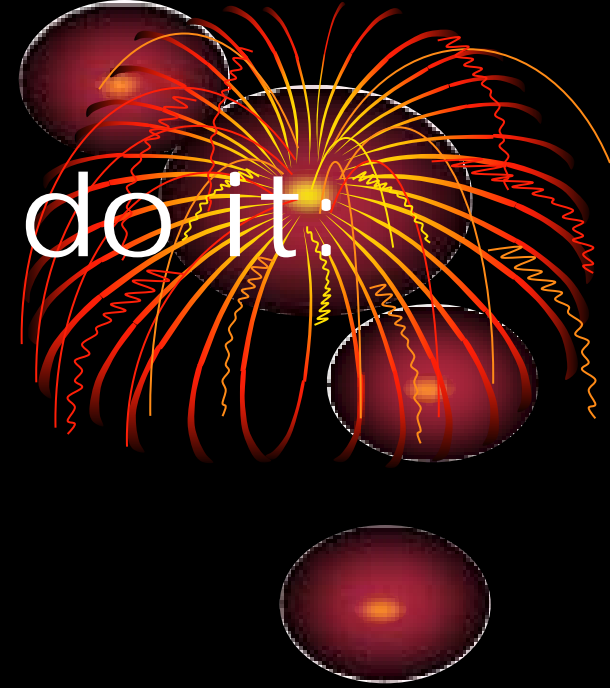
- Math
- Engineering Analysis





Not everyone can do it:

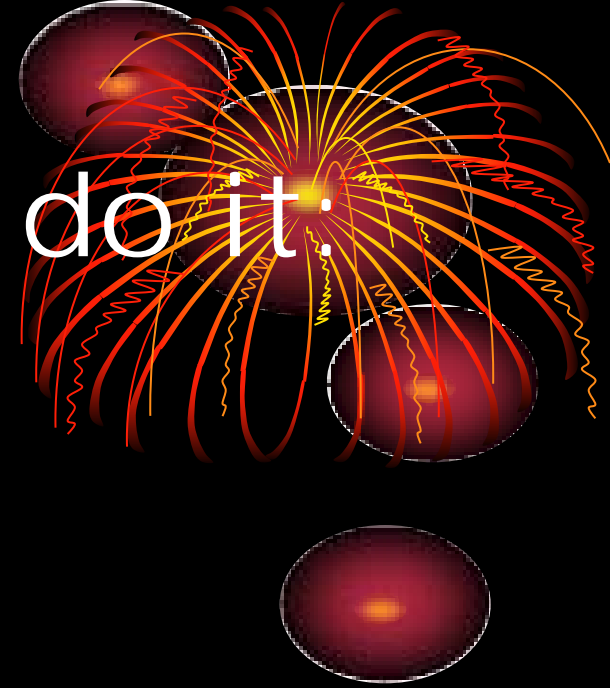
- Math
- Engineering Analysis
- Engineering Synthesis





Not everyone can do it:

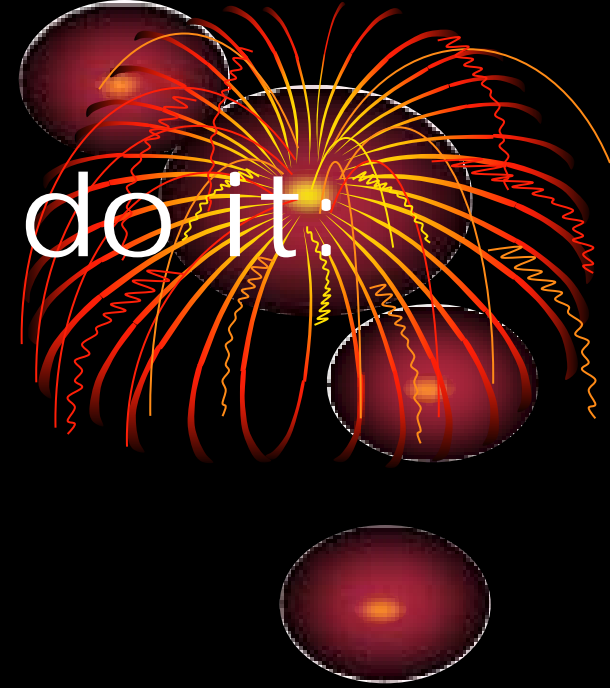
- Math
- Engineering Analysis
- Engineering Synthesis
- Engineering Innovation



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

