Leonardo as observer, scientist and inventor

How did Leonardo da Vinci succeed in foreseeing so much, and why did he sometimes fail?
increasing Idenity of technical systems

During their evolution the technical systems tend to improve the ratio between the SYSTEM PERFORMANCES and the EXPENSES required to perform these performances.

\[ I = \frac{\sum P}{\sum E} \]  

(performance)  

(expenses)  

*G.S. Altshuller: 1979. CREATIVITY AS AN EXACT SCIENCE. Sovietskoe radio, Moscow

Useful for practice*:

**Ideal machine** – there is no machine, but the required action is performed.

**Ideal process** – there are no energy expenses and no time expenses, but required action is performed (self-acting control).

**Ideal substance** – there is no substance, but function is performed.
## From invention to innovation

<table>
<thead>
<tr>
<th>Type of innovation (according to degree of radicalness)</th>
<th>Weighting (according to degree of radicalness)</th>
<th>Frequency (in the period 1953-1973)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic innovation</td>
<td>32 to 35</td>
<td>7</td>
</tr>
<tr>
<td>2. Radical innovation</td>
<td>28 to 31</td>
<td>29</td>
</tr>
<tr>
<td>3. Very important improvement innovations</td>
<td>24 to 27</td>
<td>62</td>
</tr>
<tr>
<td>4. Important improvement innovations</td>
<td>20 to 23</td>
<td>145</td>
</tr>
<tr>
<td>5. Mundane improvements</td>
<td>16 to 19</td>
<td>239</td>
</tr>
<tr>
<td>6. Minor product or process differentiation with new technology</td>
<td>0 to 15</td>
<td>760</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Range of weights</th>
<th>0 to 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total frequency</td>
<td>1242*</td>
</tr>
</tbody>
</table>

* The lower classes of innovation are increasingly underestimated in quantity

From invention to innovation

<table>
<thead>
<tr>
<th>NAME</th>
<th>INVENTION</th>
<th>INNOVATION</th>
<th>YEARS LEAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>High voltage generator</td>
<td>1820</td>
<td>1849</td>
<td>29</td>
</tr>
<tr>
<td>Electro-medical stimulator</td>
<td>1831</td>
<td>1846</td>
<td>15</td>
</tr>
<tr>
<td>Deep sea cable</td>
<td>1847</td>
<td>1866</td>
<td>19</td>
</tr>
<tr>
<td>Electricity production</td>
<td>1708</td>
<td>1800</td>
<td>92</td>
</tr>
<tr>
<td>Insulated conductors</td>
<td>1744</td>
<td>1820</td>
<td>76</td>
</tr>
<tr>
<td>Arc lights</td>
<td>1810</td>
<td>1844</td>
<td>34</td>
</tr>
<tr>
<td>Pedal bicycle</td>
<td>1818</td>
<td>1839</td>
<td>21</td>
</tr>
<tr>
<td>Rolled rails</td>
<td>1773</td>
<td>1835</td>
<td>62</td>
</tr>
<tr>
<td>Rolled wires</td>
<td>1773</td>
<td>1820</td>
<td>47</td>
</tr>
<tr>
<td>Pudding furnace</td>
<td>1783</td>
<td>1824</td>
<td>41</td>
</tr>
<tr>
<td>Blast furnace with coke</td>
<td>1713</td>
<td>1796</td>
<td>83</td>
</tr>
<tr>
<td>Crucible steel</td>
<td>1740</td>
<td>1811</td>
<td>71</td>
</tr>
<tr>
<td><strong>Locomotives</strong></td>
<td>1769</td>
<td>1824</td>
<td>55</td>
</tr>
<tr>
<td>Telegraph</td>
<td>1793</td>
<td>1833</td>
<td>40</td>
</tr>
<tr>
<td>Lead chamber process</td>
<td>1740</td>
<td>1819</td>
<td>79</td>
</tr>
<tr>
<td>Pharmaceutical industries</td>
<td>1771</td>
<td>1827</td>
<td>56</td>
</tr>
<tr>
<td>Quinine industries</td>
<td>1790</td>
<td>1820</td>
<td>30</td>
</tr>
<tr>
<td>Hard rubber</td>
<td>1832</td>
<td>1852</td>
<td>20</td>
</tr>
<tr>
<td>Portland cement</td>
<td>1756</td>
<td>1824</td>
<td>68</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>1777</td>
<td>1831</td>
<td>54</td>
</tr>
<tr>
<td>Photography</td>
<td>1727</td>
<td>1838</td>
<td>111</td>
</tr>
</tbody>
</table>

**Basic Innovations in the First Half of the Nineteen Century**

From invention to innovation

The case of Locomotive

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1769</td>
<td>Watt: Low pressure machine</td>
</tr>
<tr>
<td>1770</td>
<td>Cugnot: Steam gun vehicle</td>
</tr>
<tr>
<td>1790</td>
<td>Read: Steam road vehicle</td>
</tr>
<tr>
<td>1800</td>
<td>Watt's: Patent on steam engines expires</td>
</tr>
<tr>
<td>1801</td>
<td>Trevithick starts work on locomotives</td>
</tr>
<tr>
<td>1804</td>
<td>Evans: Road locomotive</td>
</tr>
<tr>
<td>1811</td>
<td>Blenkinskop: First toothed gear locomotive</td>
</tr>
<tr>
<td>1813</td>
<td>Hadley: Locomotive on rails</td>
</tr>
<tr>
<td>1814</td>
<td>Stephenson: starts work</td>
</tr>
<tr>
<td>1824</td>
<td>Stephenson: built first locomotive plant</td>
</tr>
<tr>
<td>1825</td>
<td>Stephenson: open Stockton-Darlington line</td>
</tr>
</tbody>
</table>

“...a technical event is a technological basic innovation when the newly discovered material or newly developed technique is being put into regular production for the first time, or when an organized market for the new product is first created.”

"...We observe long innovation periods for avant-garde innovations and shorter periods for innovation that follow familiar ground. Only pseudo-innovations occur with the wave in of a hand..."

"Gerard Mensch did classify innovations with the state of the first commercial sell and the inventions with the date of the first working prototype."

"...the distance [between invention and innovation] decreases regularly inside a certain wave, but starts larger again in the next [wave]..."
what is contradiction meaning?

Demand-1

Because of...

ELEMENT (or its Feature or Value of Feature)

Demand-2

Because of...


Dmitry Kucharavy | Vinci, Tuscany, Italy | June 2008
types of contradiction models

Administrative contradiction
we know what is required, but we do not know how to achieve that.

Technical contradiction
we know how to achieve required result, but it will make system worse.
\[ TC-1: \text{If there is } \langle V \rangle, \text{ then } \langle R1- \rangle, \text{ but } \langle R2+ \rangle. \]
\[ TC-2: \text{If there is } \langle \Lambda \rangle, \text{ then } \langle R1+ \rangle, \text{ but } \langle R2- \rangle. \]

Physical contradiction
we know what is required and how it has to work but we do not know working principle.
\[ \langle \text{Feature} \rangle \text{ has to be } \langle \text{Value} \rangle, \text{ to } \langle R2+ \rangle \]
\[ \langle \text{Feature} \rangle \text{ has to be } \langle \text{opposed Value} \rangle, \text{ to } \langle R1+ \rangle \]
CONTRADICTION

It is recommended to start construction of such a description from Right side (from Desired result) and to continue what are the positive and negative Results take place when known (typical) ways are in use.

Result(s) 1 and 2 for opposed Values of Feature should be inverse. If R1 is negative for V it should become positive for Λ.

Values of Feature should be opposed. Feature and Element are disclosed to complete model. Model should be logically harmonized in accordance with initial situation.
Forecasting contexts

**Sociological context:**
- Public acceptance of new technology (e.g. safety issue, public comfort)
- Political context (e.g. security and energy supply, energy independence, fiscal & regulatory policies, local and global environmental policies)
- Educational context (e.g. manpower capacity, existing skills)
- Employment context...

**Economic context:**
- Economic growth
- Energy production context (e.g. distributed power, centralized one)
- Energy cost & profitability ...

**Technological context**
- Industrial structure (e.g. local environmental policies)
- Compatibility with existing infrastructure (super-systems)
- Technological challenges, safety issue...

**Environmental context**
- Occupied space use, natural resources use (e.g. materials, energy, water...)
- Environmental awareness (e.g. noises issue, air quality, global warming...)
- Safety and long-run reproducibility issues...

system dynamics -> system archetypes

Systems Archetypes describe common patterns of system’s behavior (e.g. organizations)

1. Limits to Growth (aka Limits of Growth)
2. Shifting the Burden
3. Eroding Goals
4. Escalation
5. Success to the Successful
6. Tragedy of the Commons
7. Fixes that Fail
8. Growth and Underinvestment
9. Accidental Adversaries
10. Attractiveness Principle

**Sunspots**

**Sunspot** is a region on the Sun's surface (photosphere) that is marked by a lower (4000-4500K) temperature than its surroundings (5800K) and has *intense magnetic activity*.

The **Wolf number** (International sunspot number, relative sunspot number, or Zürich number)

It is computed using the formula (collected as a daily index of sunspot activity):

\[ R = k(10g + s) \]

where \( R \) is the relative sunspot number, \( s \) is the number of individual spots, \( g \) is the number of sunspot groups, and \( k \) is a factor that varies with location and instrumentation (also known as the observatory factor).

The Sun

- The Sun's mass is roughly $1.99 \times 10^{30}$ kg. This is about 333,000 times the mass of the Earth.
- The Sun contains 99.8% of all of the mass of the Solar System.
- The Sun is 149,680,000 km (or 1 Astronomical Unit) from the Earth; this is 107.5 diameters of Sun.
- Light from the Sun takes about 8 minutes to reach the Earth.

- Sunspots, Solar Flares, Prominences, the Solar Wind, and Coronal Mass Ejections.
The Sun: electromagnetic radiation

- Sun emits 63,000,000 Watts/m² of electromagnetic radiation.
- Electromagnetic Radiation (Waves): emission of energy in the form of electromagnetic waves.
Solar energy

Solar energy is energy from the Sun in the form of radiated heat and light.

SOLAR ENERGY TECHNOLOGIES

Solar buildings and urban heat island
Agriculture and horticulture
Solar lighting
Solar thermal
  Water heating
  Heating, cooling and ventilation
  Process heat
  Cooking
  Desalination and disinfection
Solar electricity
  Photovoltaics
  Concentrating solar energy
  Experimental solar power
Solar chemical
Solar mechanical
Solar vehicles

Annual average insolation at Earth's surface. The black dots represent the land area required to replace the total world energy supply with electricity from solar cells.

* http://en.wikipedia.org
Solar system

Along with light, the Sun radiates a continuous stream of charged particles (a plasma) known as the solar wind. This stream of particles spreads outwards at roughly 1.5 million km/h creating the heliosphere.

This is known as the interplanetary medium. Geomagnetic storms on the Sun's surface, such as solar flares and coronal mass ejections, disturb the heliosphere, creating space weather.

Earth's magnetic field protects its atmosphere from interacting with the solar wind.

The orbits of the bodies in the Solar System to scale (clockwise from top left)

Fractal structure of Natural Growth

The per capita annual energy consumption worldwide: data, fits, and a scenario for the future.
The small circles show what happened in the last fourteen years.
The prediction is largely confirmed.


* Source: Modis, T. Predictions - 10 Years Later. (Growth Dynamics, Geneva, Switzerland, 2002)
Oil: the growing gap

The rate of global oil production compared to the rate at which oil is added to global proved reserves.

Source: http://www.eoearth.org/article/Fundamental_principles_of_energy
Primary source: ASPO-Ireland http://www.peakoil.ie/
Transitions in energy systems

Composition of U.S. energy use. Electricity refers to power from primary sources only: nuclear, hydropower, solar, wind, and geothermal.

* Source: http://www.eoearth.org/article/Fundamental_principles_of_energy
Transitions to new energy source

The global flux of fossil and renewable fuels.

Is it big difference $10^{13}$ and $10^{16}$?

**The Solar System**

Scale: $10^{13}$ meters = 10 Tm = 10 terameters: Light takes ~8 hours to cross this picture.

**The Oort Cloud**

Scale: $10^{16}$ meters = 10 Pm = 10 petameters ~1 light year

Source: http://www.wordwizz.com/pwrsof10.htm
World-Wide distribution of radioactive waste...

Case Study: Dumping of Radioactive Waste at Sea

The Report of the United Nations Conference on Human Environment held in Stockholm in 1972 defined the principles for environmental protection, specifically for the assessment and control of marine pollution. These were forwarded to an Inter-Governmental Conference held in London later that year, where the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (also known as the London Convention of 1972) was adopted and which entered into force on 30 August 1975.

The contracting parties to the London Convention agreed to promote the effective control of all sources of pollution of the marine environment and to take all practicable steps to prevent the pollution of the ocean by dumping of waste and other matter that is liable to create hazards to human health and to harm living resources and marine life. The International Atomic Energy Agency (IAEA) was designated as the international body that should oversee matters related to the disposal of radioactive wastes in the ocean.

The first reported ocean disposal operation of radioactive waste was carried out by the USA in 1946 in the North-East Pacific Ocean and the latest was carried out by the Russian Federation in 1998 in the Japan Sea/East Sea. During the 48 year history of sea disposal, 14 countries have used more than 80 sites to dispose of approximately 85 PBq (1 PBq = 1015 Bq) of radioactive waste.

The figure shows the geographical distribution of disposal operations.

Source: Modified from http://www.oceansatlas.com/servlet/CTISServletstatus=ND0xNDExMzY3PWVuYFZomNjU9e29t. Figure has been modified from http://www.oceansatlas.com/atlas/about/physicalandchemicalproperties/radioact/index.htm.

World-Wide distribution of radioactive waste...
World-Wide distribution of radioactive waste...

North Atlantic Ocean Sites
- Germany, Italy, Sweden: <0.01%
- Switzerland: 9.8%
- Netherlands: 0.8%
- France: 0.8%
- Belgium: 4.7%
- United States: 6.5%
- United Kingdom: 77.6%

Pacific Ocean Sites
- United States: 30.9%
- Japan: 1.2%
- New Zealand, Russian Federation: 0.3%
- Former Soviet Union: 50.5%

Arctic Ocean Sites
- Former Soviet Union: 100%

Relative contributions by country to radioactive waste dumping in the Atlantic, Pacific and Arctic Oceans

Source: [http://www.oceansatlas.org/unatlas/about/physicalandchemicalproperties/radiosp/htm/Geographical.html](http://www.oceansatlas.org/unatlas/about/physicalandchemicalproperties/radiosp/htm/Geographical.html)
World-Wide distribution of radioactive waste...

Source: http://www.oceansatlas.org/unatlas/about/physicalandchemicalproperties/radiosp/htm/Geographical.html
World-Wide distribution of radioactive waste...

Source: [http://www.informaction.org/cgi-bin/gPage.pl?menu=menua.txt&main=weapons_effects.txt&s=Weapons](http://www.informaction.org/cgi-bin/gPage.pl?menu=menua.txt&main=weapons_effects.txt&s=Weapons)
Functions of Science & Technology roadmaps*

1. To portray the structural relationships among science, technology, and applications.
2. To enhance communications among stakeholders (researches, managers, suppliers, users etc.)
3. S&T marketing.
4. S&T management (Strategy, Planning, Executing, Reviewing, Transitioning etc.)
5. Identify gaps and opportunities in S&T programs.
6. Identify obstacles to rapid and low-cost product development.
7. Provide a consensus view or vision of the future S&T landscape available to decision makers.
8. Help develop consensus among decision makers about a set of S&T needs.
9. Provide a way to identify, evaluate, and select strategic alternatives to achieve desired S&T objectives.
10. Helps narrow the field of requirements and possible solutions to those most likely to be pursued.
11. Provide a mechanism to help experts forecast S&T developments in target areas.
12. Present a framework to help plan and coordinate S&T developments at different levels: organization-company; discipline-industry; cross-industry – national/international.
13. To assess future technological development within an environment of constant change.
14. Facilitate in enhancing efficiency of the technology transfer process.
15. Assist in filtering out the less promising technologies from the more promising ones.
16. To elicit champions for supporting S&T.
17. To identifying S&T gaps and opportunities.
18. To enhance communications among all the interested parties in S&T program development.
19. To promote a common understanding of the global context of S&T development.
20. To identify potential impacts...