Engineering and the Modern World

Transformation of Society by Engineering

Prof. Michael G. Littman
Princeton University

VTEEA 2015

Language, History, and Meaning of Engineering

Scientific: formulas
relationships

Social: innovators
changes in society

Symbolic: images
changes in vision

Language, History, and Meaning of Engineering

Scientific: formulas
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Social: innovators
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Symbolic: images
changes in vision

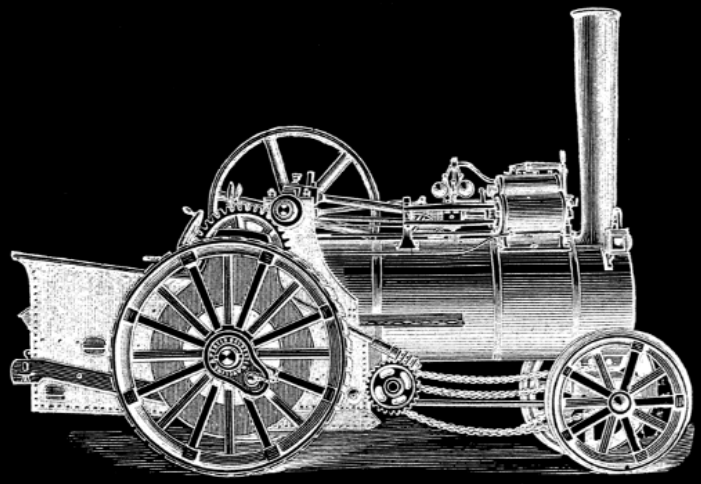
Symbolic

Transformation of Vision

Thomas Cole

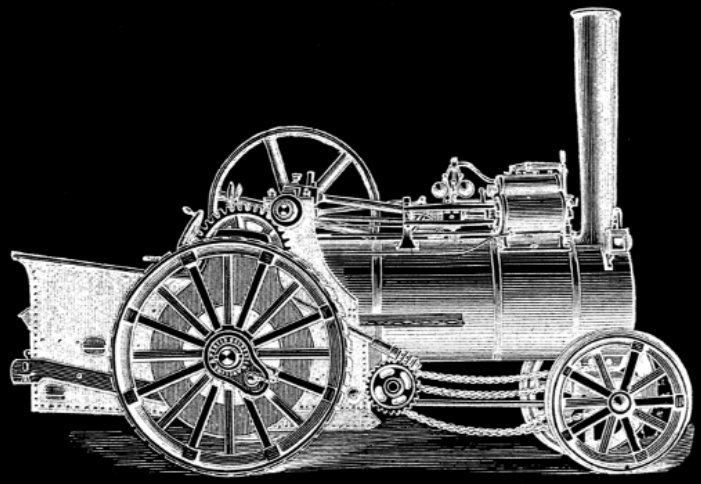
1828 - 1846

Steamboat – artist to landscape



Steam Tractor – tames nature

Steamboat – artist to landscape



Steam Tractor – tames nature

Building an Urban Society

structures

machines

networks

processes

Building an Urban Society

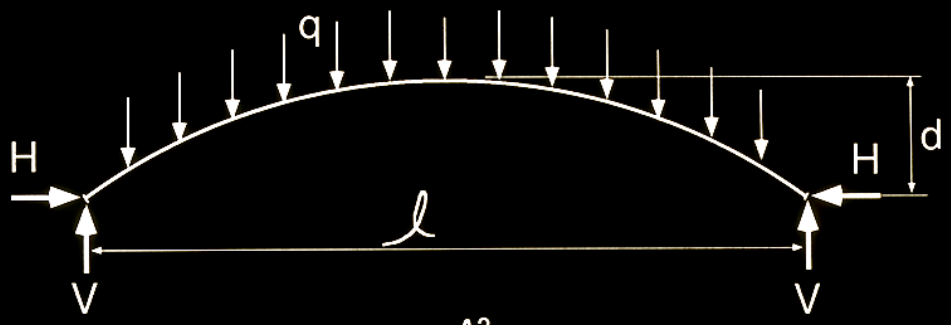
- structures
- machines
- networks
- processes

Scientific

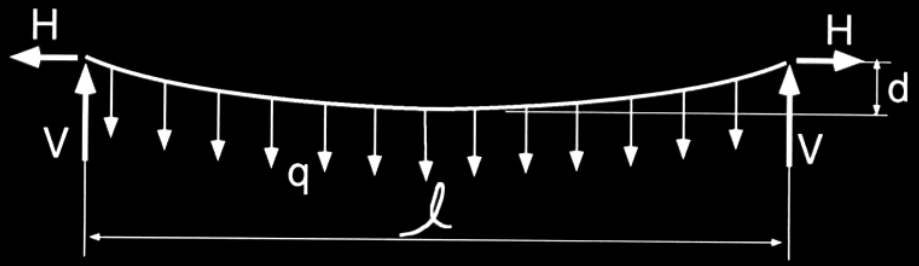
Transformation of Nature

Thomas Telford

1814 – 1826



$$H = \frac{q\,l^2}{8d}$$



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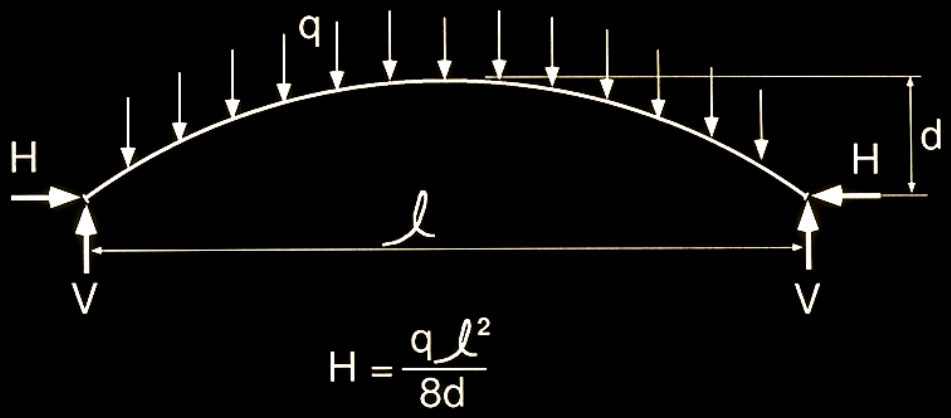

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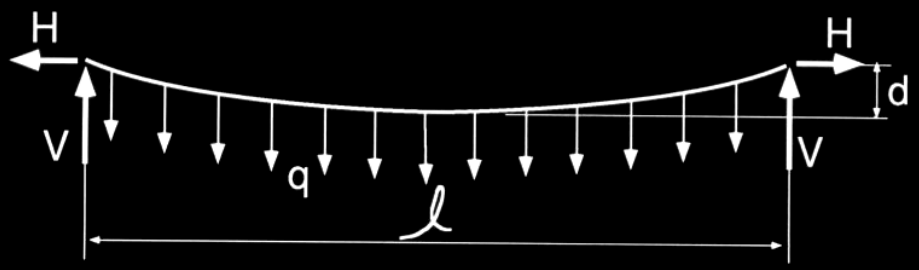


$$H = \frac{q\,l^2}{8d}$$

Structures: Cable or Arch

Vertical Deck Weight : q *l*

Transformed by Form : *l* / d

Into Horizontal Force : H

Economics – Art – Science

George Washington Bridge - 1931

Structures: Cable or Arch

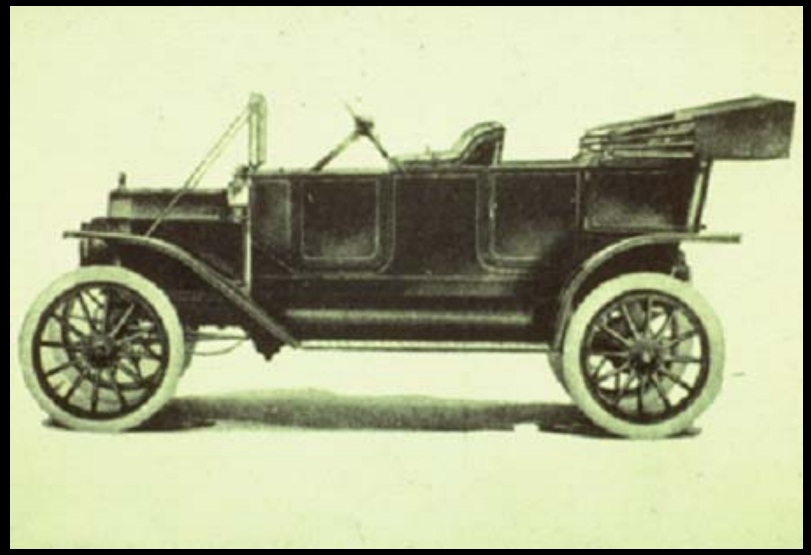
Vertical Deck Weight : q *l*

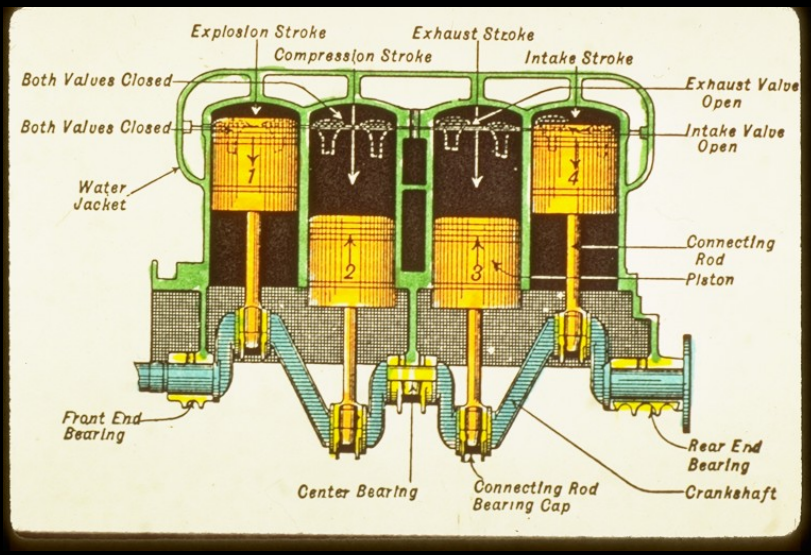
Transformed by Form : *l* / d

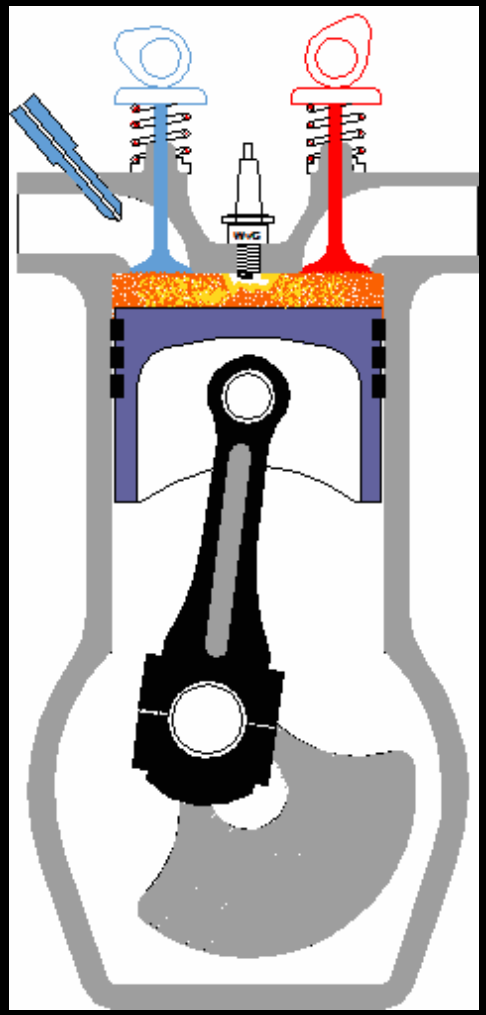
Into Horizontal Force : H

Economics – Art – Science

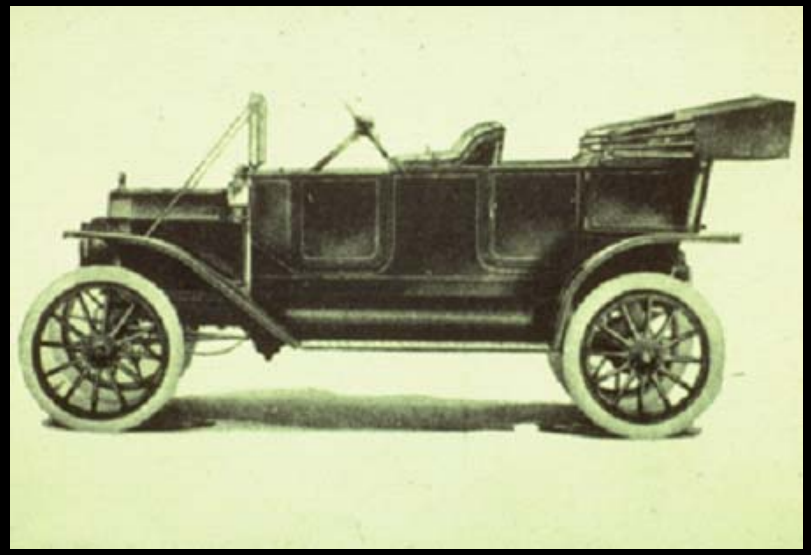
George Washington Bridge - 1931

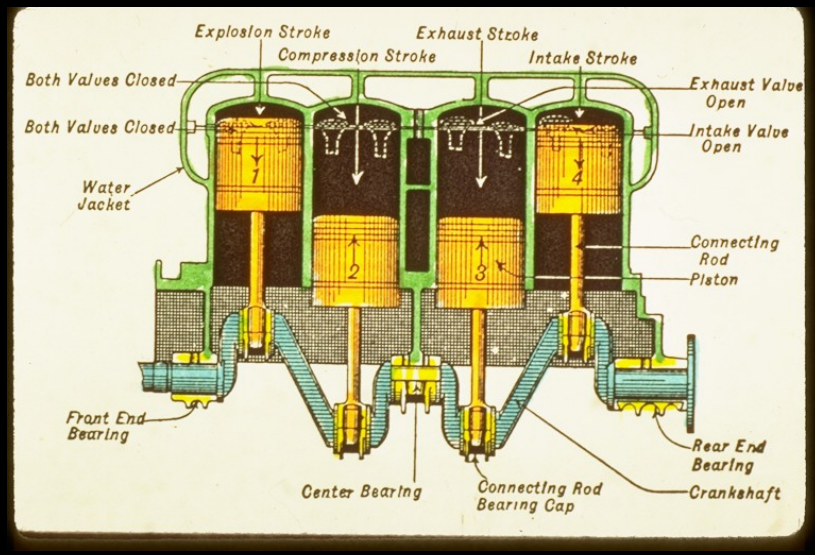




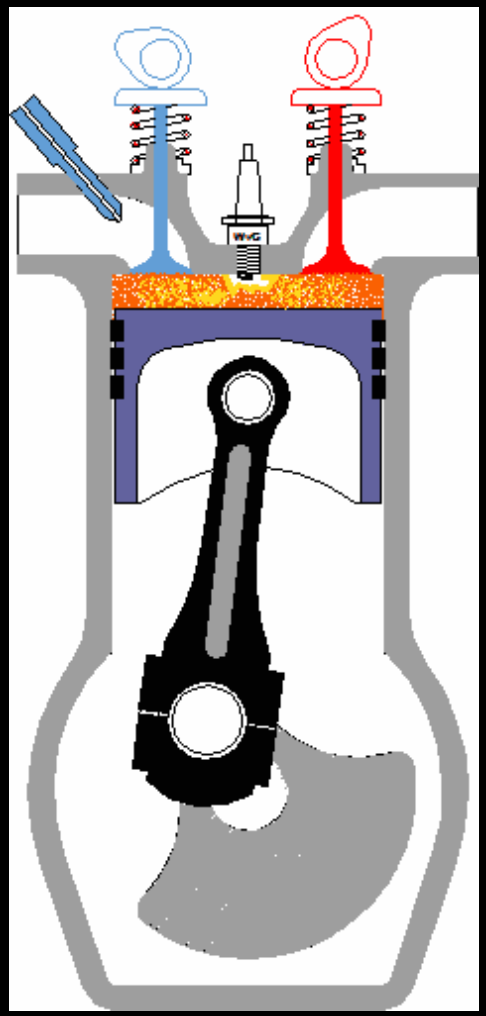


P = pressure
L = stroke
A = area
N = frequency





Thermodynamics: Heat to Work



P = pressure
L = stroke
A = area
N = frequency

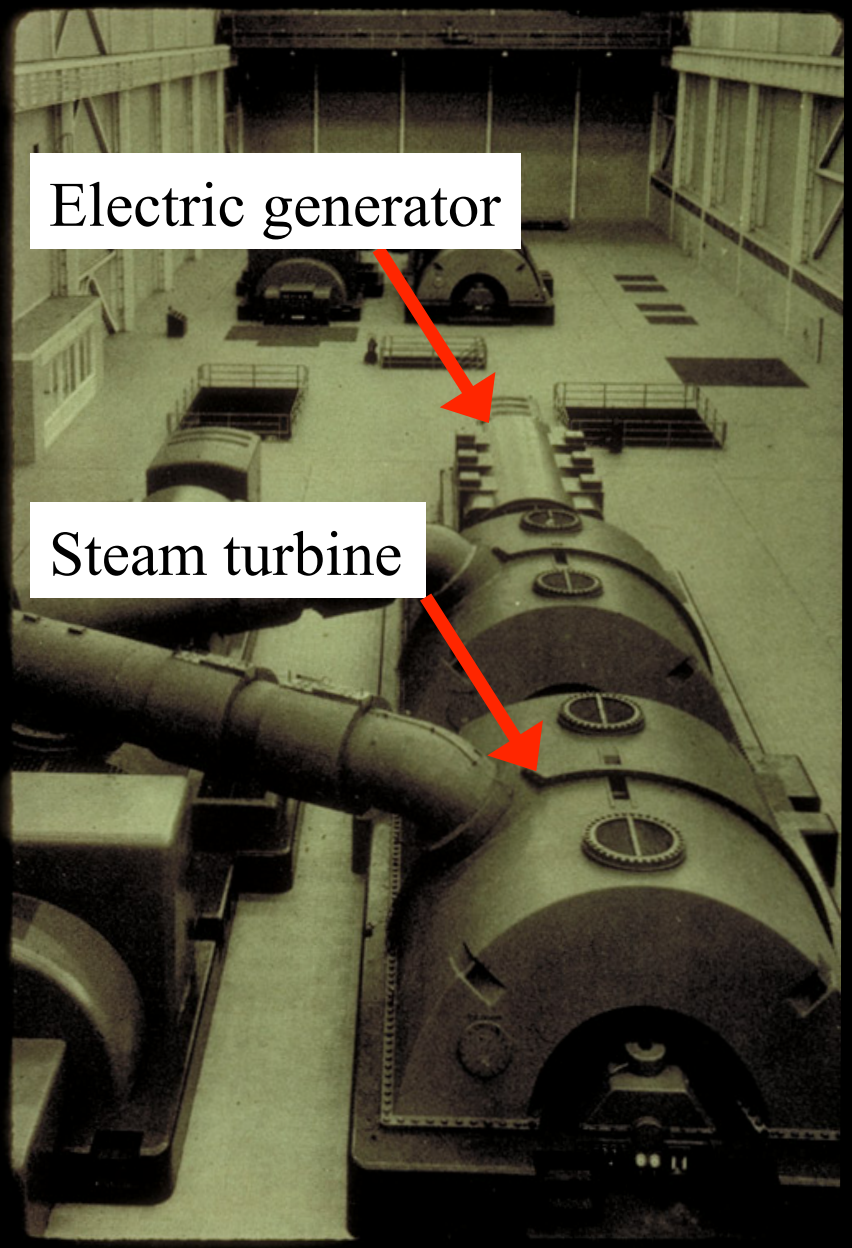
Machines: Piston Engine

Piston Force : P A

Maintained at Speed : L N

Transformed to Horsepower : Hp

Power – Speed – Progress



Coal-Fired Steam to Electricity

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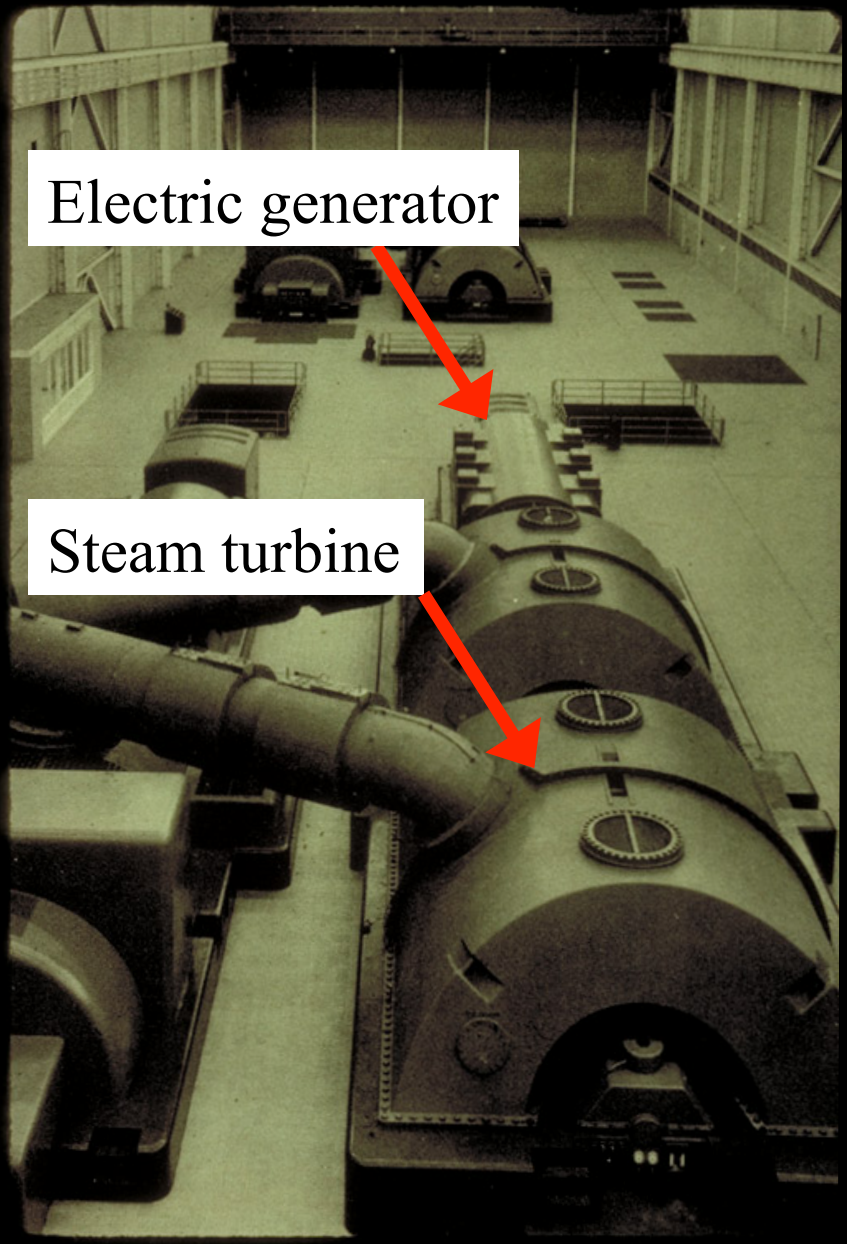

Coal-Fired Steam to Electricity

Networks: Electric Generator

$$Hp = \frac{VI}{746}$$

Generator Voltage : V

Maintained at Current : I

Transformed to Power : Hp

Power – Speed – Progress

Networks: Electric Generator

$$Hp = \frac{VI}{746}$$

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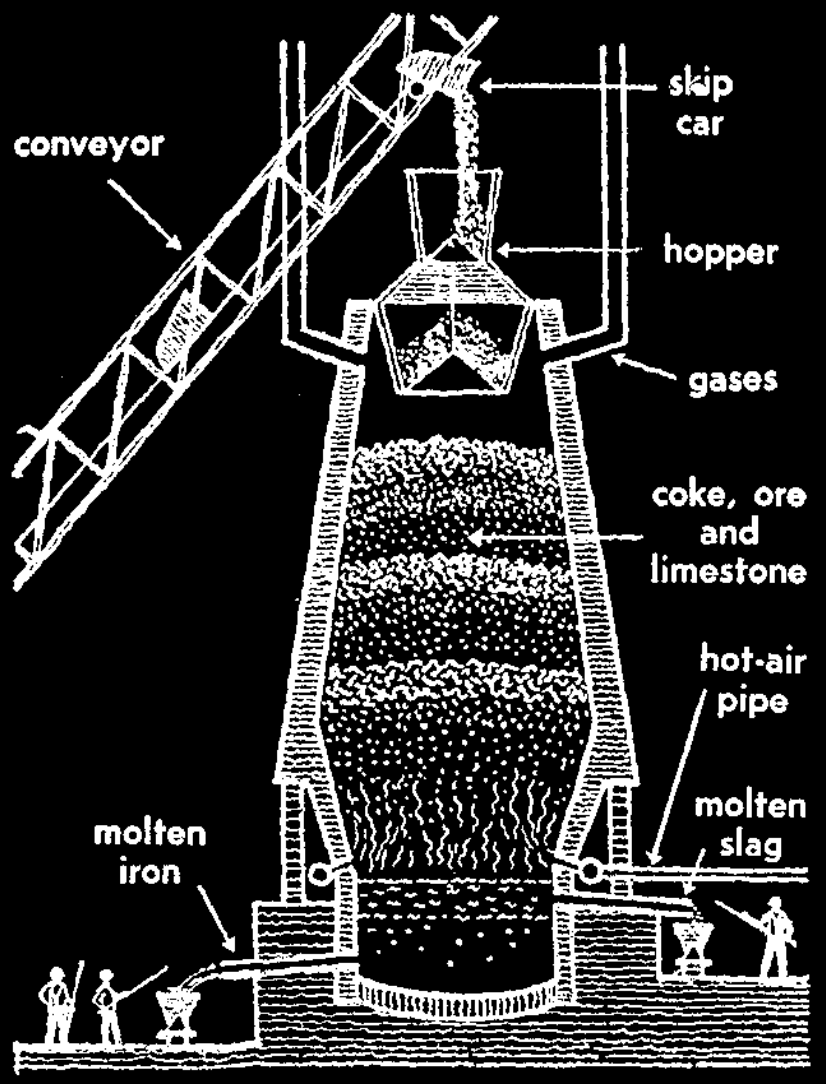


Coal-Fired Hematite (Fe_2O_3) to Iron

Processes: Blast Furnace

$Fe_2O_3 + 3C + (3/2)O_2 \rightarrow 2Fe + 3CO_2$

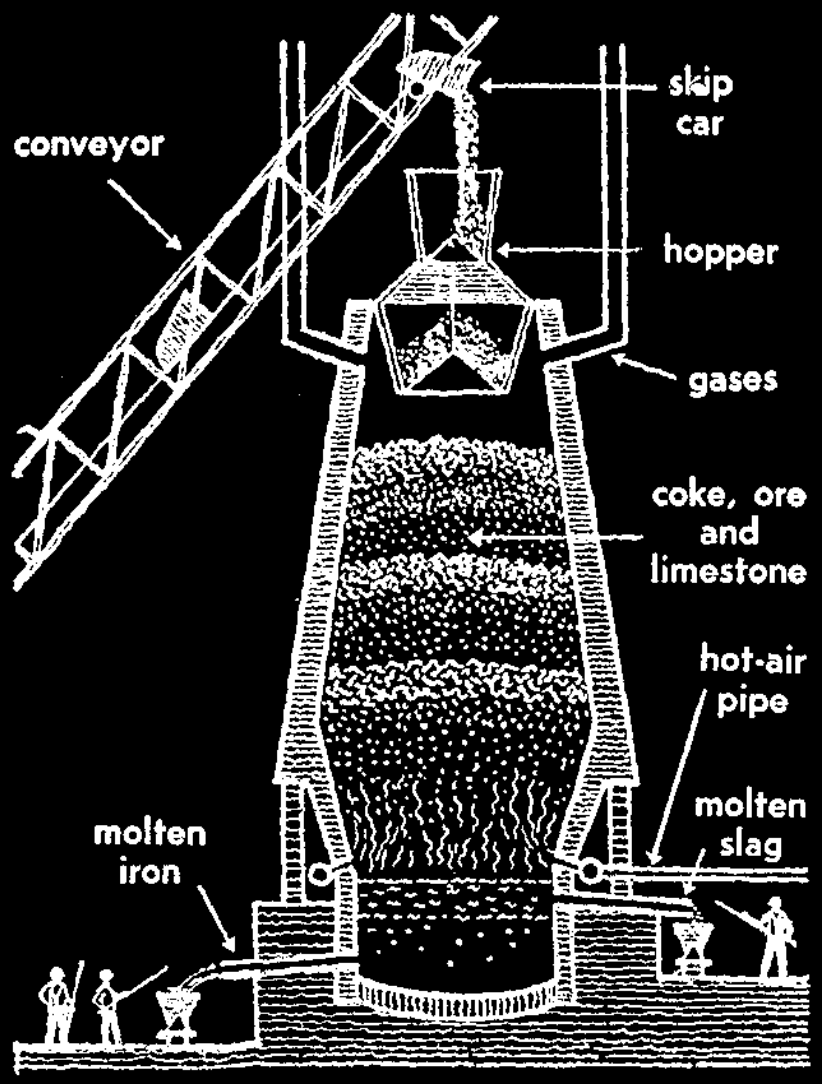
Iron Ore : Fe_2O_3

Heated with Coal (Coke) : C

and Air : O_2

Transformed into Iron : Fe

Material – Form – Scale



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Material – Form – Scale


1889


1779

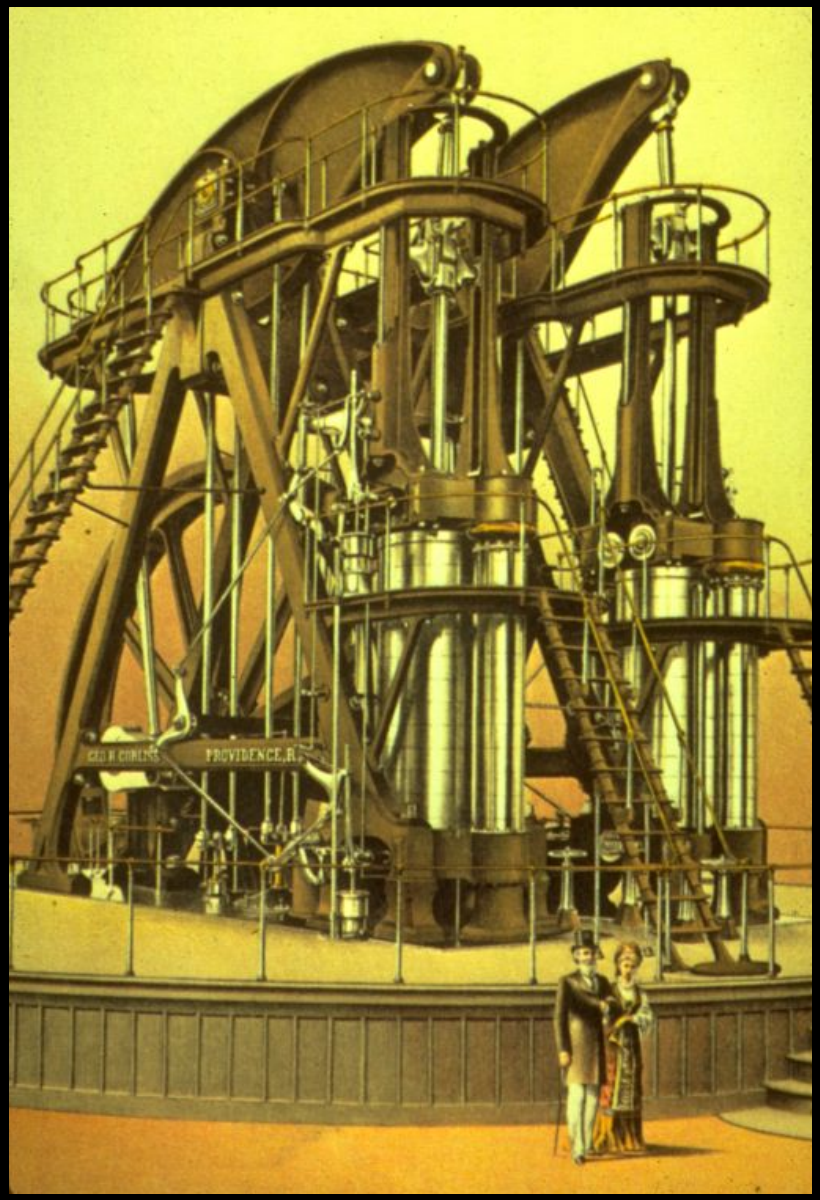
Social

Transformation of Society

Structures and Machines

Politics of Public Works

Economics of Private Enterprise



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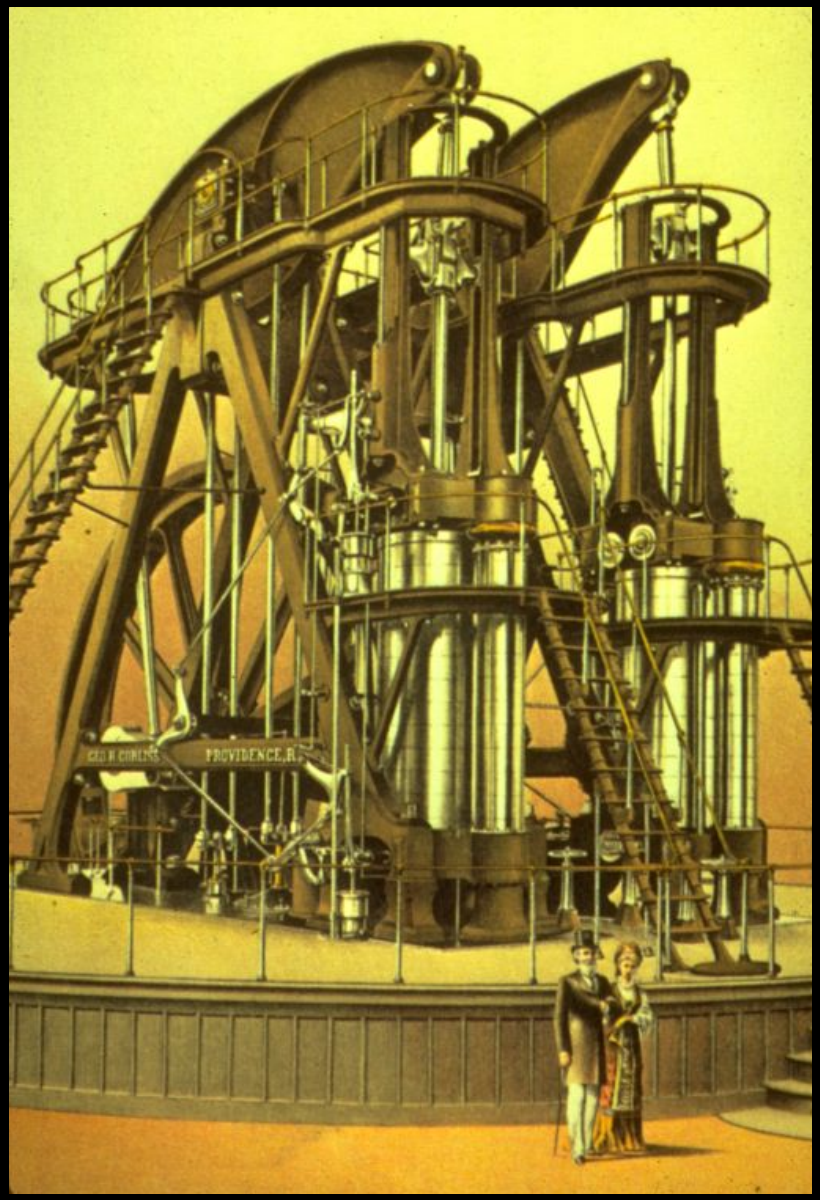


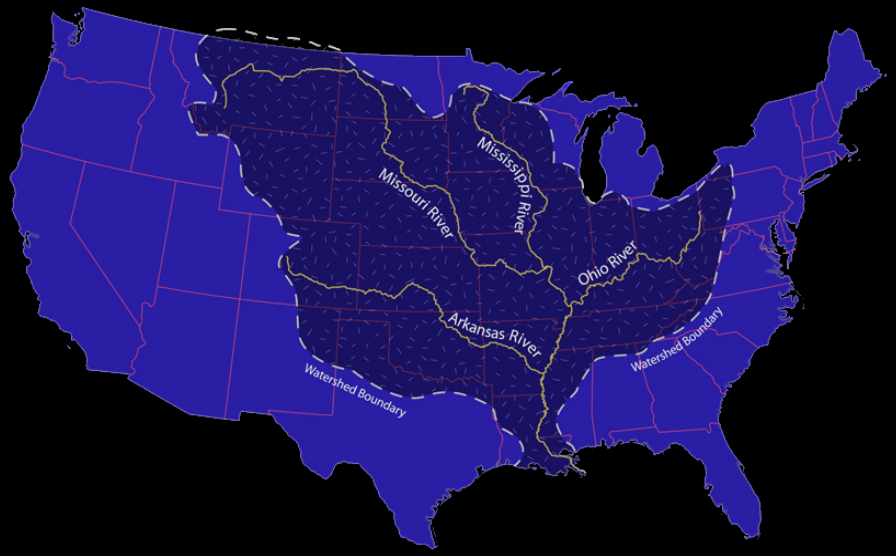
Social

Transformation of Society

Networks and Processes

Industry Restructures Regions

Public Resources and Private Profits



Transportation: River to Rail

Social

Transformation of Society

Networks and Processes

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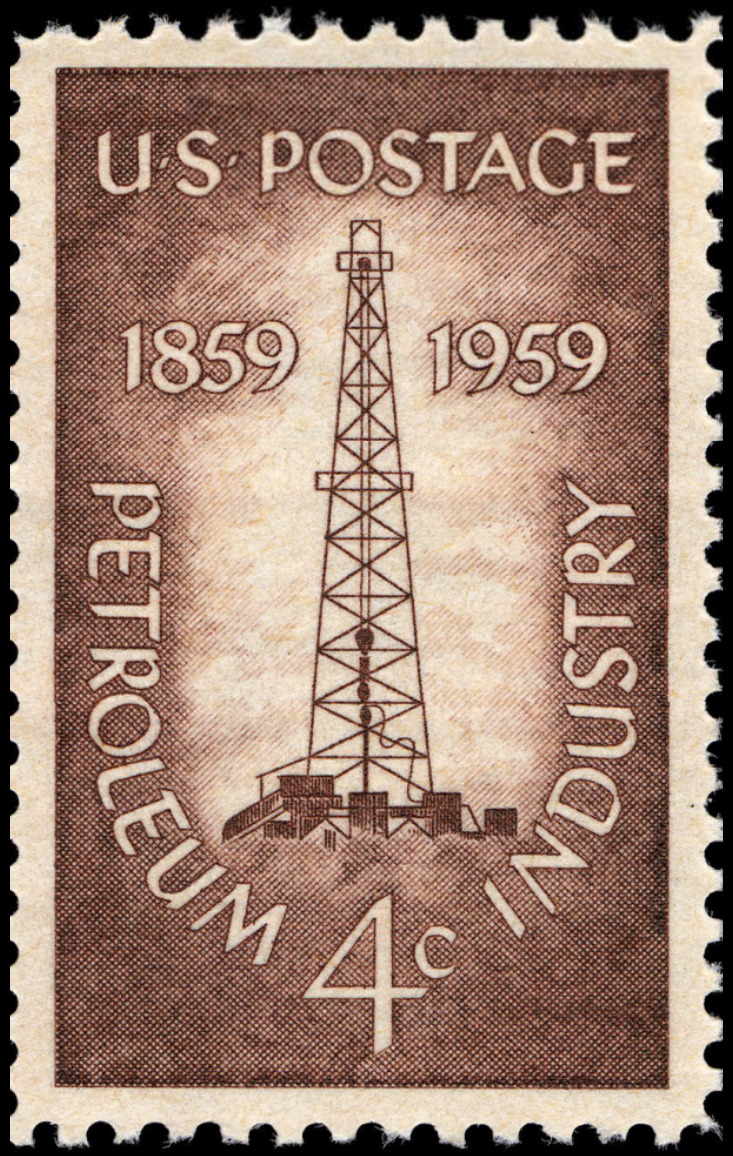

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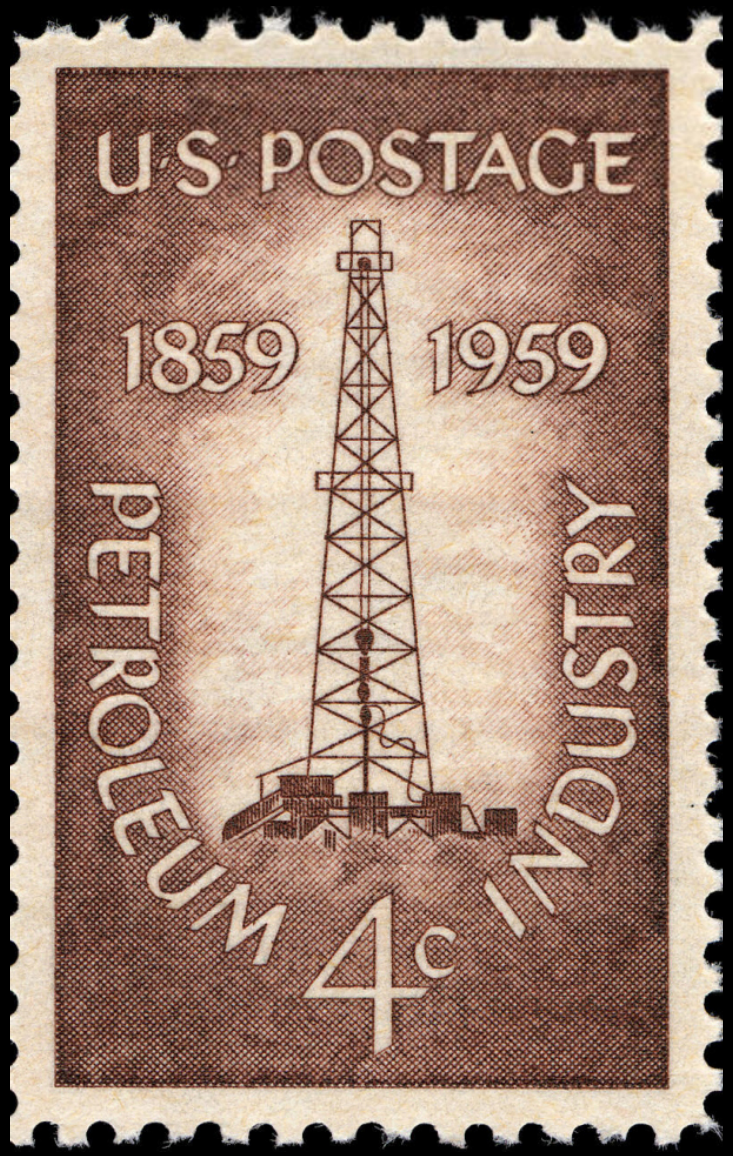
Resources: Oil to Wealth



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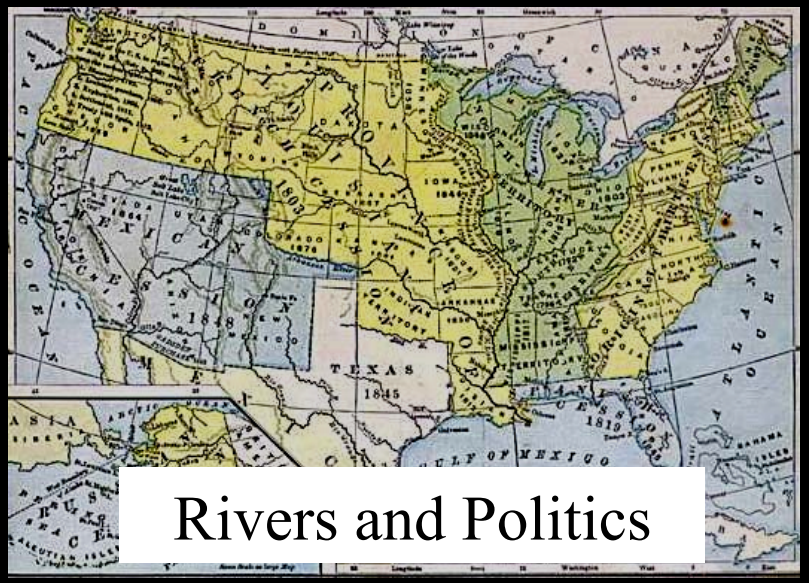

Rivers and Politics

Age of Iron and Steel

1. Independence, Iron, and Industry: 1776 – 1855
2. Connecting the Continent: 1830 – 1876

Age of Power and Speed

3. The Rise of the Great American Industries: 1876 – 1939
4. Regional Restructuring: 1921 – 1964
5. Information and Infrastructure: 1946 –

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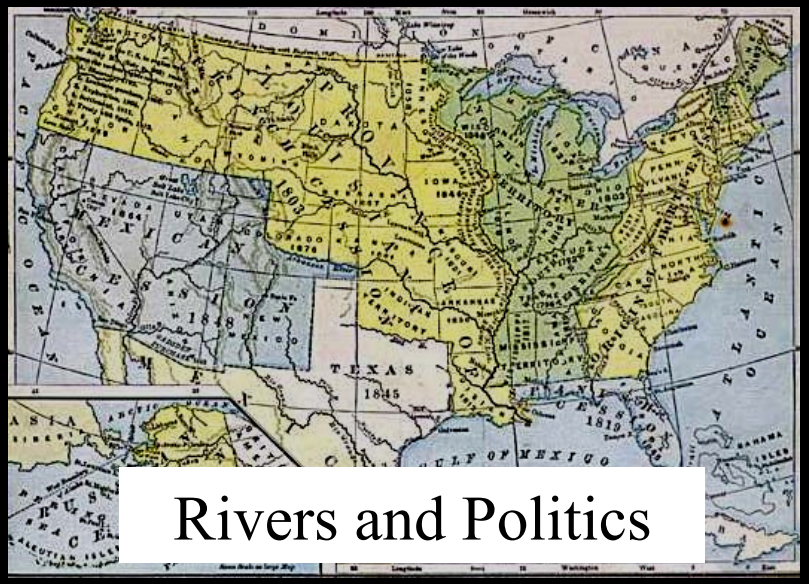

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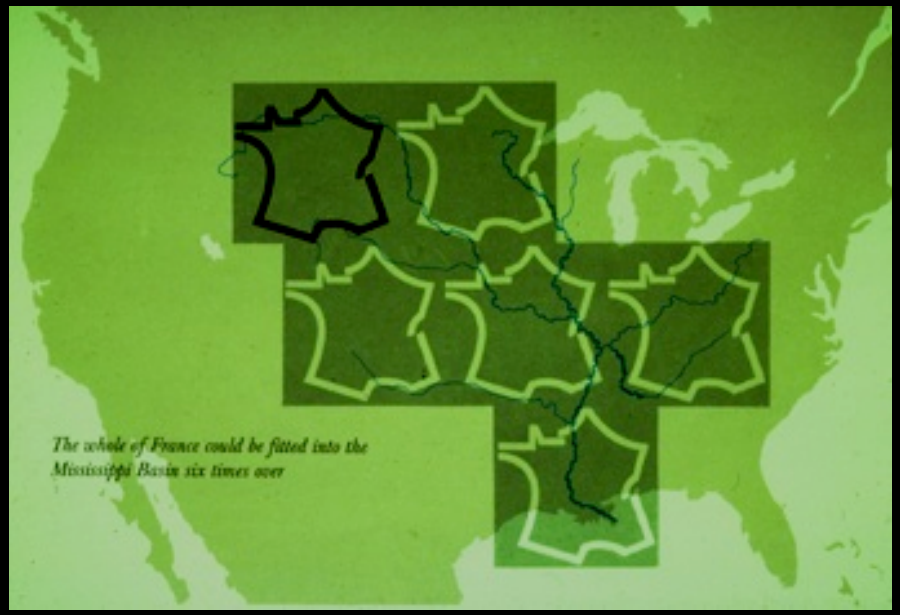
Independence, Iron, & Industry
1776 - 1855

Fulton, Livingston
and the steamboat

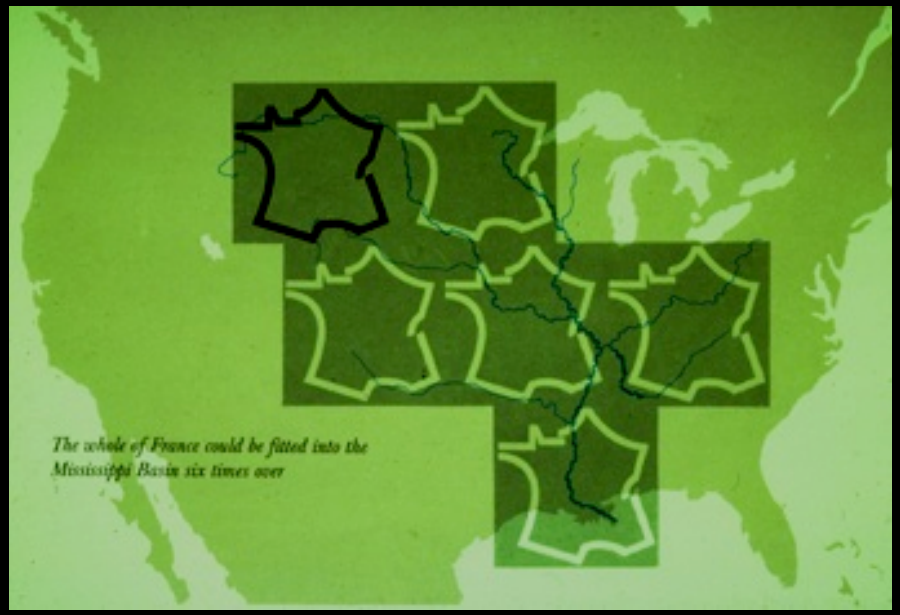
Lowell, Francis
and textiles

Stephenson, Thomson
and railroads



"The whole of France fits into the Mississippi Basin six times over."

Louisiana Purchase motives the development of the steamboat



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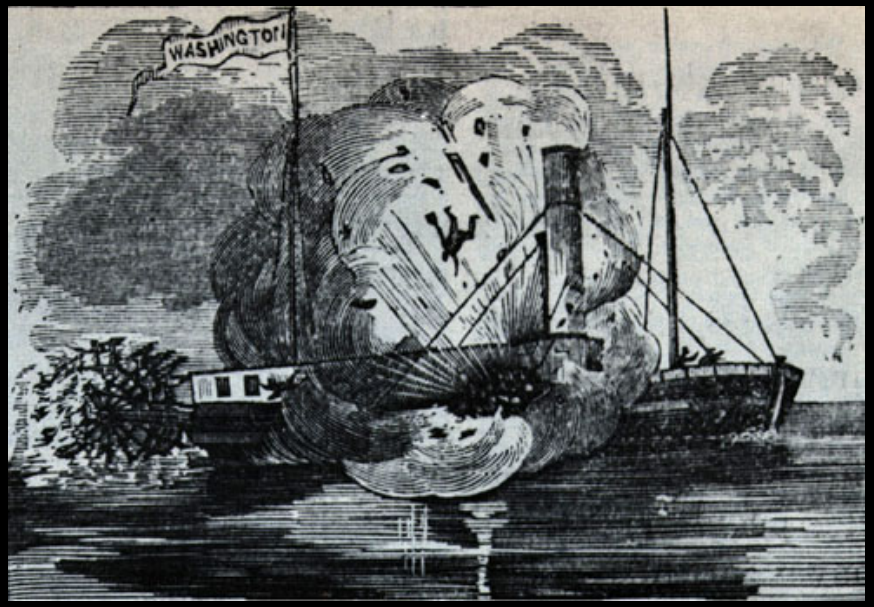
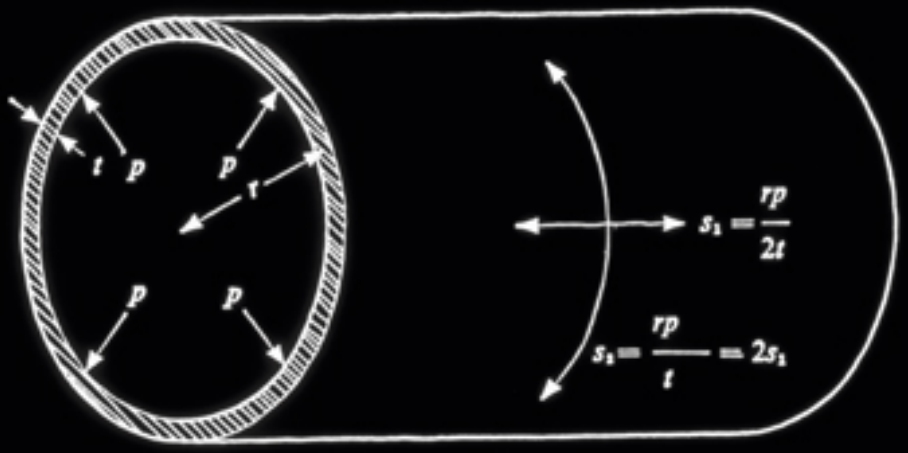
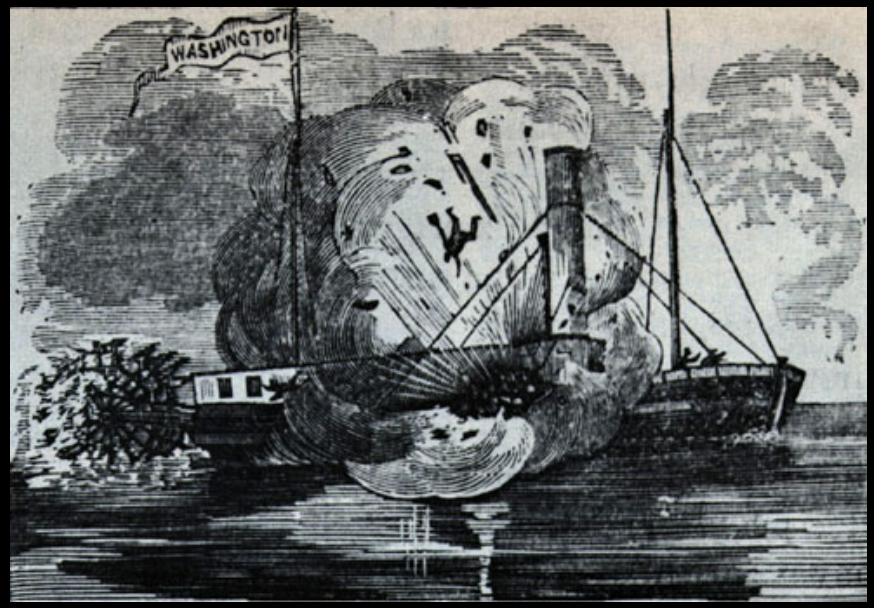


Mississippi River 1824

Economics versus Safety



$$f_1 = \frac{Pr}{h}$$



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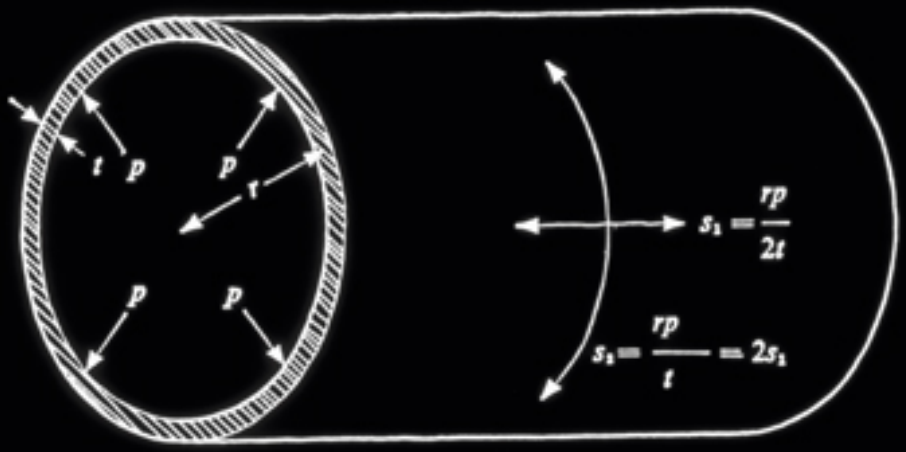

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Boiler Explosions

Franklin Institute

STRESSES

Alfred Guthrie

STATISTICS

Mark Twain

STORIES

Boiler Explosions

Edward Hopper : Railroad Sunset

Franklin Institute

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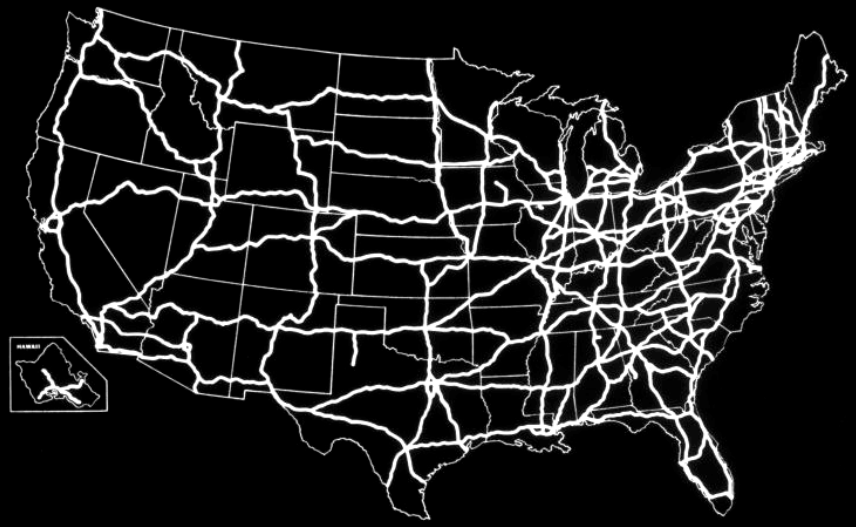
Connecting the Continent
1830 - 1876

Stanford
and the continental railroad

Henry, Morse
and the telegraph

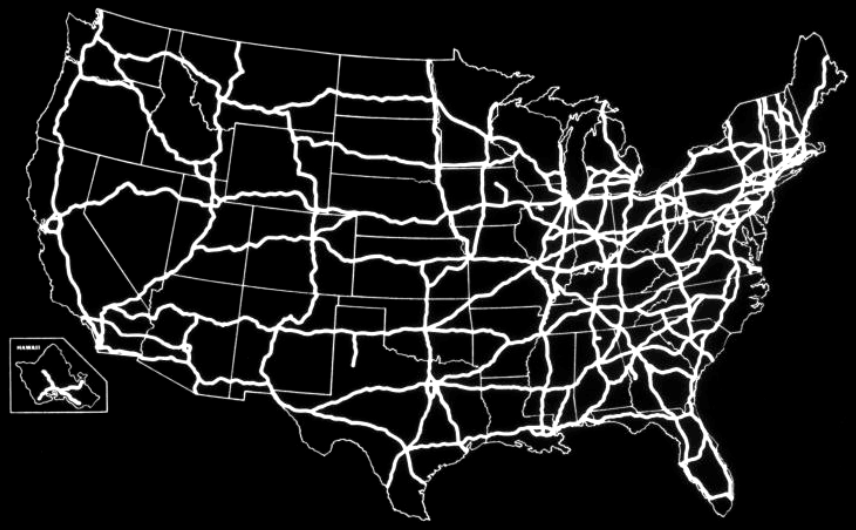
Carnegie, Holley
and steel rails

Edward Hopper : Railroad Sunset



Federal Highway Act - 1956

Transportation: Rail to Road



Federal Highway Act - 1956

The Rise of the Great Industries 1876 - 1939

SPEED

Ford and Model T

The Wright Brothers and Flyer

Douglas and DC – 3

Transportation: Rail to Road

The Rise of the Great Industries
1876 - 1939

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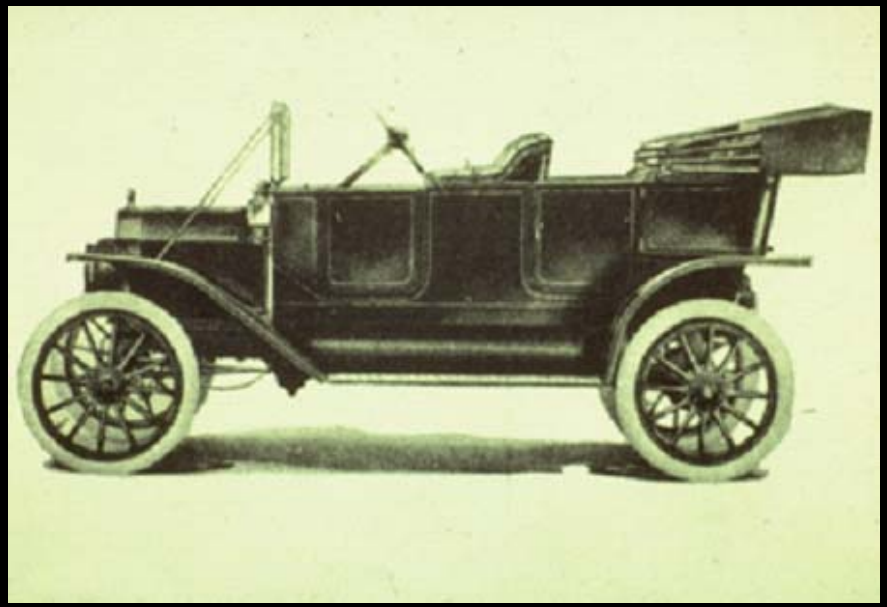
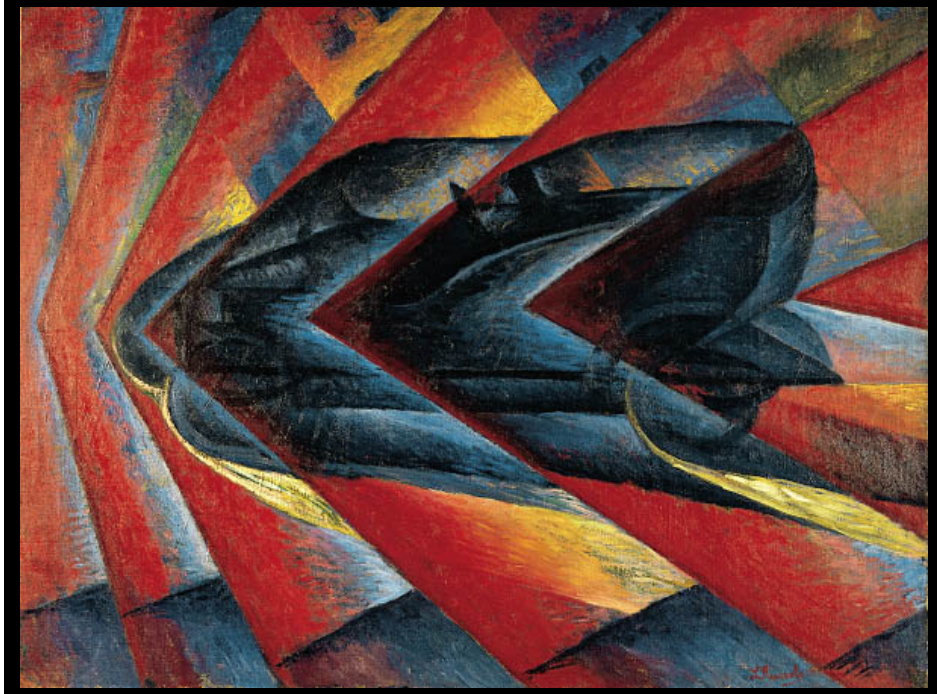
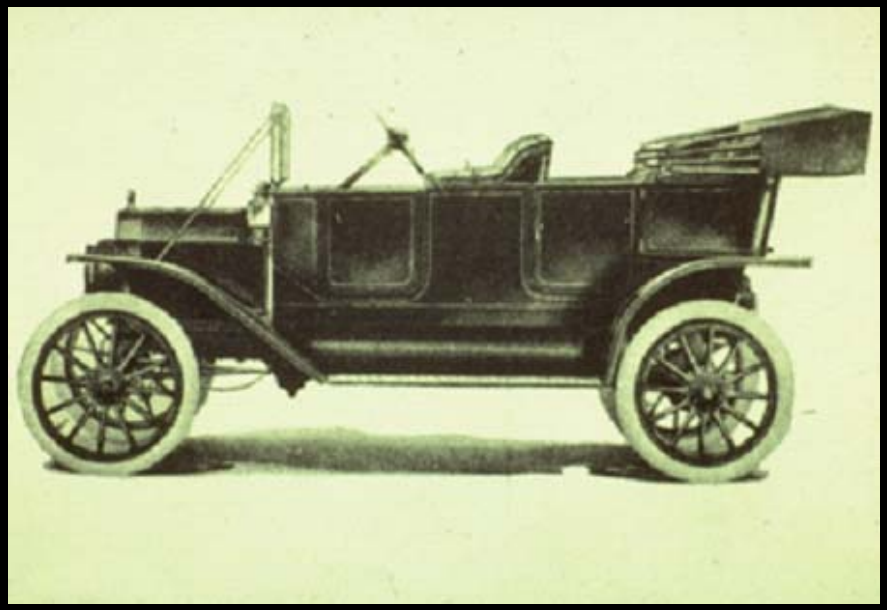






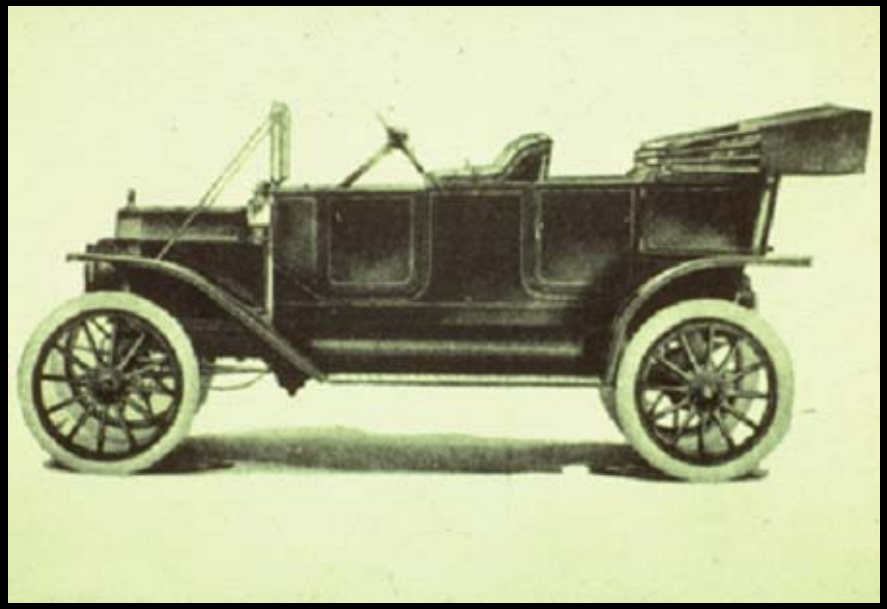
Luigi Russolo: Dynamism of Auto

The Rise of the Great Industries
1876 - 1939

POWER

Edison, Westinghouse
and electricity

Rockefeller, Burton
and oil refining



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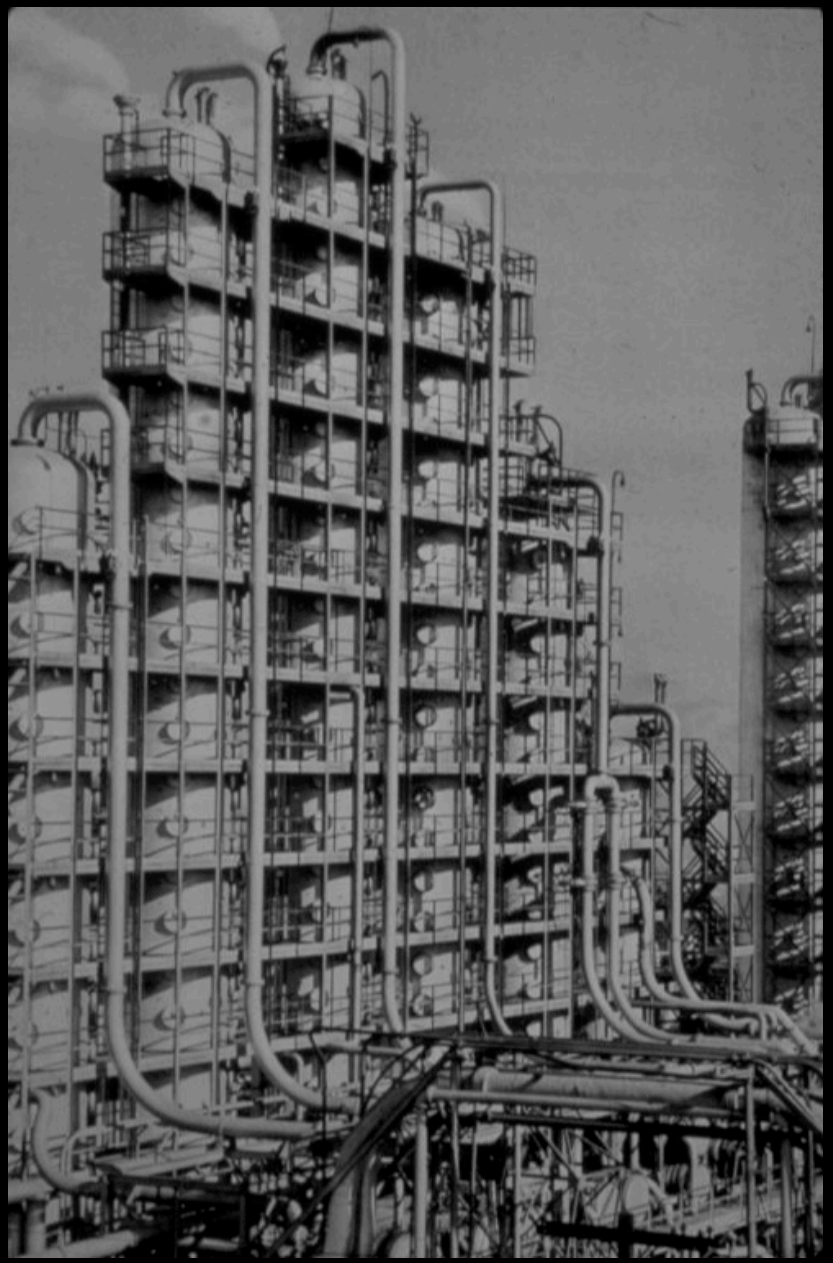
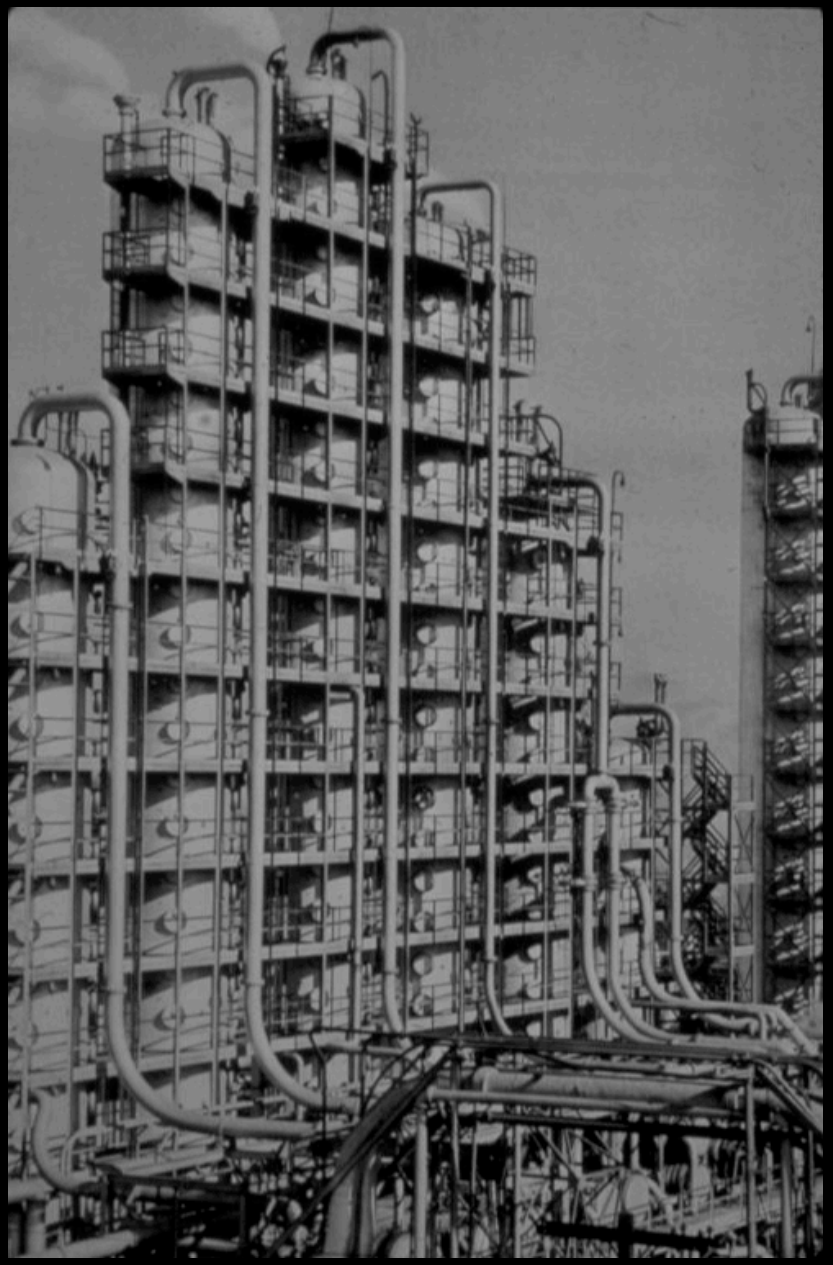
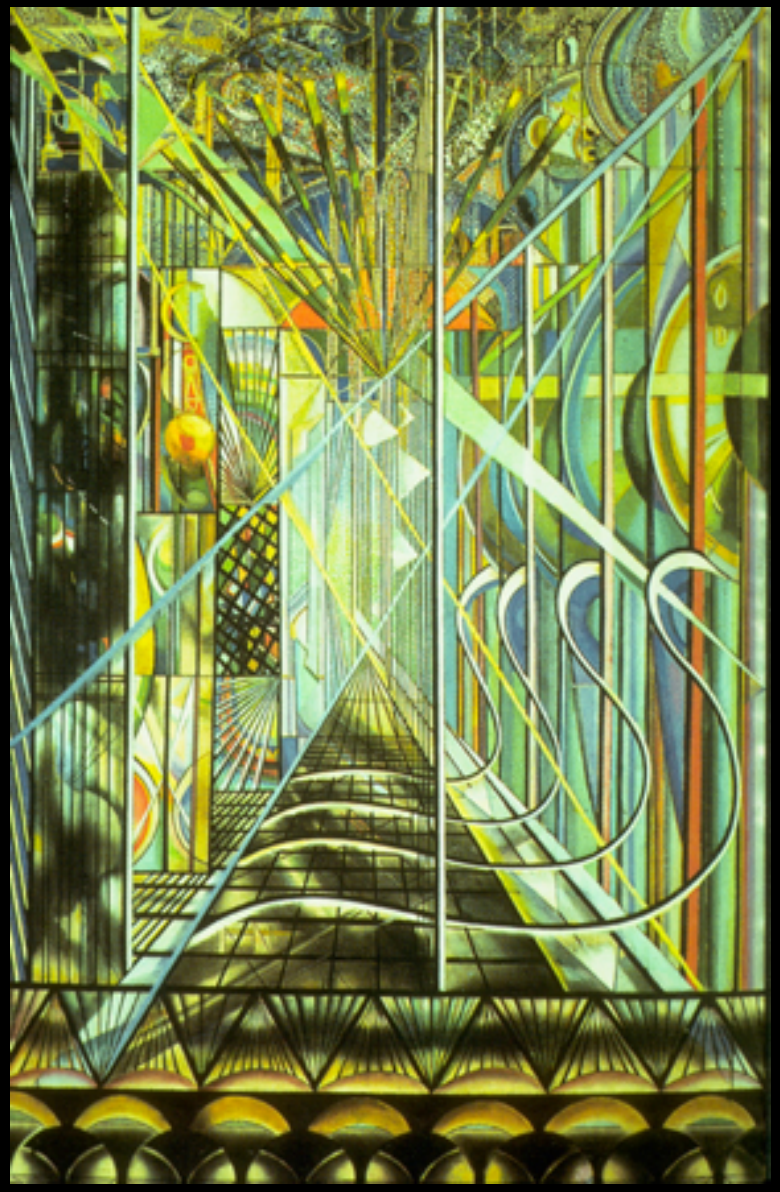
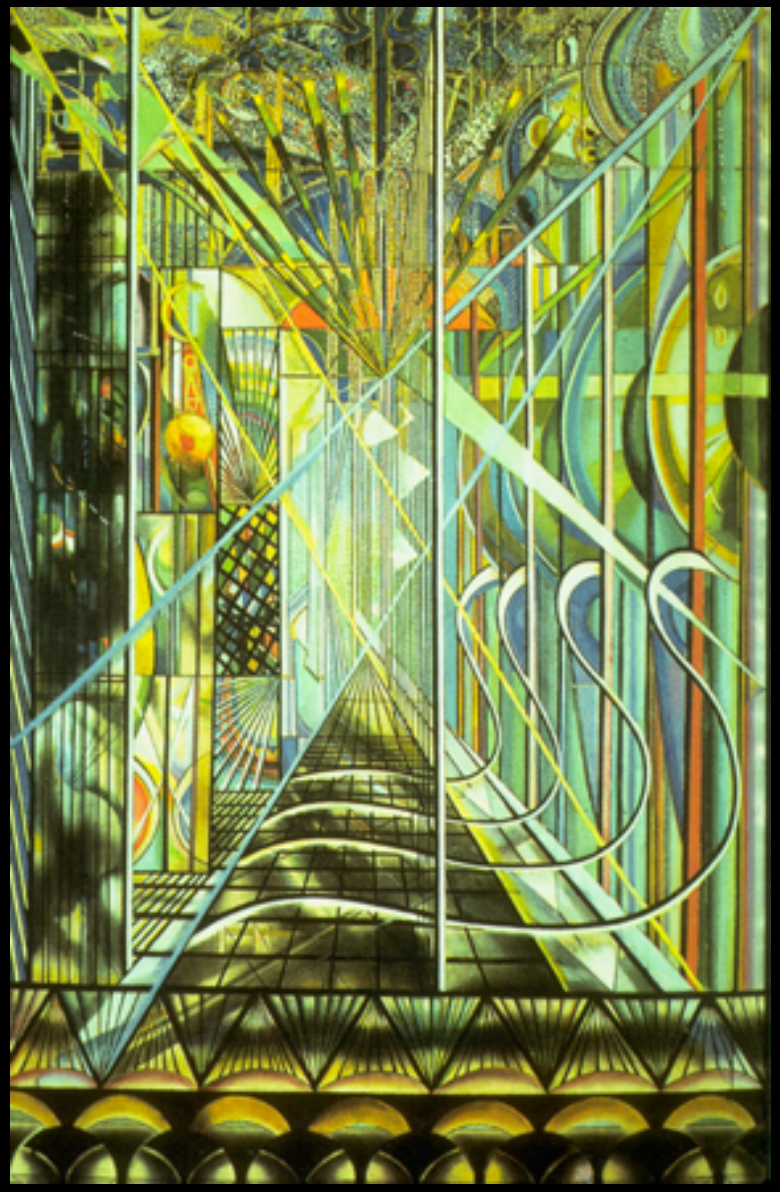






Hoover Dam lit by its own Power



Hoover Dam lit by its own Power

Regional Restructuring
1921 - 1964

POWER

Morgan and Lilienthal
and Tennessee Valley Authority

Crowe
Hoover Dam and Los Angeles

Regional Restructuring
1921 - 1964

SPEED

Ammann
and the Port Authority of NY & NJ

Douglas
Streamline, Shapes, and Style

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Santa Clara Valley

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Santa Clara Valley

Silicon Valley

from Agriculture to Industry

Information and Infrastructure
1946 –

INFORMATION

Kilby, Noyce
and the integrated circuit

Turing, Von Neumann
and the digital computer

Jobs, Gates
and the personal computer

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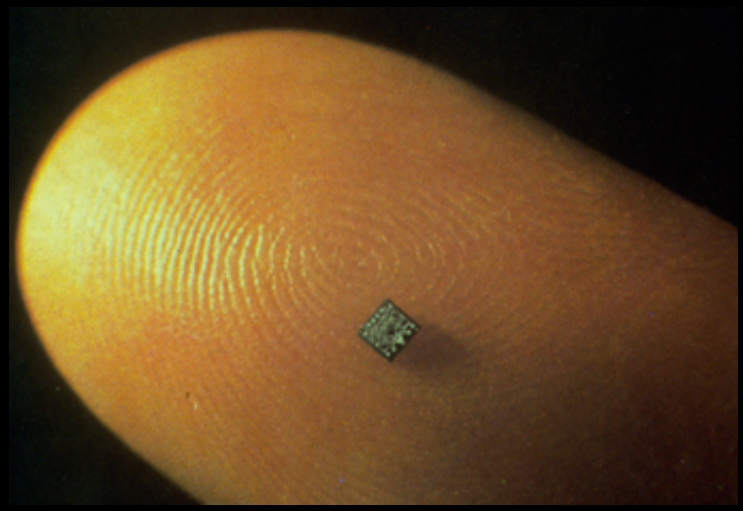
The Microchip

1958—**The monolithic idea:**
Jack St. Clair Kilby
TEXAS INSTRUMENTS

1959—**The integrated circuit:**
Robert Noyce
FAIRCHILD



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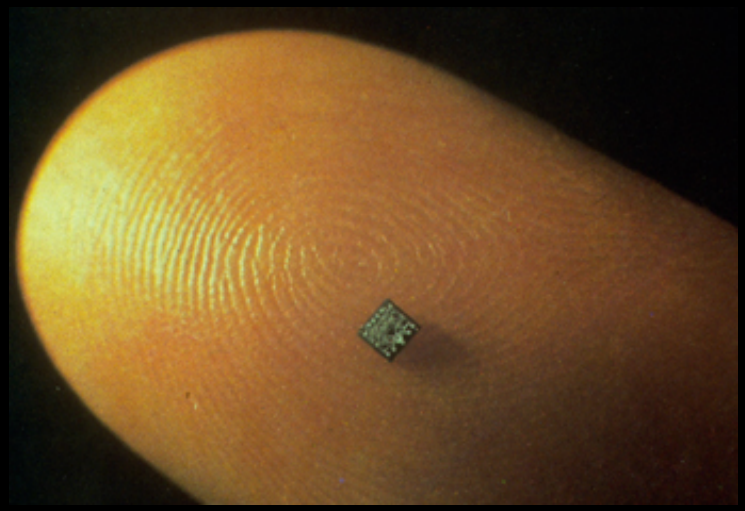

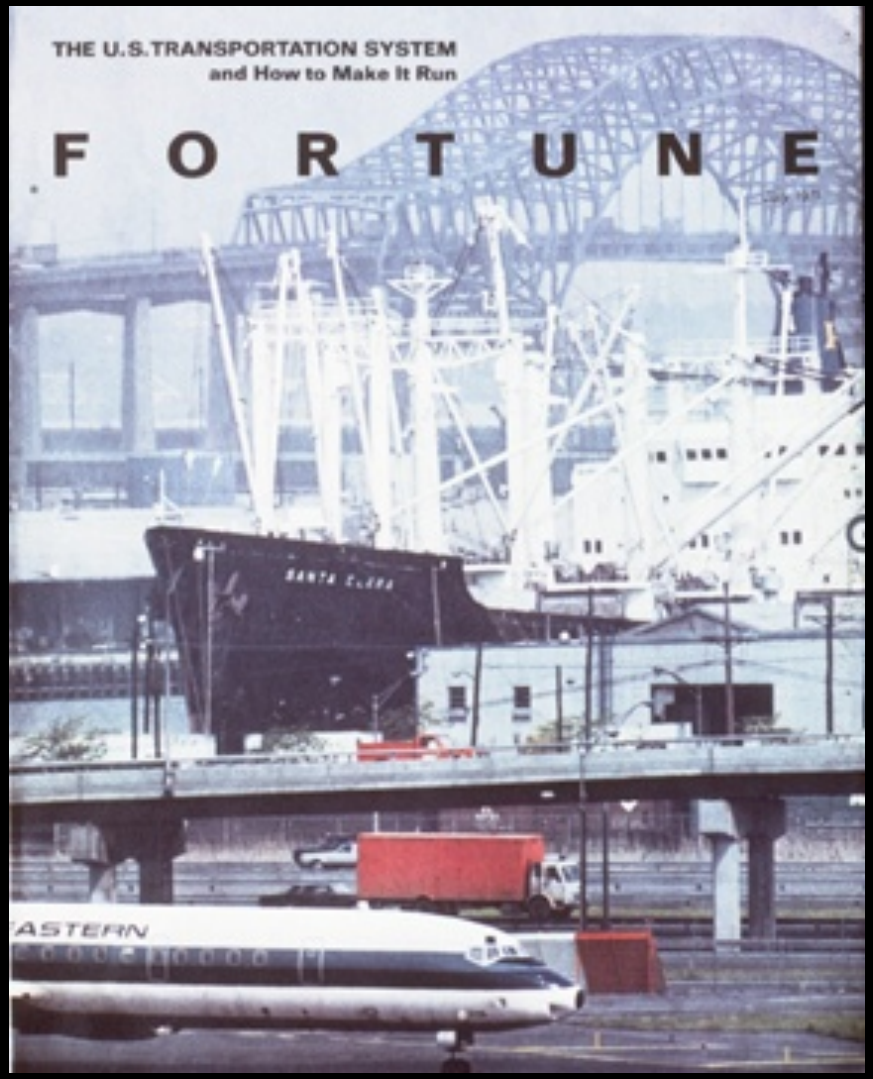

Infrastructure

- **River and Rail**
- **Road and Airway**
- **Grid, Pipeline, Net**

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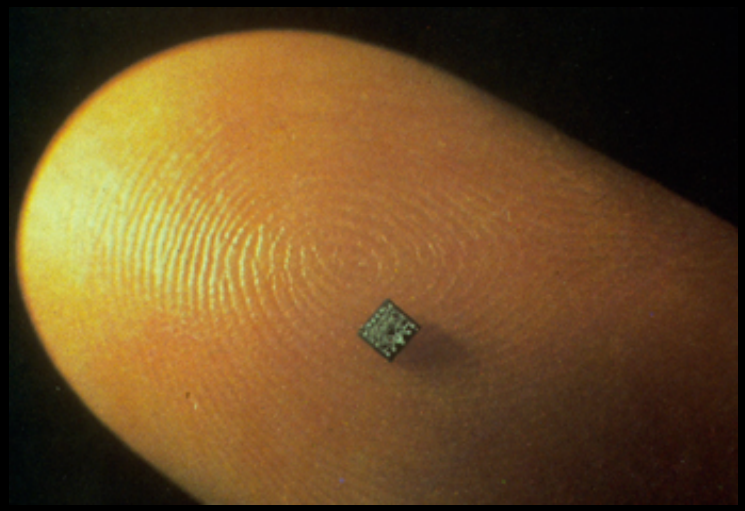
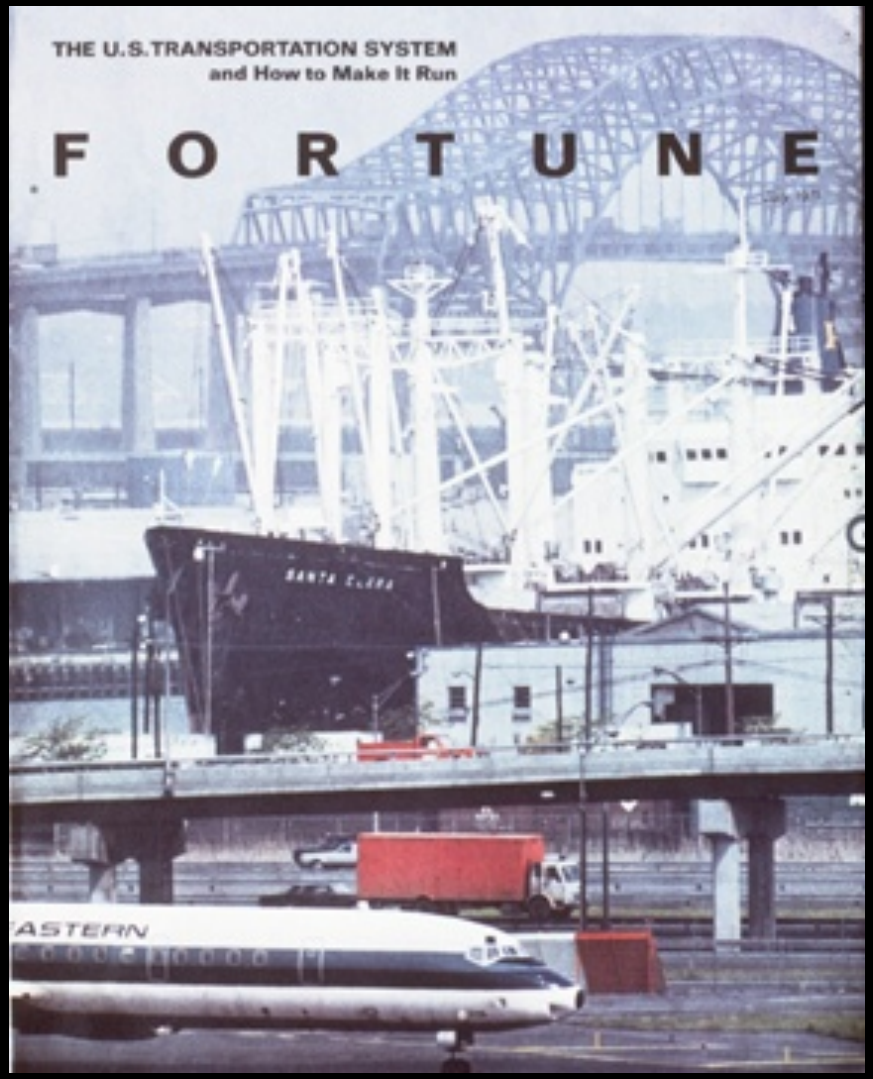




Information and Infrastructure 1946 –

2003 – Northeast Blackout

2005 – New Orleans Flood

2007 – Minneapolis Bridge Collapse

2010 – Gulf Oil Spill

2013 – Leak of Information

Infrastructure

- **River and Rail**
- **Road and Airway**
- **Grid, Pipeline, Net**

Information and Infrastructure 1946 –

Power: Smart Grid

Energy: Wind, Solar

Materials: Composites

Information: GPS, Wi-Fi

Information and Infrastructure 1946 –

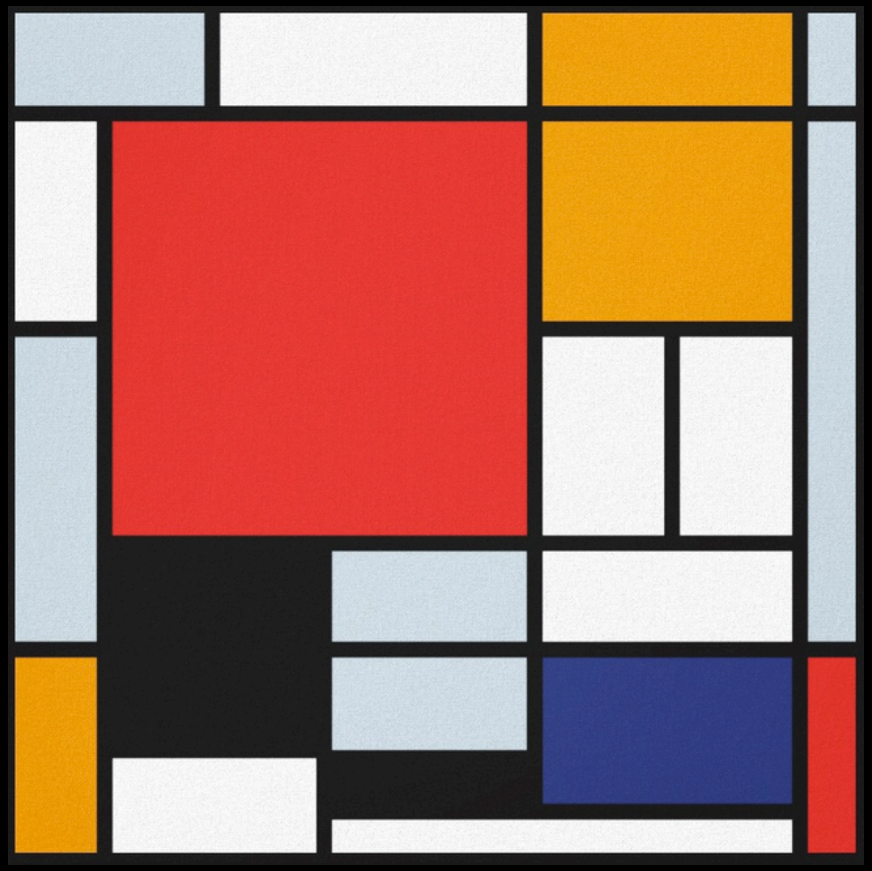
2003 – Northeast Blackout

2005 – New Orleans Flood

2007 – Minneapolis Bridge Collapse

2010 – Gulf Oil Spill

2013 – Leak of Information



Piet Mondrian: Composition

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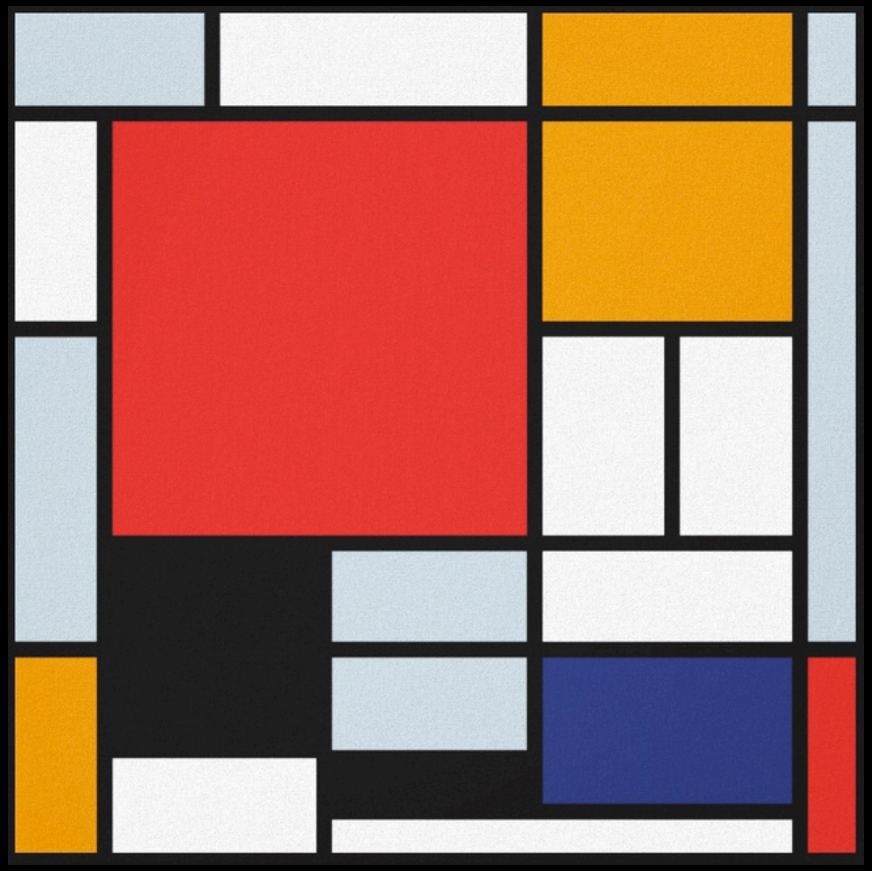

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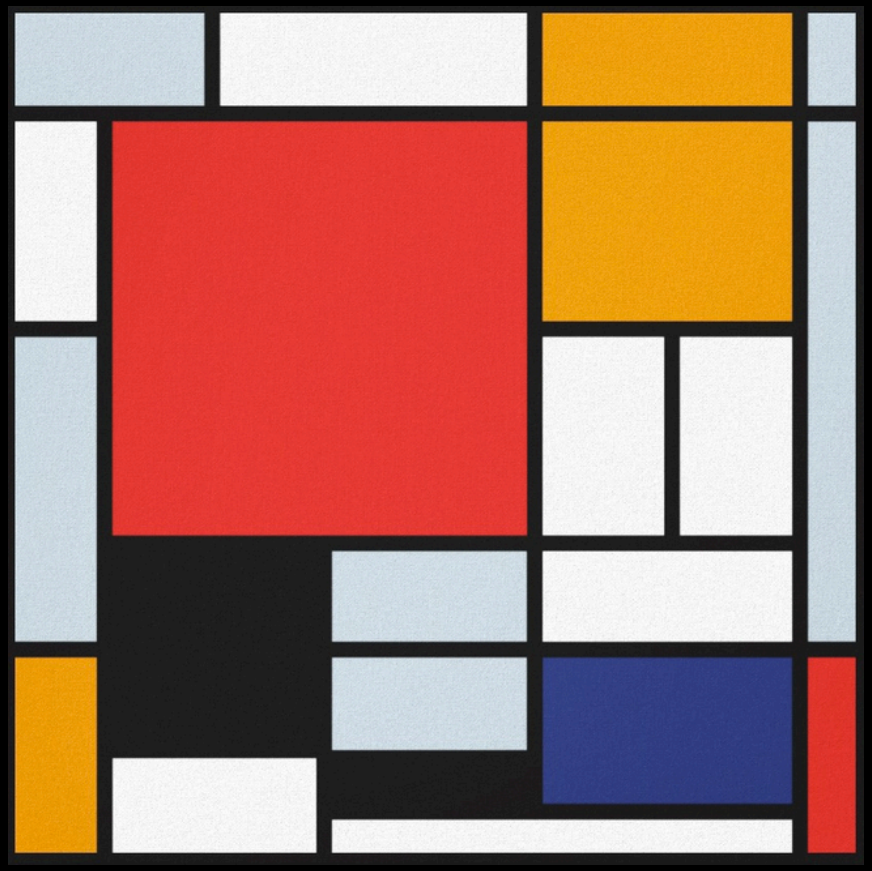

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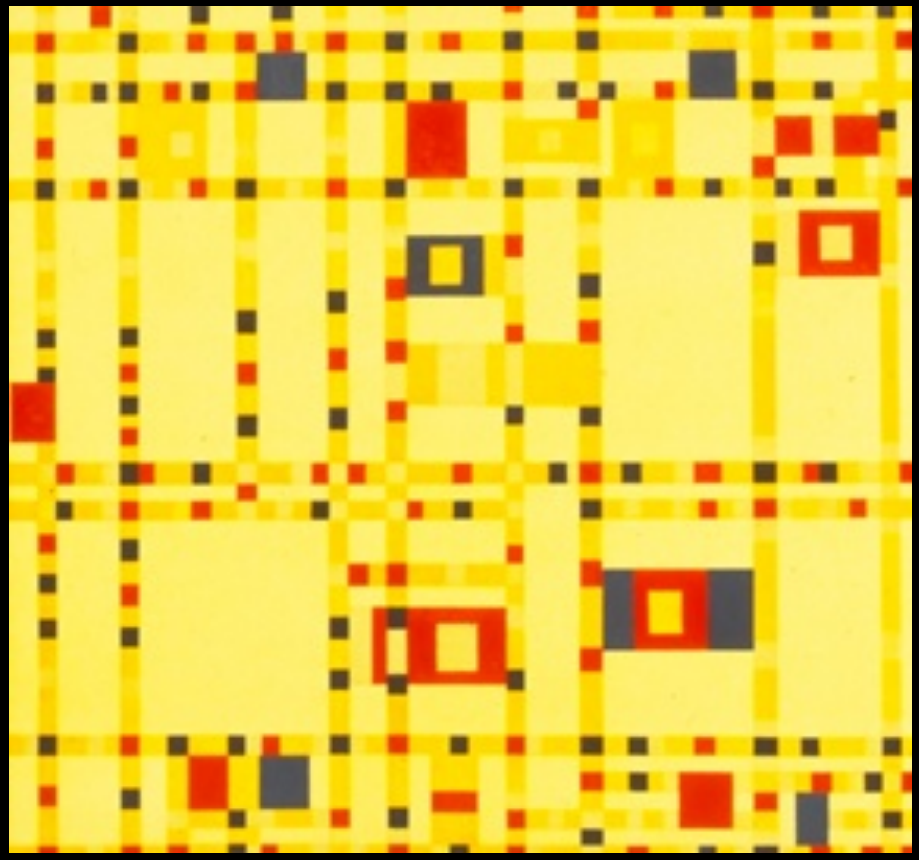


Broadway Boogie Woogie

Course Objectives

What are the great works of modern engineering?

Who are key innovators?

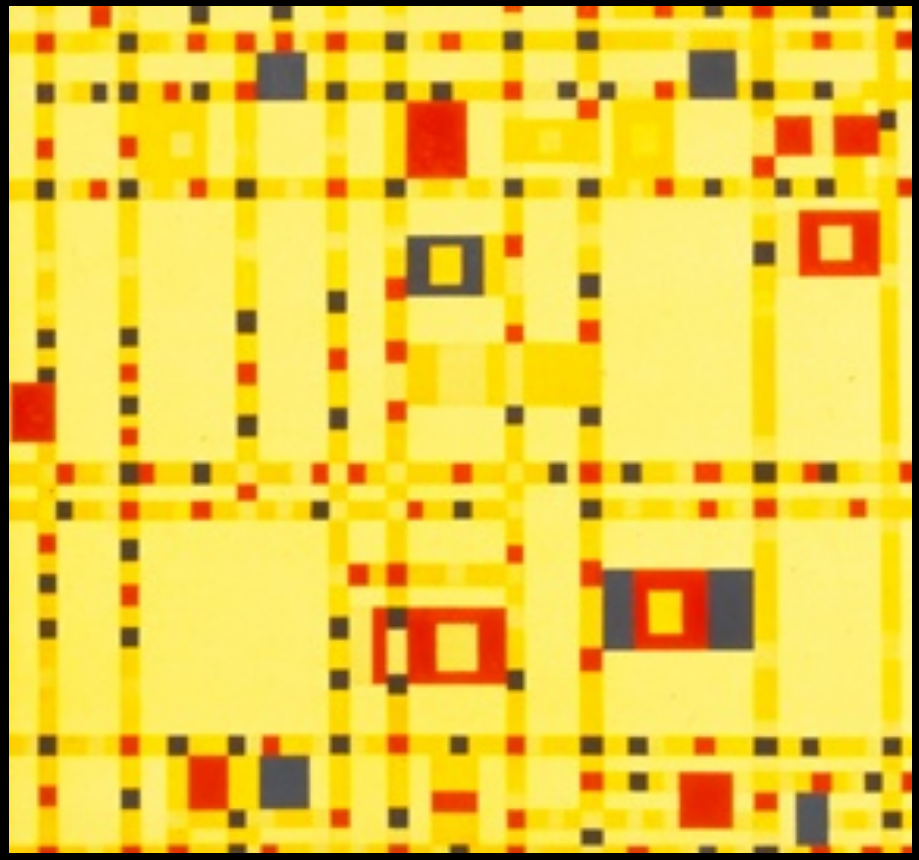
What are their contributions?

What was their experience?

What is a radical innovation?

How do innovations happen?

How has the modern world been transformed?



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Educational Philosophy

- teach fundamentals – keep it simple
- radical innovations change the world
- less is more – stay out of the weeds
- engineering design is work of individuals
- tell them, show them, have them do it - and right after it is presented
- make connections to the modern day
- have fun