

Scientific Communication and visual reasoning

presentation for Institute for
Leadership in Technology and
Management

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Edward Tufte, theorist of scientific graphics

- A political scientist who has provided a high standard for evaluating, designing, and criticizing scientific graphics
- *The Visual Display of Quantitative Information* (1983)
- *Visual Explanations* (1997)

Tufte's program

- “Modern data graphics can do much more than simply substitute for small statistical tables. At their best, graphics are instruments for reasoning about quantitative information. Often the most effective way to describe, explore, and summarize a set of numbers -- even a very large set -- is to look at pictures of those numbers.” (VDQI, p. 9)

Tufte's program

- “Assessments of change, dynamics, and cause and effect are at the heart of thinking and explanation. To understand is to know what cause provokes what effect, by what means, at what rate. How then is such knowledge to be represented?” (VE, p. 9)

The critique

- Tufte finds that much graphic communication is faulty, both in the popular press and in scientific and technical publications. He urges that we develop more sophisticated standards of graphical communication, and adhere to those standards as an element of good thinking and good science.

The Challenger disaster

- The data
- The analysis
- The inference and conclusion
- The presentation

Tufte's diagnosis

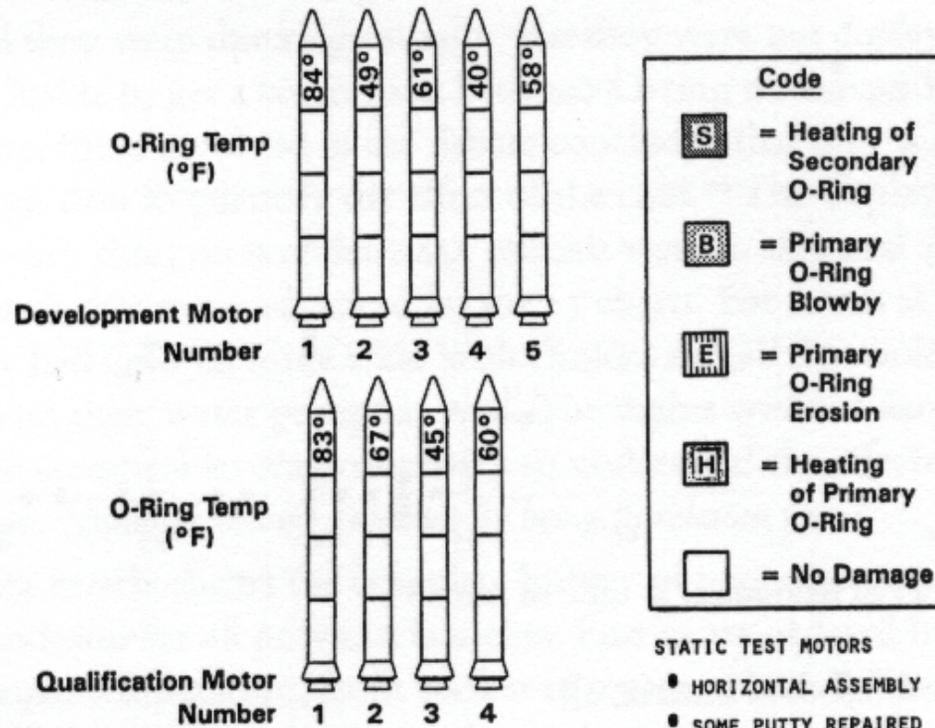
- Tufte argues that a crucial failure in the sequence of analysis, communication, and persuasion that led up to the Challenger disaster was critically flawed scientific communication. The Thiokol engineers reached the right conclusion; but they couched their findings in scientific documents that failed to make the case for non-scientists.

O-Ring Data

Flight	Date	Temperature °F	Erosion incidents	Blow-by incidents	Damage index	Comments
51-C	01.24.85	53°	3	2	11	Most erosion any flight; blow-by; back-up rings heated.
41-B	02.03.84	57°	1		4	Deep, extensive erosion.
61-C	01.12.86	58°	1		4	O-ring erosion on launch two weeks before Challenger.
41-C	04.06.84	63°	1		2	O-rings showed signs of heating, but no damage.
1	04.12.81	66°			0	Coolest (66°) launch without O-ring problems.
6	04.04.83	67°			0	
51-A	11.08.84	67°			0	
51-D	04.12.85	67°			0	
5	11.11.82	68°			0	
3	03.22.82	69°			0	
2	11.12.81	70°	1		4	Extent of erosion not fully known.
9	11.28.83	70°			0	
41-D	08.30.84	70°	1		4	
51-G	06.17.85	70°			0	
7	06.18.83	72°			0	
8	08.30.83	73°			0	
51-B	04.29.85	75°			0	
61-A	10.30.85	75°		2	4	No erosion. Soot found behind two primary O-rings.
51-I	08.27.85	76°			0	
61-B	11.26.85	76°			0	
41-G	10.05.84	78°			0	
51-J	10.03.85	79°			0	
4	06.27.82	80°			?	O-ring condition unknown; rocket casing lost at sea.
51-F	07.29.85	81°			0	

Bad View (1)

History of O-Ring Damage in Field Joints

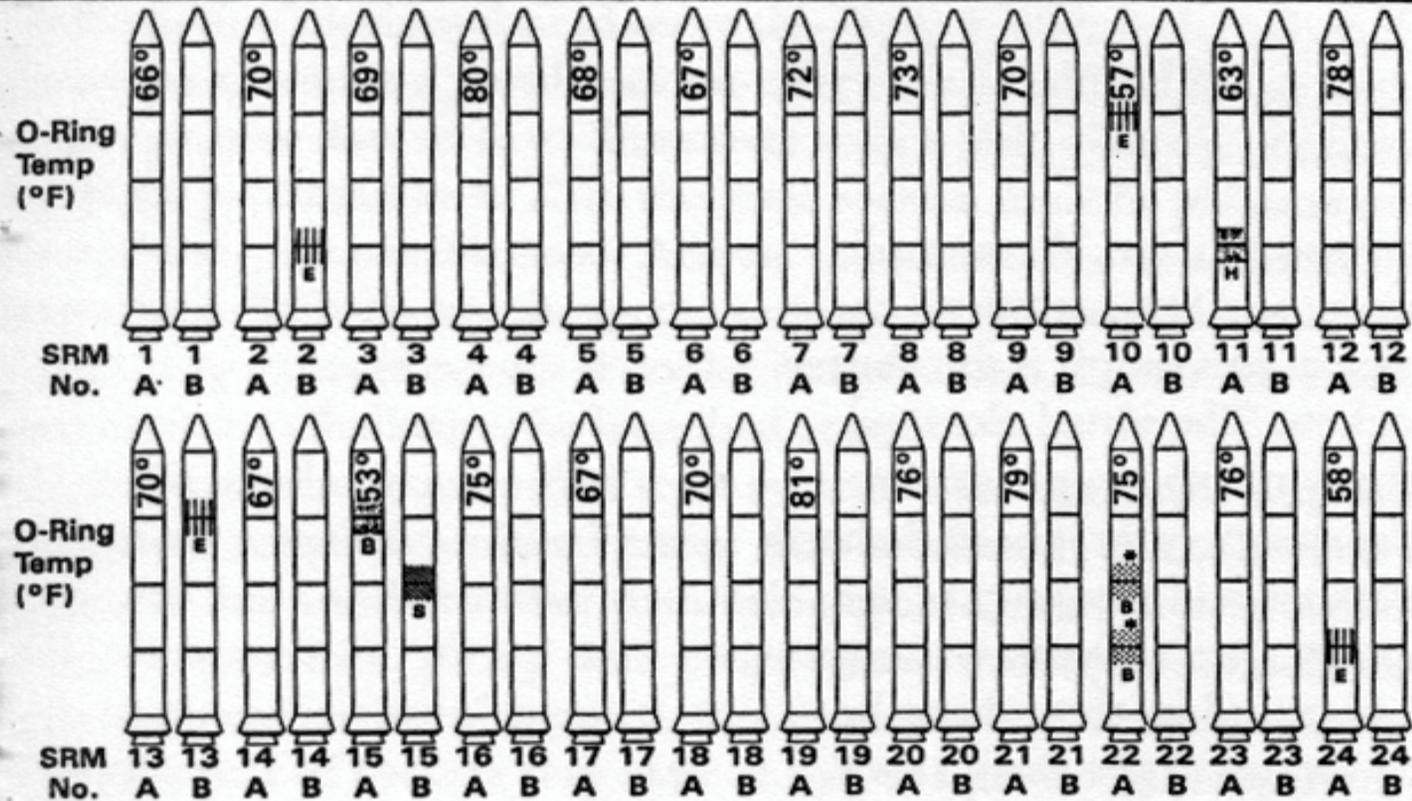


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Bad view (2)

History of O-Ring Damage in Field Joints (Cont)



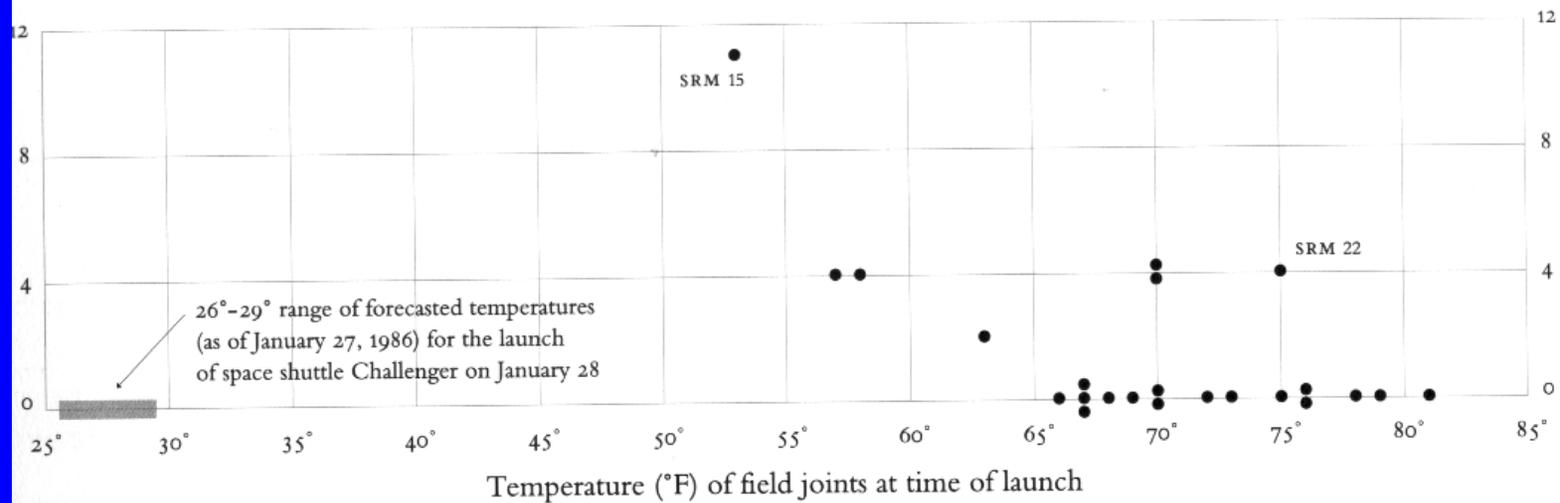
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* No Erosion

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The Good View

O-ring damage
index, each launch



Importance of scientific communication

- engineers and technical specialists need to communicate technical issues effectively to non-specialists
- managers need accurate information
- managers need clear understanding of technology choices and alternatives
- managers need to be able to make appropriate inferences and predictions

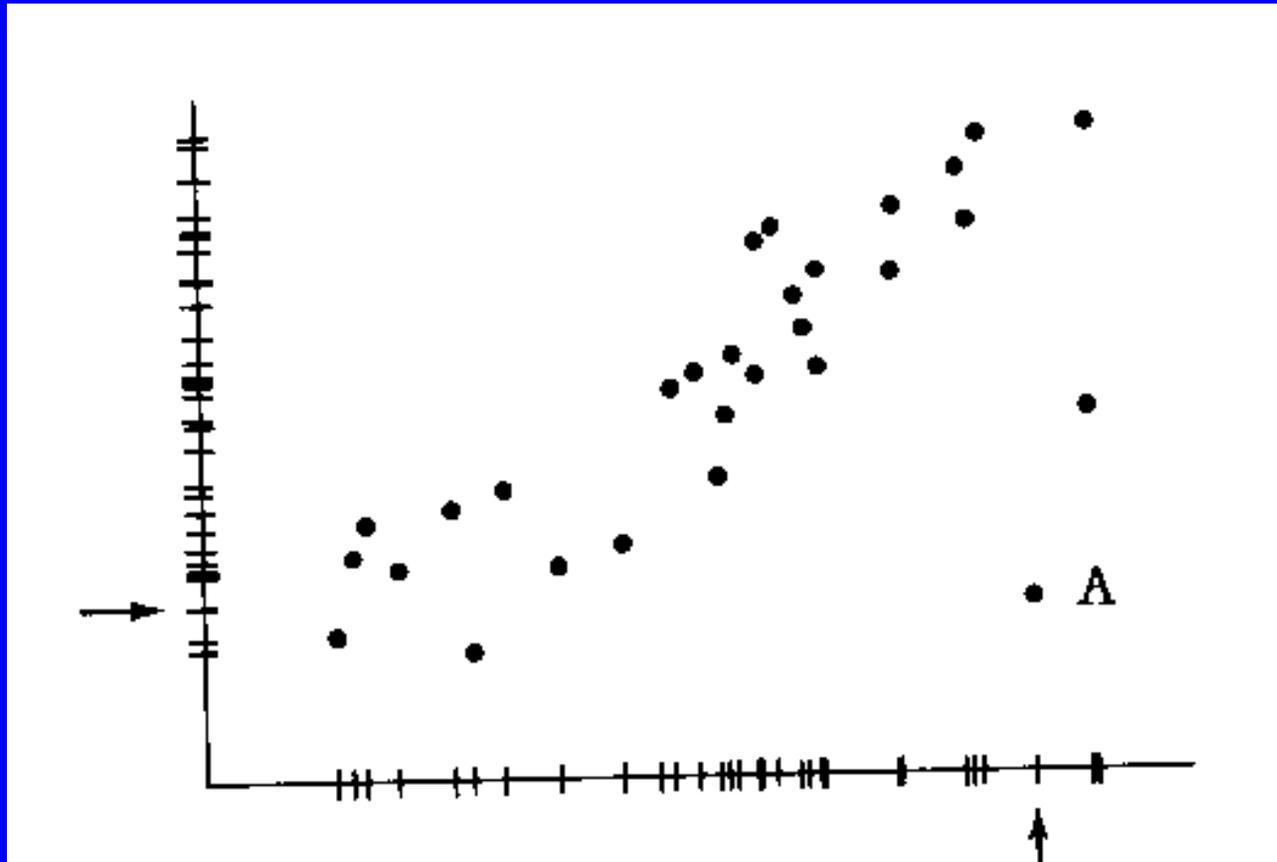
Varieties of scientific communication

- graphs and charts
- maps / GIS analysis
- technical reports / recommendations
- statistical analysis

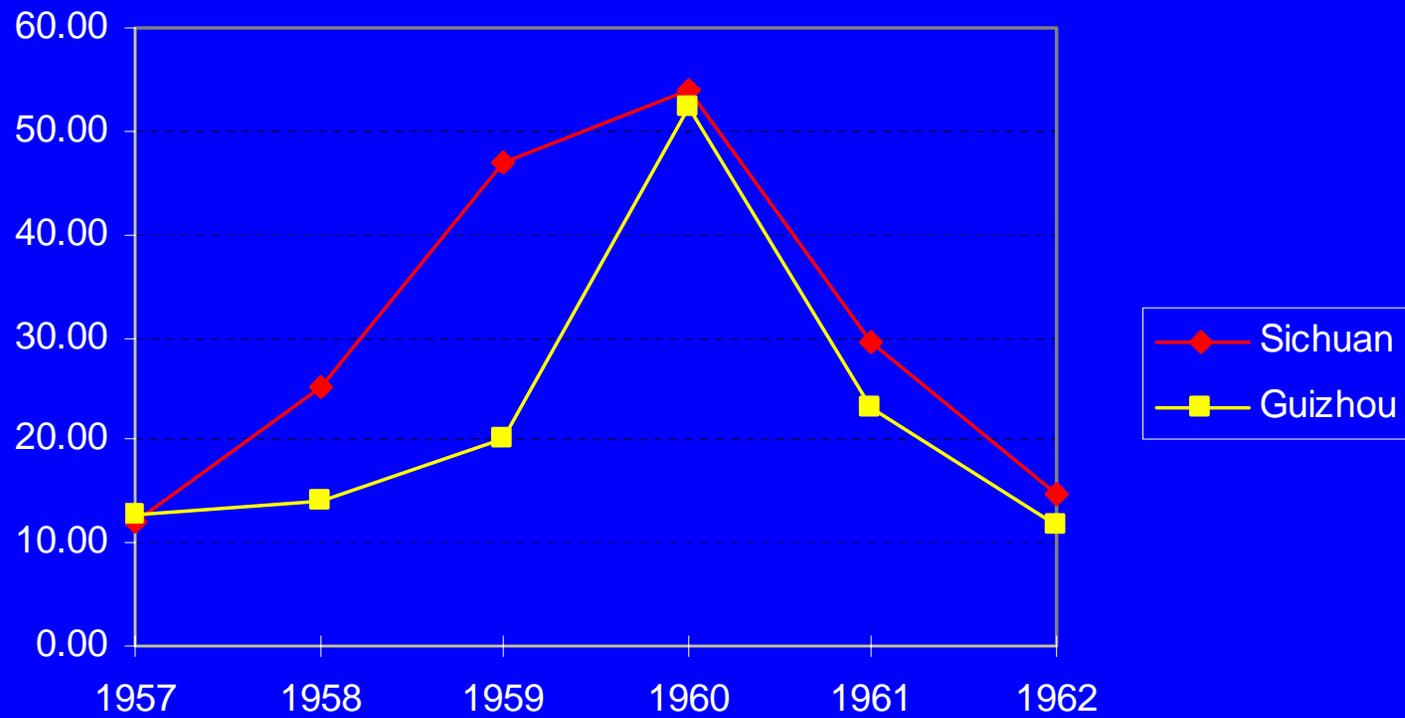
Data tables

- What is quantitative reasoning?
- time series--stock prices, blood pressure
- bivariate associations -- sunspots and weather, tension and fracture, economic growth and population growth
- multivariate associations -- rainfall, fertilizer, sunshine, pesticide, crop yield
- tools: regression, correlation, spatial analysis

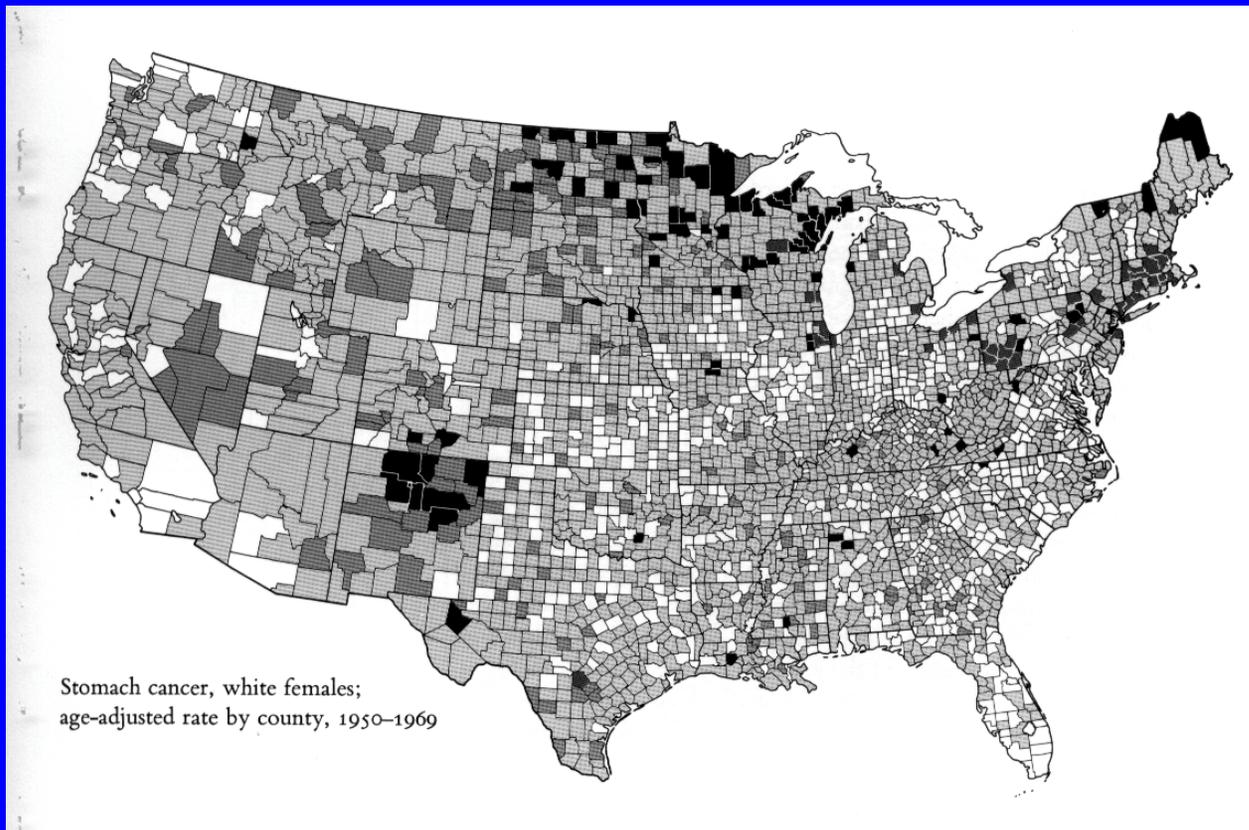
data plot



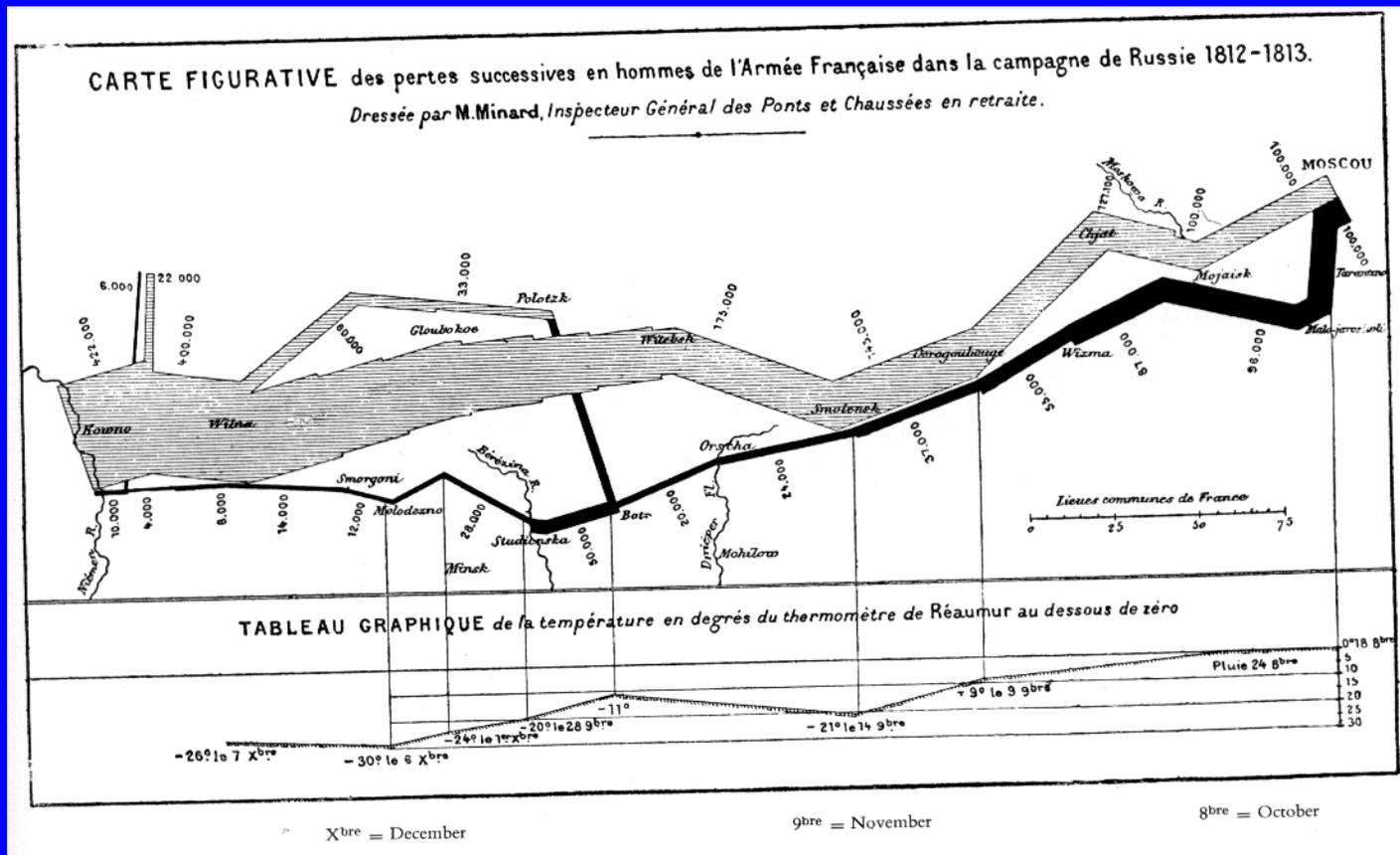
China Famine



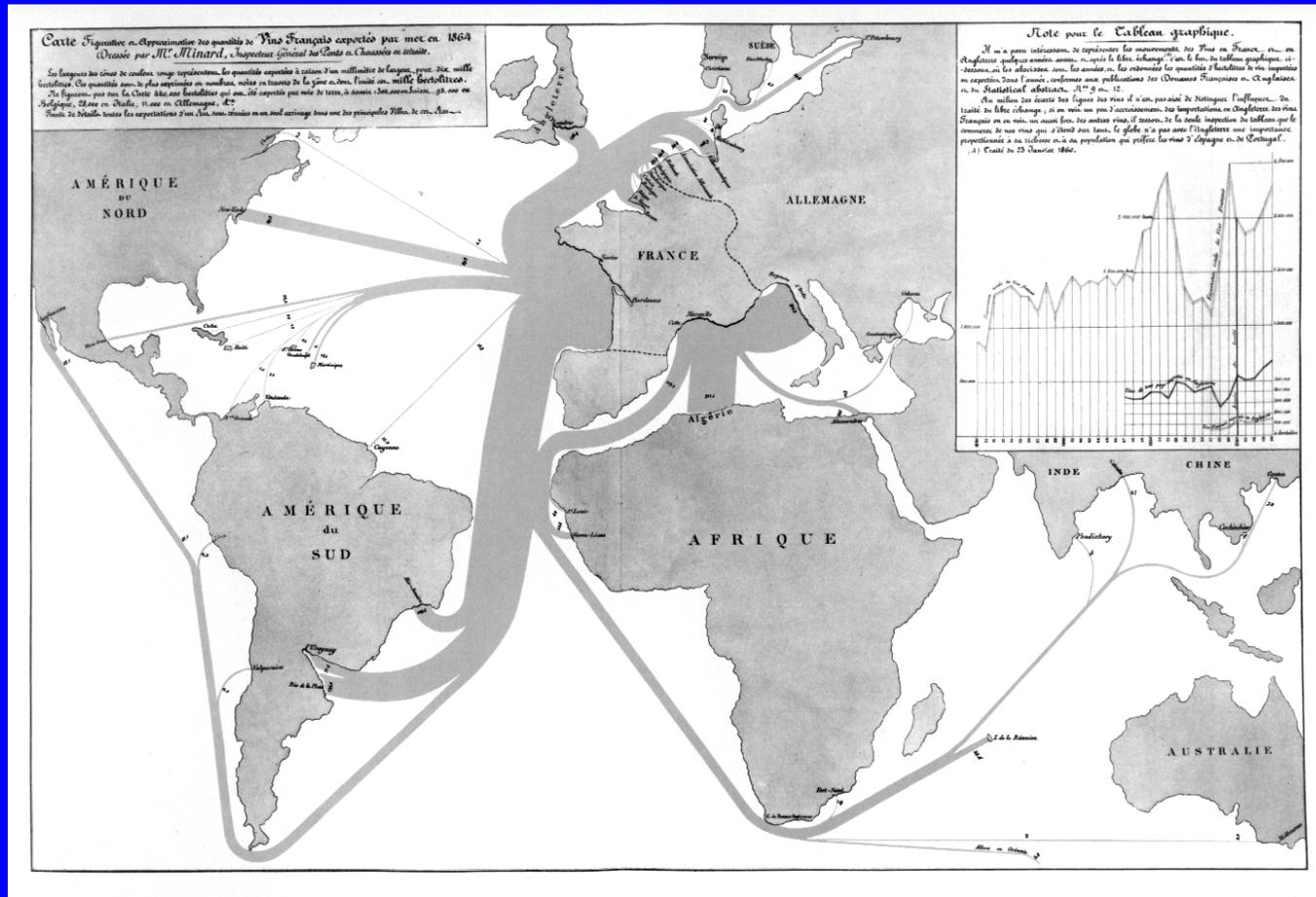
Stomach cancer



Napoleon's Army



Wine Trade



What is conveyed in a scientific graphic?

- Analysis, hypothesis formation, and presentation
- Information content
- density of information--data set and graphic representation
- presentation of causal relations among variables in a data set
- analysis of patterns implicit in a data set

Scientific graphics and scientific method

- analysis -- probe data to discover patterns and associations
- explanation
- causal inquiry
- hypotheses and confirmation; induction, deduction, abduction
- validity and scientific method

Data Table

I		II		III		IV	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

statistics

$N = 11$

mean of X's = 9.0

mean of Y's = 7.5

equation of regression line: $Y = 3 + 0.5X$

standard error of estimate of slope = 0.118

$t = 4.24$

sum of squares $X - \bar{X} = 110.0$

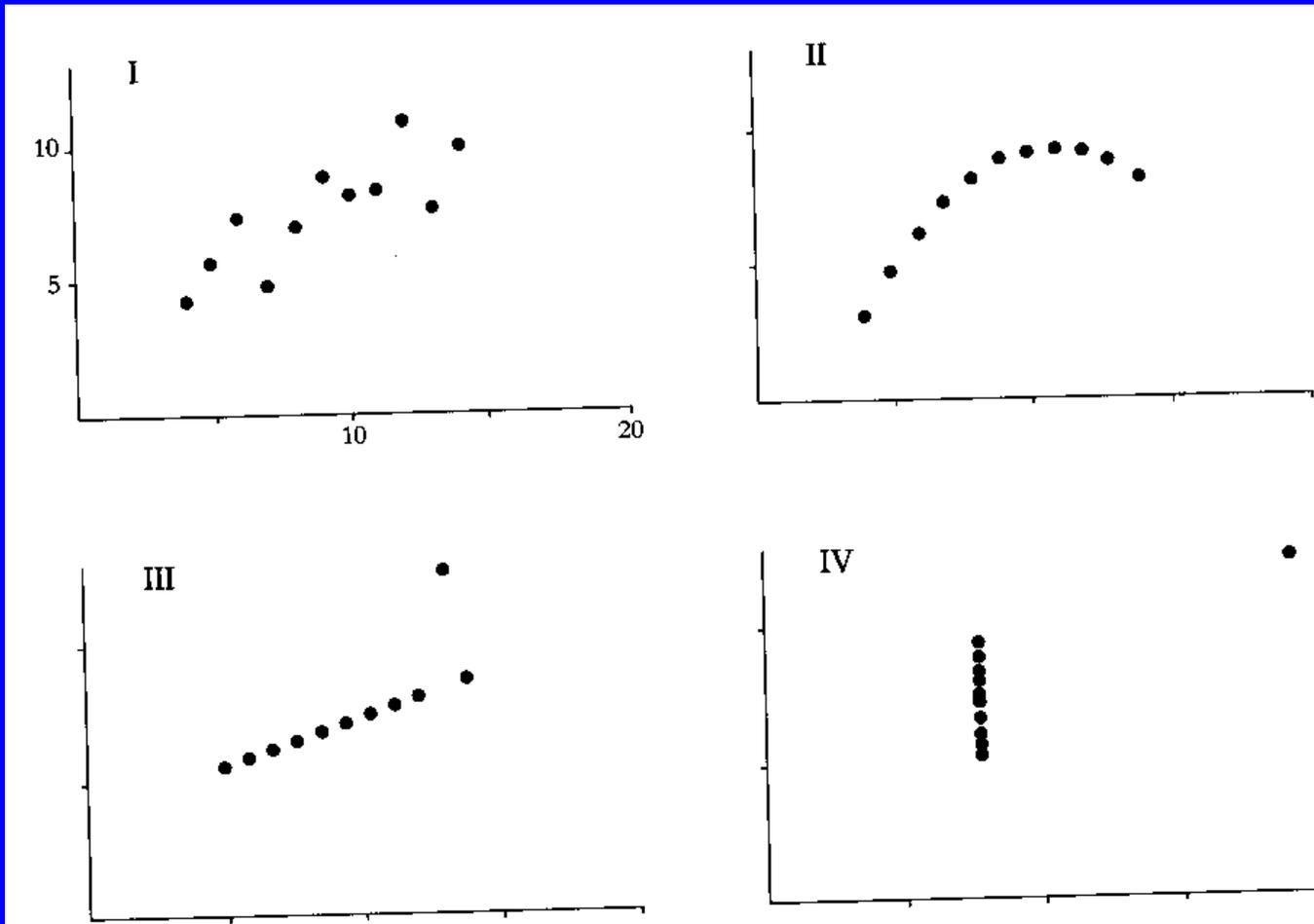
regression sum of squares = 27.50

residual sum of squares of Y = 13.75

correlation coefficient = .82

$r^2 = .67$

Data Plot



Examples of good scientific communication

- Cholera inference
- spatial analysis of economic and social data
- GIS software
- scatter plot to demonstrate causal connections

Failures of scientific communication

- Challenger disaster
- air crash in Columbia (navigation software which gave same label to two beacons)
- software failure: implementation of US design standards into CAD software for industrial buildings

The cholera case

- The difficulty of analysis: what variables are significant?
- spatial analysis
- importance of scale of analysis

What standards should govern scientific graphics?

- accuracy of content
- easy to read
- analytical insight--reveal previously unidentified patterns
- easy to make appropriate inferences
- easy to read scale, data limitations
- Inference and communication -- separate functions

Tufte's principles of graphical excellence

- well-designed presentation of interesting data
- complex ideas communicated with clarity, precision, and efficiency
- gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space

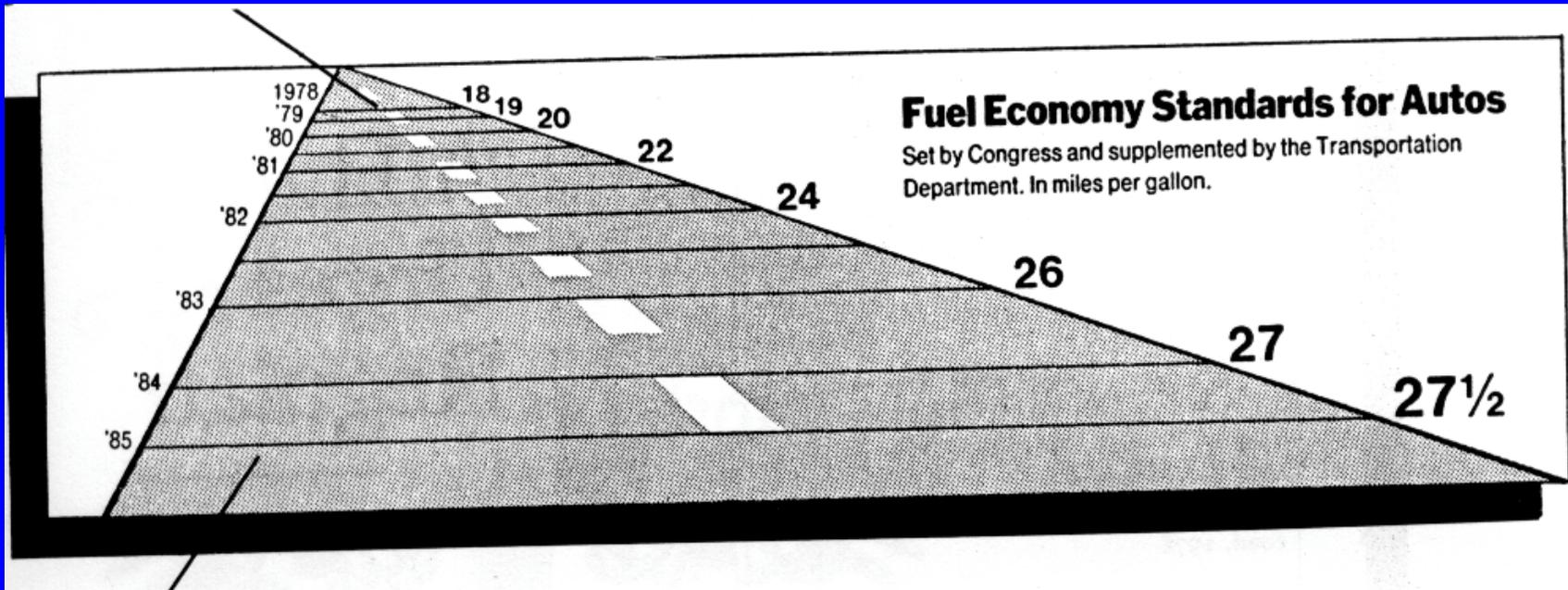
Tufte's principles (cont.)

- nearly always multivariate
- tell the truth about the data
- do not quote data out of context (74)

Chart junk

- excessive ink
- “cute” elements
- unnecessary data labels

The Bad View



The Good View

