

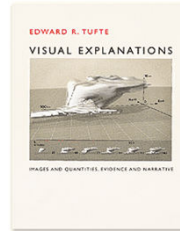
Displaying Scientific Evidence for Making Valid Decisions:

Lessons from Two Case Studies



Steve Lee
The CLIMB Program
Research Communication Workshop
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These case studies are from Edward Tufte's "Visual Explanations"



Effective displays help lead to valid arguments and true conclusions.

Ineffective displays often lead to invalid arguments and false conclusions.

Garbage In - Garbage Out

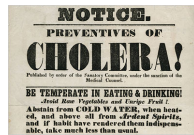
Case 1: John Snow intervenes in a cholera epidemic

C Cholera breaks out in central London in 1854. Cholera: severe watery diarrhea, vomiting, rapid dehydration death can occur within hours of infection; fatality rate of 50% killed millions in the 1800's in India, Russia, Europe, and N. America

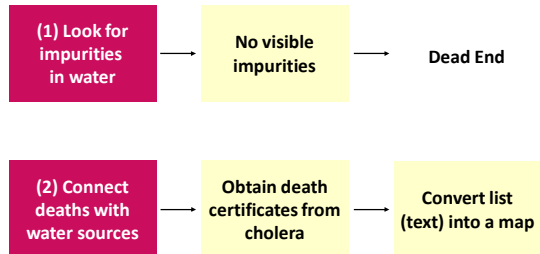
C Deficiencies in: understanding of bacteria technology sanitary living conditions

Q How is cholera transmitted?
How can we stop this cholera epidemic in central London?

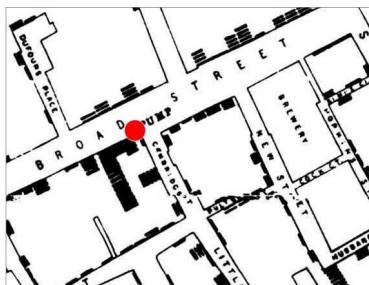
H Cholera is spread by: (1) breathing vapors of decaying matter or (2) drinking contaminated water.



John Snow's Designs and Methods: He searches for correlations between water and cholera.



Snow correlates locations of deaths with a water source



● Water pump
■ Residence of cholera victim

Strong correlation of cholera victims near the Broad St water pump!

Results and Conclusions: Snow reports to the authorities

- Handle on the Broad Street water pump was removed
- Epidemic soon ended

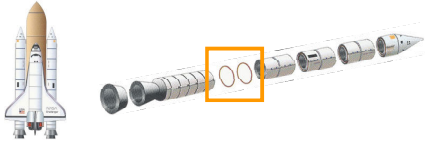
● **Snow's analysis and map provided strong evidence that cholera is transmitted by drinking contaminated water.**

"For close upon 100 years we have been free in this country from epidemic cholera, and it is a freedom which, basically, we owe to the logical thinking, acute observations and simple sums of Dr. John Snow"

*Bradford Hill
Proceedings of the Royal Society of Medicine, 1955*

Case 2: Decision to Launch the Space Shuttle Challenger in January 1986

C In the space shuttle, O-rings seal segments of the booster rockets. Previous launches showed damage to the O-rings.



C All previous launches had occurred at temperatures of $\geq 53^\circ\text{F}$. Forecasted temperature of the launch was $26\text{--}29^\circ\text{F}$.

Q Will the O-rings maintain their seal at $26\text{--}29^\circ\text{F}$? Should the launch proceed?

H Engineers: No, and then Yes
NASA officials: Yes

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How did the engineers at Morton Thiokol Inc initially argue for their first decision?

• 13 slides were faxed from MTI to NASA

EXCERPT OF A FAX FROM MTI TO NASA JAN 1986

MOTOR	MTI	AMB	O-RING	WIND
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29	10 MPH
			27	25 MPH

BLOW-BY HISTORY
SRM-15 WORST BLOW-BY
◦ 2 CASE JOINTS (80°), (110°) ARC
◦ MUCH WORSE VISUALLY THAN SRM-22

SRM 22 BLOW-BY
◦ 2 CASE JOINTS (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A
◦ NOZZLE BLOW-BY

HISTORY OF O-RING TEMPERATURES (DEGREES - F)

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RECOMMENDATIONS:
• O-RING TEMP MUST BE $\geq 53^\circ\text{F}$ AT LAUNCH
DEVELOPMENT MOTORS AT 47°F TO 52°F WITH PUTTY PACKING HAD NO BLOW-BY
SRM 15 (THE BEST SIMULATION) WORKED AT 53°F
• PROJECT AMBIENT CONDITIONS (TEMP & WIND) TO DETERMINE LAUNCH TIME

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- How would you respond to this argument? Was this an effective argument?
- This was MTI's only no-launch recommendation in 12 years.
- A NASA official responded that he was "appalled" by MTI's recommendation not to launch.

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NASA officials ask MTI to reconsider, and MTI reverses their original decision

MTI ASSESSMENT OF TEMPERATURE CONCERN ON SRM-25 (S1L) LAUNCH

- CALCULATIONS SHOW THAT SRM-25 O-RINGS WILL BE 20° COLDER THAN SRM-15 O-RINGS
- TEMPERATURE DATA NOT CONCLUSIVE ON PREDICTING PRIMARY O-RING BLOW-BY
- ENGINEERING ASSESSMENT IS THAT:
 - COLDER O-RINGS WILL HAVE INCREASED EFFECTIVE DIAMETER ("HARDER")
 - "HARDER" O-RINGS WILL TAKE LONGER TO "SEAT"
 - MORE GAS MAY PASS PRIMARY O-RING BEFORE THE PRIMARY SEAL SEATS (RELATIVE TO SRM-15)
 - DEMONSTRATED SEALING THRESHOLD IS 3 TIMES GREATER THAN 0.058"
 - IF THE PRIMARY SEAL DOES NOT SEAT, THE SECONDARY SEAL WILL SEAT
 - PRESSURE WILL GET TO SECONDARY SEAL BEFORE THE METAL PARTS MATE
 - O-RING PRESSURE LEAK CHECK PLACES SECONDARY SEAL IN OUTBOARD POSITION WHICH MINIMIZES SEALING TIME
- MTI RECOMMENDS STS-51L LAUNCH PROCEED ON 28 JANUARY 1986
- SRM-25 WILL NOT BE SIGNIFICANTLY DIFFERENT FROM SRM-15

Joe C. Kinnaman
Joe C. Kinnaman, VICE PRESIDENT
SPACE BOOSTER PROGRAMS

MORTON THIOKOL, INC.
WASAC/DALLAS

INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN O-RING PRESENTATION AND SHOULD BE CONSIDERED CONFIDENTIAL TO THE O-RING PRESENTATION

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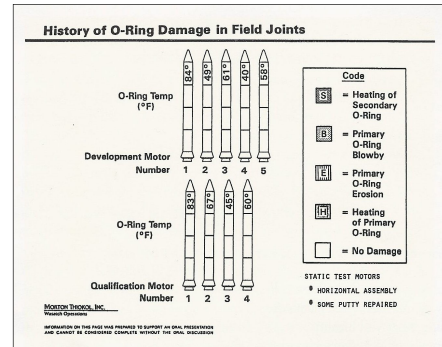
Post-Analysis: MTI's engineers had originally reached the right conclusion, but with an ineffective argument.

• Commission investigating the accident:

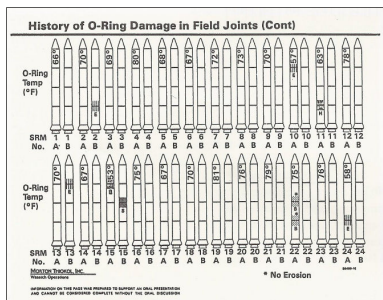
“A careful analysis of the flight history of O-ring performance would have revealed the correlation of O-ring damage and low temperature. Neither NASA nor Thiokol carried out such an analysis; consequently, they were unprepared to properly evaluate the risks of launching the 51-L [Challenger] mission in conditions more extreme than they had encountered before.”

- How might the data have been better analyzed, presented and communicated?

Attempt #1 shows a full analysis correlating temperature with damage to the O-rings



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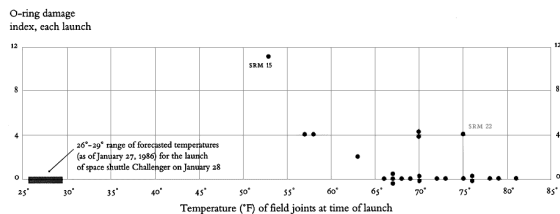


- What are the pro's and con's of this data display?
- Can it be improved?

Attempt #2: Tufté summarizes all data into a table with a “Damage Index”

Flight	Date	Temperature °F	Erosion Incidents	Blow-by incidents	Damage Index	Comments
51-C	01.24.85	51°	3	2	11	Most erosion any flight; blow by; secondary 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-ring showed signs of heating, but no damage
1	04.12.81	66°			0	Cooltest launch without O-ring problems
6	04.04.83	67°			0	
51-A	11.08.84	67°			0	
51-D	04.12.85	69°			0	
5	11.11.82	68°			0	
3	02.22.82	69°			0	
2	11.12.81	70°			0	
51-D	04.12.85	69°	1		4	Extent of erosion not fully known
9	11.28.83	70°			0	
41-D	08.30.84	70°			0	
51-G	06.17.85	70°	1		4	
7	06.18.83	72°			0	
8	08.30.83	73°			0	
51-B	04.29.85	75°		2	0	No erosion. Soot found behind two primary O-Rings
61-A	10.30.85	76°			0	
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	08.27.82	80°			?	O-ring condition unknown; rocket casing lost at sea
51-F	07.29.85	81°			0	

Attempt #2: Tufté summarizes all data into a graph with a “Damage Index”



- What are the pro's and con's of this data display?
- Can it be improved?

Key Lessons from Two Case Studies

- Case 1: John Snow intervenes in a cholera epidemic
 - Snow provided an effective data display
 - His map:
 - summarized all important info
 - in a simple format that was easy to understand
- Case 2: Decision to launch the space shuttle
 - MTI engineers had all the necessary info, but created an ineffective data display, even after the accident
 - Tufté provided an effective alternative that:
 - summarized all important info
 - in a simple format that was easy to understand

Case 3: Group Project assigned by President Obama

- President Obama's 2020 challenge for higher education:
 - "That is why, at the start of my administration I set a goal for America: by 2020, this nation will once again have the highest proportion of college graduates in the world."
- Obtain the "Winning the Future" presentation.
 - www.ed.gov/sites/default/files/winning-the-future.ppt
- Are the relevant data contained in these slides? What other data would you want to include? How would you display that data? Does the data in these slides sufficiently analyze the situation?
- What data and arguments would you include in a proposal to "Win the Future" and provide a strategy to accomplish President Obama's challenge?