Displaying Visual Evidence in Scientific Research:

Help viewers make valid scientific decisions

CLIMB
Collaborative Learning and Integrated Mentoring in the Biosciences

CREATING A DIVERSE COMMUNITY OF YOUNG SCIENTISTS

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Our CLIMB curriculum of workshops on communication in scientific research

1) **Delivering scientific presentations and posters for impact:**

   Make it stick with SUCCESs

2) **Crafting the introduction to a scientific presentation:**

   Create a mystery box

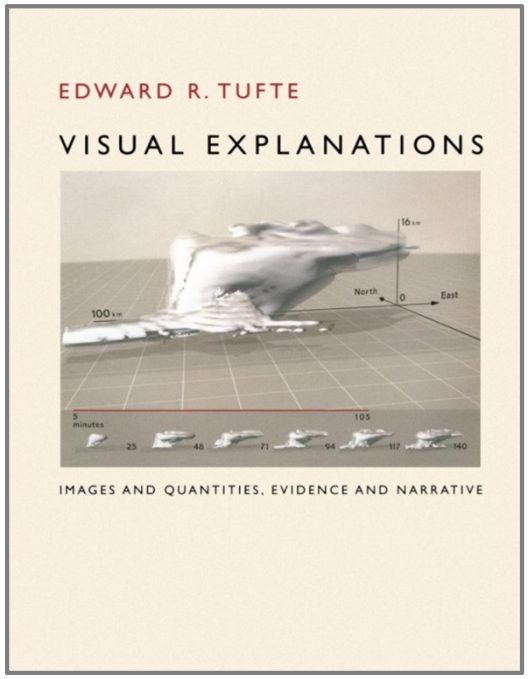
3) **Communicating and collaborating across disciplines:**

   Use simple words

4) **Displaying visual evidence in scientific presentations:**

   Help viewers make valid scientific decisions

Let's consider 2 case studies from 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

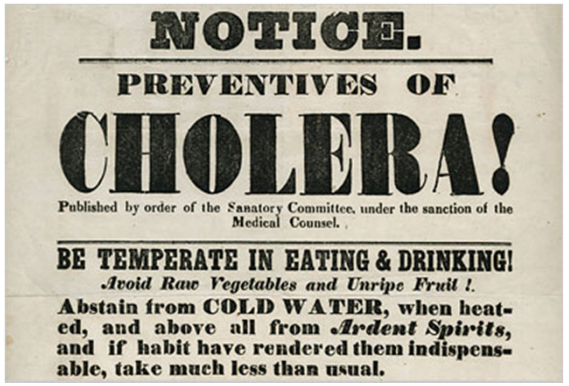
Case 1: Dr John Snow intervenes in a cholera epidemic

Context

- Cholera breaks out in London in 1854
- Cholera: rapid dehydration (diarrhea, vomiting) and death
- fatality rate: 50%
- killed millions in other epidemics

Problems

- Deficiencies in:
  - understanding of bacteria
  - technology
  - sanitary living conditions



NOTICE.

PREVENTIVES OF

CHOLERA!

Published by order of the Sanatory Committee, under the sanction of the Medical Counsel.

BE TEMPERATE IN EATING & DRINKING!

Avoid Raw Vegetables and Unripe Fruit !.

Abstain from COLD WATER, when heated, and above all from *Ardent Spirits*, and if habit have rendered them indispensable, take much less than usual.

Questions

- How is cholera transmitted?
- How can we stop this cholera epidemic?

Hypotheses

Cholera is spread by:

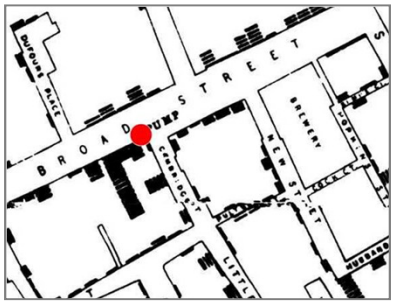
(1) breathing vapors of decaying matter

(2) drinking contaminated water

Dr John Snow investigated the cholera epidemic

Consider the data

- Are locations of water sources and deaths significant?
- He obtained death certificates and created a visual map.



(see handout)

Communicate and convince

- He reported his findings to the local authorities
- He had to convince them that a specific water source was contaminated, and caused cholera

Conclusions

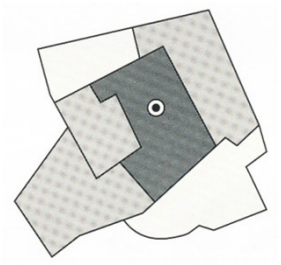
- Handle on the Broad Street water pump was removed
- Epidemic soon ended

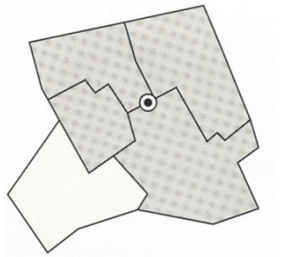
Snow's visual evidence helped to make valid scientific decisions.

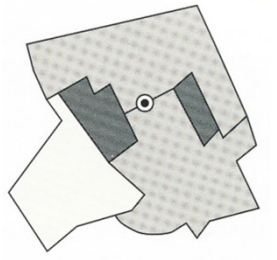
Is your visual display helping or hindering valid scientific decisions?

Mark Monmonier's *How to Lie with Maps*

aggregates of Snow's map:

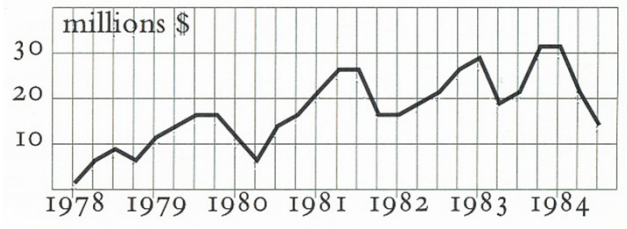




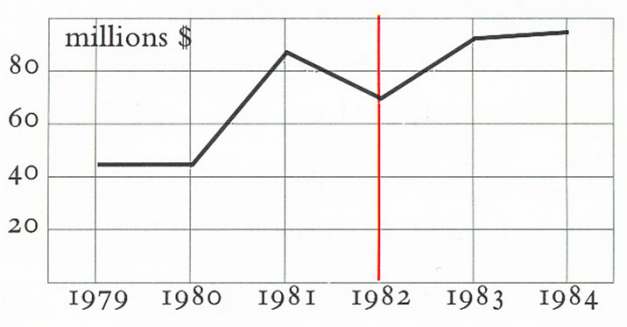


Gregory Joseph's *Modern Visual Evidence*

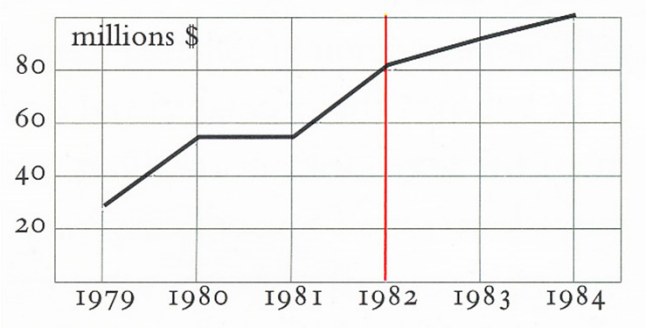
quarterly data



fiscal years



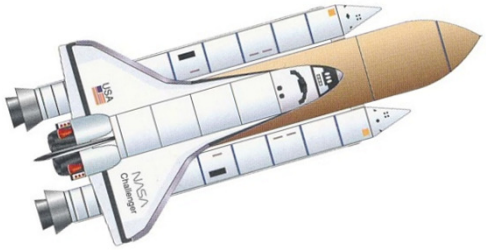
calendar years

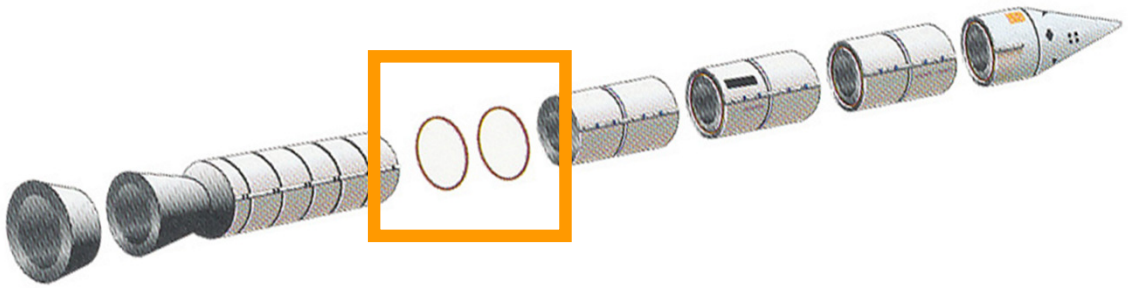


Case 2: Decision to Launch the Space Shuttle Challenger in January 1986

Context

- O-rings seal segments of the booster rockets.
- Previous launches showed damage to the O-rings.





Problems

- All past launches occurred at temperatures of >53 °F.
- Forecasted temperature of the launch was 26-29 °F.

Questions

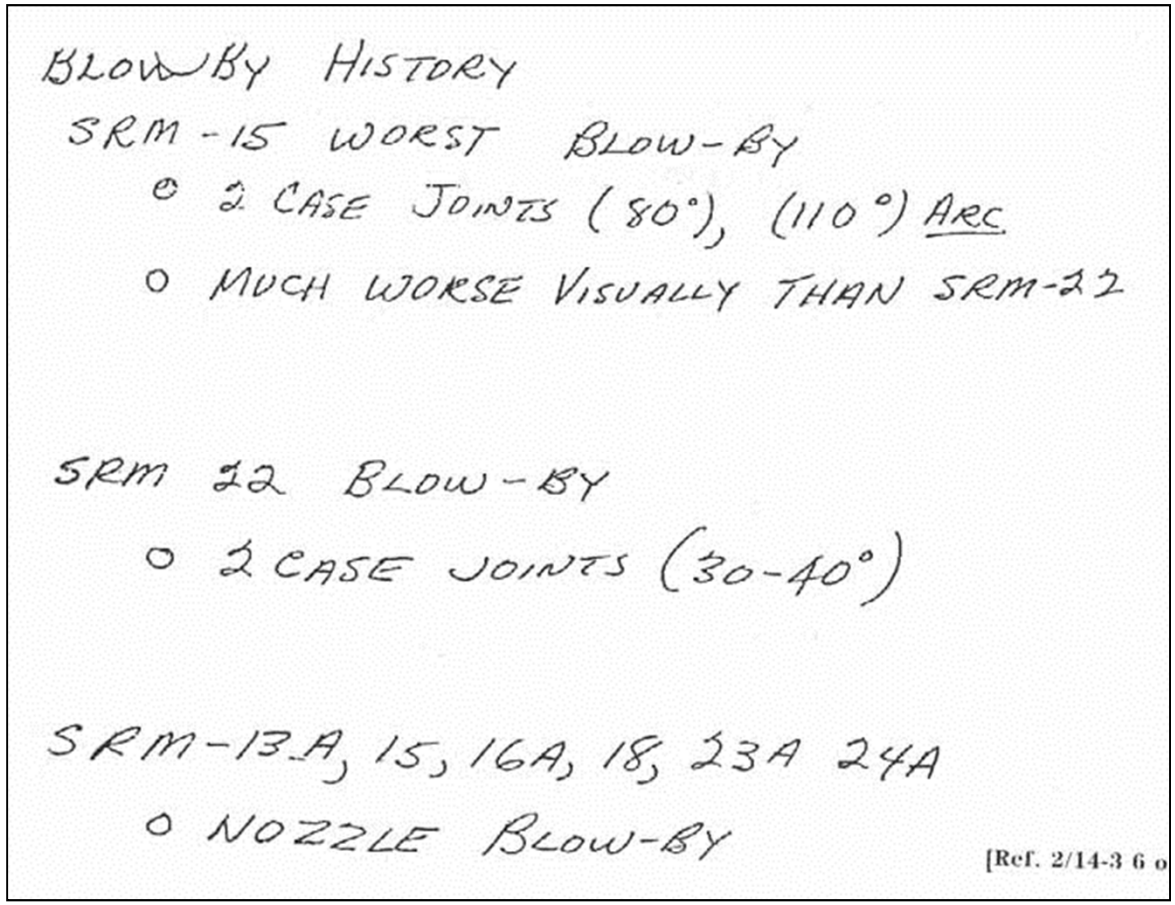
- Will the O-rings maintain their seal at 26-29 °F?
- Should the launch proceed?

Hypotheses

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

Engineers at Morton Thiokol Inc (MTI) initially argued against the launch

- MTI faxed 13 slides to NASA
- Slide 1 of 13


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

[Ref. 2/14-3 6 o

Blow-by = soot and gases blowing by O-ring seals

SRM = solid rocket motor

What's missing here?

Engineers at Morton Thiokol Inc (MTI) initially argued against the launch

- Slide 2 of 13

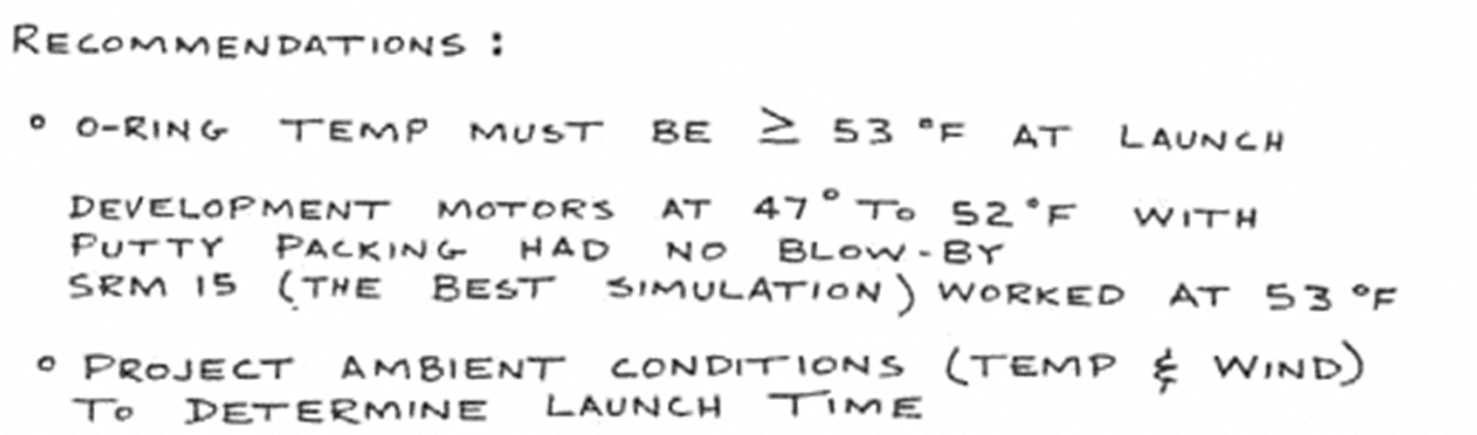
HISTORY OF O-RING TEMPERATURES (DEGREES - F)

MOTOR	MBT	AMB	O-RING	WIND
DM-1	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 27	10 MPH 25 MPH

What's missing here?

MTI initially argued against the launch

- MTI faxed 13 slides to NASA


RECOMMENDATIONS :

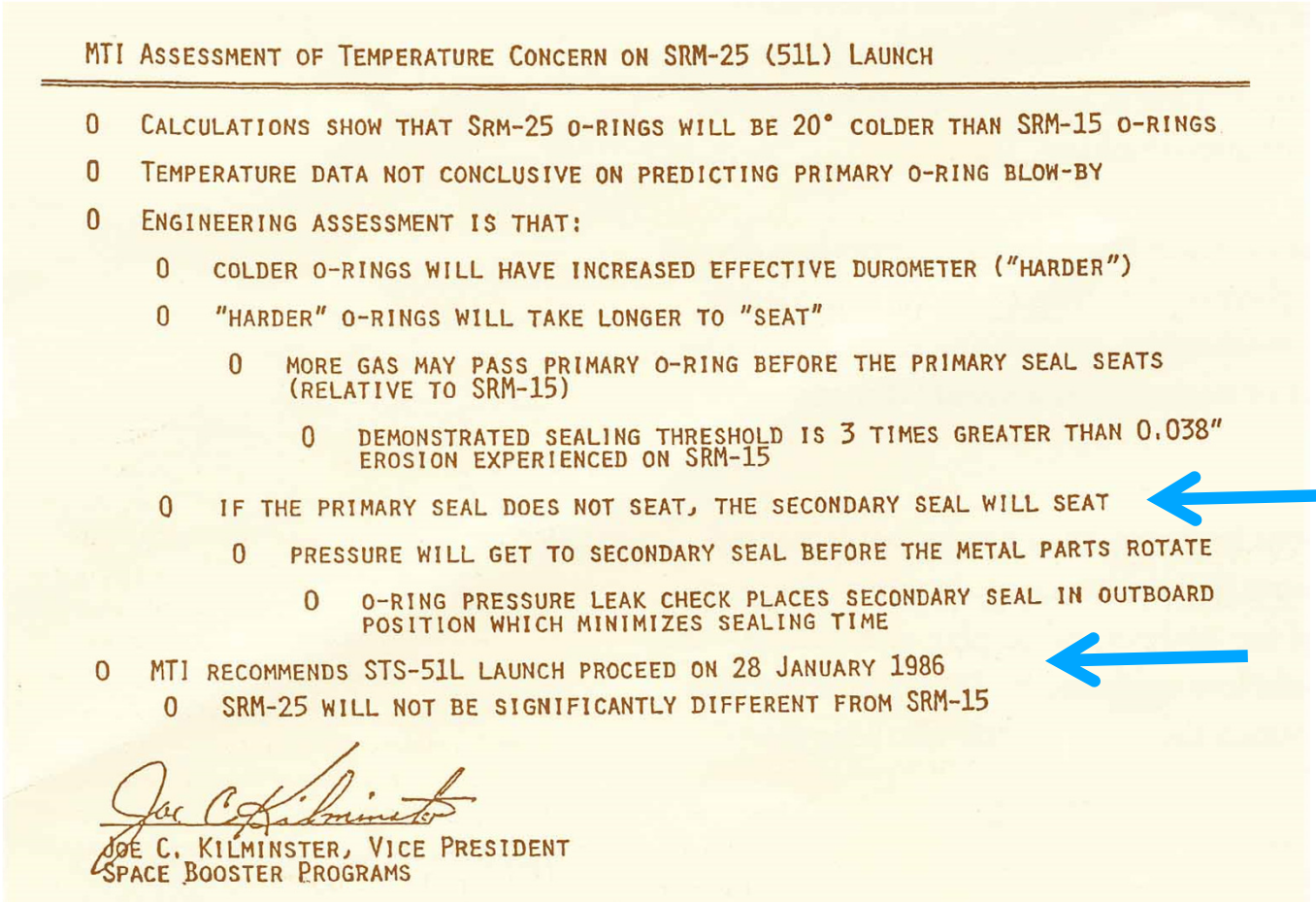
° O-RING TEMP MUST BE ≥ 53 °F AT LAUNCH

DEVELOPMENT MOTORS AT 47° 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

- How would you respond to this argument? Was this effective?
- 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, and asked them to reconsider.

NASA officials asked MTI to reconsider, and MTI reversed their decision



MTI ASSESSMENT OF TEMPERATURE CONCERN ON SRM-25 (51L) 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 DUROMETER ("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 0.038" EROSION EXPERIENCED ON SRM-15
  - IF THE PRIMARY SEAL DOES NOT SEAT, THE SECONDARY SEAL WILL SEAT
    - PRESSURE WILL GET TO SECONDARY SEAL BEFORE THE METAL PARTS ROTATE
      - 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. KILMINSTER, VICE PRESIDENT
SPACE BOOSTER PROGRAMS

After 1 minute from launch, the space shuttle Challenger exploded and 7 astronauts died.

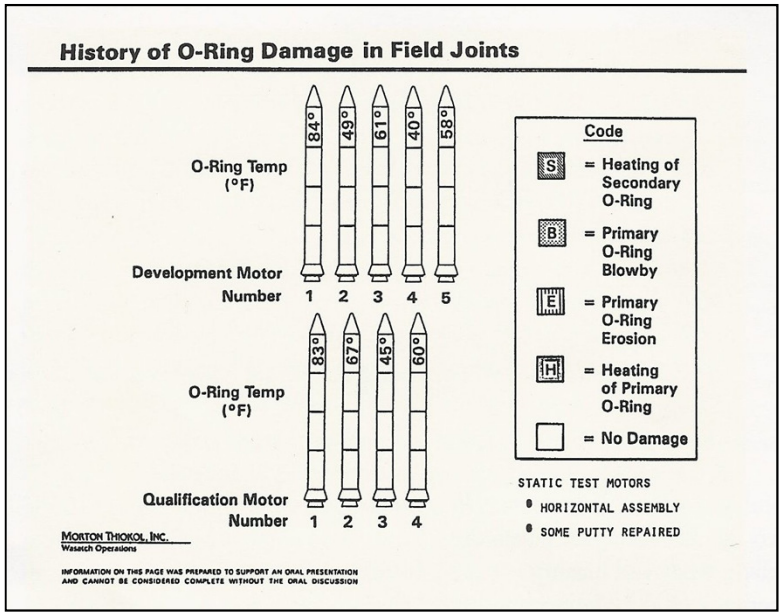
Post-Analysis: MTI's original conclusion was true, but with an ineffective argument.

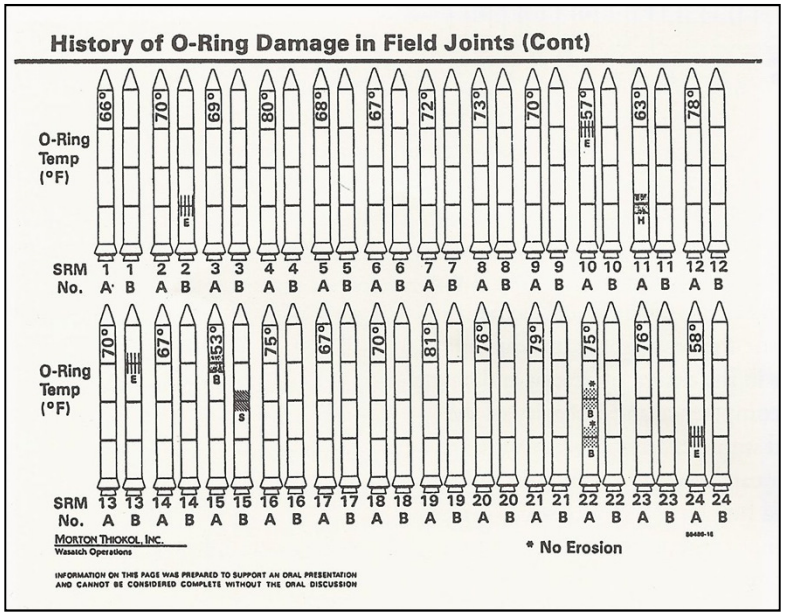
- Commission investigating the accident:

  "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?**

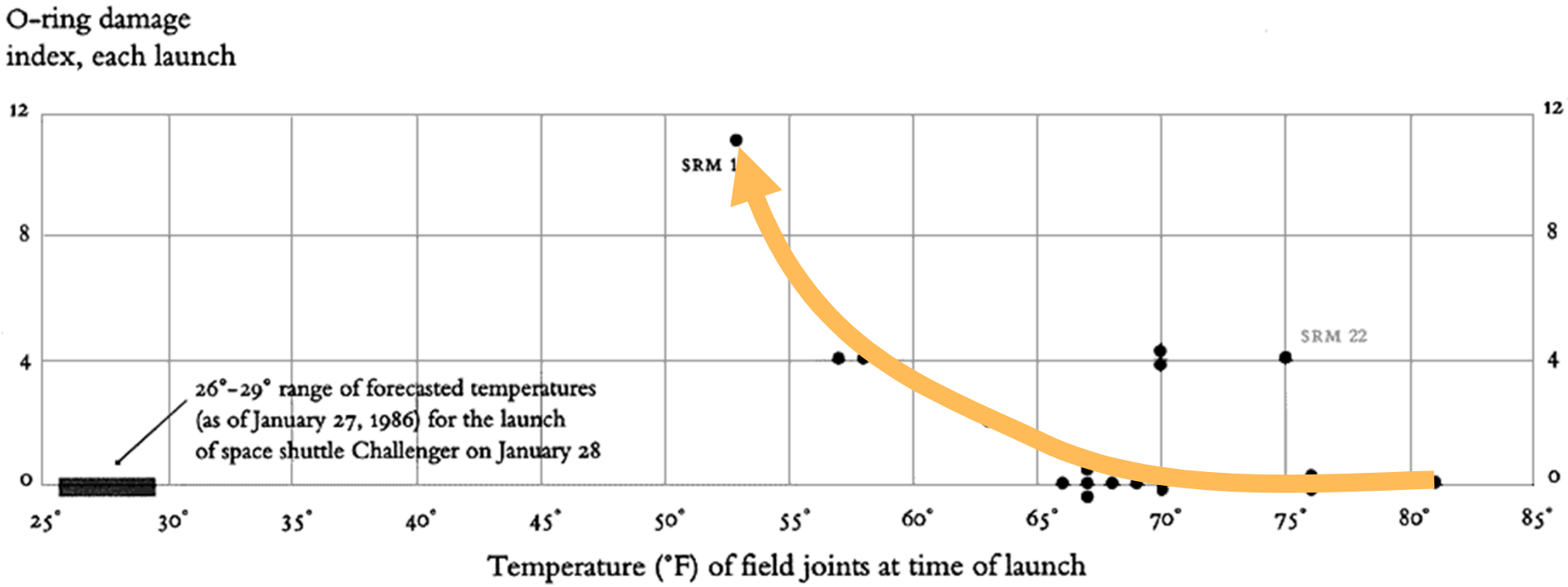
Let's evaluate MTI's 2nd attempt in visual displays after the accident





- *See the handout*
- **What are the pro's and con's of this data display?**
- **What can be done to help viewers make a valid scientific decision?**

Tufte's revision summarizes all data into a graph with a "Damage Index"



Tufte's visual display would have helped viewers make a valid scientific decision.

Take-Home Lessons from Two Case Studies

- Case 1: John Snow intervened in a cholera epidemic
  - He summarized all relevant info in a simple map
  - **He helped viewers make a valid scientific decision**

- Case 2: Decision to launch the space shuttle
  - MTI had all info, but created an ineffective data display, even after the accident
  - Tufte's revision summarized all relevant info in a simple graph
  - **Tufte helped viewers make a valid scientific decision**