

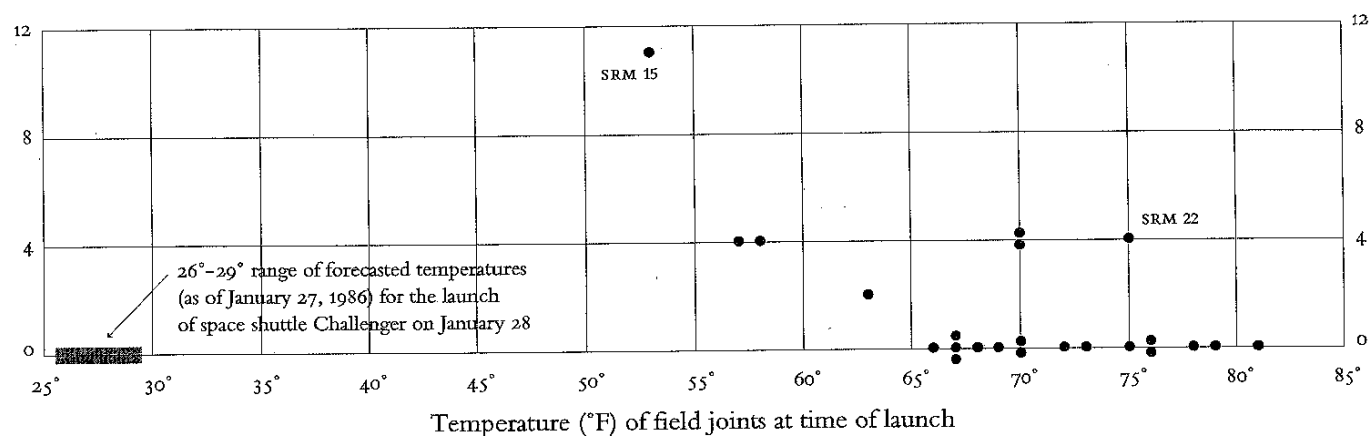
# EXHIBIT 2

## TUFTE VISUAL AND STATISTICAL THINKING

# EDWARD R. TUFTE

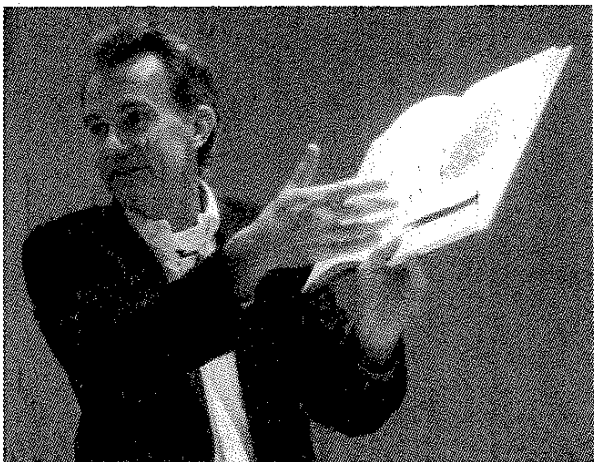
## VISUAL AND STATISTICAL THINKING: DISPLAYS OF EVIDENCE FOR MAKING DECISIONS

O-ring damage  
index, each launch



JOHN SNOW AND THE CHOLERA EPIDEMIC

THE DECISION TO LAUNCH THE SPACE SHUTTLE CHALLENGER



Edward Tufte has written seven books, including *Visual Explanations*, *Envisioning Information*, *The Visual Display of Quantitative Information*, *Data Analysis for Politics and Policy*, *Political Control of the Economy*, and *Size and Democracy* (with Robert A. Dahl). He writes, designs, and self-publishes his books on information design, which have received more than 40 awards for content and design. He is Professor Emeritus at Yale University, where he taught courses in statistical evidence, information design, and interface design. His current work includes a new book called *Beautiful Evidence*, landscape sculpture, and printmaking.

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# *Introduction*

THIS booklet, meant for students of quantitative thinking, reproduces chapter 2 of my recent book *Visual Explanations: Images and Quantities, Evidence and Narrative*.

The general argument is straightforward:

An essential analytic task in making decisions based on evidence is to understand how things work—mechanism, trade-offs, process and dynamics, cause and effect. That is, intervention-thinking and policy-thinking demand causality-thinking.

Making decisions based on evidence requires the appropriate display of that evidence. Good displays of data help to reveal knowledge relevant to understanding mechanism, process and dynamics, cause and effect. That is, displays of statistical data should directly serve the analytic task at hand.

What is reasonable and obvious in theory may not be implemented in the actual practice of assessing data and making decisions. Here we will see two complex cases of the analysis and display of evidence—the celebrated investigation of a cholera epidemic by Dr. John Snow and the unfortunate decision to launch the space shuttle Challenger.

*Edward Tufte*

*Although we often hear that data speak for themselves, their voices can be soft and sly.*

Frederick Mosteller, Stephen E. Fienberg, and Robert E. K. Rourke, *Beginning Statistics with Data Analysis* (Reading, Massachusetts, 1983), p. 234.

*Negligent speech doth not only discredit the person of the Speaker, but it discrediteth the opinion of his reason and judgment; it discrediteth the force and uniformity of the matter, and substance.*

Ben Jonson, *Timber: or, Discoveries* (London, 1641), first printed in the Folio of 1640, *The Workes . . .*, p. 122 of the section beginning with *Horace his Art of Poetry*.

MTI ASSESSMENT OF TEMPERATURE CONCERN ON SRM-25 (51L) LAUNCH

- 0 CALCULATIONS SHOW THAT SRM-25 O-RINGS WILL BE 20° COLDER THAN SRM-15 O-RINGS
- 0 TEMPERATURE DATA NOT CONCLUSIVE ON PREDICTING PRIMARY O-RING BLOW-BY
- 0 ENGINEERING ASSESSMENT IS THAT:
  - 0 COLDER O-RINGS WILL HAVE INCREASED EFFECTIVE DUROMETER ("HARDER")
  - 0 "HARDER" O-RINGS WILL TAKE LONGER TO "SEAT"
    - 0 MORE GAS MAY PASS PRIMARY O-RING BEFORE THE PRIMARY SEAL SEATS (RELATIVE TO SRM-15)
      - 0 DEMONSTRATED SEALING THRESHOLD IS 3 TIMES GREATER THAN 0.038" EROSION EXPERIENCED ON SRM-15
  - 0 IF THE PRIMARY SEAL DOES NOT SEAT, THE SECONDARY SEAL WILL SEAT
    - 0 PRESSURE WILL GET TO SECONDARY SEAL BEFORE THE METAL PARTS ROTATE
      - 0 O-RING PRESSURE LEAK CHECK PLACES SECONDARY SEAL IN OUTBOARD POSITION WHICH MINIMIZES SEALING TIME
- 0 MTI RECOMMENDS STS-51L LAUNCH PROCEED ON 28 JANUARY 1986
  - 0 SRM-25 WILL NOT BE SIGNIFICANTLY DIFFERENT FROM SRM-15

  
JOE C. KILMINSTER, VICE PRESIDENT  
SPACE BOOSTER PROGRAMS

MORTON THIOKOL INC.  
Wasatch Division

INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION

The final approval and rationale for the launch of the space shuttle Challenger, faxed by the rocket-maker to NASA the night before the launch. The rocket blew up 12 hours later as a result of cold temperatures.

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