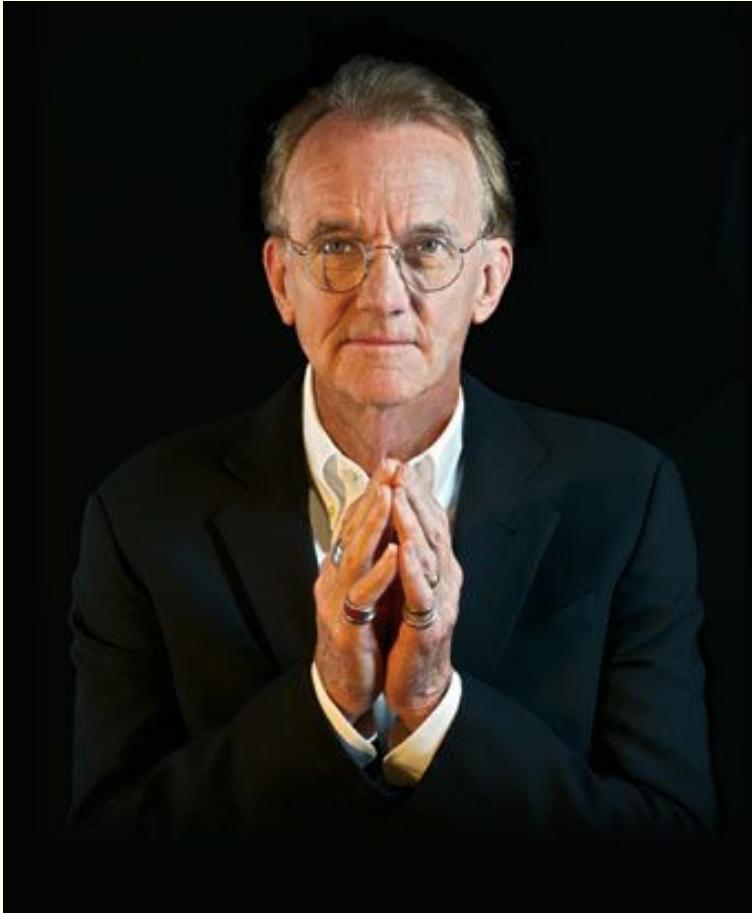


VISUAL EXPLANATIONS

IMAGES AND QUANTITIES, EVIDENCE AND NARRATIVE

EDWARD R. TUFTE

MIO AKASAKO-DVIA 2018



Visual Explanations is about *pictures of verbs*:

mechanism and motion
process and dynamics
causes and effects
explanation and narrative

IMAGES AND QUANTITIES

How can we represent quantities in visual expressions of ideas,
experience, evidence in a meaningful manner?
(How do we represent quantities within images?)

IMAGES AND QUANTITIES

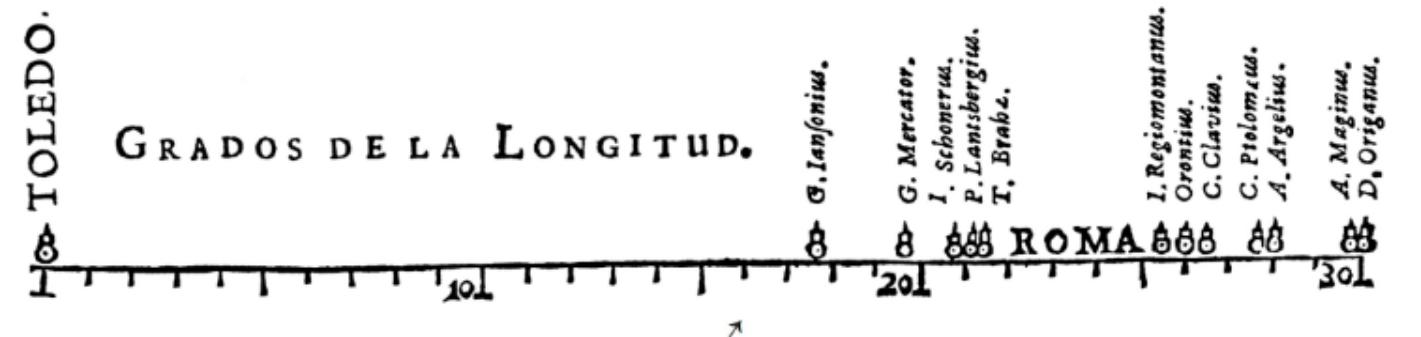
How can we represent quantities in visual expressions of ideas, experience, evidence in a meaningful manner?
(How do we represent quantities within images?)

- Direct labels (grids)
- Encodings (color scales)
- Self-representing scales (object of known size appearing in image)



TOLEDO.

GRADOS DE LA LONGITUD.



Left: Stone engraving of China, ~1137 ; Right: Michael Florent van Langren, *La Verdadera Longitud por Mar y Tierra*

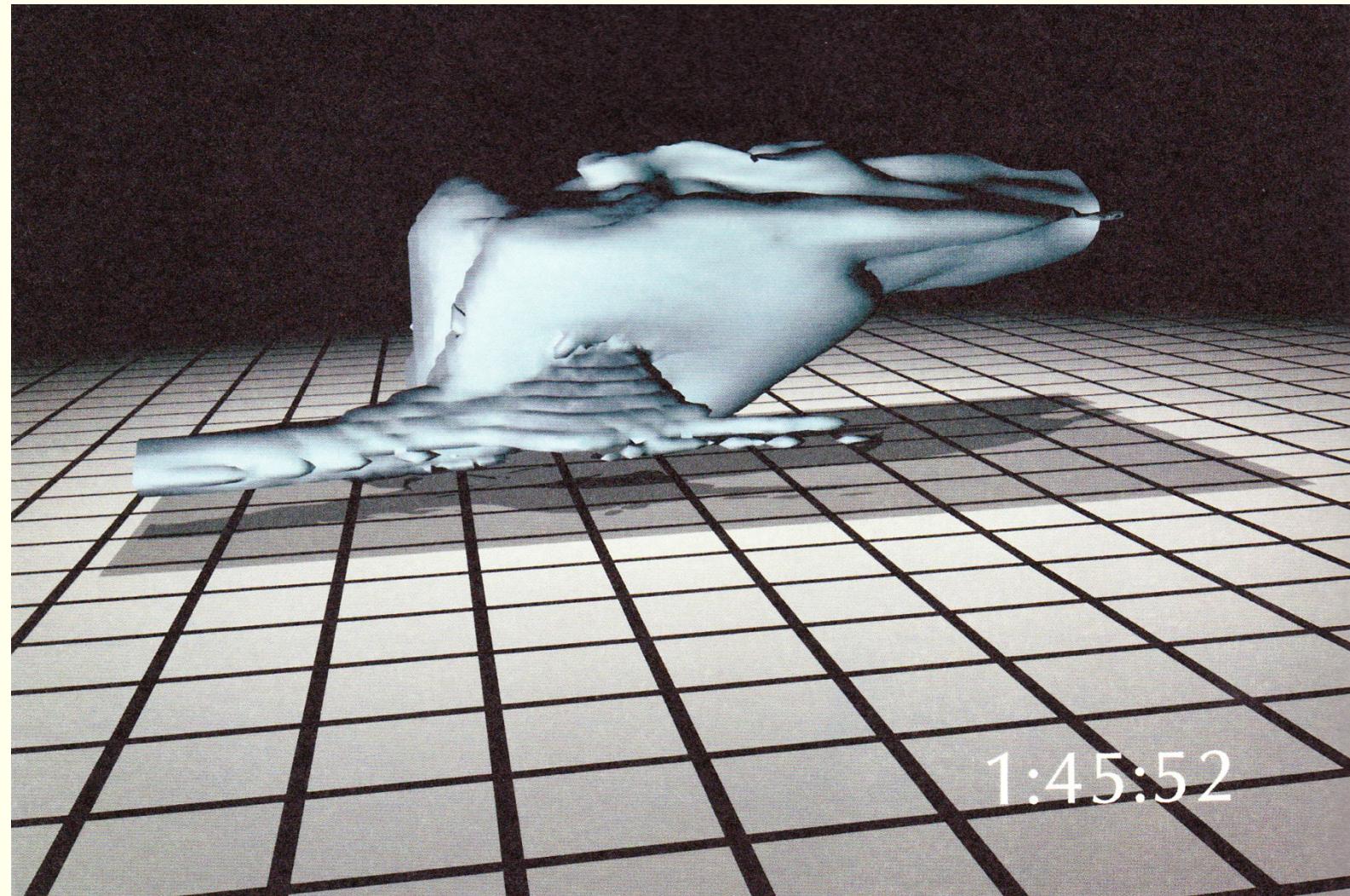
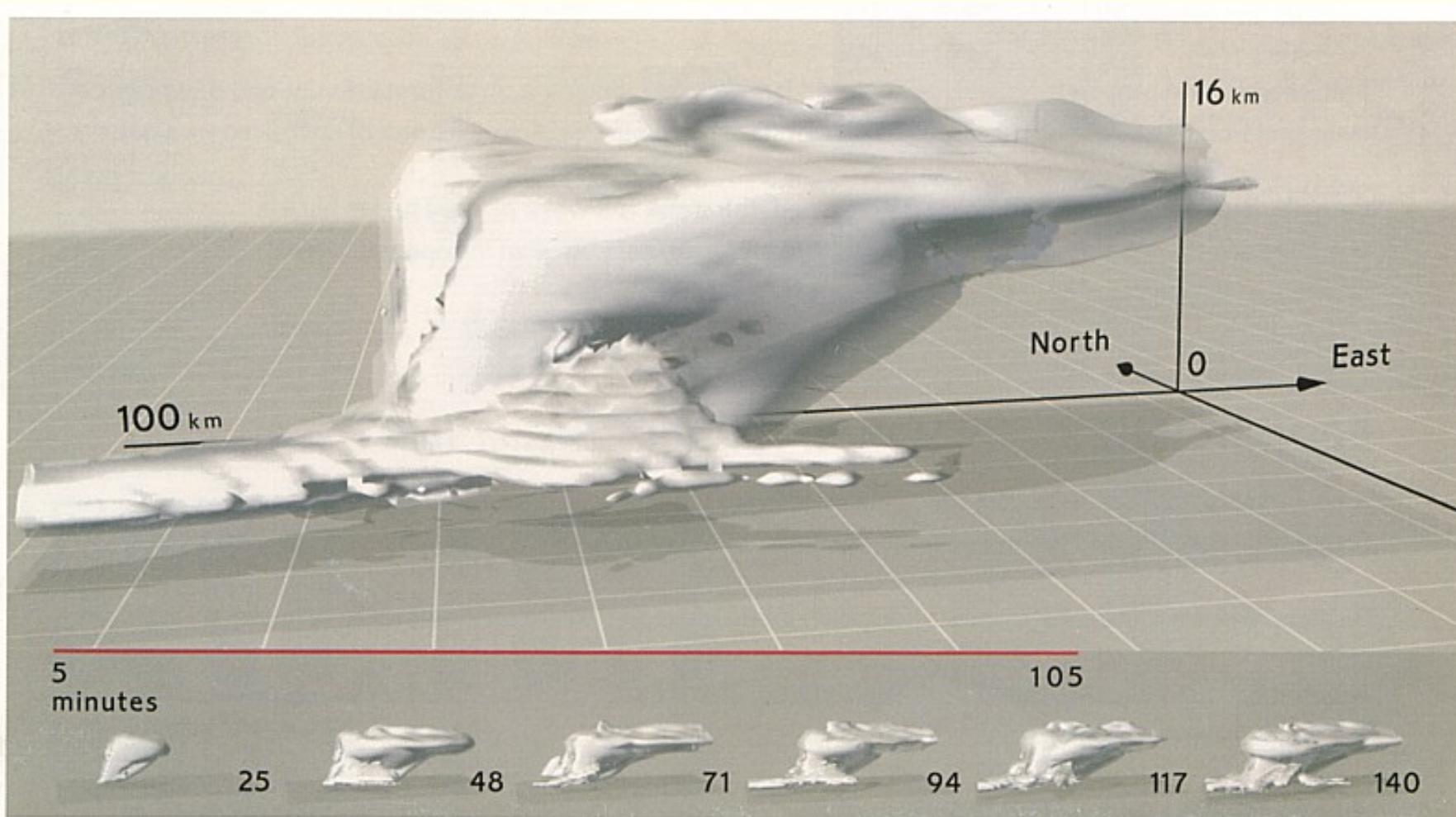


Image from the videotape "Study of a Numerically Modeled Severe Storm"



Redesigned animation by Edward Tufte and Colleen B. Bushell

Your visual should be able to answer the questions:
How many? How often? Where? How much? At what rate?

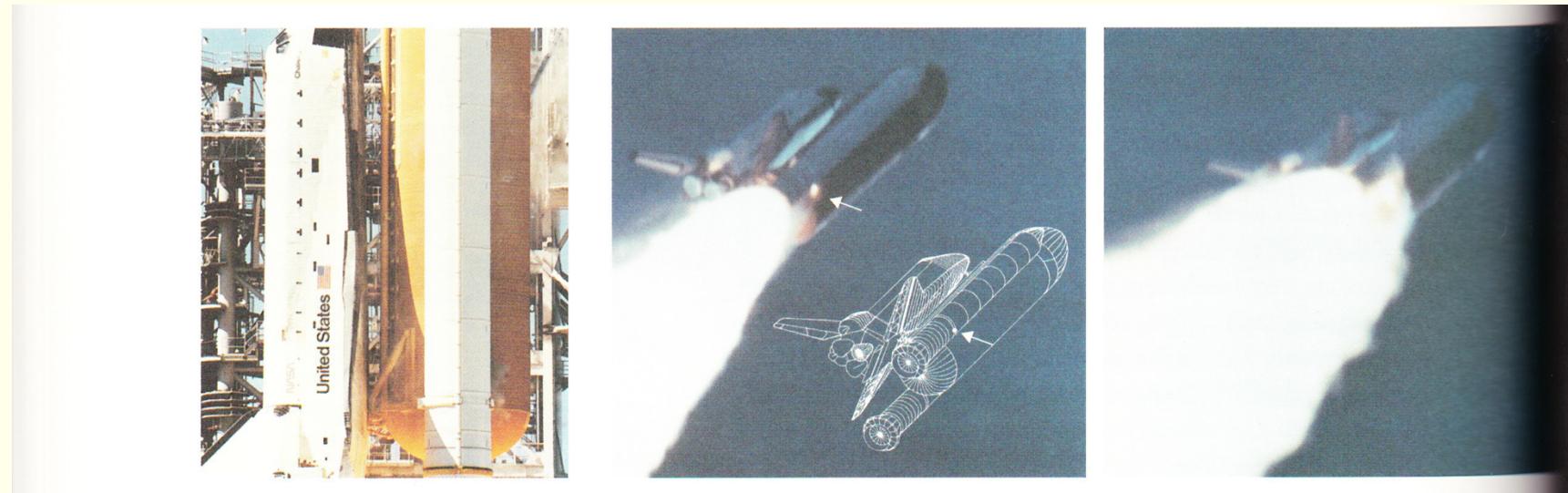
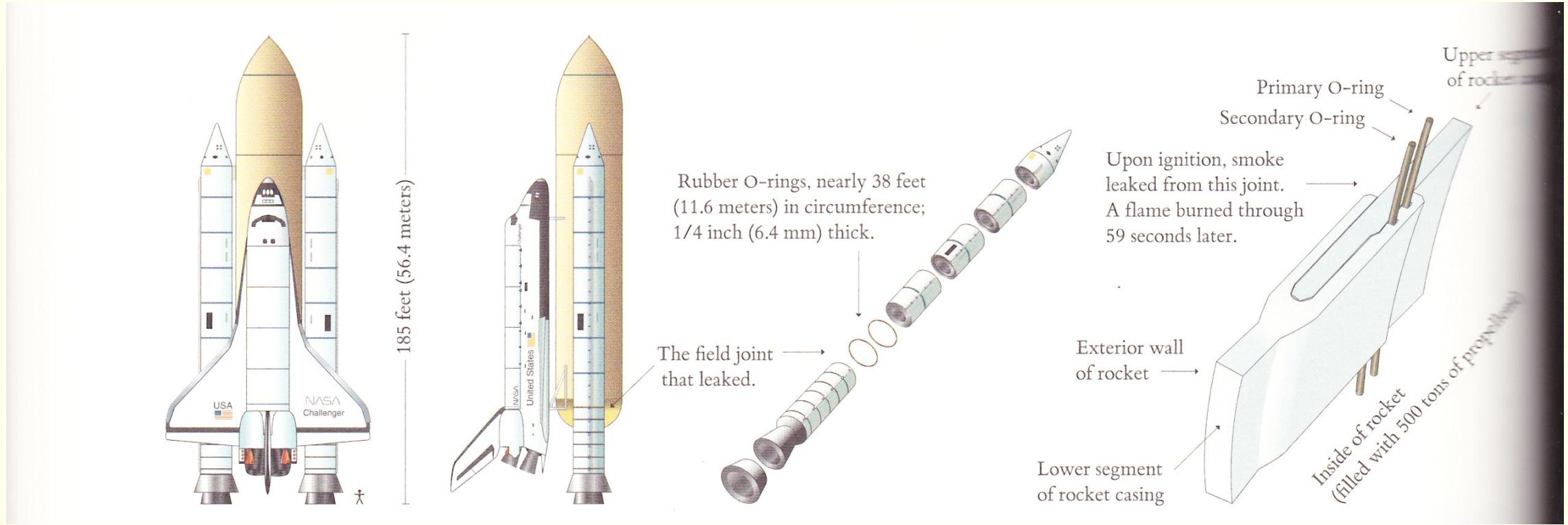
VISUAL AND STATISTICAL THINKING

How does the quality of your visuals influence reasoning and thus decision making?

VISUAL AND STATISTICAL THINKING

How does the quality of your visuals influence reasoning and thus decision making?

The way you quantify your data can make or break your argument:
Need smart analysis of evidence AND effective presentation



Space shuttle Challenger and its O-ring failure

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

	SRM No.	Cross Sectional View			Top View			Clocking Location (deg)
		Erosion Depth (in.)	Perimeter Affected (deg)	Nominal Dia. (in.)	Length Of Max Erosion (in.)	Total Heat Affected Length (in.)		
OCT 30, 1985 APT	61A LH Center Field**	22A	None	None	0.280	None	None	36°--66°
	61A LH CENTER FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338°-18°
X	51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
X	51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
X	51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
	41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
	41C LH Aft Field*	11A	None	None	0.280	None	None	--
	41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
	STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	--	90

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.

**Soot behind primary O-ring.

***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

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 ($30-40^\circ$)

SRM-13A, 15, 16A, 18, 23A 24A

- NOZZLE Blow-By

*HISTORY OF O-RING TEMPERATURES
(DEGREES - F)*

<u>MOTOR</u>	<u>MBT</u>	<u>AMB</u>	<u>O-RING</u>	<u>WIND</u>
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 27	10 MPH 25 MPH

Chart that mentions O-ring temperature and blow-by history

CONCLUSIONS :

- TEMPERATURE OF O-RING IS NOT ONLY PARAMETER CONTROLLING BLOW-BY
SRM 15 WITH BLOW-BY HAD AN O-RING TEMP AT 53°F
SRM 22 WITH BLOW-BY HAD AN O-RING TEMP AT 75°F
FOUR DEVELOPMENT MOTORS WITH NO BLOW-BY WERE TESTED AT O-RING TEMP OF 47° To 52 °F
DEVELOPMENT MOTORS HAD PUTTY PACKING WHICH RESULTED IN BETTER PERFORMANCE
- AT ABOUT 50°F BLOW-BY COULD BE EXPERIENCED IN CASE JOINTS
- TEMP FOR SRM 25 ON 1-28-86 LAUNCH WILL BE 29°F 9 AM
38°F 2 PM
- HAVE NO DATA THAT WOULD INDICATE SRM 25 IS DIFFERENT THAN SRM 15 OTHER THAN TEMP

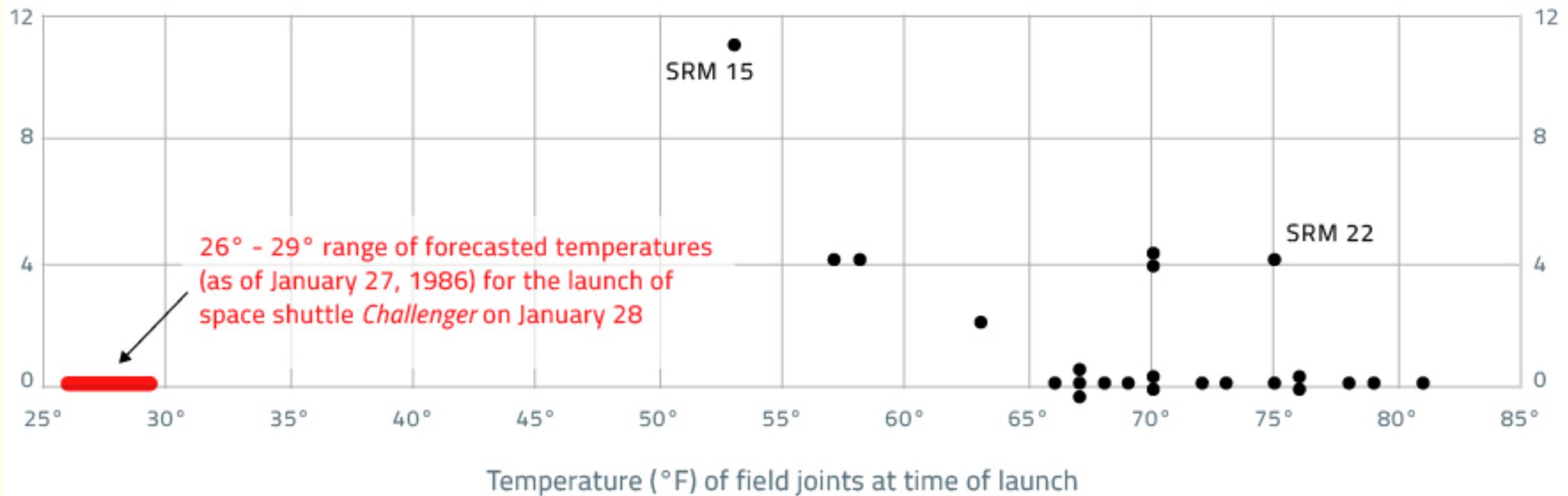
RECOMMENDATIONS :

- O-RING TEMP MUST BE \geq 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

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	
	06.27.82	80°			?	O-ring condition unknown; rocket casing lost at sea.
51-F	07.29.85	81°			0	

Chart by Edward Tufte showing all flights and complete damage index

O-ring damage
index, each launch



Graph by Edward Tufte showing all flight temperatures in relation to O-ring damage

“There are right ways and wrong ways to show data;
There are displays that reveal the truth and displays that do not”

Can you think of any modern examples that showcase how visuals can misrepresent a story/lead to significant consequences?

How can we make sure our visuals are displaying “the truth” and don’t mislead our viewers?

How can we make sure our visuals are displaying “the truth” and don’t mislead our viewers?

- Make controlled comparisons
- Document sources of data
- Enforce appropriate comparisons
- Demonstrate cause and effect
- Express this cause and effect quantitatively
- Recognize multivariate nature of problems
- Evaluate alternative explanations

EXPLAINING MAGIC

How can magic and explanations of magic help us learn how to make clear, concise visuals?

EXPLAINING MAGIC

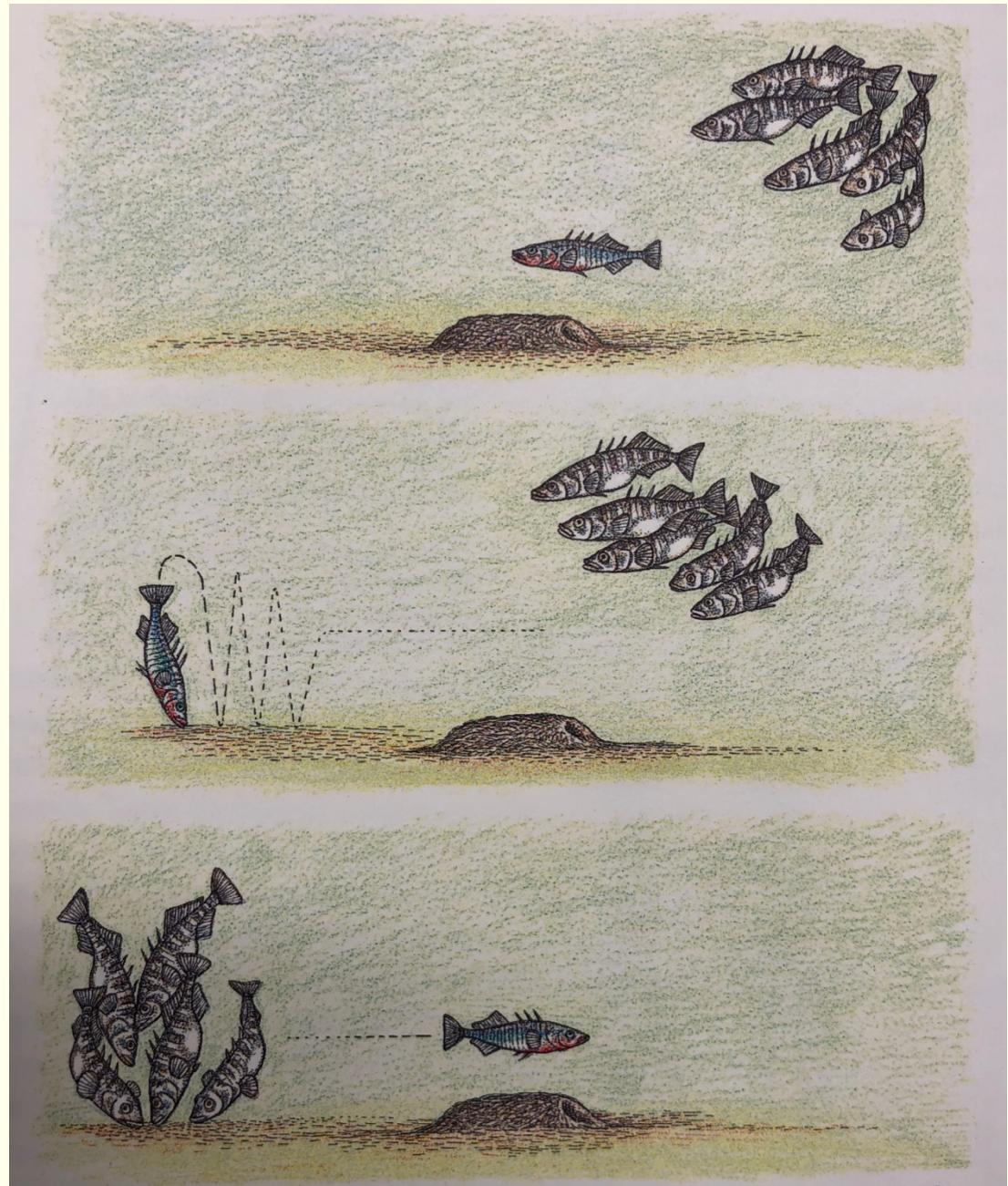
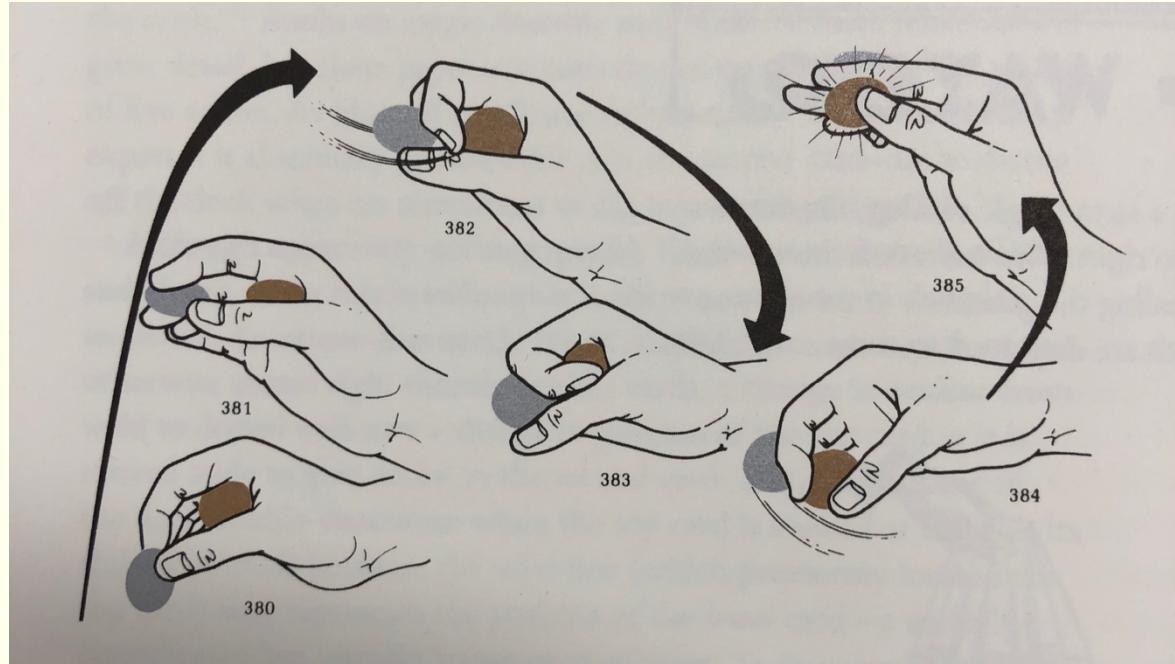
How can magic and explanations of magic help us learn how to make clear, concise visuals?

Pictoral instructions of magic:

must document a process clearly, must make verbs visible; must simultaneously depict revealed and concealed aspects of process

Disinformation design:

the making of illusions engages in deception of audience; it suggests what not to do if our aim is to tell the truth to our audience



Left: Richard Kaufmann, Coinmagic; Right: Patricia J Wynne, "The Reproductive Behavior of the Stickleback"

Nel
book
“The
expla
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The first rule to be borne in mind by the aspirant [magician] is this: “*Never tell your audience beforehand what you are going to do.*” If you do so, you at once give their vigilance the direction which it is most necessary to avoid, and increase ten-fold the chances of detection. . . . It follows, as a practical consequence of this first rule, that *you should never perform the same trick twice on the same evening.* The best trick loses half its effect on repetition, but besides this, the audience knows precisely what is coming, and have all their faculties directed to find out at what point you cheated their eyes on the first occasion.²⁷

“These techniques of disinformation design, when reversed, reinforce strategies of presentation used by good teachers. Your audience should know beforehand what you are going to do; then they can evaluate how your verbal and visual evidence supports your argument.”

THE SMALLEST EFFECTIVE DIFFERENCE

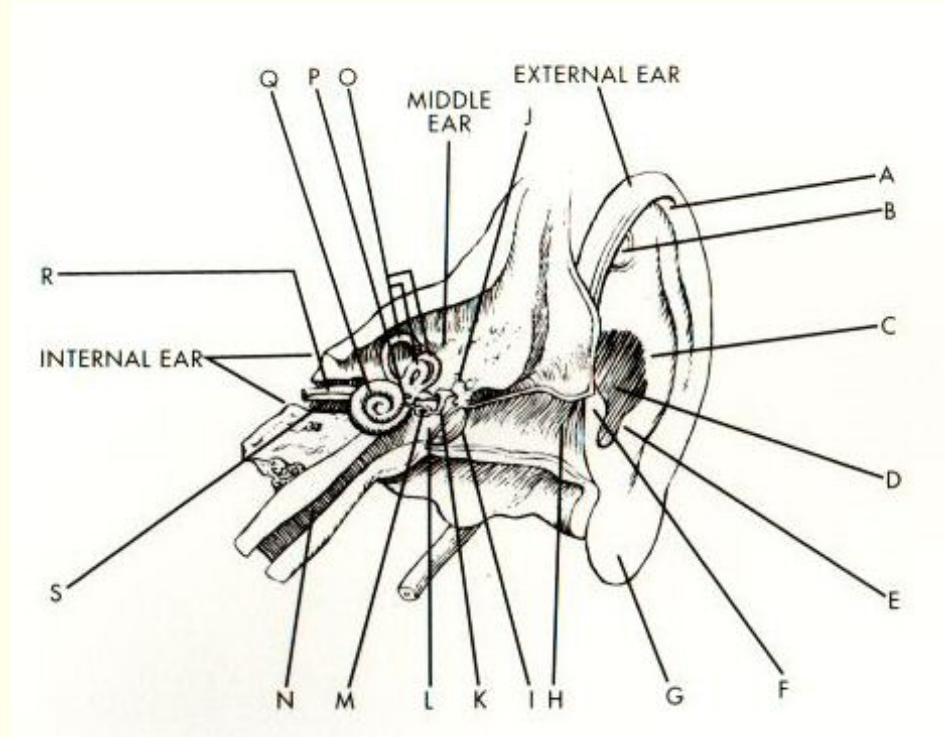
How can we use principles of visual perception to make clear and effective visuals without cluttering?

THE SMALLEST EFFECTIVE DIFFERENCE

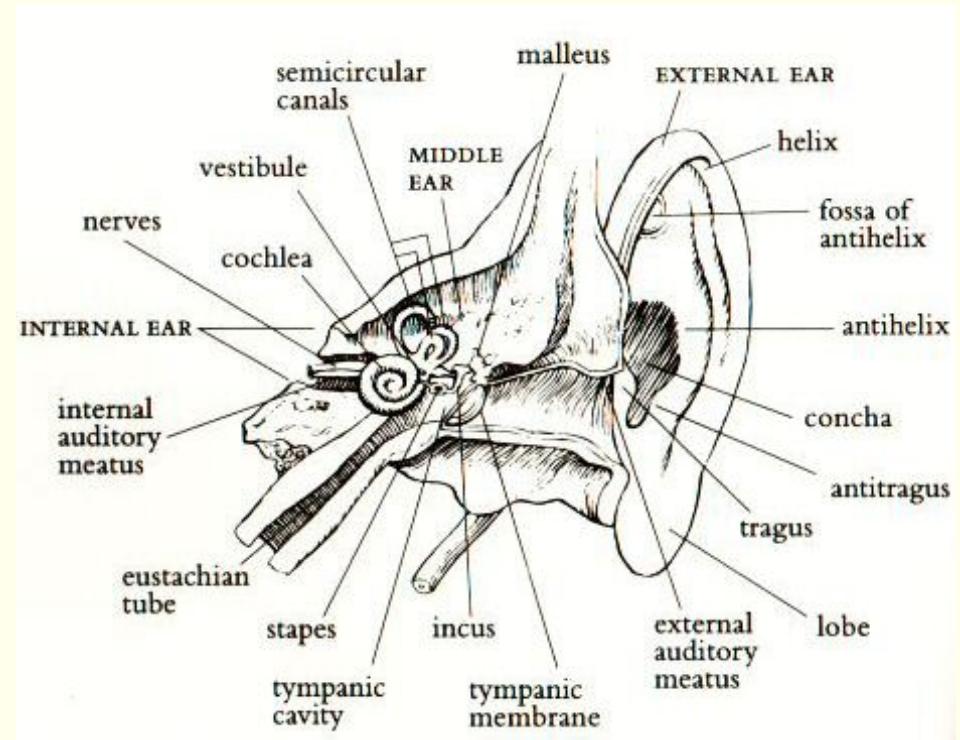
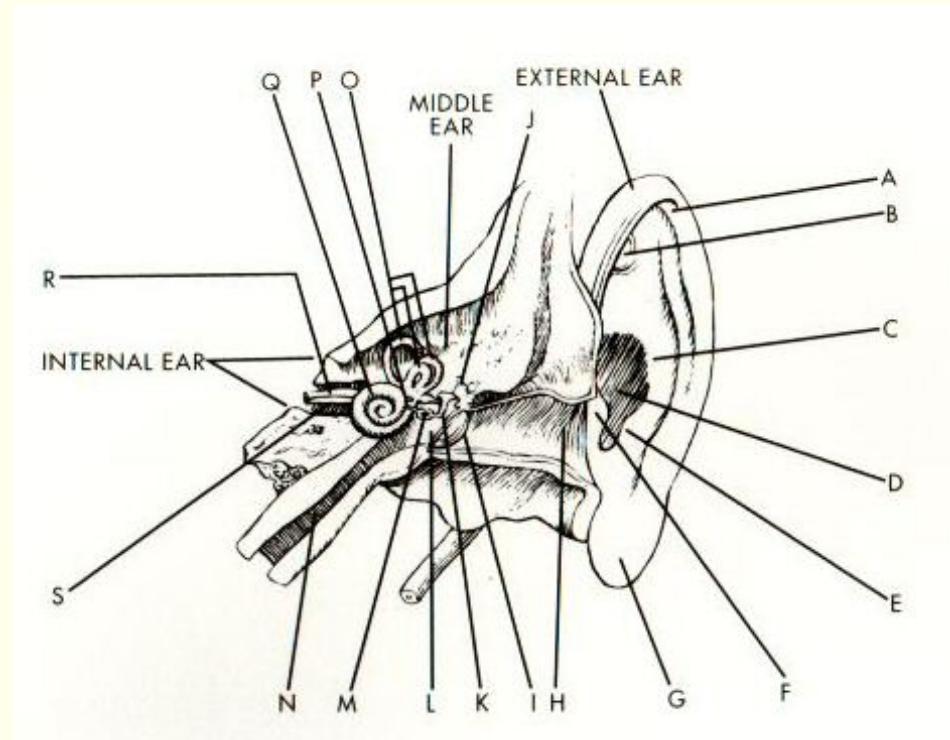
How can we use principles of visual perception to make clear and effective visuals without cluttering?

Make all visual distinctions as subtle as possible, but still clear and effective

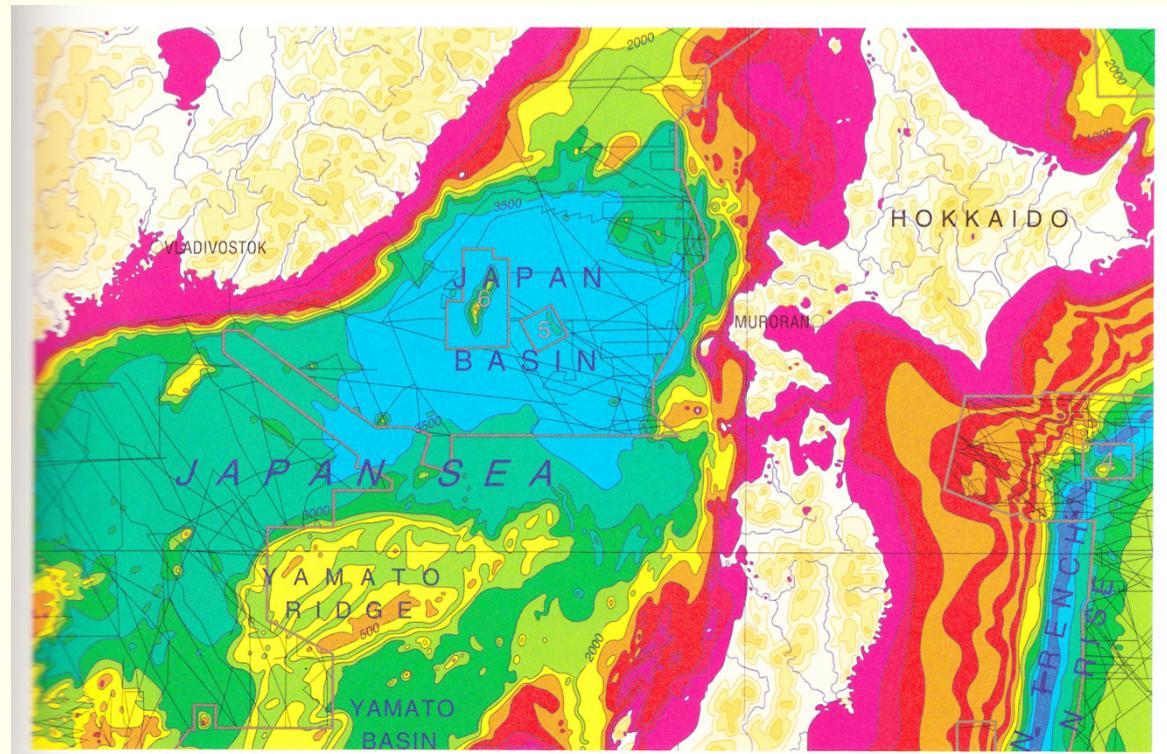
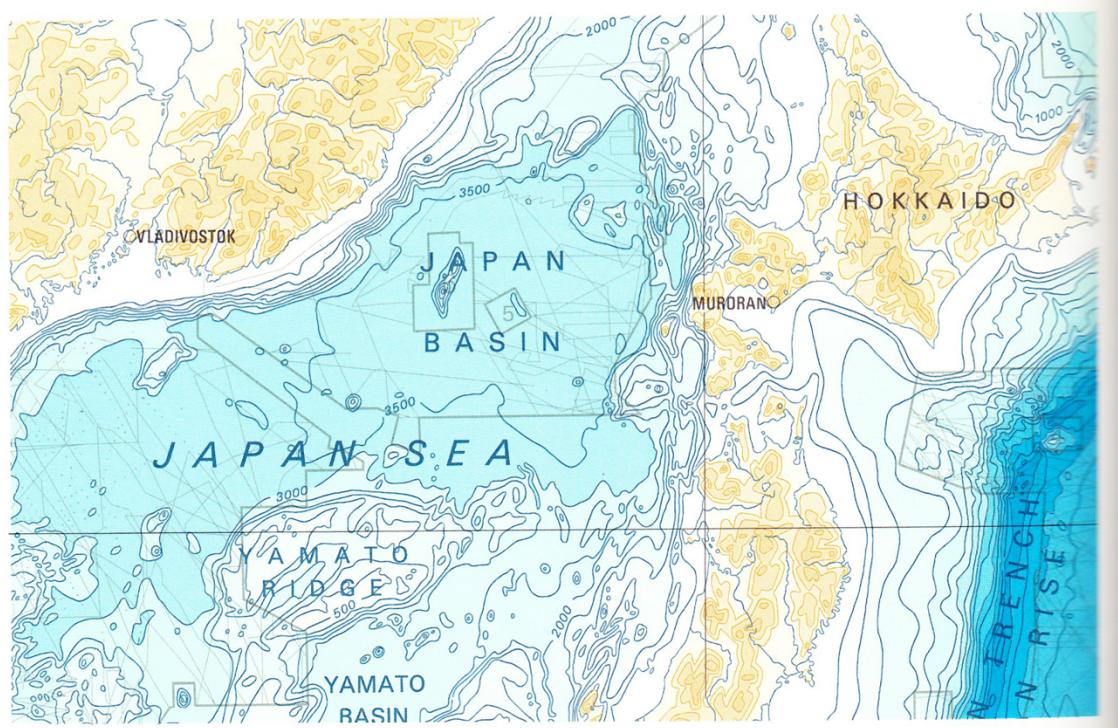
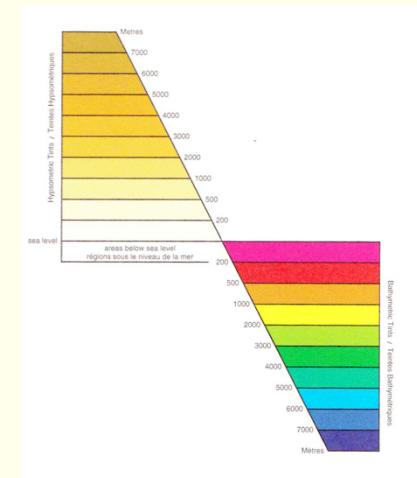
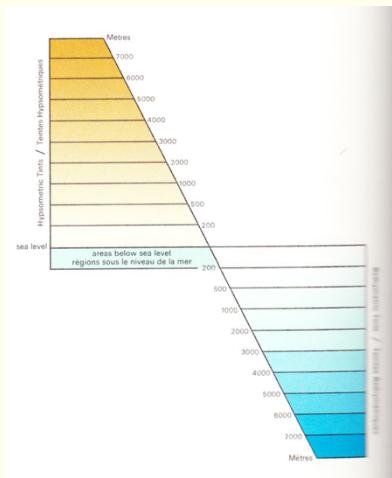
Useful for designing secondary and structural elements in displays of information



Two interpretations of a visual of a human ear



Two interpretations of a visual of a human ear



Two interpretations of a topographical map of Japan

Minimal distinctions reduce visual clutter;
Small contrasts increase the number of distinctions that can be made
within a single image

PARALLELISM

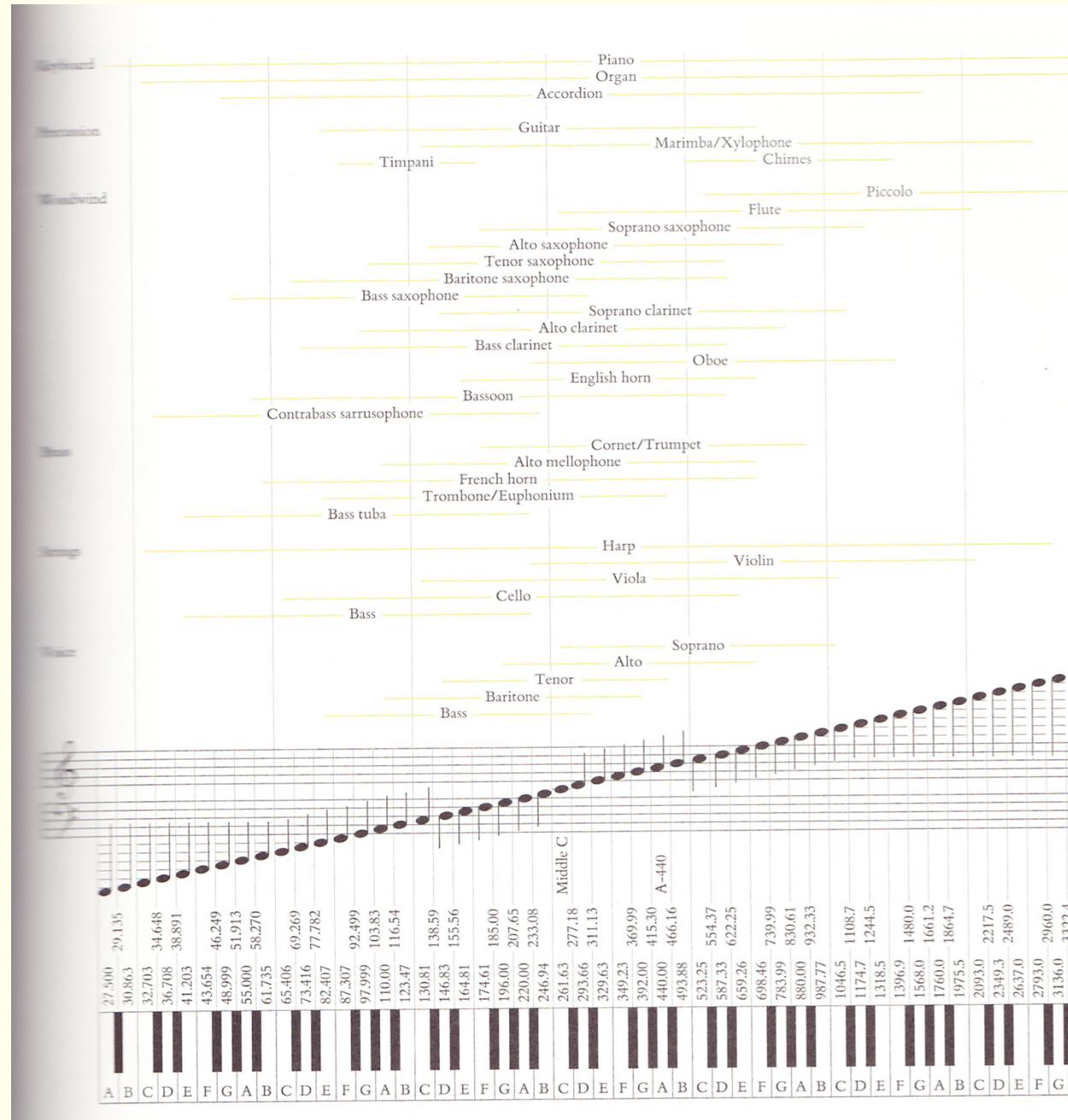
How can we use parallelism (visuals in parallel) to organize our images and extract meaningful information from them?

PARALLELISM

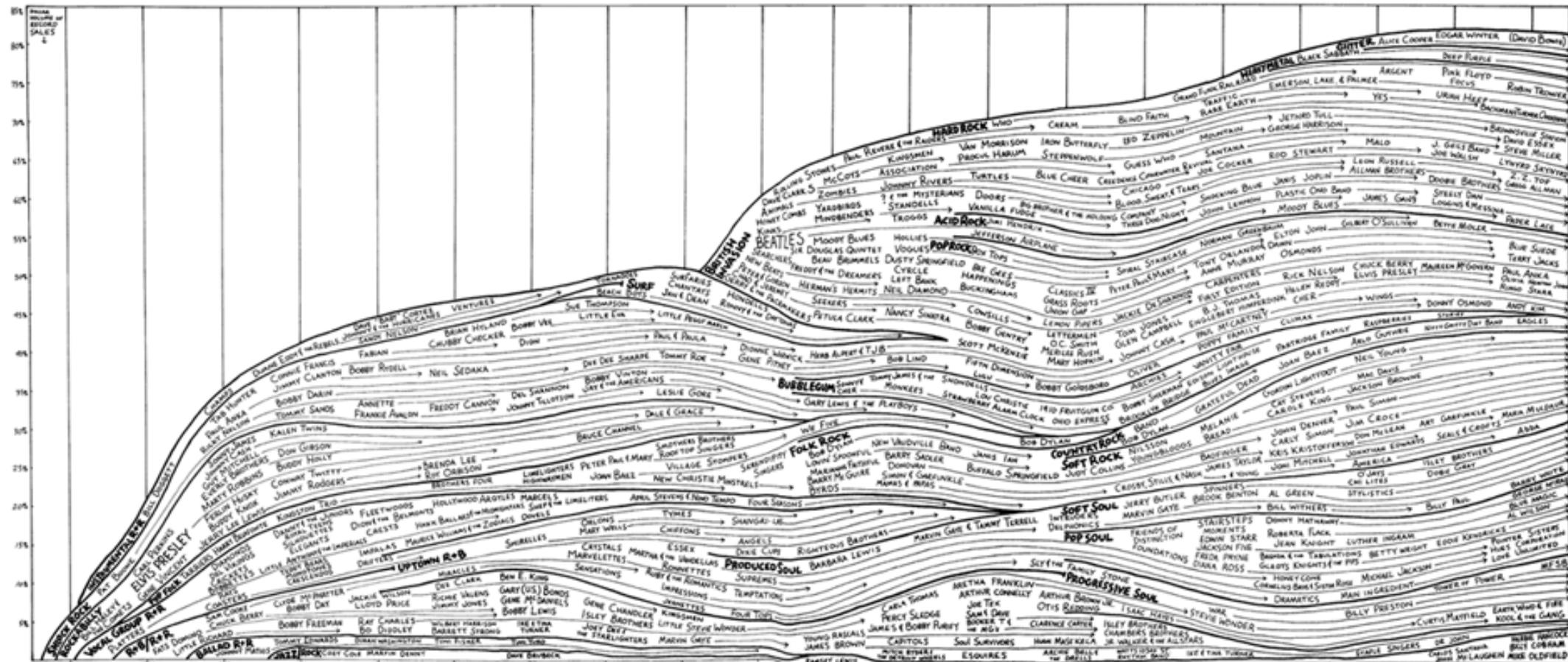
How can we use parallelism (visuals in parallel) to organize our images and extract meaningful information from them?

Parallelism is useful for making visual connections, comparisons and contrasts; it relates like to like and synchronizes multiple channels of information

Design strategies: pairing, orientation, simultaneity, overlap, superimposition, flowing together on a common track, codes, pointer lines, sequence, analogy, similar content



John R Pierce, *The Science of Musical Sound*



Steve Chapple and Reebee Garofalo, *Rock 'N' Roll is Here to Pay: The History and Politics of the Music Industry*

“Parallelism provides a coherent architecture for organizing and learning from images...by establishing a structure of rhythms and relationships, parallelism becomes the poetry of visual information.”

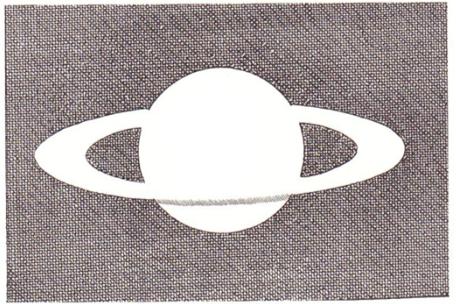
MULTIPLES IN SPACE AND TIME

Similarly to parallelism, how can we use multiples of images to organize our images and extract meaningful information from them?

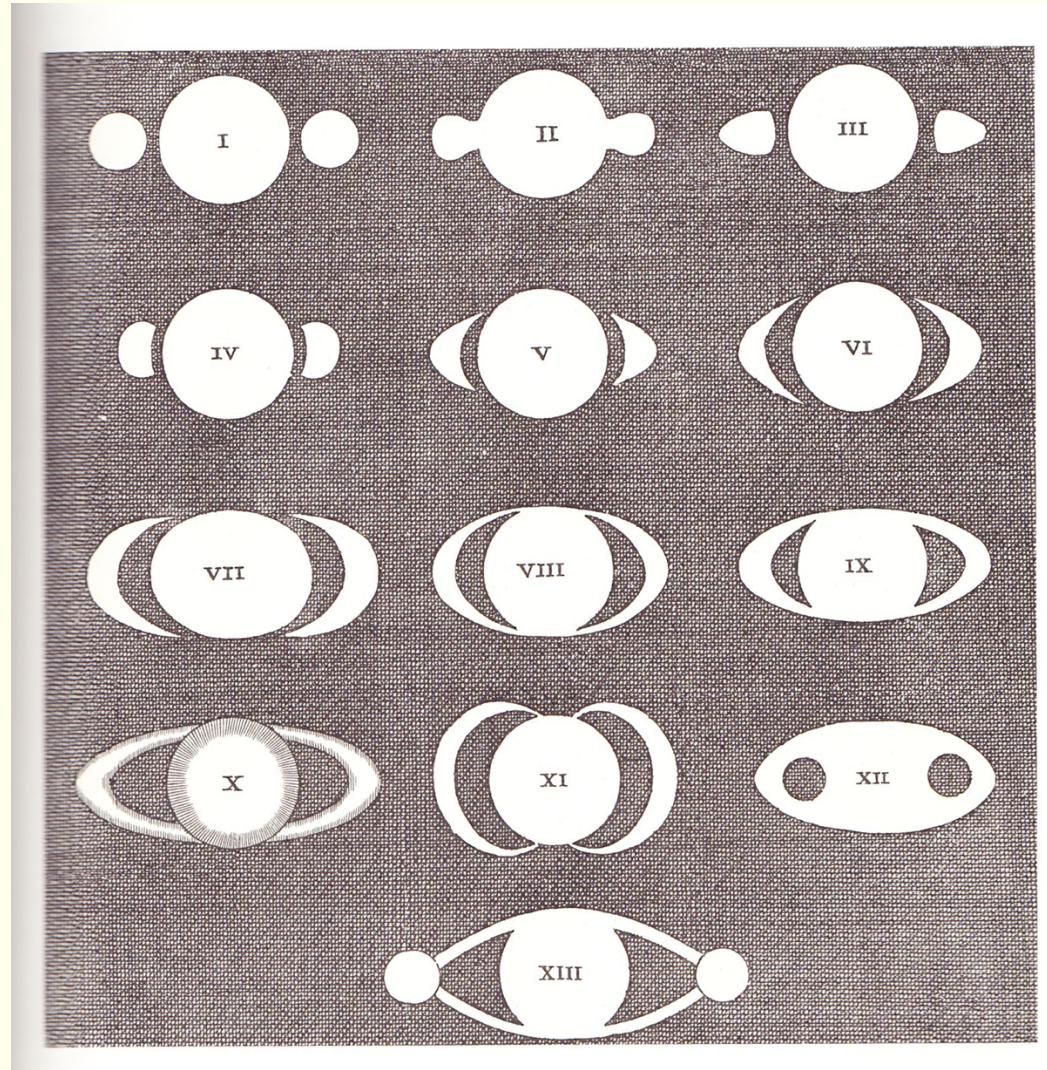
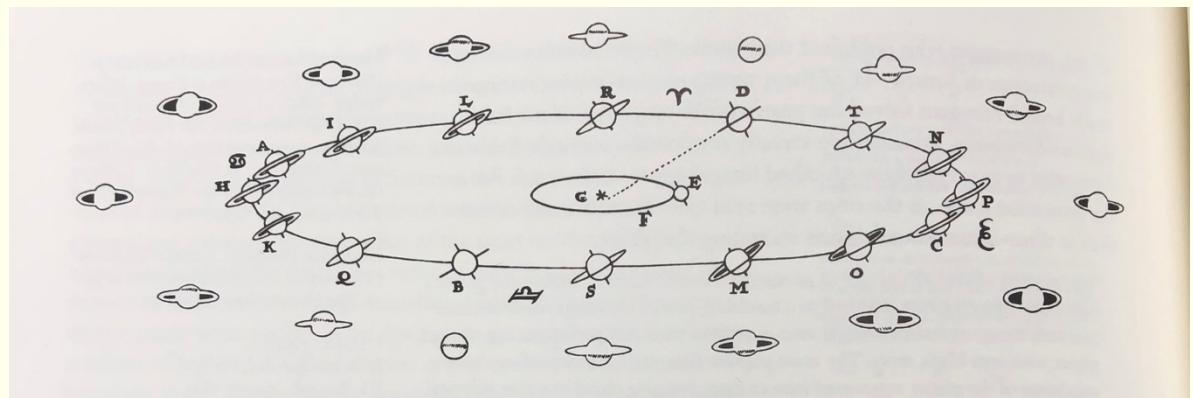
MULTIPLES IN SPACE AND TIME

Similarly to parallelism, how can we use multiples of images to organize our images and extract meaningful information from them?

Multiples enable us to reveal changes, patterns, sequences of motion; allows comparisons to be made



- I. Galileo, 1610
II. Scheiner, 1614
III. Riccioli, 1641 or 1643
IV-VII. Hevel, theoretical forms
VIII-IX. Riccioli, 1648-1650
X. Divini, 1646-1648
XI. Fontana, 1636
XII. Biancani, 1616; Gassendi, 1638, 1639
XIII. Fontana and others, 1644, 1645.



Multiples allow viewers to detect contrasts and correspondences at a glance with little help from words; it allows for uninterrupted visual reasoning

When do you think it is better to use multiples rather than motion graphics (videos, gifs) in order to depict ideas?

VISUAL CONFECTIONS

How can we use images from multiple events to tell an effective story?

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How can we use images from multiple events to tell an effective story?

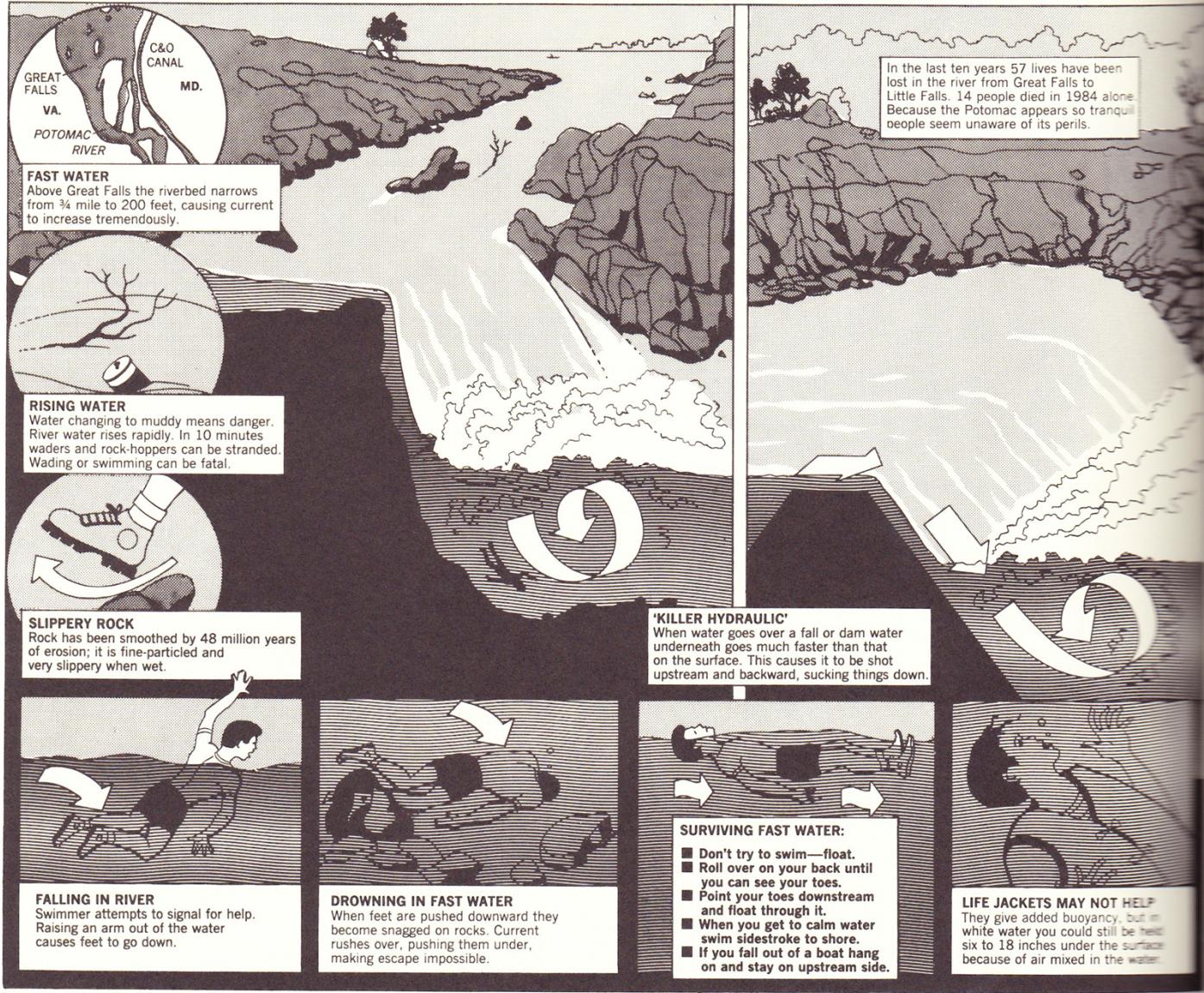
Confection: an assembly of many visual events selected from various timelines, then put together in the same 2D plane

Two general strategies: compartments of images & imagined scenes



Title page of Thomas Hobbes' *Leviathan*

WHY IS THE POTOMAC RIVER SO DANGEROUS?



The dangers of the Potomac River illustrated by Johnstone Quinan, for *The Washington Post*

“Confections place selected, diverse images into the narrative context of a coherent argument. And, by virtue of their arguments, confections make reading and seeing and thinking identical.”

TO THINK ABOUT...

How can we take Tufte's lessons and design methods and use them in more modern data visualization (ie. consider interface design, interaction design)?

Tufte covers a variety of more “artistic” visualizations in a greater part of this book. Is there an opportunity to use these methods in our visualizations, if we are working with big datasets? Should we consider using them?