SCIENTIFIC THINKING to Remedy "Black Swans," "Wicked Problems," and Assorted Science/ Policy Failures

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1. **Science-as-process of inquiry**, serving as a continually updated guide to action **SCIENCE**, NOT as facts, but **as ACTS**
2. **Black Swans** - surprising extreme-impact events that exceed expected possibilities
3. **Wicked Problems** - unique, seemingly endless questions without true or false answers, that get viewed from conflicting perspectives, and whose supposed "solutions" lead to yet more wicked problems
4. Failure of **Science-as-knowledge**, effectively serving as the authoritative basis for wise, publically understood action

Main Concern of Philosophy

"…to question and understand very common ideas that all of us use every day without thinking about them."

Thomas Nagel (1987)
What Does It All Mean?

Philosophy is not so popular these days:

Philosophy: a discipline offering "**worthless courses**" that offer "**no chances of getting people jobs**"

Governor Pat McCrory

North Carolina

"We need **more welders** and **less philosophers**"

Senator Marco Rubio

Although **all the humanities suffer disdain**, philosophy keeps on attracting special negative attention -- perhaps because in addition to appearing **worthless**, it also appears **vaguely subversive**.

Across the nation there's unbounded adulation for the STEM disciplines, which seem so **profitable**.

Martha Nussbaum (Huffington Post, 3/14/2016)

Science

The branch of knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws.

American College Dictionary

Science is above all **an activity and an attitude**, held by **a community of like-minded investigators**, who are **passionately driven** by their desire to uncover the truths of nature. In order to pursue this **inquiry into nature** it is actually necessary to have uncertainty, not to suppress it. How could one possibly do science, as just defined, if its subject matter consisted of facts and absolute truths? There would be nothing to pursue. Science is **a living, dynamic process of inquiry**, not a dead collection of presumed factual truths. Scientific inquiry is **open ended**. Questions (hypotheses) are pursued to generate understanding that makes for more and more **reliable knowledge**.

Why is Scientific Thinking Important?

The world is changing in completely and totally **unpredictable** ways, and this change is happening faster and faster.

Science is being **misunderstood** and/or **misrepresented** in regard to the coping with these changes.

Many of our modes of policy formulation and decision-making are predicated upon this misunderstanding of science and its proper role, which is to **guide wisdom** in regard to dealing with this change--**NOT** to serve as the **Factual Basis (TRUTHS) For Action**.

The Earth and Environmental Sciences employ ways of thinking about the natural world--particularly an emphasis **ABDUCTIVE INFERENCE**--that get much less emphasis in many other sciences, and these are absolutely essential for reversing these trends.

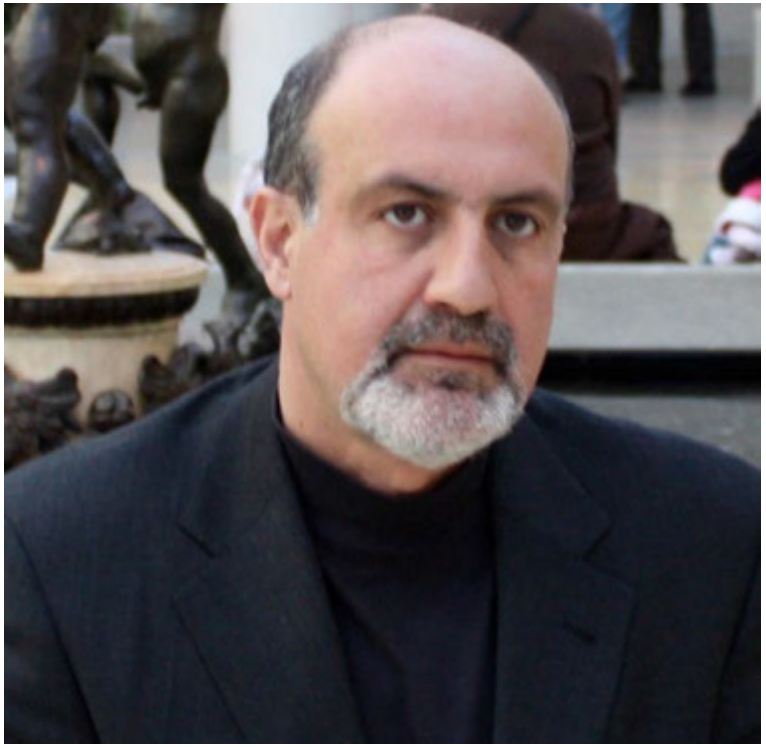
The **black swan theory** or **theory of black swan events** is a metaphor describing an event that

(1) is a **surprise** (to the observer). It it is an **outlier**, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility

(2) has a major effect (**extreme** 'impact').

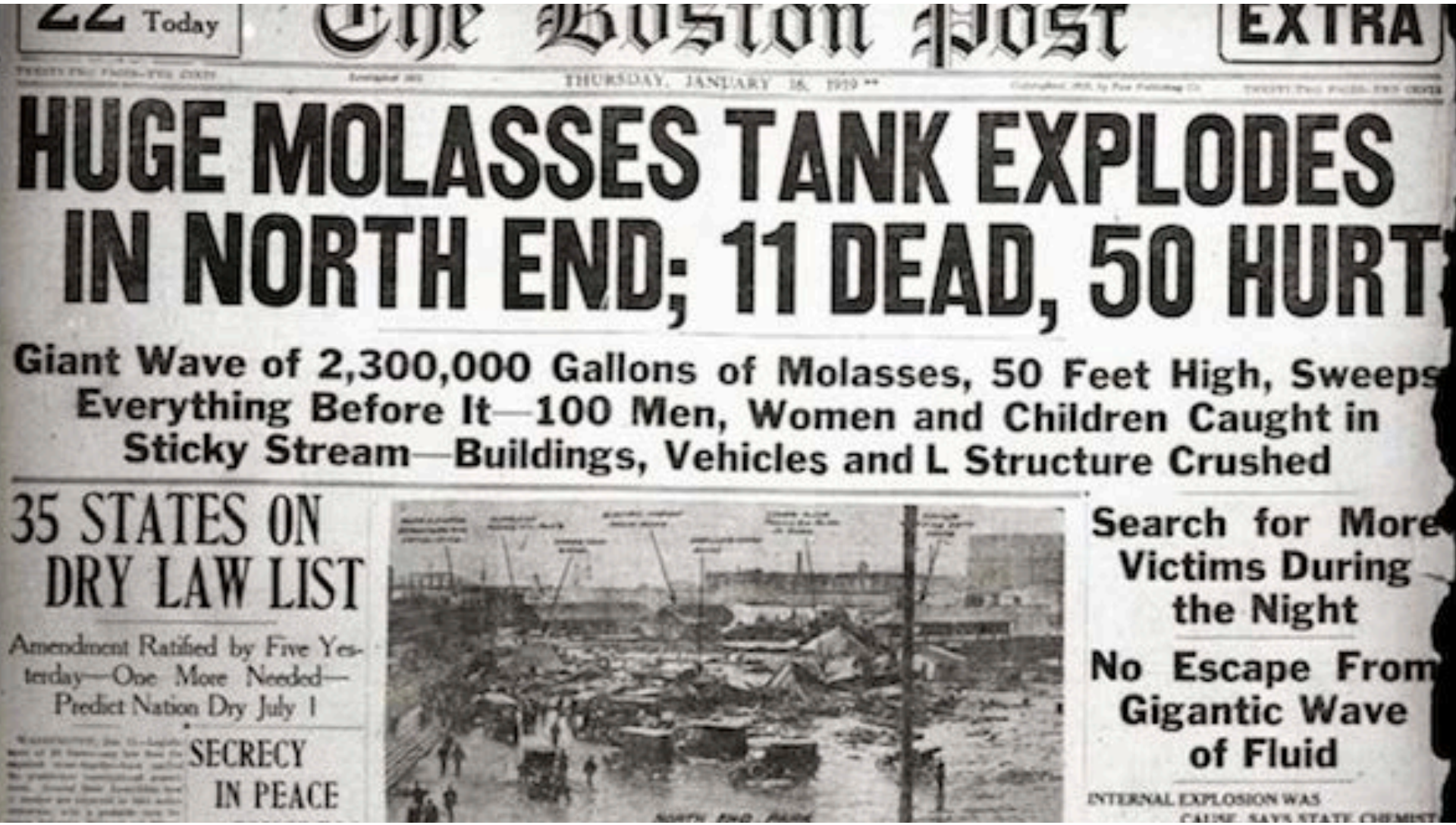
(3) human nature, in spite of the outlier status, makes us **concoct explanations** for its occurrence after the fact, making it explainable and predictable.

The Black Swan: The Impact of the Highly Improbable (2007, 2010)



Nassim Nicholas Taleb (b. 1960)

Boston's "Tsunami of Molasses" of January 15, 1919
The wave was perhaps 7.5 meters high and 50 meters wide at its peak, and it moved at a frightening 35 miles per hour, resulting 21 fatalities



22 Today

The Boston Post

EXTRA

THURSDAY, JANUARY 16, 1919

HUGE MOLASSES TANK EXPLODES IN NORTH END; 11 DEAD, 50 HURT

Giant Wave of 2,300,000 Gallons of Molasses, 50 Feet High, Sweeps Everything Before It—100 Men, Women and Children Caught in Sticky Stream—Buildings, Vehicles and L Structure Crushed

35 STATES ON DRY LAW LIST

Amendment Ratified by Five Yesterday—One More Needed—Predict Nation Dry July 1

SECRECY IN PEACE

Search for More Victims During the Night

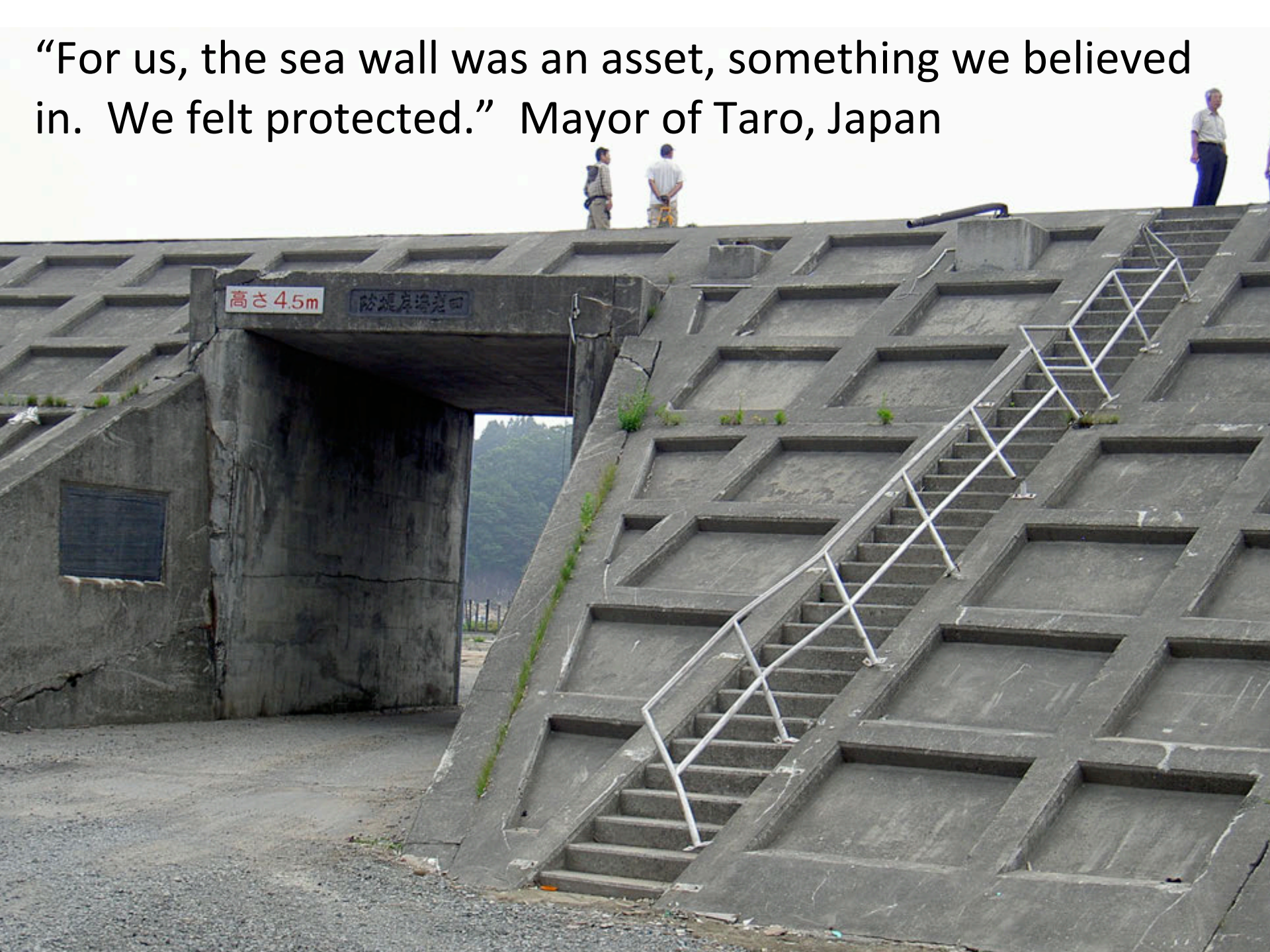
No Escape From Gigantic Wave of Fluid

INTERNAL EXPLOSION WAS


WARREN LINE
SAVANNAH LINE

Taro, Japan before the Earthquake on March 11, 2011

“For us, the sea wall was an asset, something we believed in. We felt protected.” Mayor of Taro, Japan



Kamaishi Bay Tsunami

1896 and 1933

1,950 m (6,400 ft) long and 63 m (207 ft) deep Kamaishi Tsunami Protection Breakwater,[7] which had been completed in March 2009 after three decades of construction, at a cost of $1.5 billion


本吉郡
南三陸町
南島
野島
松島
保呂羽山


SHIZUGAWA HIGH SCHOOL


Minami SanRiku Japan
宮城県
Jr High School
Elementary School
Train Station
City Office
八幡川
Red Cross Hospital
Total Population
人口:17,296人(県24位)
With 10,000 Living in Basin Area
Miyagi Pref.

Tsunami hits town of Minami-Sanriku, Miyagi Prefecture on March 11, 2011. (Provided by Isao Takahashi)

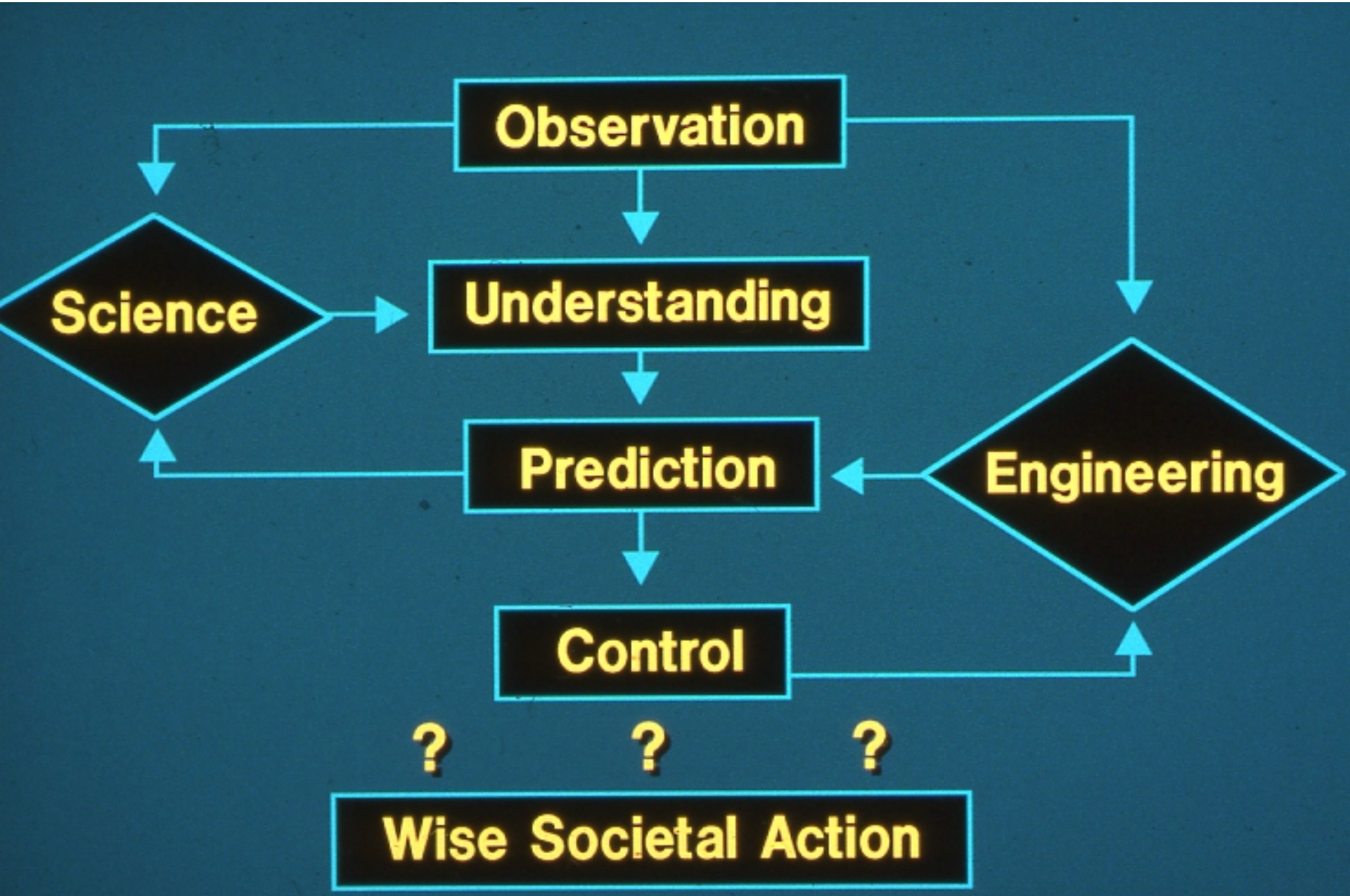

© AP

Engineering - Design for a System That is Limited in Time and Space.

Facts are Constraints that Must be Overcome.

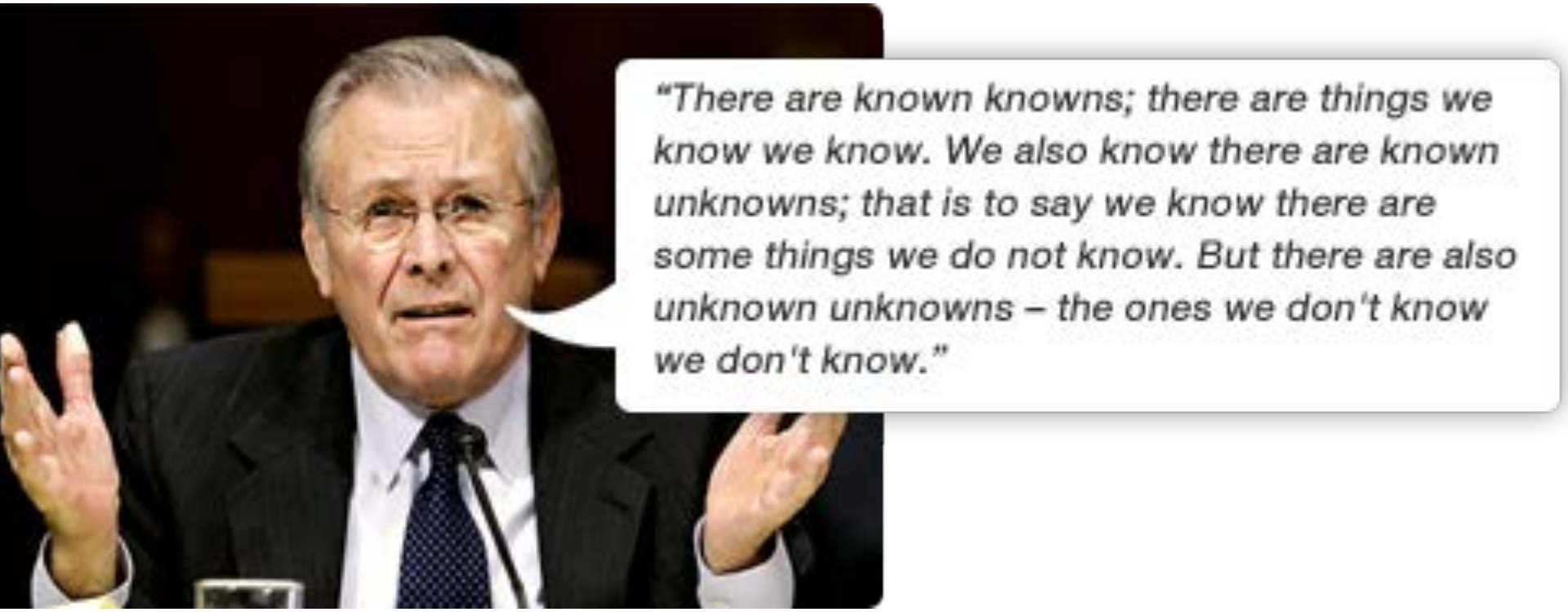
Science - Learn the Truths Nature has to Tell Us.

Facts are tools in the Process of Inquiry Toward that Truth.


Observation
Science
Understanding
Prediction
Engineering
Control
? ? ?
Wise Societal Action

Engineering, employs many of the same kinds of models as those used in science. Engineering **seeks applications of current understanding**, not the discovery of new truths about nature. Engineering seeks **REDUCED UNCERTAINTIES** in order to produce solutions to problems, but those **solutions are severely limited** by available time and resources. Moreover, they apply to very **limited circumstances**, and they can be totally invalidated because **of unknown factors or changing conditions relative to the assumptions** that are necessary for generating the proposed solutions.

From Press Briefing by **U.S. Secretary of Defense Donald Rumsfeld** on February 12, 2002 about the lack of evidence linking the government of Iraq with the supply of weapons of mass destruction to terrorist groups.



Unknown Unknowns – **Aleatoric Uncertainty** – Statistical Uncertainty – Straightforward Quantification by Inductive Reasoning (probabilities)

Known Unknowns **– Epistemic Uncertainty** – Could be known in principle, but may not be known in practice

Known Knowns

Certainties

Unknown Unknowns

Uncertainty as uncaused randomness (can't be known with certainty, but can be expressed as probabilities)

Aleatory Uncertainty

Known Unknowns

Things yet unknown (uncertain) that can can be known

Epistemic Uncertainty

UNKNOWN KNOWNS

Actual realities (possibilities) of which we are unaware (because of ignorance, deliberate deception, etc.) – see also "politics" and "fake science

Fukushima Dai-ichi Nuclear Power Plant (福島第一原子力発電所,

Commissioned, March 26, 1971.

Six boiling water reactors with combined power of 4.7 Gwe.

The world's 15th largest nuclear power station.

Standard tsunami hazard assessment procedures (**international standards** employed by Japan) were followed to design the sea wall at the Fukushima Daiichi nuclear plant:

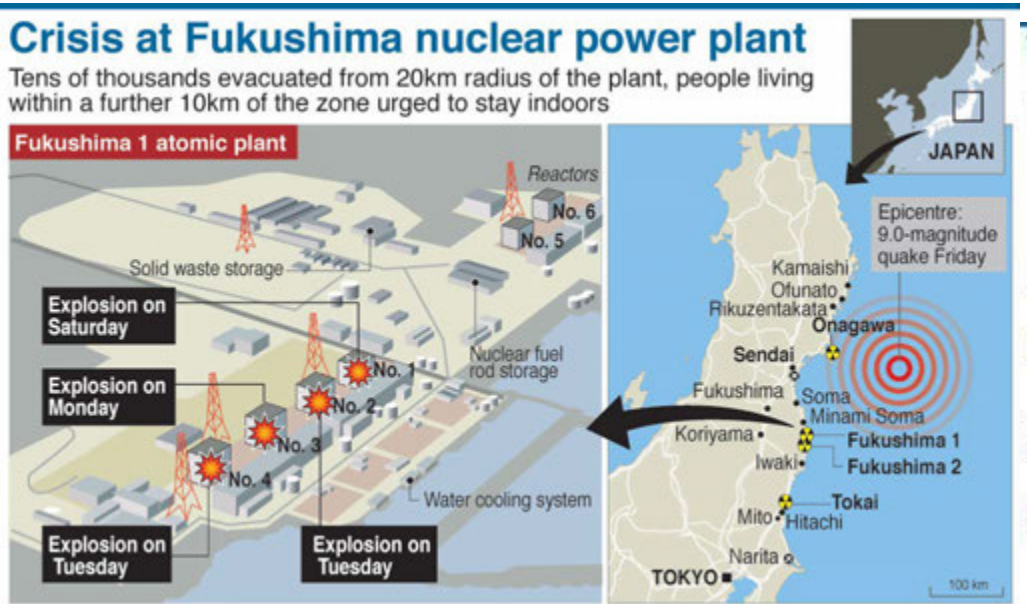
(**Inductive** and **Deductive** Reasoning)

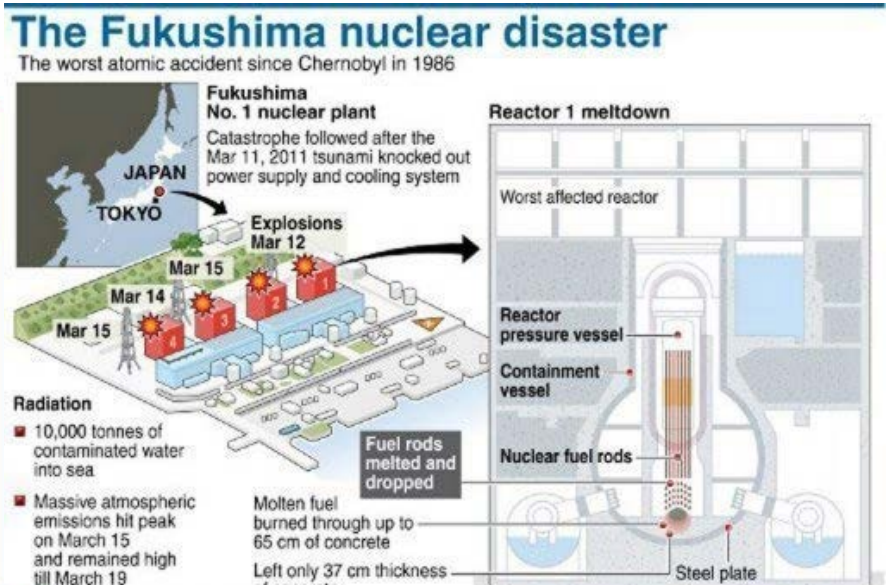
(1) a **probabilistic seismic hazard assessment**,
(2) estimation of the **Probable Maximum Earthquake** (PME),
(3) creation of a tsunami generation scenario for the PME ,
(4) **computer modeling** of propagation for this presumed tsunami,
(5) resulting **prediction** of the tsunami runup on the Sendai Plain,
(6) estimation of the hazard at the Fukushima Daiichi Plant (a 5-m wave).

After adding a **factor of safety** of 0.7 m, the sea wall at Fukushima was constructed to a height of 5.7 m.

The March 11, 2011, tsunami wave height was 15 m !!!

Fukushima Daiichi nuclear complex in 2009, and in 2011 after tsunami.





…the…accident at the Fukushima Daiichi nuclear power plant cannot be regarded as a natural disaster. It was **a profoundly man-made disaster** – that could and **should have been foreseen and prevented**. Our report catalogues a multitude of errors and willful negligence that left the Fukushima plant unpre-pared for the events of March 11. . . . What must be admitted – very painfully – is **this was a disaster 'Made in Japan'**. Its **fundamental causes** are to be found in the **ingrained conventions** of Japanese culture: our **reflexive obedience**, our **reluctance to question authority**, our **devotion to 'sticking with the program'**, our **groupism**, and our **insularity**.

2012 report of the National Diet of Japan Fukushima Nuclear Accident Independent Investigation (the first independent investigation commission appointed by the National Diet in the 66-year history of Japan's constitutional government)

"Though it was difficult to anticipate a giant tsunami, we should **not simply blame nature** for this accident. We must sincerely accept that **we were unable to draw upon human wisdom** to prevent **it.**" (emphasis added)

Acknowledgment in 2013 report by Tokyo Electric Power Company—representing a reversal from the company's earlier assertion that the waves were bigger than it could have predicted.

Impediments to Progress in Hazard Mitigation

1. Political Effect - "Politicians Love Natural Disasters"
2. Regulatory Effect - Everyone is treated equally. *(Equally ignorant of the hazard and personal responsibility.)*
3. Scientific Effect -Most support to hazard science comes as a by-product of the political regulatory effects.

Modeling (Positivist) Science

Model the **System**

Predict the **System** Parameters

Compare the Predictions to Measurements

Use Verified (**Validated?**) Predictions as the Basis for Future Action (Policy)

DEDUCTIVE SCIENCE

PRESUME features relevant to IDEALIZED phenomena (TIMELESS laws of physics, boundary conditions, system parameters, SIMPLICITY…..)

The THEORIST (e.g., physicist) deduces idealized properties of phenomena, then tests the deductions by CORRESPONDENCE (Experiment).

(Testing is misleading because of logical principle – The UNDERDETERMINATION of Theory by Data)

"A Man's Got to Know His Limitations" Dirty Harry, *Magnum Force* (1973):

(Logical) Positivism is the Only Branch of Philosophy Ever to be Totally Falsified

Modeling "Systems" Will Always Be Based on Overly Simple Assumptions

"Prediction" is a Logical Construct - Not Prophesy

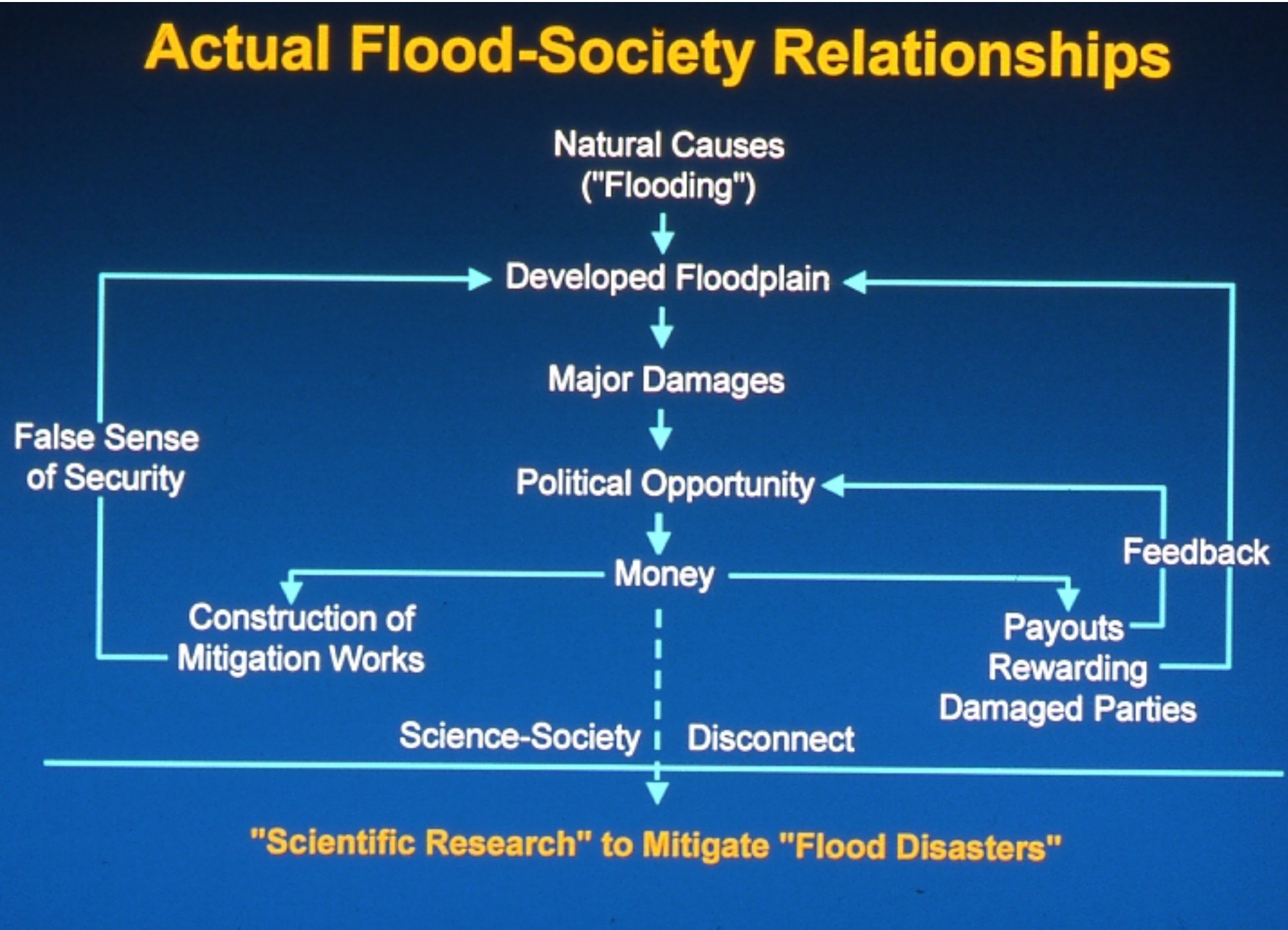
Verification is Logically Impossible For Complex (Real-World) Systems (The Duhem/Quine Underdetermination Thesis)

Policy is Based on Authority Masquerading as "Science"

Some Aspects of "Wicked Problems"

- They have **no definitive formulation**.
- It is commonly **impossible to claim success**.
- Solutions can be only good or bad, **not true or false**. There is no end state.
- There is **no template** ("cookbook") to follow; solutions must be developed as things go along.
- There are **multiple explanations** that vary greatly with individual perspectives.
- Every wicked problem **leads to another problem**.
- Wicked problems have **human causes**.
- Every wicked problem is **unique**.

Actual Flood-Society Relationships



The Types of Hazard Study

	Applicative	Investigative (Scientific)
Purpose	Authoritatively tell what should be done	Enlighten as to the reality of the hazard
Product	Reasonable statements about future events.	Observed reality of actual hazardous processes
Models	Based on assumptions (guesses) to provide answers to application problems	Serve to ask questions about the real world
Seeking	Verification/validation of answers (fit of the models)	Falsification of the models themselves with empirical data
Leading to	A defensible judgment/ pronouncement	A new, deeper question (understanding)

Advantages and Disadvantages

Applicative Approach	Investigative Approach
1. Results under the control of the analyst	1. Results subject to the vagaries of nature
2. Efficiently yields reproducible answers	2. Answers are locally contingent
3. Can invest with mathematical rigor and quantitative precision	3. Subject to the limitations of the real world
4. Realistic testing is anathema	4. Provides real test of theory
5. Obscures causal understanding through unrealistic presumption	5. Enhances understanding of fundamental causal process
6. May provide elegant answers to a bad question	6. Discovers better questions
7. May abuse public perception (e.g. “100 – year flood”)	7. Relates directly to public perception

Unknown Knowns

These are **actual realities** (e.g., lack of evidence for WMDs) that are **not accessed** (they are unrecognized, ignored, not considered, suppressed, lied about, etc.).

Result – The Iraq War (cost > $ 1 trillion) and subsequent mid-East very, very "wicked" problem (continuing expenditures)

The seemingly less elegant scientific understanding of what **nature says to us** as opposed **to what scientists can say about nature** has better prospects in regard to conveying wisdom to our current ("scientifically illiterate") society.

For example: the fact that flood hazards are best understood in terms of what has actually happened and therefore are the sorts of things that actually can happen---as opposed to being abstractions conveyed by experts who make law-based, mathematical predictions of what should happen (if all the assumptions are absolutely correct).

ABDUCTIVE SCIENCE

Evidence (indicators, signs, traces…) of the phenomena is DISCOVERED. The experienced INVESTIGATOR (not "theorist") then infers the responsible conditions (causes by which these phenomena could be produced)

The relationships of causes to effects are tested in terms of their CONSISTENCY, COHERENCE, and CONSILIENCE with related phenomena. This testing is fruitful because of CAUSAL OVERDETERMINATION).

Abduction (Retroduction)

The surprising fact A is observed;

But if B → A were true, then A would be a matter of course.

Hence, there is reason to suspect that B → A is true.

(B → A is a potentially fruitful hypothesis)

A 901 C.E. **historical document** described an earthquake in 869 C.E. that destroyed a castle town and generated a tsunami that killed 1000 people in northeast Japan.

Journal of Natural Disaster Science, Volume 23, Number 2, 2001, pp83-88

Published in 2001!!!

The 869 Jōgan tsunami deposit and recurrence interval of large-scale tsunami on the Pacific coast of northeast Japan

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(Received for 11 Mar., 2002)

ABSTRACT

The fore-arc region of northeast Japan is an area of extensive seismic activity and tsunami generation. On July 13, 869 a tsunami triggered by a large-scale earthquake invaded its coastal zones, causing extensive deposition of well-sorted fine sand over the coastal plains of Sendai and Sōma. Sediment analysis and hydrodynamic simulation indicate that the tsunami inferred to be triggered by a magnitude 8.3 earthquake spread more than 4 km inland then coast. We postulate that the sand layer was developed by the tsunami's first wave. Traces of large-scale invasion by old tsunami as recorded in the coastal sequences of the Sendai plain show about a 1000-year reoccurrence interval. We suggest that the Jōgan tsunami was much larger than tsunami generated by normal earthquakes in the subduction interface.

INTRODUCTION

An earthquake offshore of northeast Japan on July 13, 869 (Usami, 1987) produced a large-scale tsunami that damaged the low-lying coastal zones of northeast Japan. This 869 tsunami, named the Jōgan tsunami after the reign of then emperor, is unusual because of its widespread flooding.

The historical document Sandai-jitsuroku, which gives a detailed history of all of Japan for 1200 years, describes the Jōgan earthquake and subsequent tsunami as follows: "The large earthquake was accompanied by a luminous phenomenon, and coastal areas were illuminated in the dark. Some time after severe seismic shocks, a gigantic tsunami reached the coast and invaded entire Sendai plain. Rising seawater flooded an old castle town (Tagajō; Fig. 1A), causing the loss of 1000 lives." There is no historical evidence of co-seismic subsidence of the plain (Usami, 1987), therefore the prolonged period of flooding indicates that waves from the Jōgan tsunami sequentially invaded the coastal areas. Destroyed structural foundations that date from the 8th and 9th centuries, discovered in the ruins of Tagajō, are overlain by sediment layers containing artifacts from the middle 10th century. The committee studying the remains considers that exposed structures in the castle town collapsed owing to erosion by the Jōgan tsunami (Board of Education, Tagajō City, 2000).

More than a century has passed since scientific observations were begun in northeast Japan. During that time no tsunami has penetrated more than 2 km inland (Watanabe, 1998). On the basis of the Tagajō findings remains, seawater inundation by the Jōgan tsunami is thought to have reached 4 km or more inland. Is this deep penetration of seawater evidence of the occurrence of an unprecedented large-scale tsunami?

The Pacific coast of northeast Japan is known for repeated tsunami invasions (Fig. 1B; Watanabe, 2000). The Sendai plain, however, has not been struck by such a large tsunami since the Jōgan event. Urbanization has rapidly advanced to the coastal area, and most of the land inundated by the Jōgan tsunami is now developed. An understanding of the cause and effect of the region's extensive invasion by the Jōgan tsunami is important, not only for disaster prevention, but to gain an understanding of fore arc tectonic processes. We studied Jōgan tsunami deposits by sediment analyses and numerical hydrodynamic model to clarify the origin of that tsunami.

KEY WORDS: Jōgan earthquake, Historical tsunami, tsunami deposits, northeast Japan arc, numerical simulation

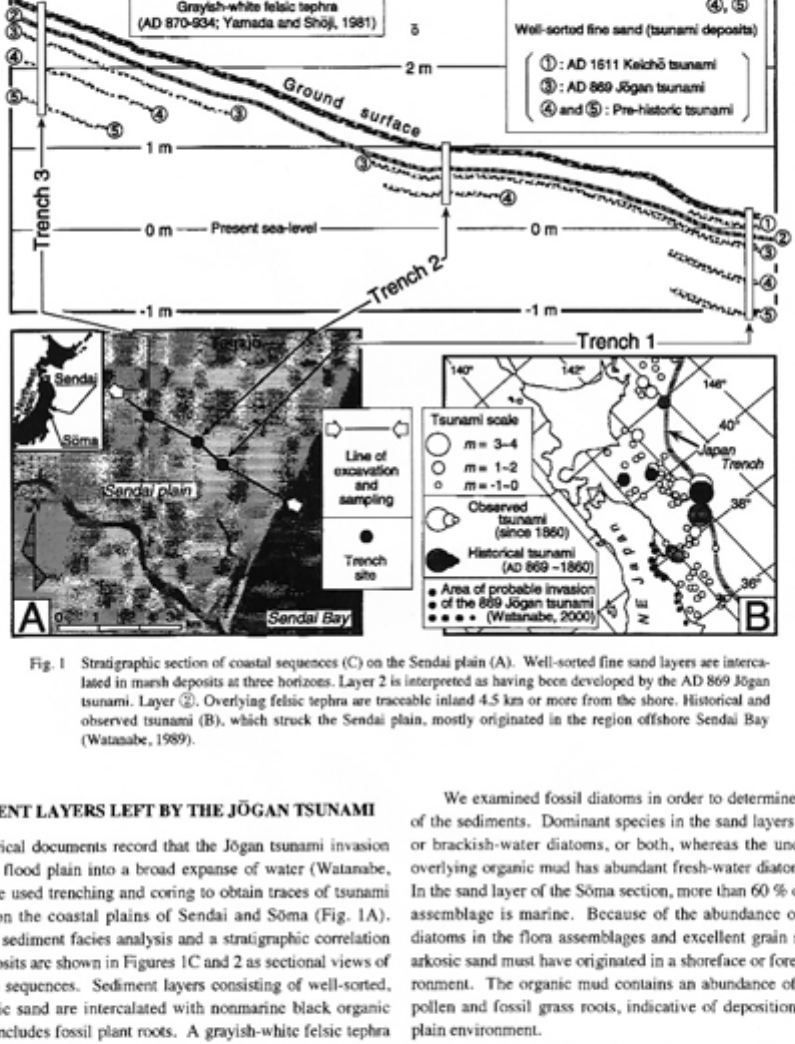


Fig. 1 Stratigraphic section of coastal sequences (C) on the Sendai plain (A). Well-sorted fine sand layers are intercalated in marsh deposits at three horizons. Layer 2 is interpreted as having been developed by the AD 869 Jōgan tsunami. Layer ②. Overlying felsic tephra are traceable inland 4.5 km or more from the shore. Historical and observed tsunami (B), which struck the Sendai plain, mostly originated in the region offshore Sendai Bay (Watanabe, 1989).

SEDIMENT LAYERS LEFT BY THE JŌGAN TSUNAMI

Historical documents record that the Jōgan tsunami invasion turned the flood plain into a broad expanse of water (Watanabe, 1998). We used trenching and coring to obtain traces of tsunami invasion on the coastal plains of Sendai and Sōma (Fig. 1A). Results of sediment facies analysis and a stratigraphic correlation of the deposits are shown in Figures 1C and 2 as sectional views of subsurface sequences. Sediment layers consisting of well-sorted, fine arkosic sand are intercalated with nonmarine black organic mud that includes fossil plant roots. A grayish-white felsic tephra underlies the Sendai plain. Below this tephra, we found three 2- to 15-cm-thick layers of well-sorted sand exposed at approximately 40cm intervals on our trench walls (Fig. 1C). The sand layer just beneath the tephra (layer 3 in Figure 1C) was traceable inland more than 4.5 km and showed evidence of landward tapering and fining. In the coastal sequences of Sōma a 1-cm-thick felsic tephra and underlying 2-cm-thick sand layer are intercalated in organic mud at the highest horizon. The absence of sediment grading within the sand layers of Sendai and Sōma suggests rapid sediment deposition.

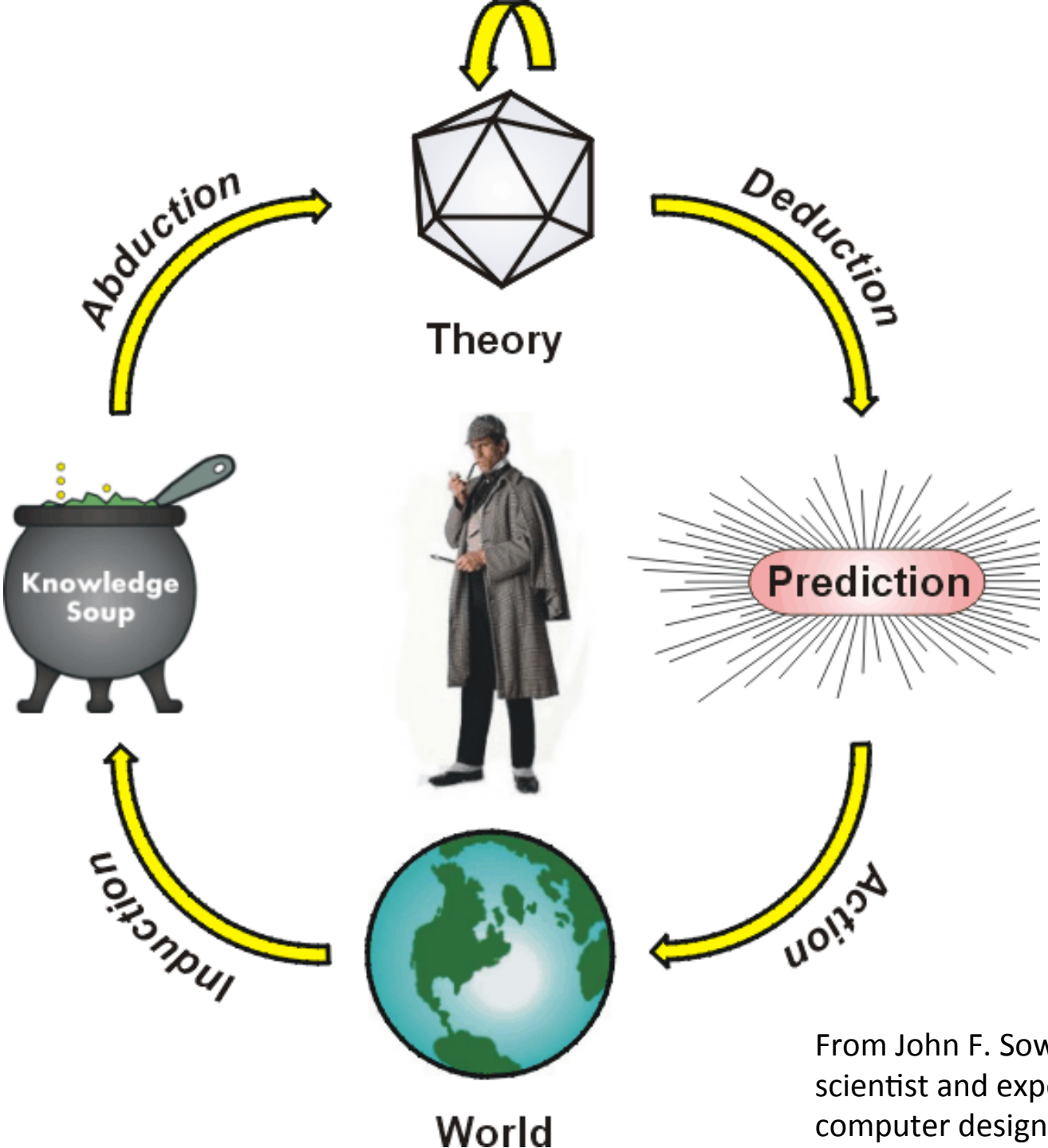
We examined fossil diatoms in order to determine the source of the sediments. Dominant species in the sand layers are marine or brackish-water diatoms, or both, whereas the underlying or overlying organic mud has abundant fresh-water diatoms (Fig. 2). In the sand layer of the Sōma section, more than 60 % of the floral assemblage is marine. Because of the abundance of saltwater diatoms in the flora assemblages and excellent grain sorting, the arkosic sand must have originated in a shoreface or foreshore environment. The organic mud contains an abundance of deciduous pollen and fossil grass roots, indicative of deposition in a flood plain environment.

Landward tapering and sediment fining indicates that arkosic grains were transported inland from the coast. We conclude that the tsunami waves that penetrated the coastal zone of Sendai formed fast-flowing currents associated with rapid lateral translation of water and the suspension of sediments of marine origin. Storm surges along the coast of northeast Japan generally are agents of erosion and do not produce regionally extensive deposits of marine sand on the flood plain (Minoura et al., 1987; Minoura et al., 1993). The transport of marine materials therefore is best explained by in the sand layer having been produced by a tsunami

Fukishima – **A Human-Caused Disaster**

Unaware (or suppressing) of **Nature's actualities** (the unknown knowns), impressive-appearing, but **assumption-based physical reasoning** was used to deduce ("predict") an outcome that was totally inconsistent with those unknown (but accessible) actualities.

Result – The most costly (hundreds of billions of dollars) "natural" disaster in history.



From John F. Sowa, IBM computer scientist and expert in AI and computer design.

CONCLUSIONS

1. **Knowledge** – well-justified, true belief – A Thing NO, not science

2. **Understanding** – a process involving the relationship of knower to object sufficient for intelligent (wise) behavior – A Process **YES, science**

3. **Policy** – on-going commitment to action – A Process **NEEDS 2, NOT 1**

CONCLUSIONS
Extrapolation

Modern flood science is almost universally based on measuring the properties of relatively common, small-scale flooding and then **extrapolating upscale** to the inferred properties of very rare, extreme flooding.

The **scaling relationships** for such extrapolations **are assumed** because the properties of the extreme flood phenomena are taken to be unknown. The assuming of unknowns IS NOT SCIENCE; science is the making of discoveries—transforming unkowns to knowns.