Basic Statistics and Probability Theory in Civil, Surveying and Environmental Engineering

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Contents of Today's Lecture

- The organisation of the lecture – practical stuff
- Why statistics and probability in engineering?
- Decision Problems in Engineering
- Examples
- The lecture program

What do we offer to you ?

- It is our intention to provide you to the best of our abilities
  - Motivation and overview of context
  - Targeted presentation of required knowledge
  - Guidance on self study
  - Help on training your abilities
  - Help on your self evaluation
- We are here for you and we take this statement seriously

Structure and organization of the course

- 13 weekly lectures of each two sessions of 45 minutes
- 11 weekly exercise tutorials of each two sessions of 45 minutes
- 2 assessments of each 90 minutes
- Self study estimated to 4 times by 45 minutes per week

The course's web page

http://www.ibk.ethz.ch/fa/education/ss_statistics

What can you find there?

- Course's program and timetable
- Tutorial's timetable
- Script (downloadable/printable)
- Exercises/Solutions for the exercise tutorials (downloadable/printable)
- Presentations of the lecture and of the exercise tutorial (uploaded a day before the respective day)
- Videos of the lecture (uploaded the day after the lecture)
- Glossary (German-English terms)
- Links to helpful web pages
- Past examination papers
- Your exercise tutorial class and group!

Organization of the Lecture

When??
Normally…Tuesdays 8-10

Where??
HIL E1

Exceptions:
Thursday 22.03.07 8-10 HPH G 3 (lecture instead of exercise tutorial)
Other exceptions: Check the course's program!

- Script (English)
  Download from the course's web page

Organization of the Exercise Tutorials

Eva Sabiote
HIL E 22.2

Harikrishna (Hari) Narasimhan
HIL E 13.1

Kazuyoshi (Kazu) Nishijima
HIL E 22.3

Vasiliki (Vicky) Malioka
HIL E 23.1

Organization of the Exercise tutorial

- **When??:**
  Normally….Thursday 8-10

- **Where??**
  HPH G 3 HCI H 2.1 HCI D 8 HCI D 2

- **Where do I go???**
  find out in the "Group lists" link on the course's web page

- **Exceptions….☺**
  First tutorial: Tuesday 27.03.07
  Where???: HIL E1 HIL B 21 HIL D 10.2 HIL F 10.3

Organization of the Exercise Tutorials

2 or more exercises will be presented in steps (based on the content of the latest lecture)

1 or more solution(s) of exercises shown in steps in the last tutorial

Group exercise
1 exercise - steps will be shown

Group Presentation 25 min

Organization of the Exercise Tutorials

Office hours:

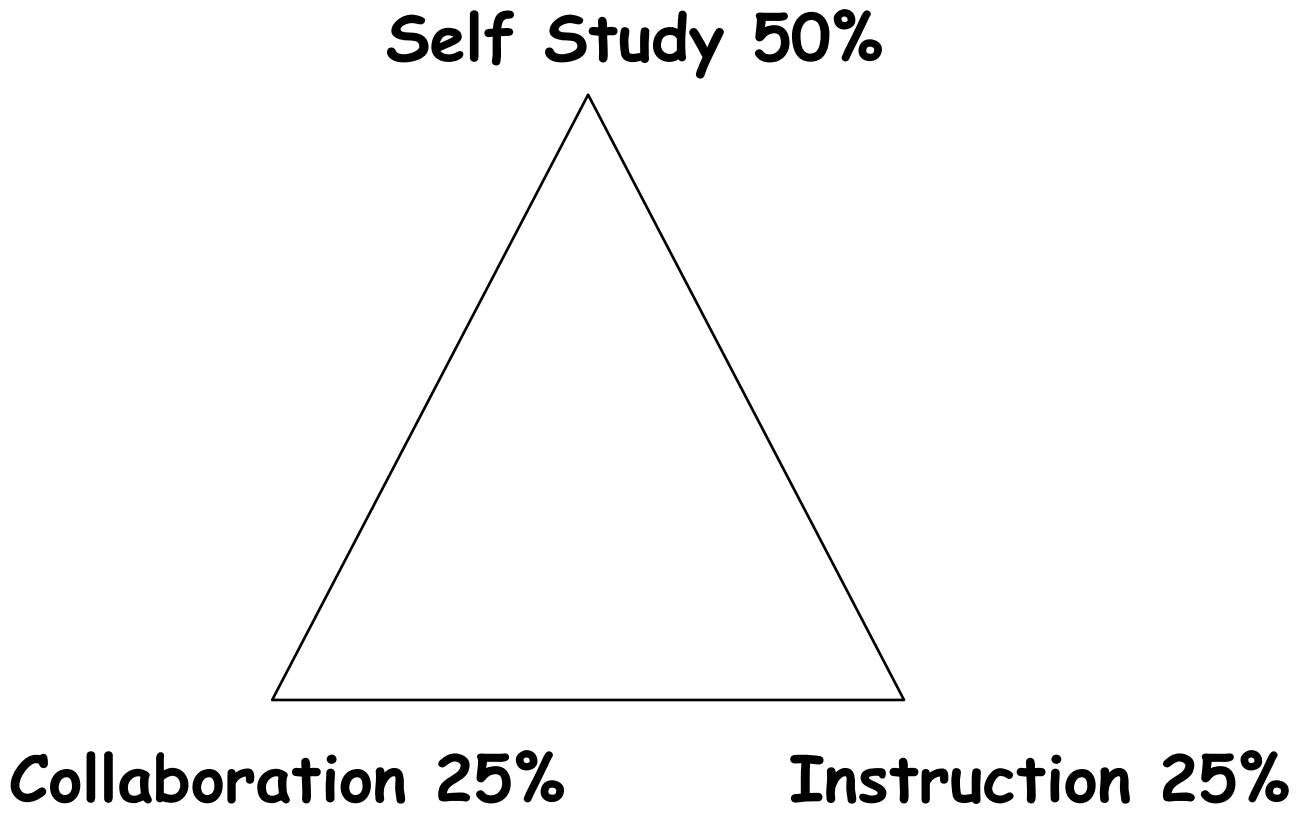
Mondays 11.30 - 12.30

Thursdays 13.30 - 14.30

What do we expect from you?

- Take advantage of the help we provide to you
  - benefit from the lectures
  - benefit from the exercise tutorials
  - benefit from the help of the assistants and professor (office hours)
- Tips and tricks
  - prepare yourself for the lectures
  - ask questions
  - try to understand the topics rather than prepare for examination
  - be curious, interested, open minded but critical to what we tell you

What do we expect from you?



Mode of assessment

- Two assessments during the semester
  one midterm (03.05.07)
  the other one towards the end of the course (14.06.07)

- Final Exam
  October/March….

  Final mark= $\frac{1}{3}(two\ assessments)+\frac{2}{3}(final\ exam)$

Programmable calculators are strictly not allowed!
Open book assessments and final exam☺

Read carefully all the information in the "Preamble" of the script!!
If you have any questions ask!

Why Statistics and Probability in Engineering?

- What do engineers do ?
  - Plan, design, build, maintain and decommission

    Infrastructure
    Roads, water supply systems, tunnels, sewage systems, waste deposits, power supply systems, channels

    Structures
    houses, hospitals, schools, industry buildings, dams, powerplants, wind turbines, offshore platforms

  - Safeguard
    - people
    - environment
    - assets

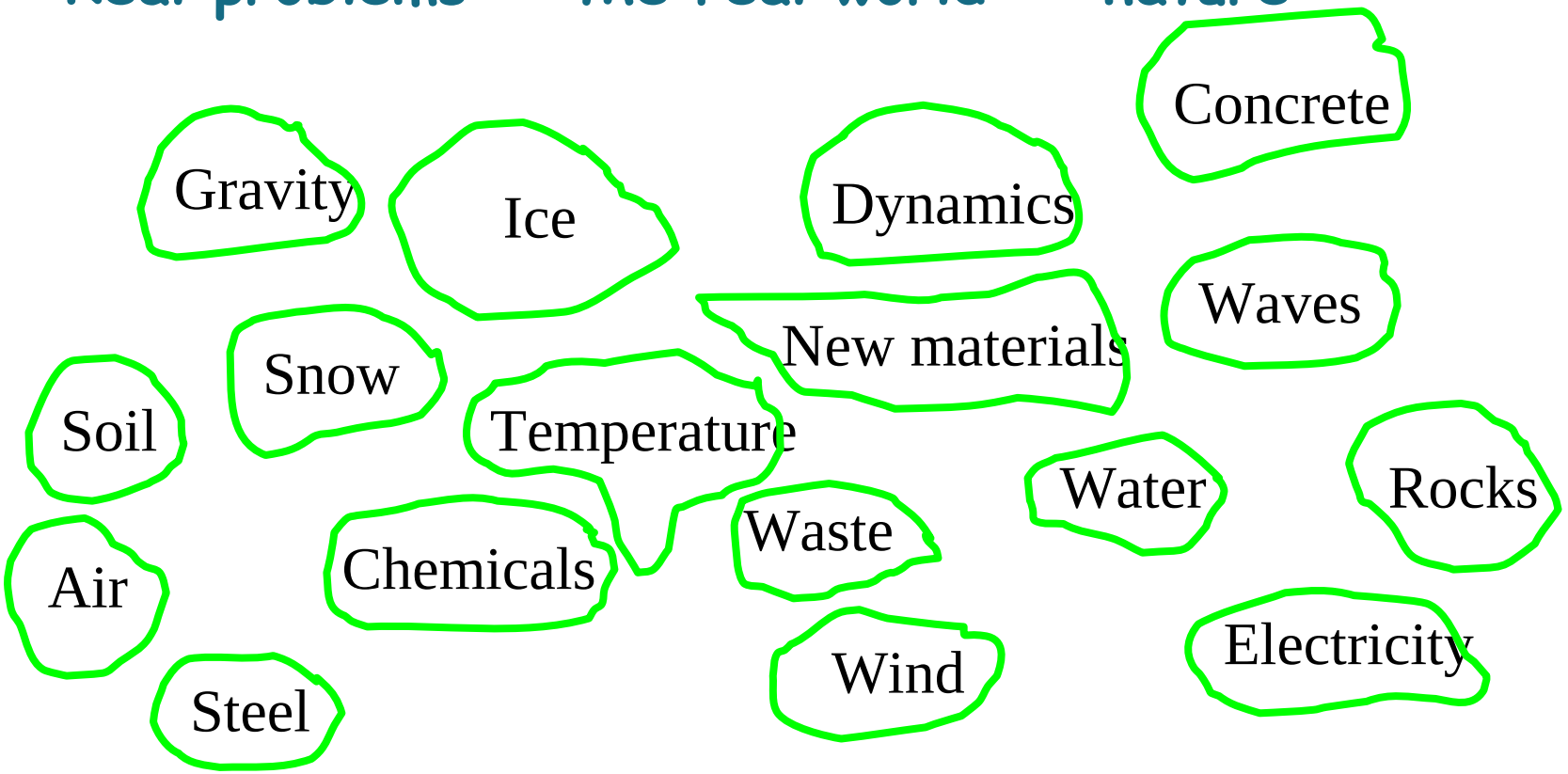
    from natural and man made hazards

SUSTAINABLE DEVELOPMENT !

Why Statistics and Probability in Engineering?

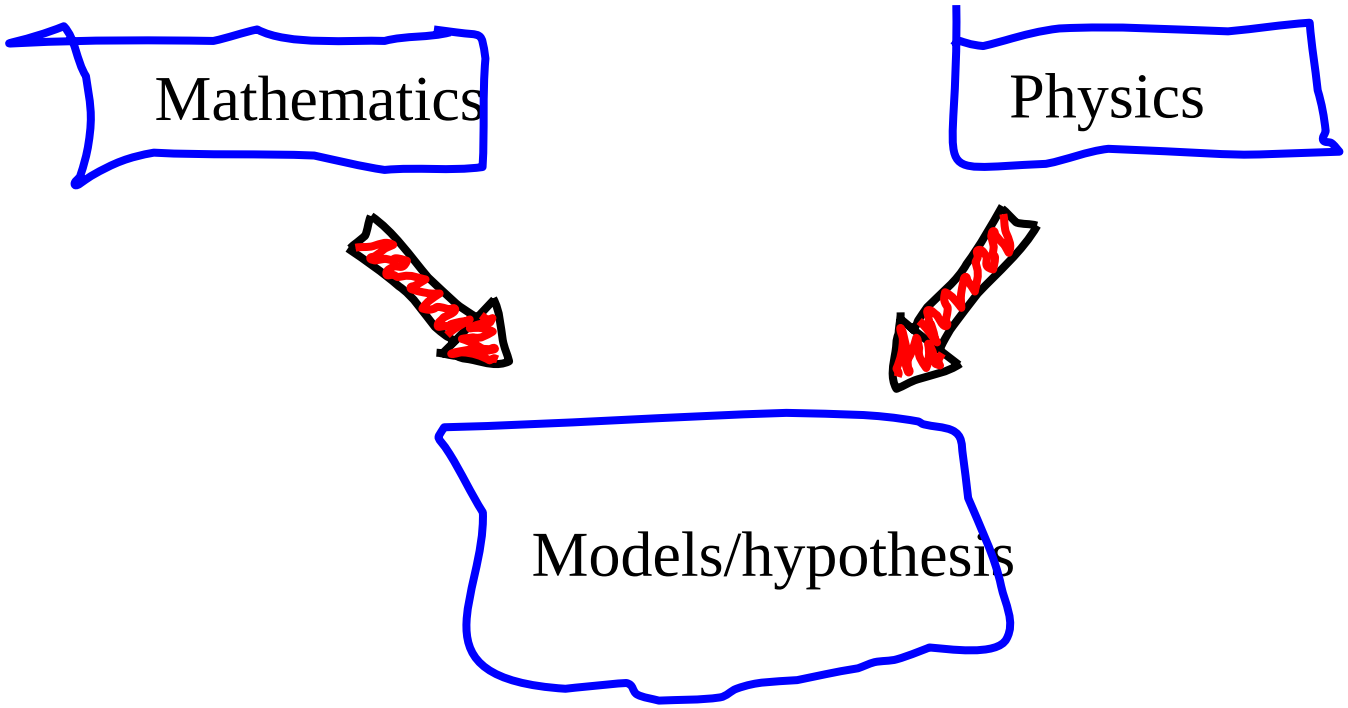
- What are engineers working with ?

  Real problems – the real world – nature



Why Statistics and Probability in Engineering?

- How do engineers work with the real world ?

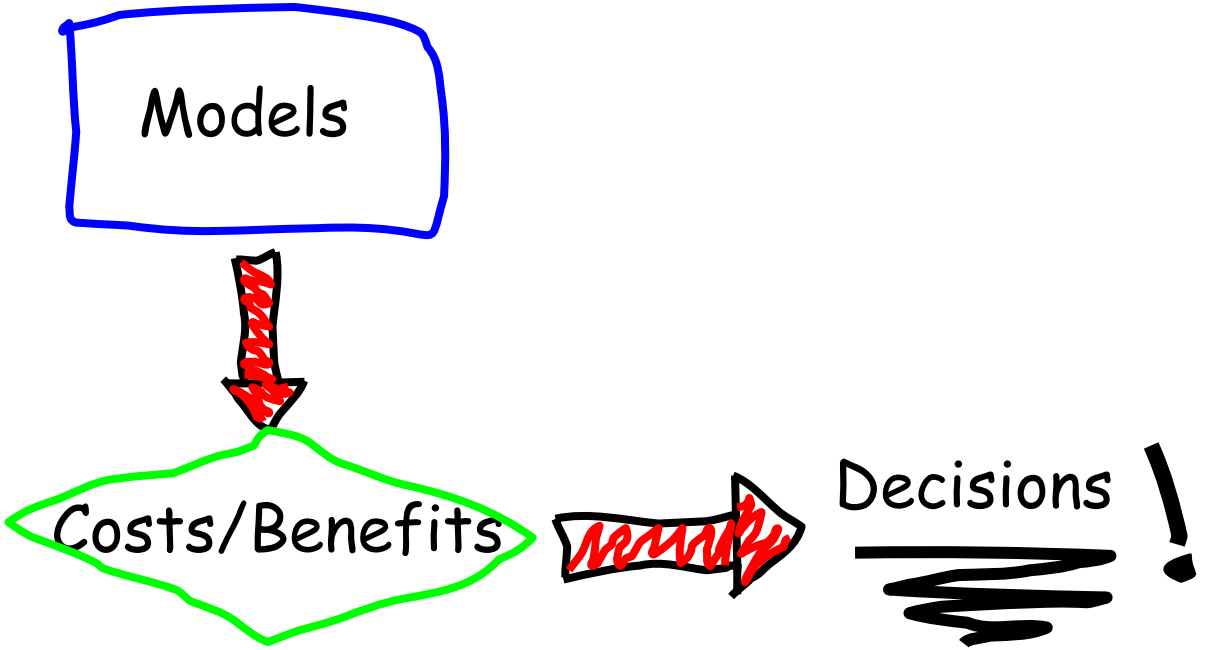


We model the real world to the „best“ of our knowledge

Why Statistics and Probability in Engineering?

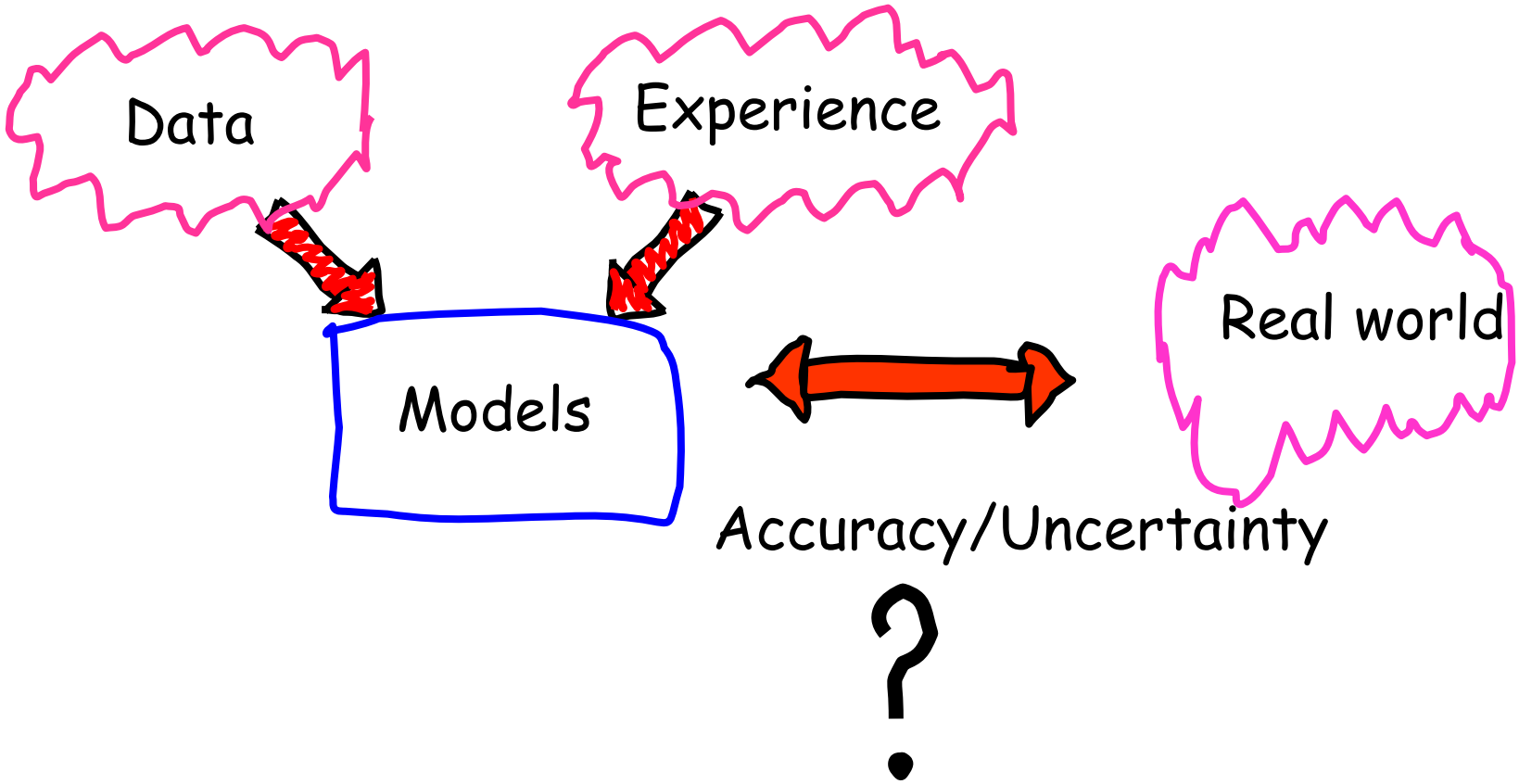
- How do engineers use knowledge

In a perfectly known world



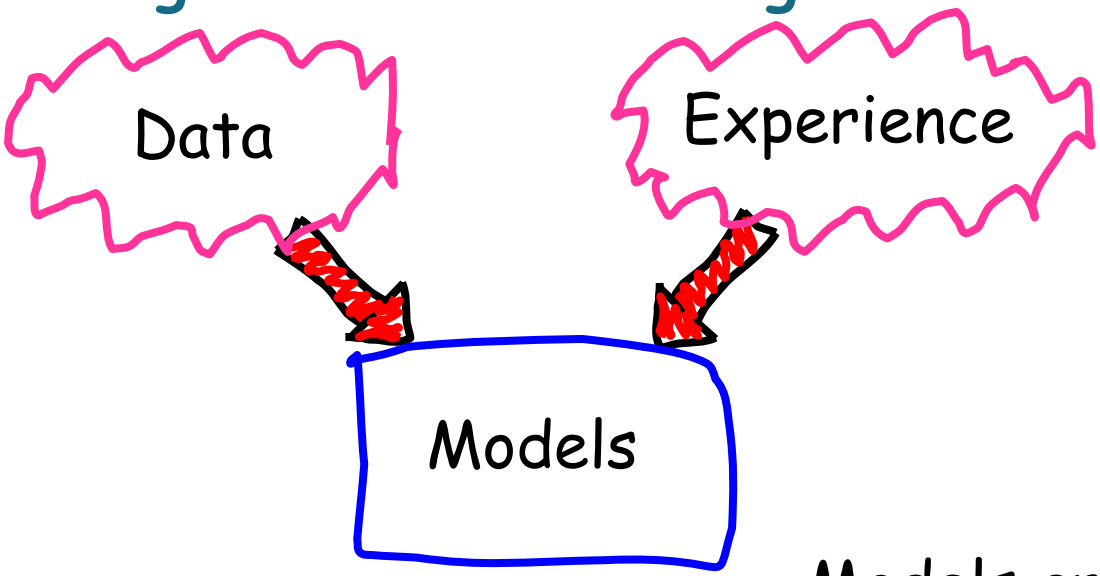
Why Statistics and Probability in Engineering?

- How do engineers establish knowledge



Why Statistics and Probability in Engineering?

- How do engineers use knowledge



Uncertainty

WHY ?

Models are not precise

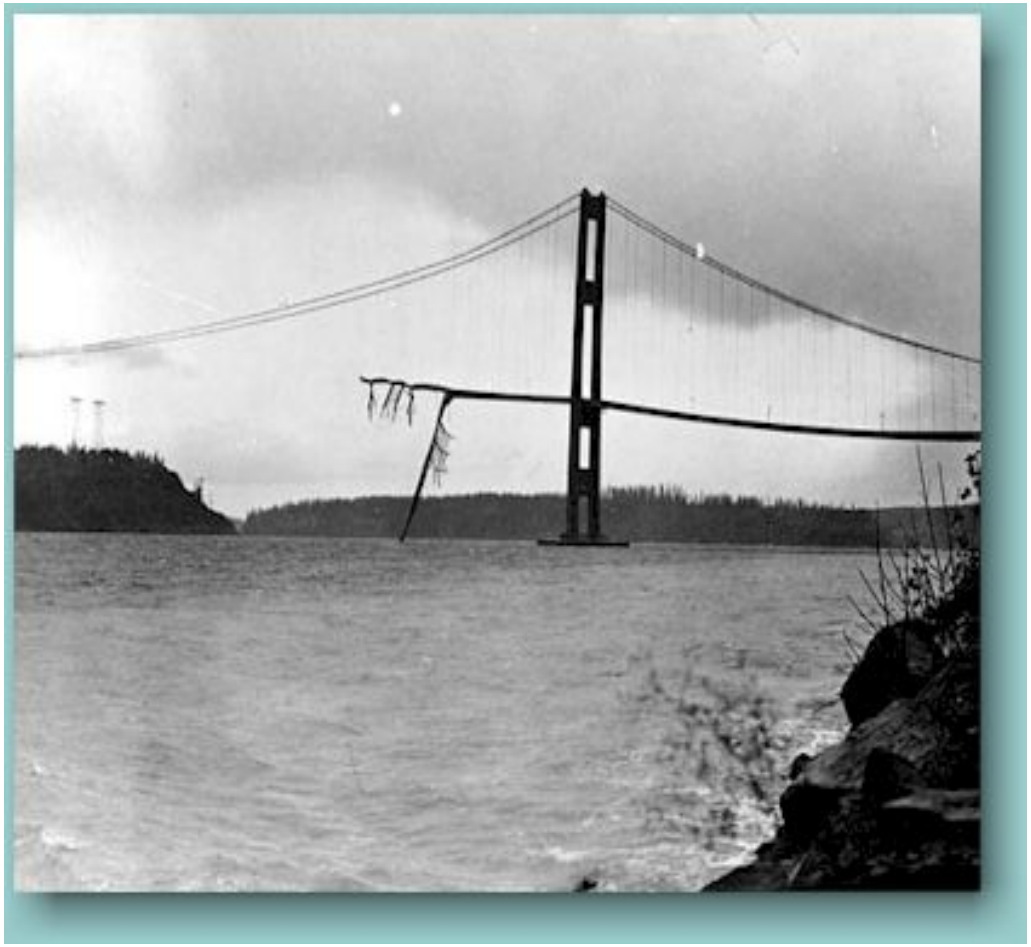
Data are not sufficient

Natural variability

Experience is subjective

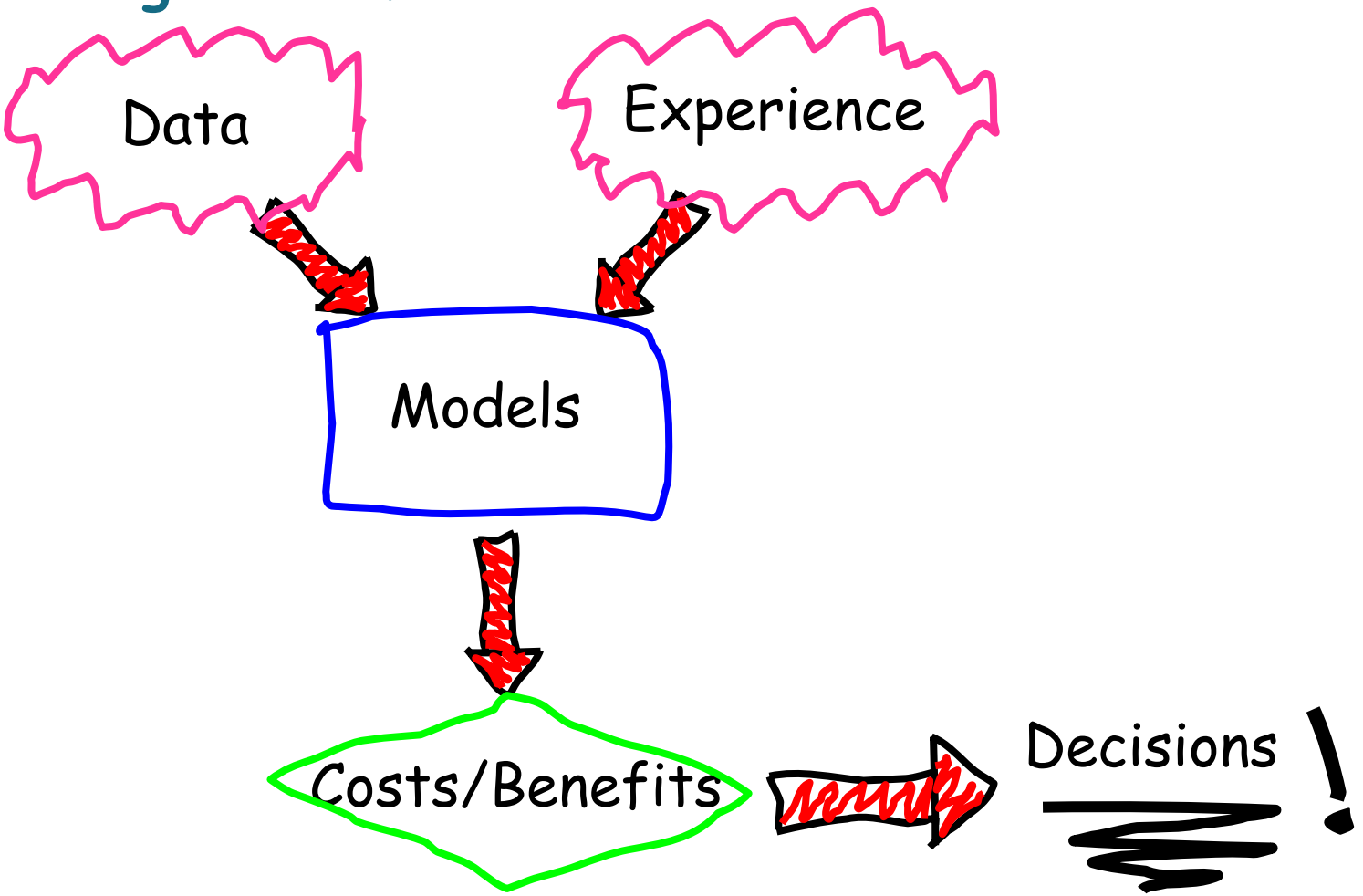
Why Statistics and Probability in Engineering?

- An example where models were not too representative



Why Statistics and Probability in Engineering?

- How do engineers make decisions



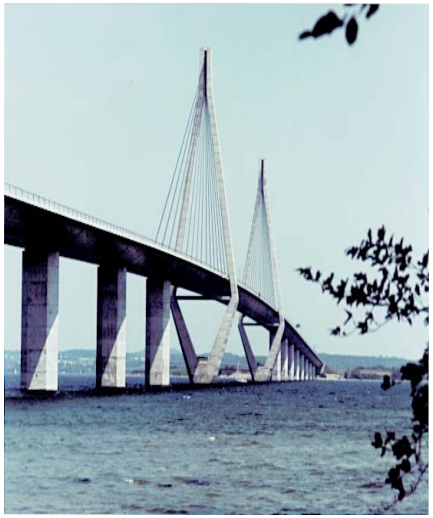
Why Statistics and Probability in Engineering?

All activities are associated with uncertainties

Activities are e.g.

- Transport
- Work
- Sport

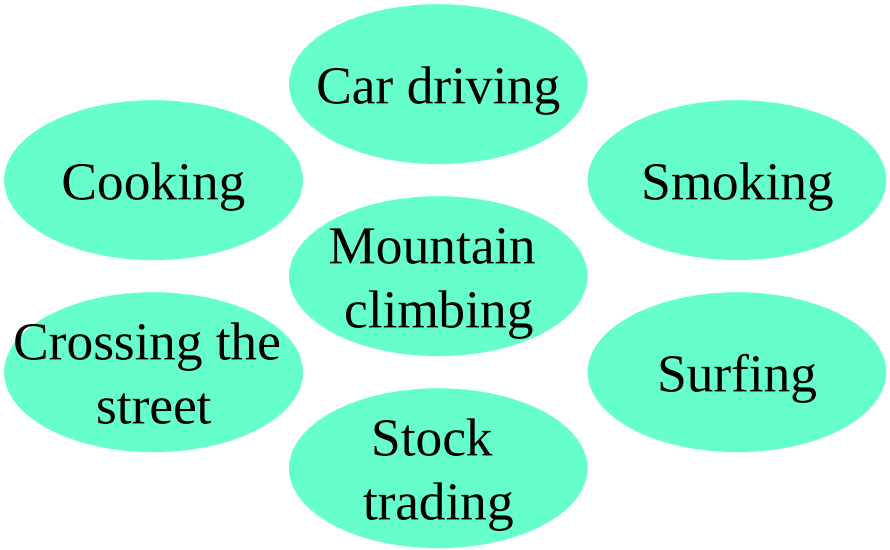
but also



- Production of energy
- Exploitation of resources
- Construction and operation of production and infrastructure projects
- Research and development

Why Statistics and Probability in Engineering?

Every day we must make decisions in regard to activities associated with uncertainties



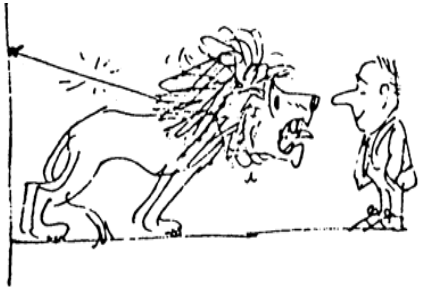
Every one of these activities is associated with uncertainties

We all have an opinion regarding the associated risks

We have gut Feelings !

Why Statistics and Probability in Engineering?

How far can we get with gut feelings ?



An example

After all - maybe it is not so
„straight forward" to comprehend uncertainties ?

What can we learn from the past ?

Why Statistics and Probability in Engineering?

Disasters and accidents have always occurred

Some examples

Tacoma Narrows, Washington, 1940

Fort Mayer, Virginia, 1908

Why Statistics and Probability in Engineering?

Disasters and accidents have always occurred

Some examples

Concord, North Carolina, 2000

Concorde, Paris, 2000

Why Statistics and Probability in Engineering?

Disasters and accidents have always occurred

Some examples

Kobe, 1995

Why Statistics and Probability in Engineering?

Disasters and accidents have always occurred

Some examples

Canada, 1993

Open questions

- did we realise the risks ?
- are the consequences acceptable ?

Why Statistics and Probability in Engineering?

Risk assessment, within the framework of decision analysis, provides a basis for rational decision making subject to uncertain and / or incomplete information

Thereby we can take into account, in a consistent manner, the prevailing uncertainties and quantify their effect on risks

Thus we may find answers to the following questions

- How large is the risk associated with a given activity ?
- How may we reduce and / or mitigate risks ?
- How much does it cost to reduce and / or mitigate risks ?
- What risks must we accept – what can we afford ?

Why Statistics and Probability in Engineering?

Risk is a characteristic of an activity relating to all possible events n_E which may follow as a result of the activity

The risk contribution R_{E_i} from the event E_i is defined through the product between

the **Event probability** P_{E_i}

and

the **Consequences** of the event C_{E_i}

The **Risk** associated with a given activity R_A may then be written as

$$R_A = \sum_{i=1}^{n_E} R_{E_i} = \sum_{i=1}^{n_E} P_{E_i} \cdot C_{E_i}$$

Decision Problems in Engineering

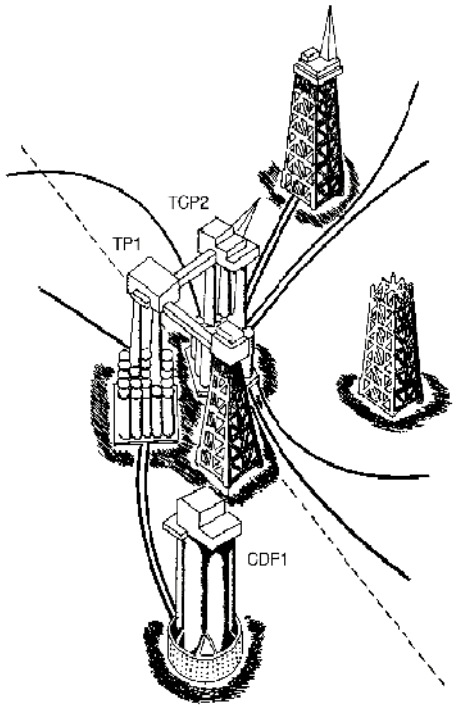
Uncertainties must be considered in the decision making throughout all phases of the life of an engineering facility

Uncertainties

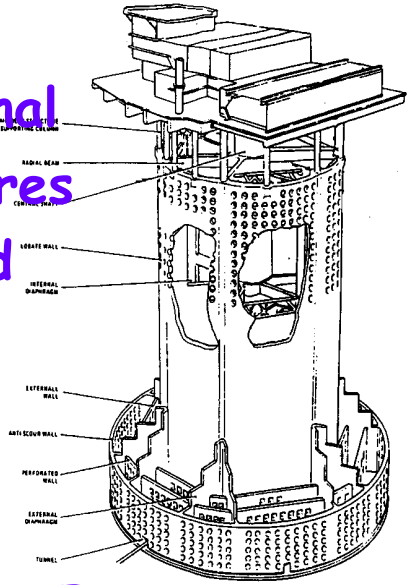
- **Traffic volume**
- **Loads**
- **Resistances (material, soil,..)**
- **Degradation processes**
- **Service life**
- **Manufacturing costs**
- **Execution costs**
- **Decommissioning costs**

Example – Decommissioning of the Frigg Field

- The Frigg Field – built 1972-1978
  - TCP2
  - TP1
  - CDP1



According to international conventions the structures must be decommissioned



Each structure :

Weight : 250000 t

Costs : 200 – 600 Mio. SFr

- None of the platforms were designed for decommissioning !

Example – Decommissioning of the Frigg Field

- The decision problem

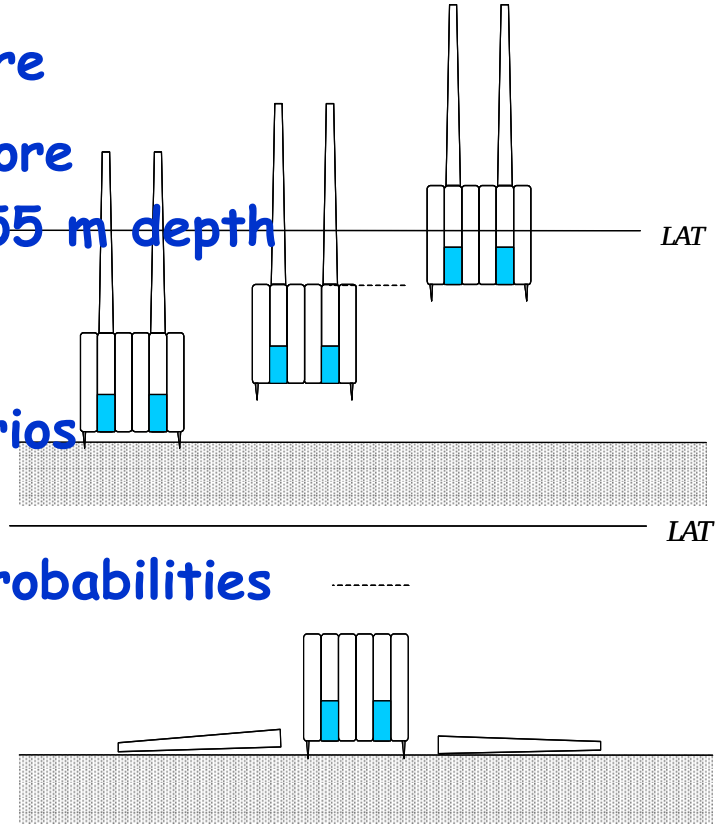
  Decommissioning/removal taking into account

  - Safety of personnel
  - Safety of the environment
  - Costs
  - Interest groups

  Greenpeace
  Fishers
  IMO
  ....

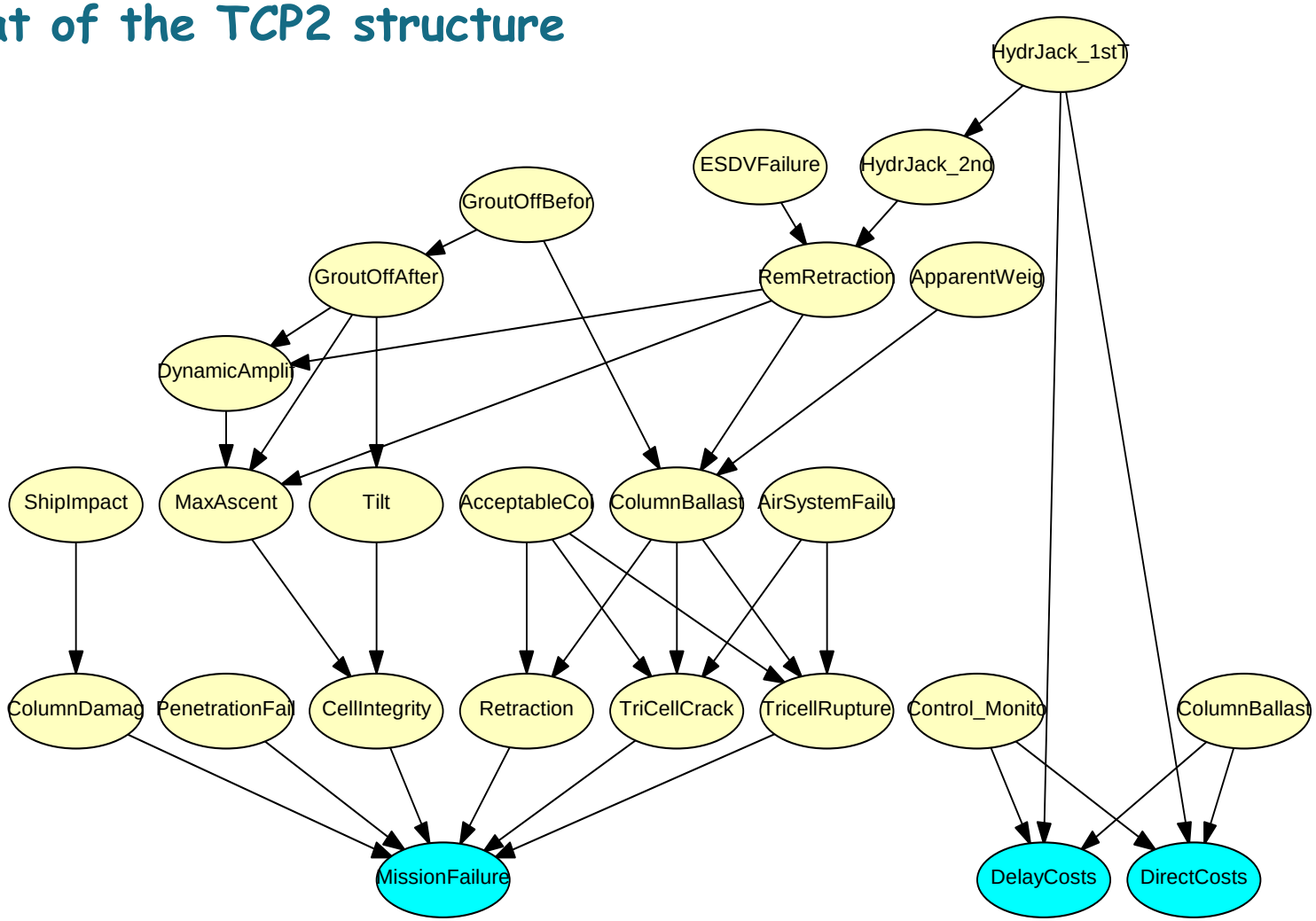
Example – Decommissioning of the Frigg Field

- Three options are considered
  - „Refloat" and demolition Onshore
  - „Refloat" and demolition Offshore
  - Removal to a free passage of 55 m depth
- The approach
  - Identification of hazard scenarios chronologically
  - Quantification of occurrence probabilities
  - Quantification of consequences
- Applied approach – Bayesian Nets



Example – Decommissioning of the Frigg Field

- Re-float of the TCP2 structure

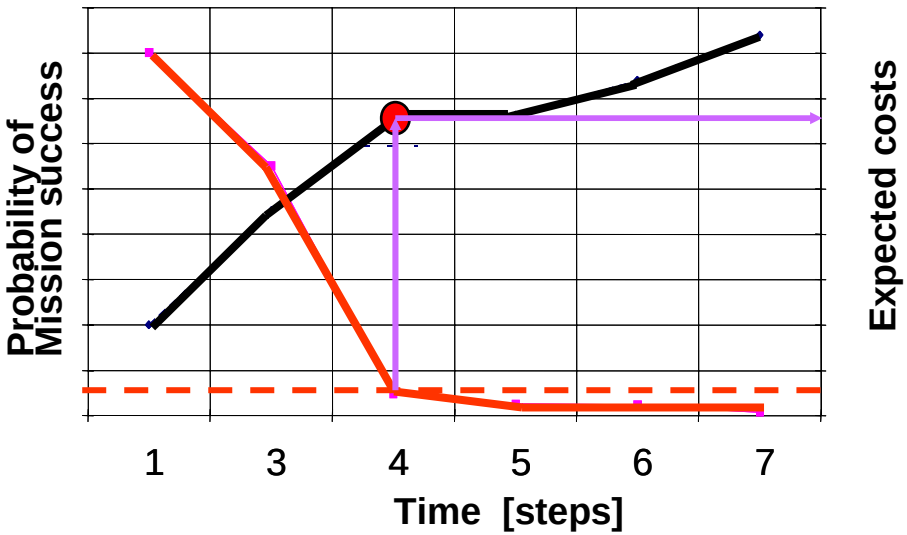


Example – Decommissioning of the Frigg Field

- Results of the decision analysis

Time variation of

- Expected costs
- Probability of mission success



Decision support

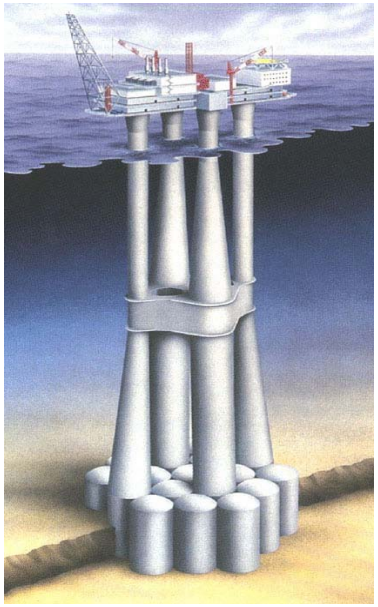
- How much to invest before a satisfactorily level of probability of mission success has been reached

Decision Problems in Engineering

- Structural Design

Exceptional structures are often associated with structures of „Extreme Dimensions“

Great Belt Bridge
under Construction



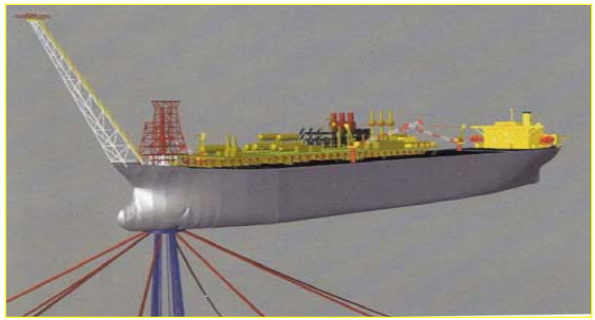
Concept drawing
of the Troll platform

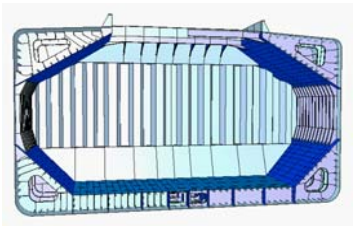
Decision Problems in Engineering

- Structural Design

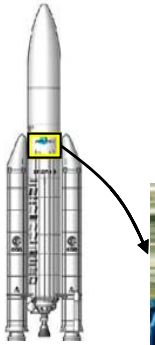
  or associated with structures fulfilling

  „New and Innovative Purposes"





Concept drawing of
Floating Production, Storage and Offloading unit



Illustrations of the ARIANE 5 rocket

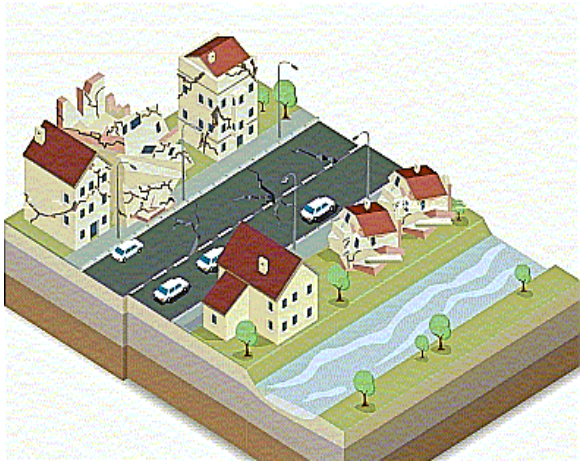
Decision Problems in Engineering

Before

Optimal allocation of available resources for risk reduction

- strengthening
- rebuilding

in regard to possible earth-quakes

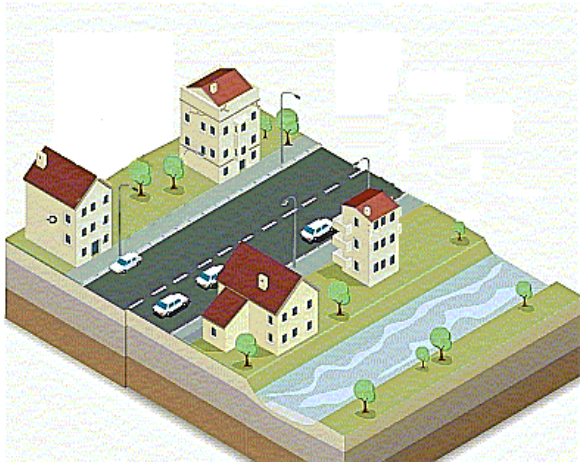


During

Damage reduction/Control

Emergency help and rescue

After quake hazards



After

Rehabilitation of infrastructure functionality

Condition assessment and updating of reliability and risks

Optimal allocation of resources for rebuilding and strengthening

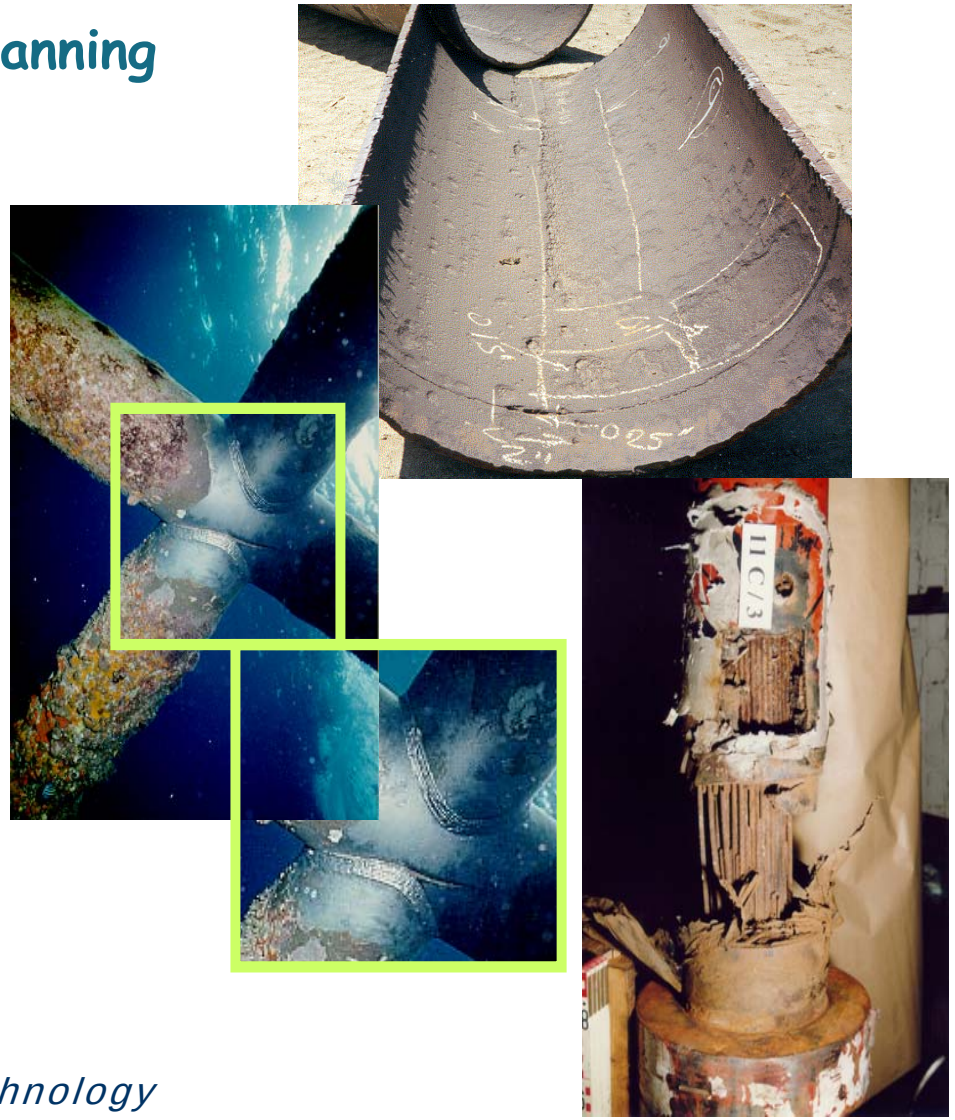
Decision Problems in Engineering

- Inspection and Maintenance Planning

  Due to
  - operational loading
  - environmental exposure

  structures will always to some degree be exposed to degradation processes such as

  - fatigue
  - corrosion
  - scour
  - wear



Why Statistics and Probability in Engineering?

- In summary

  statistics and probability theory is needed in engineering to

  - quantify the uncertainty associated with engineering models
  - evaluate the results of experiments
  - assess importance of measurement uncertainties
  - safe guard

    safety for persons
    qualities of environment
    assets

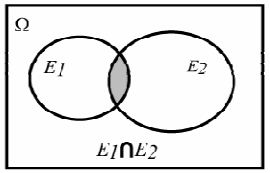
ENHANCE DECISION MAKING

Organisation of the Lecture

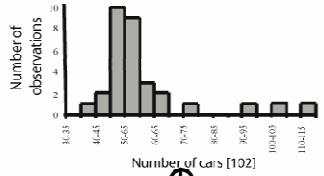
Module A

Engineering decisions under uncertainty

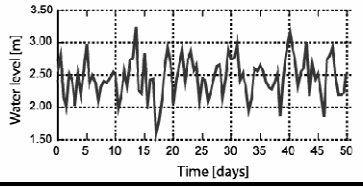
Module B - Basic probability theory



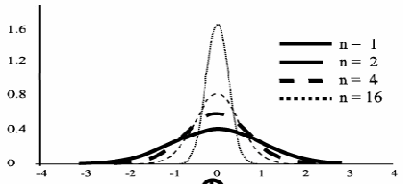
Module C - Descriptive statistics



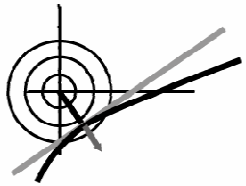
Module D - Uncertainty modeling



Module E - Estimation and model building



Module F - Methods of structural reliability



Module G - Bayesian decision analysis