Uncertainty…
how to grasp it, understand it, handle it, live with it, cope with it, …

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What to say…

My purpose is to present a personal, clearly biased opinion on:

- What to do to handle, live with, cope with,, … uncertainty,
- What we do right and what is going wrong with our research,
- What may be a proper and fruitful direction for us , going somehow beyond and advancing the present research pragmatics
- Why and to what extent is „rigor” important

We (+ I) = „probabilistic plus” people

This is by no means a critique of what we are doing!

Maybe some critique (suggestion!) of:

- **What we are not doing,**
- **What we stick to, overlooking what is going on in different fields,**
- **That we cannot cross boundaries of our fields and take adantage of a possible crossfertilization.**

Based on my experience and background

Maybe slightly „unorthodox”…

My experience:

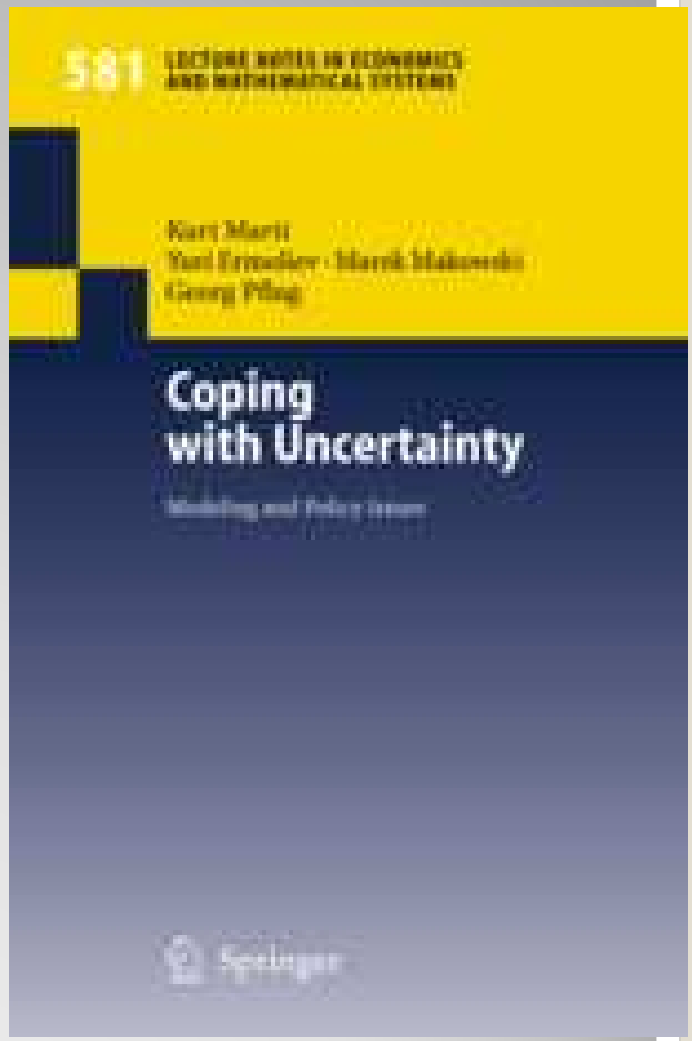
- **1975 – 1995: work at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria:**
- **Mathematical models of regional development, water systems, etc:**

One of the most famous think tanks

Contacts with famous people:

Kantorovitch, Koopmans (Nobels in Economics)

Howard Raiffa (Director, from Harvard University)



Then, through my PhD student Victor Taylor from Lincoln Labs at MIT

familiarity with uncertainty related rojects at:

- **NASA – Jet Propulsion Lab, California Institute of Technology**
- **Lawrence Livermore Labs (University of California, Berkeley)**
- **Lincoln Lab, MIT**
- **Sandia National Labs, Albuquerque, NM**

Basically, working on QRA (quantitative risk assessment)

Real, big money projects for real customers (military, NASA, Dept of Energy, etc.)

But;

- **Many top groups have participated,**
- **We have not been invited, not even considered..**

Those groups have been also in highly rigorous directions

Why?

- **Maybe we just are concerned with minor isues and not grasping the very essence of the problem,**
- **Maybe we connot pass some boundaries of our ivory tower**

A general indication resulting from my contacts with those people was that:

the problems should be:

- **dealt with in the „complex systems" context,**
- **be considered in a systems engineering perspective,**
- **Simplistic (tough maybe at a very high level) theoretical analyses do not grasp the essence and do not solve the problems (hence no real money for this research….)**

Wikipedia: Systems engineering is an interdisciplinary field of engineering that focuses on how complex engineering projects should be designed and managed over the life cycle of the project (Bell Labs, 1940s, NASA, etc.)

Basically, the dealing with uncertainty should follow the path of reasoning:

Uncertainties lead to risks or opportunities which are handled technically by mitigation (exploitation) which can lead to desired outcomes

Uncertainties: things that are not known or known imprecisely, not necessarily bad, measuable or not, in general:

- **Aleatory (inherent variations associated with the system and/or environment),**
- **Epistemic (due to lack of knowledge on the system and/or environment)**

- **Risks: pathologies created by uncertainties**

= probability x severity of consequences

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extremely low extremely high

Risk has a bad connotation but uncertainty can create opportunities!

- **Mitigations: technical approaches to minimize risk (for instance, some safety margins)**
- **Outcomes: attributes of the system the user finds valuable, fruitful, etc.**

Prof. Daniel Hastings
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Uncertainties:

- Lack of knowledge
- Lack of definitions
- Statistically characterized variables
- Known unknows

  Things that it is known that they are are not known. They are at best bounded, and may have entirely unknown values.
- Unknown unknows

  Gotchas. By definition not known. Some are hopeless to even contemplate (asteroid strikes vehicle). But, we know there are unknown unknowns which gives us some (difficult to quantify) motivation for applying conservative mitigation strategies.

Terms attributed to Donald Rumsfeld, US Secretary of Defense, but known much earlier…

Mitigations:

- Safety margins,
- Redundancy,
- Modularity,
- Open architecture,
- General purpose (sub)systems,
- …

It is clear why we do are not a player in the „market" for large and prestigious uncertainty related analyses and projects

Many possible avenues of research for us!

For instance (I like it):

So called „evolutionary acquisition" – concerns systems that can adapt but with respect to needs, requirements, etc. to be known later

This can help deal with unknown unknows!
Has a clearly „soft" flavor!

Therefore, my message is that we should :

- **continue working as before, i.e. on formal simplistic views of uncertainty, because there are great analytic results,**
- **But proceed to a more advanced analysis of a systems engineering type or paradigm with:**
  - **Holistic view,**
  - **Management of complexity,**
  - **Management and mitigation of uncertainty**

  and then analyze, deal with, manage, mitigate, etc. uncertainty in this perspective,
- **Convey our message and results in a language that will be considered promising and constructive,**
- **Try to enter with our tools and techniques the real projects, with real money, and solving socially relevant projects.**

What about „rigor”? Very important!

But we should not view it trivially as just a broad use of proper formal mathematical tools

Handling of uncertainty (analysis, coping with, managment of, etc.) in real world is a multiaspect, multifield (not all maths based!) endavor!

So, rigor should be what is considered rigorous in a particular field of knowledge employed

We, the maths oriented people should be modest as those who do not use high level maths are not ncessarily worse and can solve problems we cannot even formally formulate and handle

Coping with uncertainty is to serious a matter to be left to maths alone….