

# CSC2125: Modeling Methods, Tools and Techniques

## Winter 2018

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Introduction to Software Modeling

<http://www.cs.toronto.edu/~chechik/courses18/csc2125>

# Overview

- models, abstractions, realizations
- defining criteria
- purpose of models
- types of models

# What is a Model?

"A model is a description of something" [KT08]

"A model is a simplification of reality" [BRJ05]

"set of declarative statements" [Sei03]

"models are a simplification of reality intended to promote understanding and reasoning" [Kra07]

"Modelling... is the cost-effective use of something in place of something else for the some cognitive purpose. It allows us to use something that is simpler, safer or cheaper than reality instead of reality for some purpose." [Rot89]

"suitable for prediction of characteristics of design" [KSLB03]

# Models: A Loaded Term

**mod·el** [módd'l] noun (plural **models**)

**1. copy of object:** a copy of an object, especially one made on a smaller scale than the original (*often used before a noun*)

**2. specific version of article:** a particular version of a manufactured article had traded in her car for the latest model

**3. something copied:** something that is copied or used as the basis for a related idea, process, or system

**4. simplified version:** a simplified version of something complex used in analyzing and solving problems or making predictions; a financial model

**5. perfect example:** an excellent example that deserves to be imitated

**6. somebody paid to wear clothes:** somebody who is paid to wear clothes or demonstrate merchandise, e.g. in fashion shows or in photographs

**7. artist's subject:** somebody who poses for a painter, sculptor, photographer, or other artist

**8. zoology animal species copied by another animal:** an animal species repellent to predators that another animal mimics for protection

**9. logic interpretation:** an interpretation of a theory arrived at by assigning referents in such a way as to make the theory true

**10. U.K. fashion original garment:** the first sewn example of a couturier's or clothing manufacturer's design, from which a new line of garments is produced

MSN Encarta

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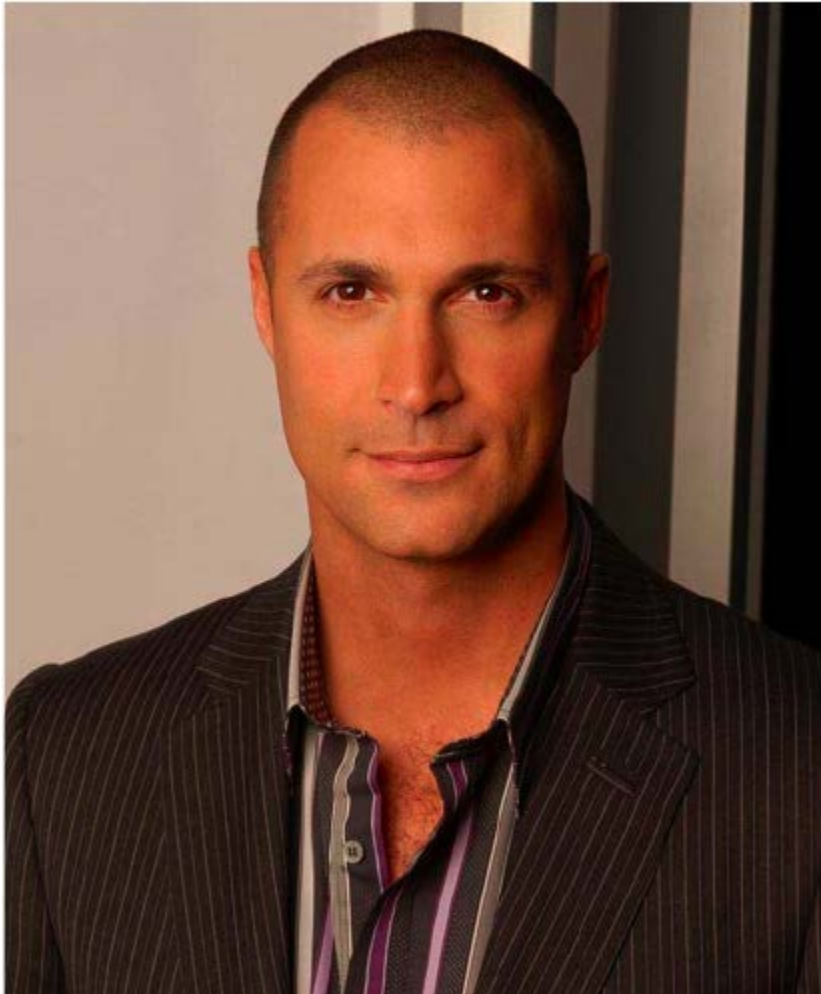
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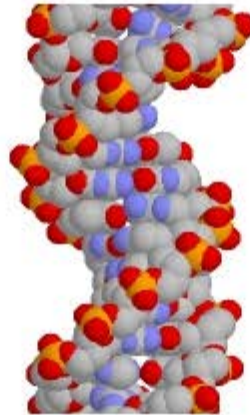
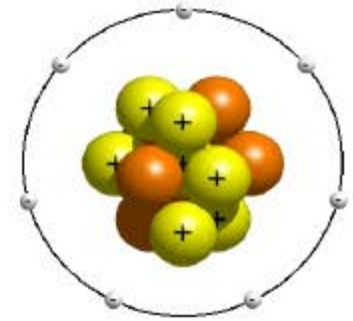
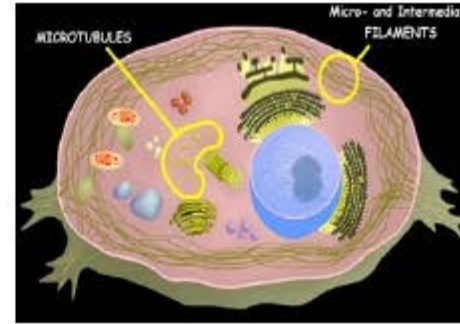
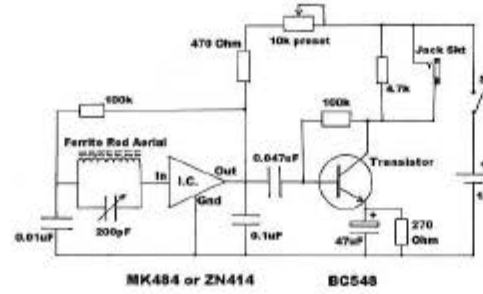
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# Google's "Definition" of a Model



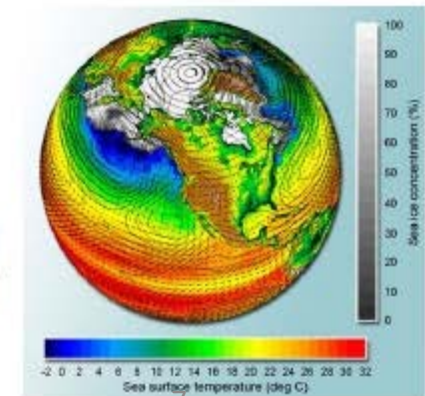
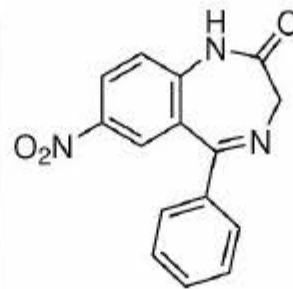
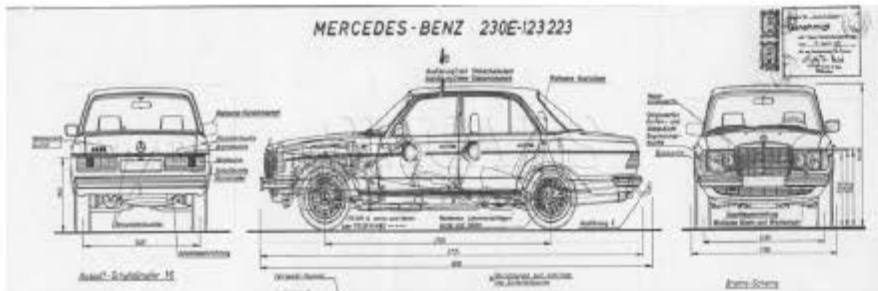


# Some Examples

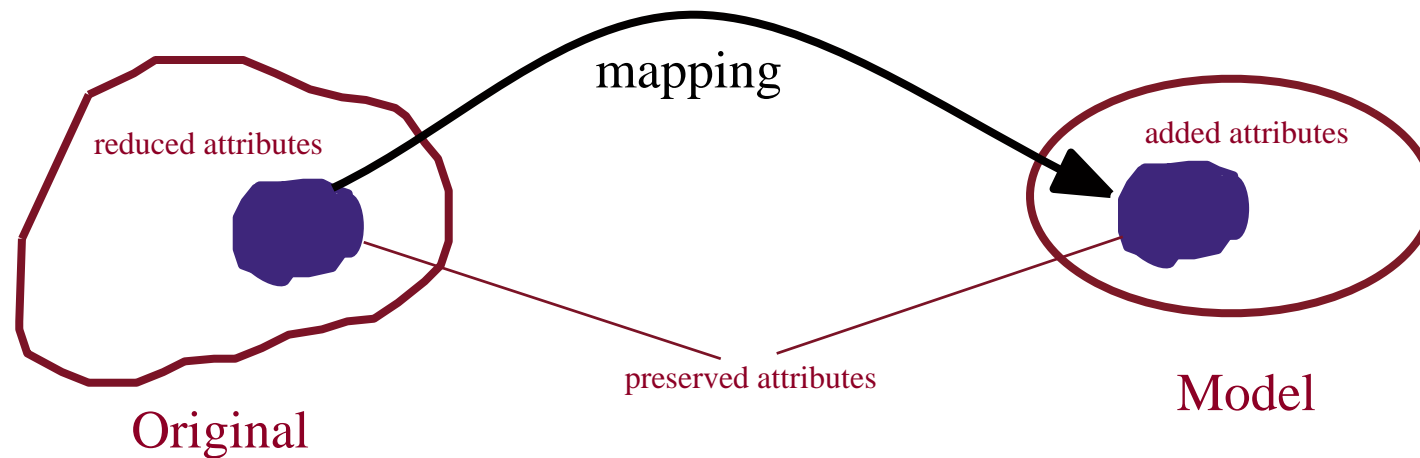


Periodic Table of the Elements

|                   |     |    |    |    |    |     |     |     |    |    |    |      |     |    |     |      |       |   |
|-------------------|-----|----|----|----|----|-----|-----|-----|----|----|----|------|-----|----|-----|------|-------|---|
| IA                | IIA |    |    |    |    |     |     |     |    |    |    | IIIA | IVA | VA | VIA | VIIA | VIIIA | 0 |
| H                 | He  |    |    |    |    |     |     |     |    |    |    | B    | C   | N  | O   | F    | Ne    |   |
| Li                | Be  |    |    |    |    |     |     |     |    |    |    | Al   | Si  | P  | S   | Cl   | Ar    |   |
| Na                | Mg  | BB | VB | VB | VB | VIB | VIB | VII | IB | IB | Ga | Ge   | As  | Se | Br  | Kr   |       |   |
| K                 | Ca  | Sc | Ti | V  | Cr | Mn  | Fe  | Co  | Ni | Cu | Zn | In   | Sn  | Sb | Te  | I    | Xe    |   |
| Rb                | Sr  | Y  | Zr | Nb | Mo | Tc  | Ru  | Rh  | Pd | Ag | Cd | Hg   | Pb  | Bi | Po  | At   | Rn    |   |
| Cs                | Ba  | La | Hf | Ta | W  | Re  | Os  | Ir  | Au | Hg | Tl | Pb   | Bi  | Po | At  | Rn   |       |   |
| Fr                | Ra  | Ac | Th | Pa | U  | Np  | Pu  | Am  | Cm | Bk | Cf | Es   | Fm  | Md | No  | Lr   |       |   |
| Lanthanide Series |     | Ca | Pr | Nd | Pm | Sm  | Eu  | Gd  | Tb | Dy | Ho | Er   | Tm  | Yb | Lu  |      |       |   |
| Actinide Series   |     | Th | Pa | U  | Np | Pu  | Am  | Cm  | Bk | Cf | Es | Fm   | Md  | No | Lr  |      |       |   |



# Defining Criteria



Stackowiak [Sta73] advocates the following criteria that distinguish models from other artefacts:

**mapping criterion:** there is an original phenomenon that is mapped to the model.

**reduction criterion:** the model reflects only a (relevant) selection of the original's properties.

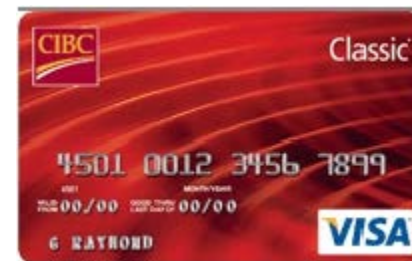
**pragmatic criterion:** the model is usable in place of the original, for some purpose.



# Example



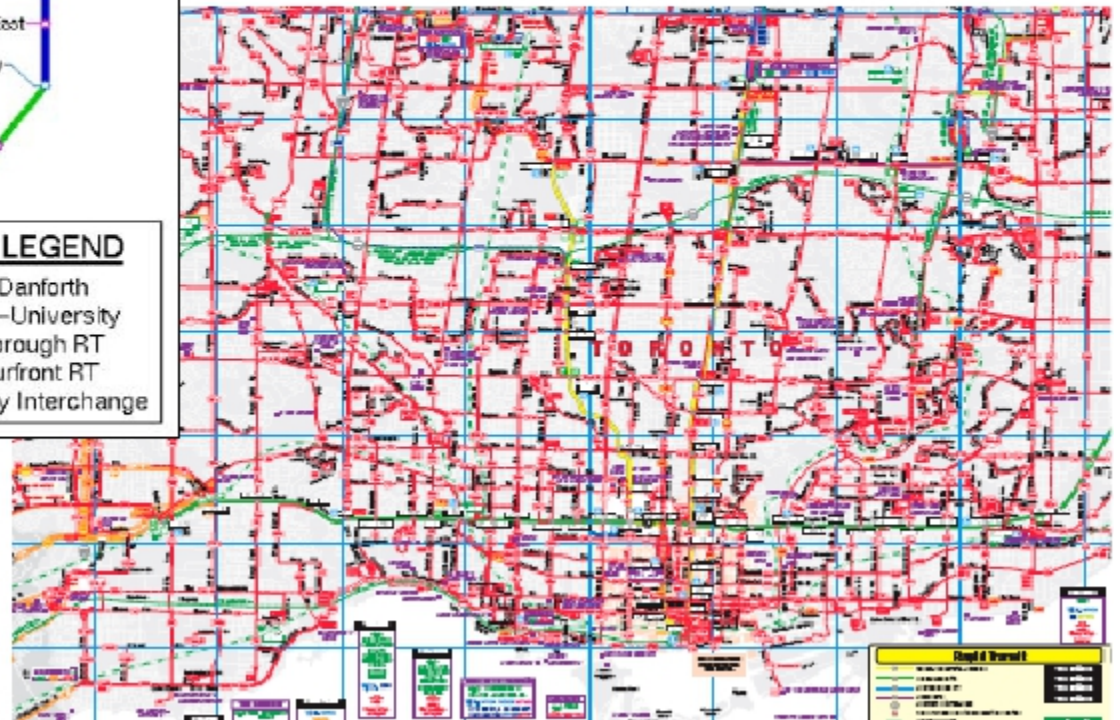
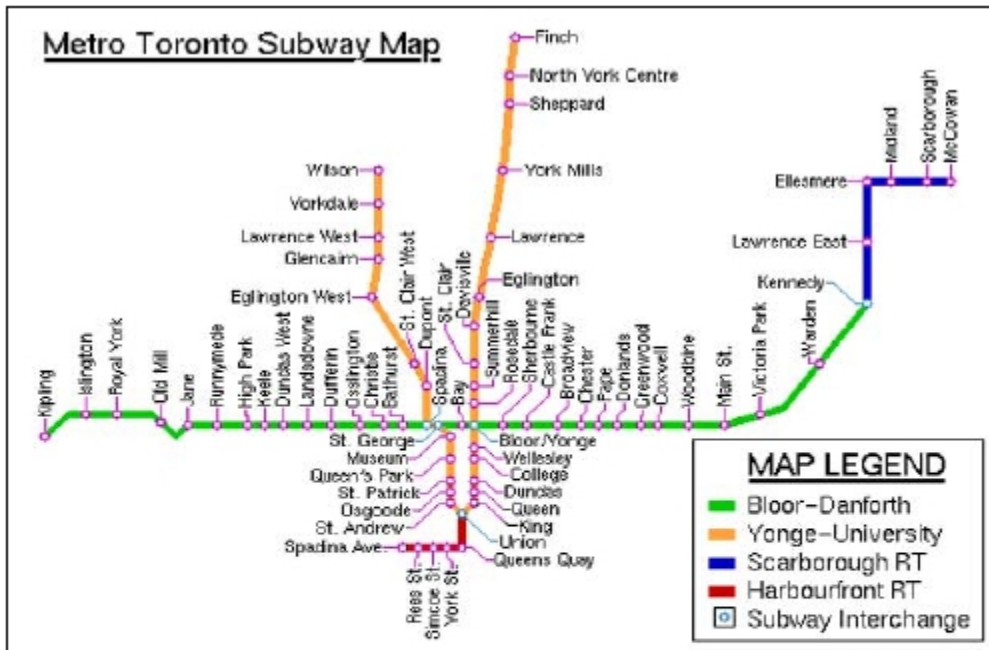
Original



Models

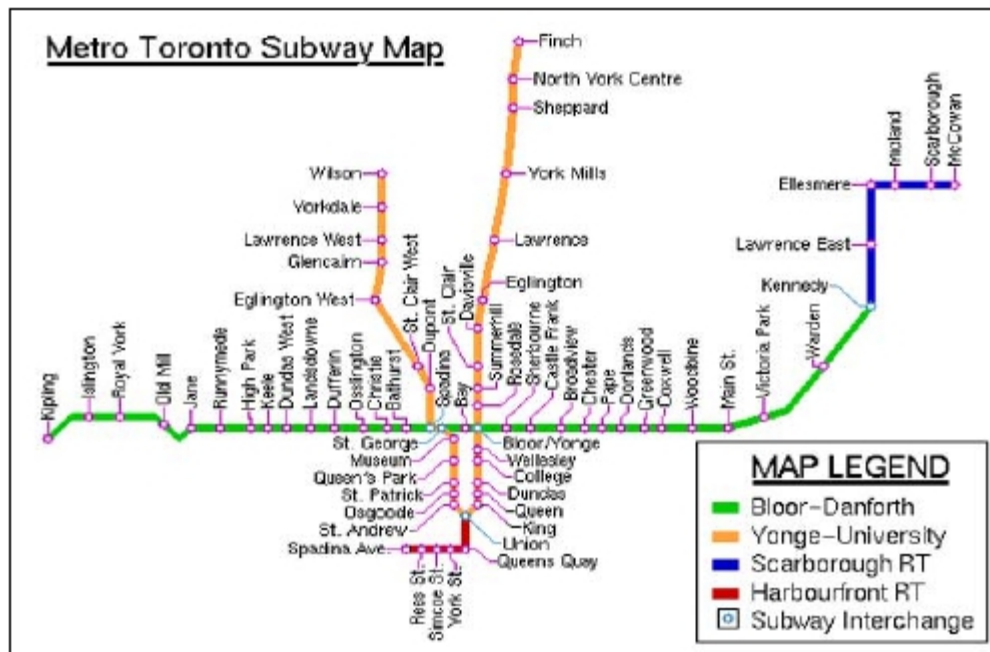
# Another Example

Two models of the Toronto Subway system, expressing different properties for different purposes.



# Inappropriate Model for Intended Purpose

A model must **preserve relevant properties**, where "relevance" is with respect to questions to be answered about the original.



Is there a stop near the Eaton Centre?

How far to the end of the line?

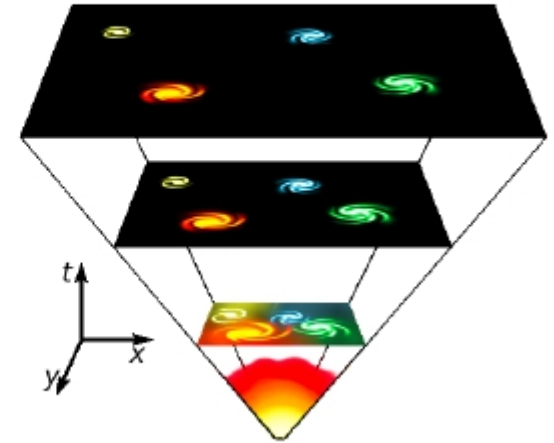
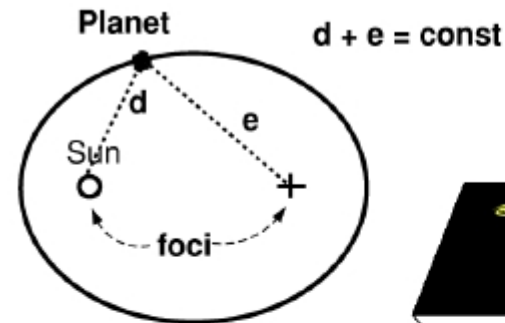
Can I travel from Lawrence East to Spadina Ave?

# Purposes of Models

1. **Exploratory** - lightweight exploration of design alternatives
2. **Documentation** - a descriptive model used to communicate information about the original
3. **Specification** - a plan (prescriptive model) for constructing an instance of the original
4. **Analysis** - descriptive models used to evaluate or predict properties of the original
  - e.g., differential equations
5. **Educational** - a substitute for the original for ethical or practical reasons
  - e.g., skeletons used in medical education, flight simulators, dolls

# Models in Natural Science

- Mostly descriptive
  - regression fit of observations
- Validated via experiments
- Facilitates predictions



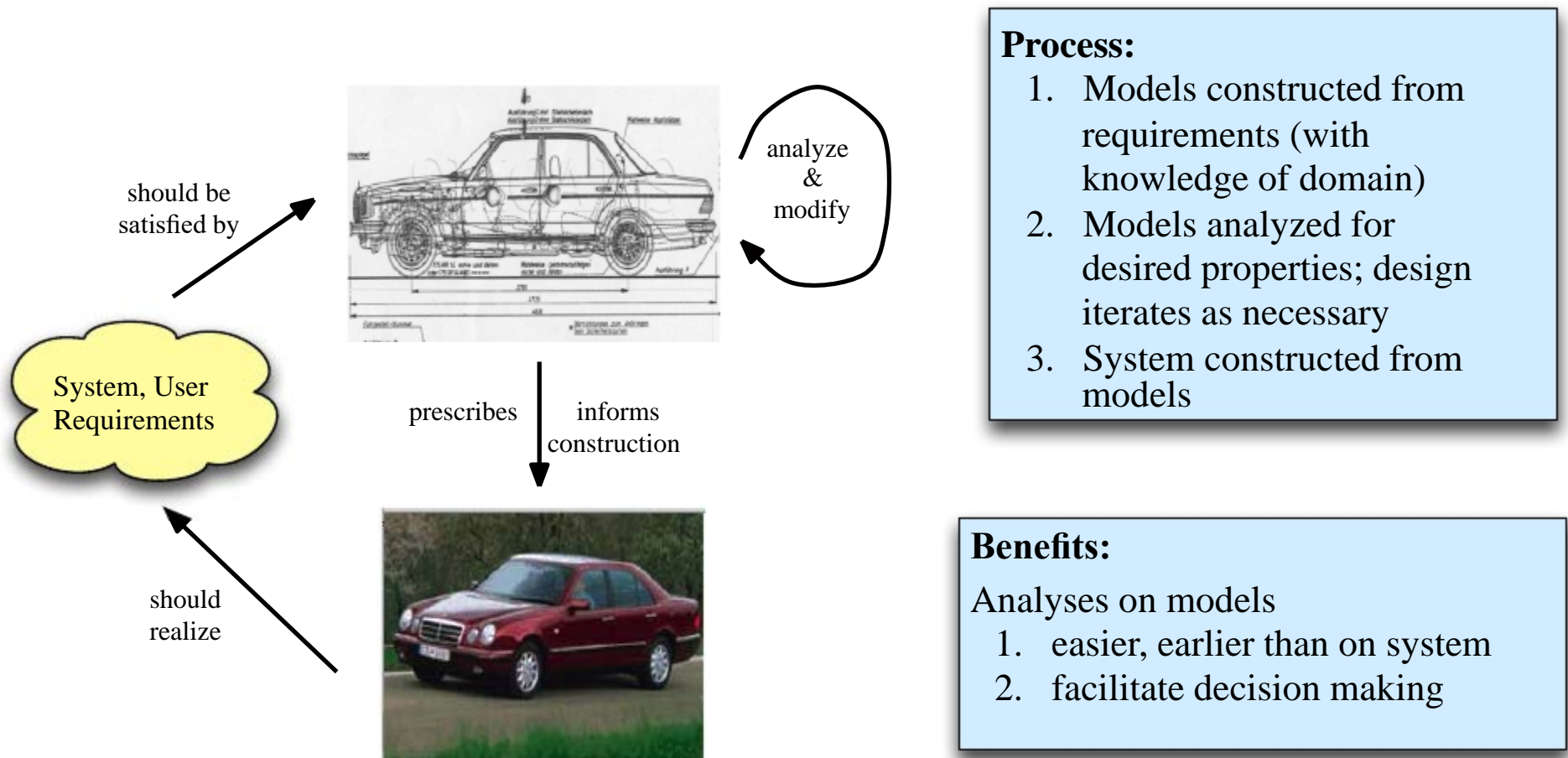
## Examples

- Kepler's laws of planetary motion (ca. 1605)
- Newton's laws of motion (1687)
  - *"the acceleration of an object is proportional to the force applied, and inversely proportional to the mass of the object":  $F = m \cdot a$*
- Einstein's formula equating mass and energy:  $E = mc^2$
- Maxwell's equations of electricity and magnetism
- Big bang theory of the origin of the universe



# Models in Engineering

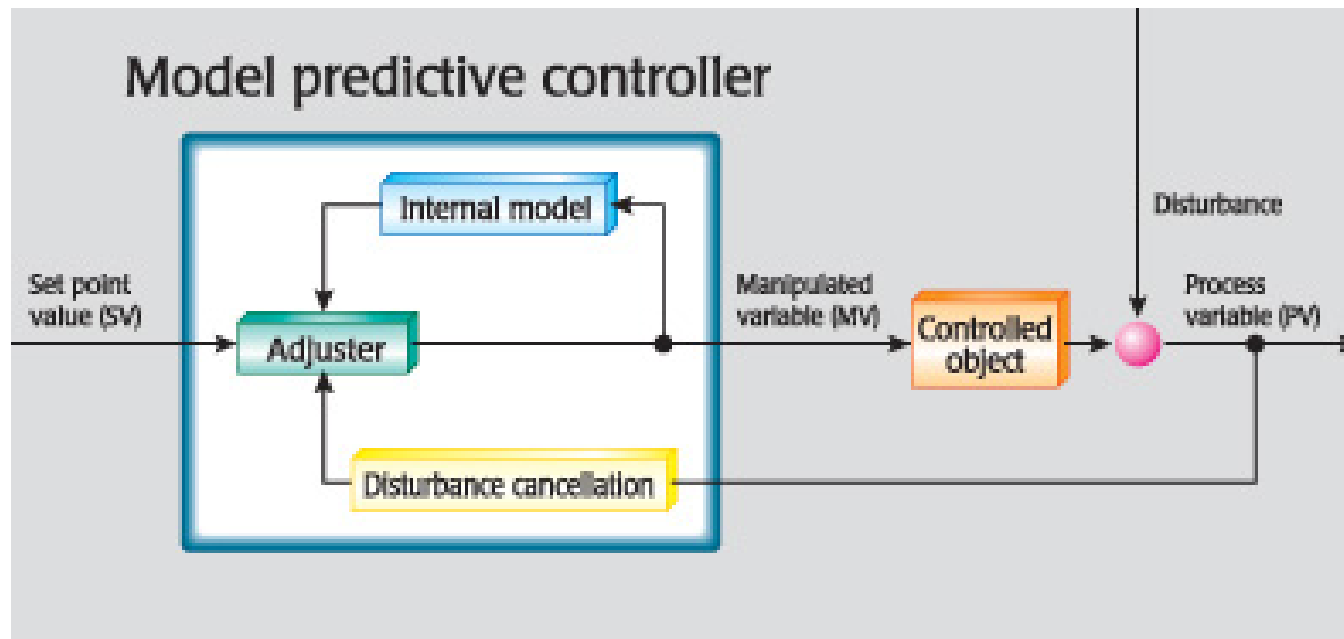
- Mostly prescriptive, facilitates construction





# Models within Executing Software

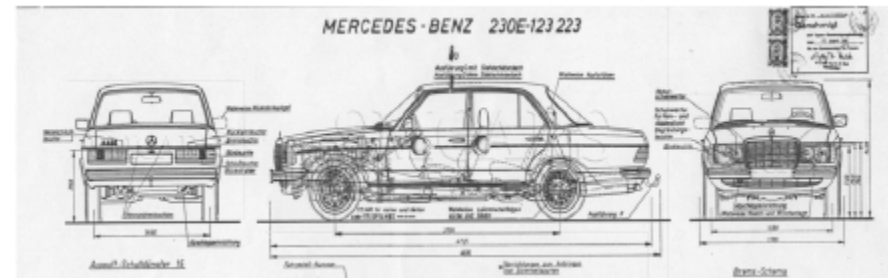
Many software systems include an internal run-time model of some part of the world -- Michael Jackson



# Types of Models

## 1. Descriptive vs. Prescriptive Models

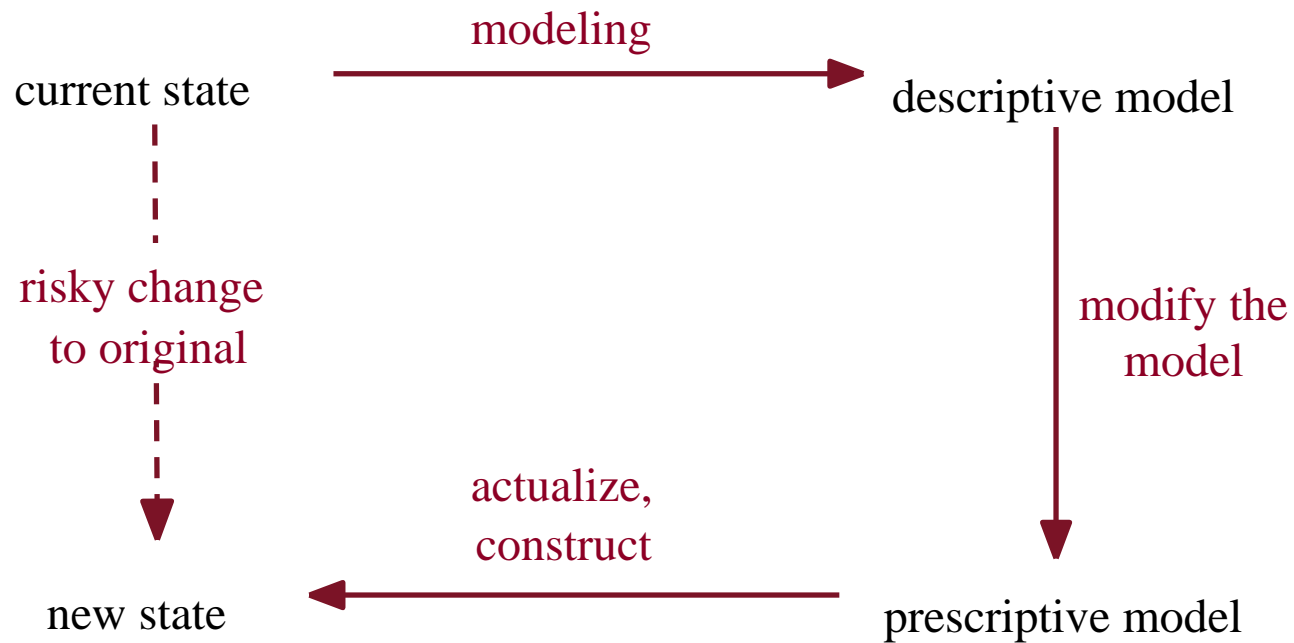
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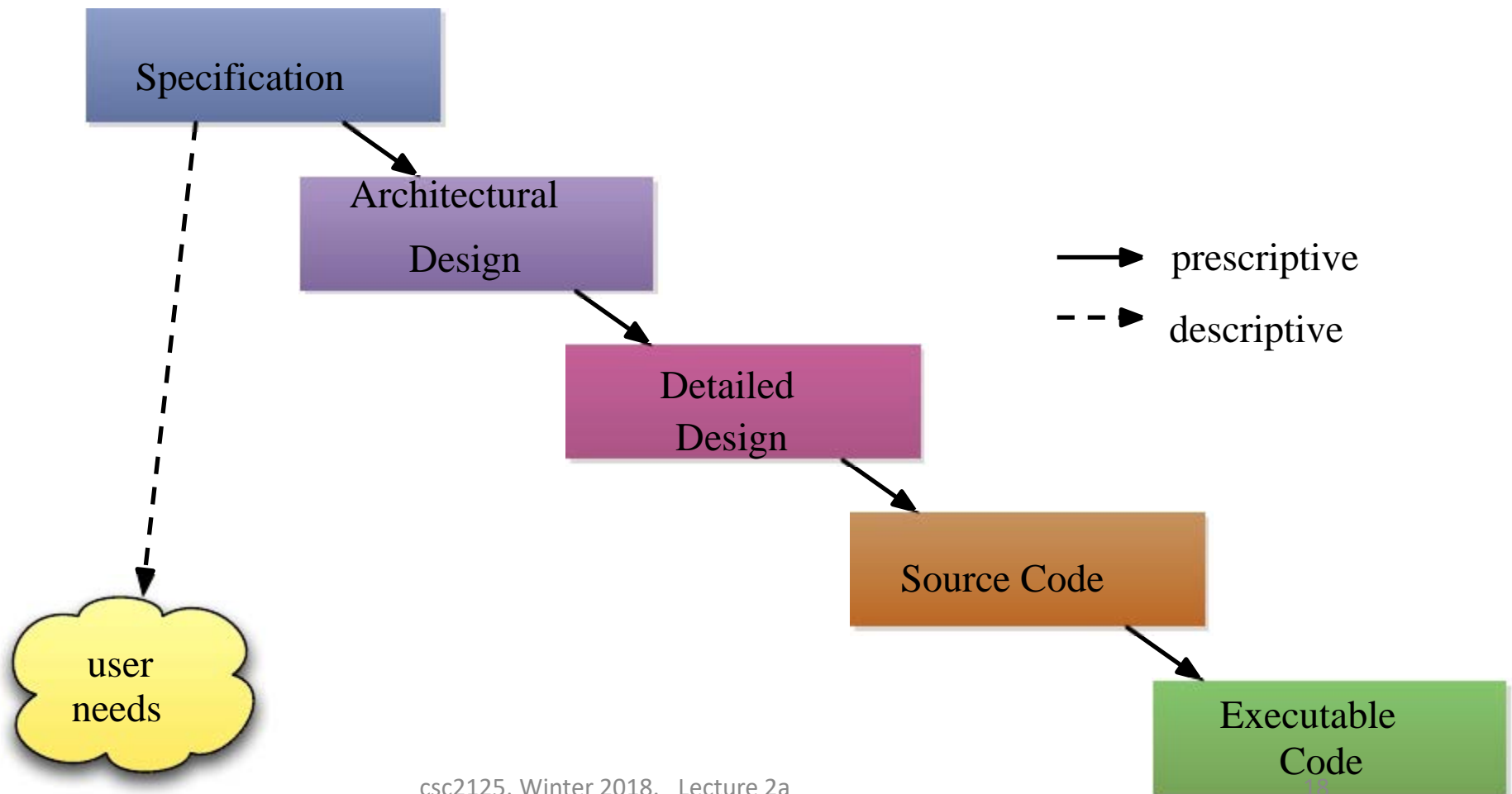
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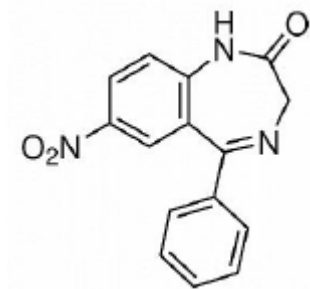
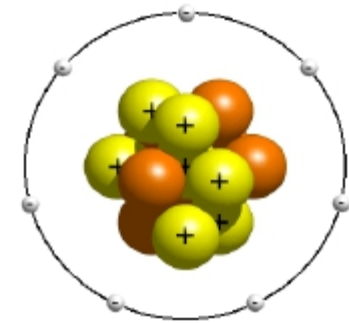
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whether model phenomena capture *singular* (“*token*”) original instances, or generically represent *multiple* (“*type*”) instances



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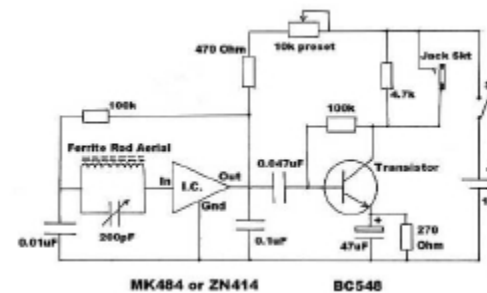
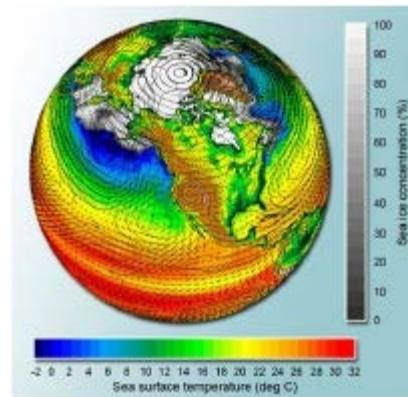
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## 4. **Sketch** vs. **Blueprint** vs. **Executable** Model

level of precision of model

# Summary

## Models as purposeful abstractions

- represents some original
- is smaller than the original
- is usable in place of the original

## Uses of models

- descriptive
- prescriptive
- predictive

## Innate human activity to model and classify

# References

- J. Ludewig, [Models in Software Engineering - An Introduction](#), In *Software and Systems Modeling*, 2(1): pp. 5-14, (March 2003).
- T. Kühne, [Matters of \(Meta-\)Modeling](#) in *Journal of Software and Systems Modeling*, 5(4): pp. 369-385, (2006)