Philosophy of Models in Engineering Design,
Karlsruhe 2017
June 27 – 28, (Tuesday 27 16:15-17:00)

Prescriptive Engineering Knowledge & Models;

Sjoerd Zwart

1: SLEIPNER A CASE 1991

Condeep GBS oil platforms

- In 1973 in Norway gravity based structures (GBS) for oil rigs were introduced: support pilings and concrete chambers, above which 3 or 4 shafts extend out to support the deck.
- Once fully ballasted, hull sits on the sea floor
- TROLL A Largest built and moved artifact ever in the world -- 1.2 million tons of concrete and steel

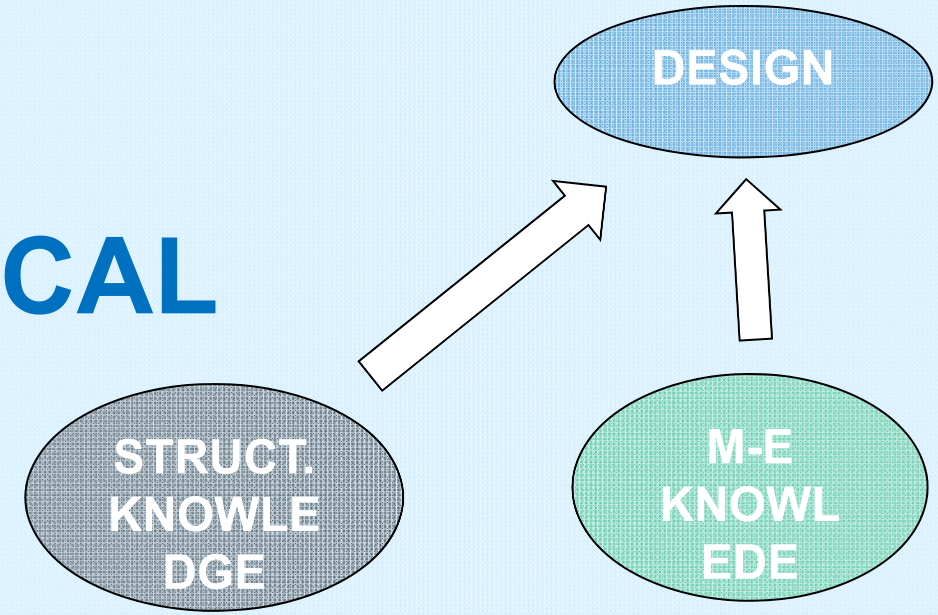
Construction Condeep Platform pf

1. Lower part foundation built in a dry dock
2. After flooding dock pf. is shipped to deep water; there, the rest of cylindrical caisson cells and shafts are built and tested.
3. Pf. is lowered by letting water in caissons and steel deck is lifted on shafts and fixed in place.

The Accident

- In August 1991, 18 years after the intro of the GBS technology, much smaller Sleipner A was lowered in controlled ballasting operation. It was the 12th exemplar.
- … at 99m, ballast tanks imploded which was registered as an earthquake 3; No casualties, US$ 250 million lost.
- CAUSE?
- Scaling down artifact without scaling down Finite Element Model (FEM) mesh
- Consequently the internal tensile forces, were underestimated; in some cases 47% (!)
- Best justification is extensive use in the real world (commercial companies). Even that not always suffices.

2: MY STANCE: METHODOLOGICAL BREAK-DOWN



New perspective Engineering Knowledge

- Difference **scientific vs technological knowledge** seems to be **too coarse grained.**
    - Houkes 2009: skeptical about *epistemic emancipation of technology*
    - Norström 2014: *Knowing how* -- *knowing that* are mutually irreducible; BUT seem almost symbiotic in the technological domain (Claudia Eckert: company stance)
- **Zwart, de Vries 2016: Methodological break-down of (innovative) engineering problem solving into a Means-End Hierarchy atomic projects Not personal!**
    - Wieringa 2009: nesting [of practical and knowledge problems] should not blind us for the fact that their problem-solving and solution justification methods are different.

Engineering Project

- **An engineering project := any (collection of concerted) engineering endeavor that has a clear predefined (although adaptable) technological goal whether in university, industry or (inter)national research centers (Cern, NASA etc).**

Zwart, S. D., & Vries, M. J. de. (2016).
Methodological Classification of Innovative Engineering Projects.

End Goal determines Method
6 atomic innovative eng. projects

- **Structural (descriptive) knowledge ~ 30%**
- **<u>M-E Knowledge (knowing how) ~ 25%</u>**
- **Design ~ 27%**
- **Models ~ 6%**
- **Technical Optimizations ~ 11%**
- **Formal/mathematical ~ 1%**

This structures Engineering (PhD) Projects

Structural vs Engineering M-E KNOWLEDGE

STRUCTURAL

Knowledge about structural properties of the natural, social and artificial world of expressed in in descriptive sentences. E.g.

- *At 1 atm, water boils at 100 degree Celsius.*
- *The stress strain curve of alloy X looks like (picture…)*
- *In well-lighted areas occur less crimes than in dark areas*
- *Etc.*

The term "*descriptive knowledge*" is a misnomer and should be avoided

TELEOLOGICAL

All goal directed knowledge; whether functional (FK), e.g.:

- *Functional descriptions*
- *functional hierarchy*
- *Working principles?*
- *Causal explanations?*

Functional (no actions)

E.g.:

- Action A leads in context C to Goal G

Descriptive

E.g.:

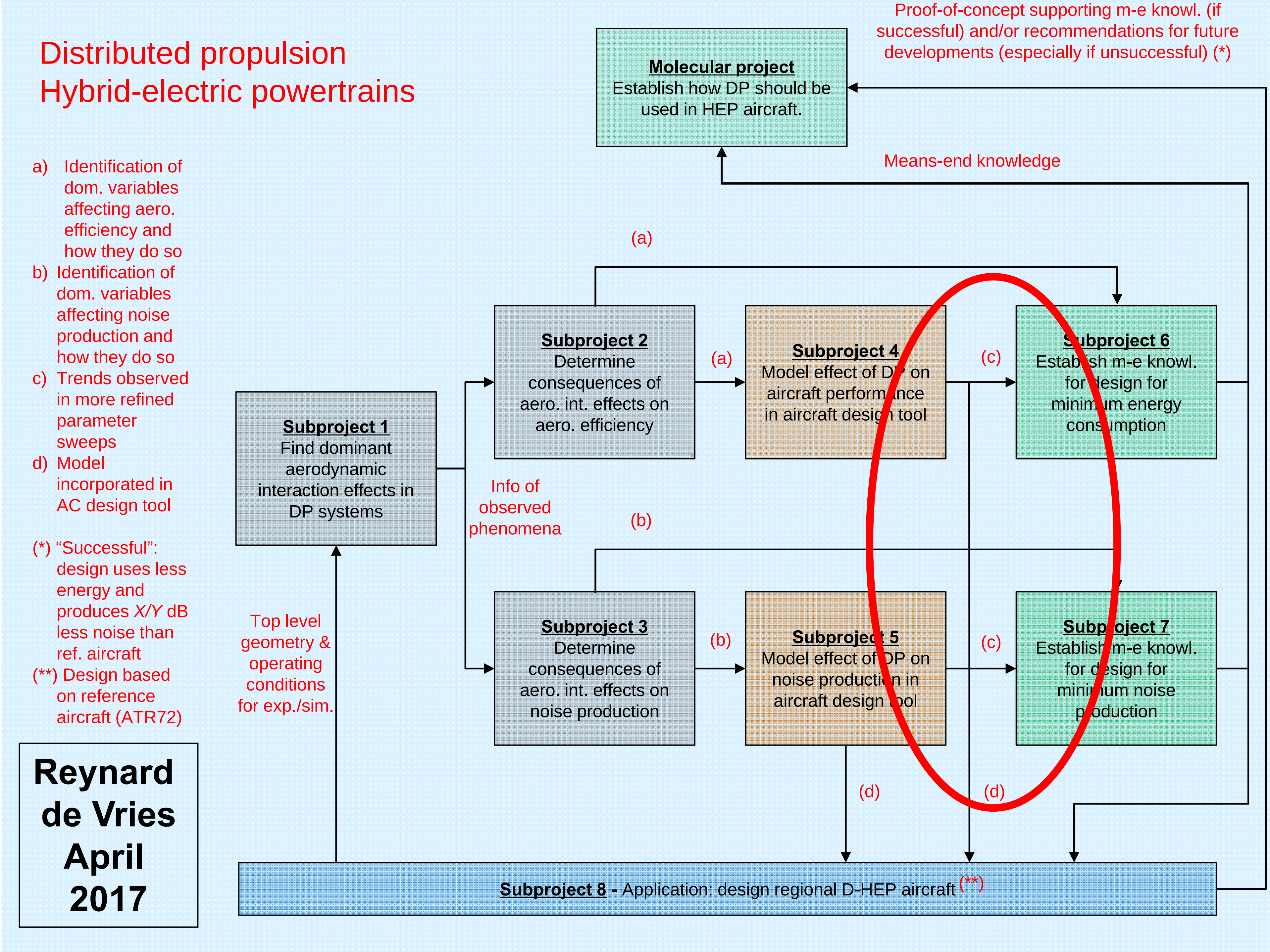
- To achieve Goal G in context C, you should carry out Action A

Prescriptive

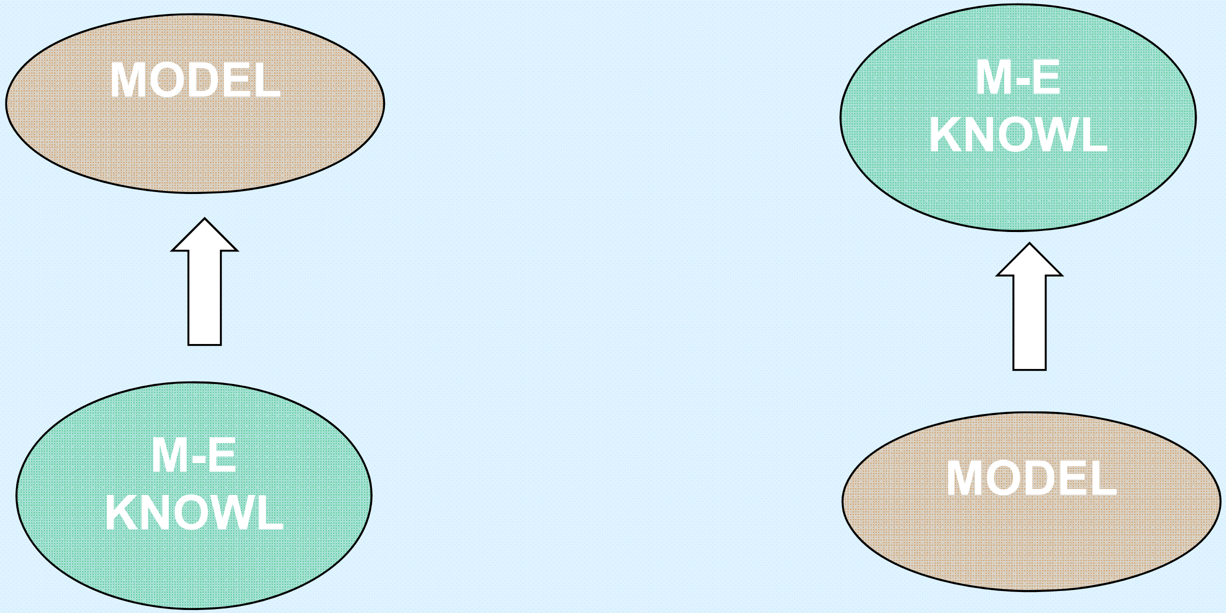
Means-End (action) based

Systematic Differences

Structural Knowledge	Pres. M-E Knowledge
Belief about structure	Belief about actions
(Knowing-that)	(Knowing-how)
True or False	Effective/rational
Value free (object level)	Intrinsically value-laden
End	Means
(intrinsically valued)	(instrumentally valued)
As abstract as possible (monotonic)	Context dependent (non-monotonic)



Distributed propulsion
Hybrid-electric powertrains
a) Identification of dom. variables affecting aero. efficiency and how they do so
b) Identification of dom. variables affecting noise production and how they do so
c) Trends observed in more refined parameter sweeps
d) Model incorporated in AC design tool
(*) "Successful": design uses less energy and produces X/Y dB less noise than ref. aircraft
(**) Design based on reference aircraft (ATR72)
Reynard de Vries April 2017
Proof-of-concept supporting m-e knowl. (if successful) and/or recommendations for future developments (especially if unsuccessful) (*)
Molecular project
Establish how DP should be used in HEP aircraft.
Means-end knowledge
(a)
Subproject 1
Find dominant aerodynamic interaction effects in DP systems
Subproject 2
Determine consequences of aero. int. effects on aero. efficiency
(a)
Subproject 4
Model effect of DP on aircraft performance in aircraft design tool
(c)
Subproject 6
Establish m-e knowl. for design for minimum energy consumption
Info of observed phenomena
(b)
Top level geometry & operating conditions for exp./sim.
Subproject 3
Determine consequences of aero. int. effects on noise production
(b)
Subproject 5
Model effect of DP on noise production in aircraft design tool
(c)
Subproject 7
Establish m-e knowl. for design for minimum noise production
(d)
(d)
Subproject 8 - Application: design regional D-HEP aircraft (**)



Start of empirical research

3: MODEL ↔ M-E K HIERARCHY

MODEL ↔ M-E K relation

- → <u>MODEL serves the purpose of M-E K</u>
  1. **Computational testing** of Design Action Consequences
  2. **Helps to structure M-E K problem**
  3. **Creates M-E K to make decisions**
  4. **Instrument in M-E Design K**
  5. **Empirical models that support from below**
  - **<u>Helps to justifies M-E K</u>**

- ← <u>M-E K serves the purpose of MODEL</u>
  - **How to build the model?**
  - **Identification relevant variables**
  - **Validation (via experts)**

1. **Computational testing** of Design Action consequences.

- **Sleipner A case is a standard way in which technical M-E K is justified in engineering**
- It is a standard example of **“support from above”** (Niiniluoto, 1993) **Bunge’s (1966, p.339) grounded rules: *A rule is grounded* if and only if it is based on a set of law formulas capable of accounting for its effectiveness (no-pseudo engineering!)**
- **IT IS NOT COMPUTATIONAL EXPERIMENTING**
- **Many computational tools help engineers to calculate outcomes of theories** (MATLAB, ANSYS fem, SIMULINK, LABVIEW COMSOL multiphysics, AUTOCAD)

1. M-E method (algorithm) validation

MPa = MegaPascal, GPa = GigaPascal, K = Kelvin, mm = millimeter

I. INTRODUCTION

HONDA has shown that an Otto engine with an elongated, oval piston supported on two connecting rods can generate a higher specific power output compared to one with a circular bore [1]. The dynamic sealing (metal rings set in grooves around the piston) of such an engine, is complicated compared to conventional circular cylinders. This is mainly due to the lack of point symmetry, which causes sealing problems when the engine goes to its working temperature [2]. The goal of this research is to develop a method to determine the unstressed geometry of a piston ring, which will lead to an effective sealing of an elliptical combustion chamber. Effective sealing is achieved when the preload induced contact pressure between the piston ring and the combustion chamber wall is uniform and lies between 0.12 and 0.25 MPa [3]. To obtain this goal an algorithm was developed to calculate the unstressed geometry. Additionally, experimental and numerical tests have been developed to validate the method.

II. PROCEDURE

The resulting shape for this piston ring is shown in Figure 1. This ring geometry is used to experimentally validate the algorithm, as described in the next section.

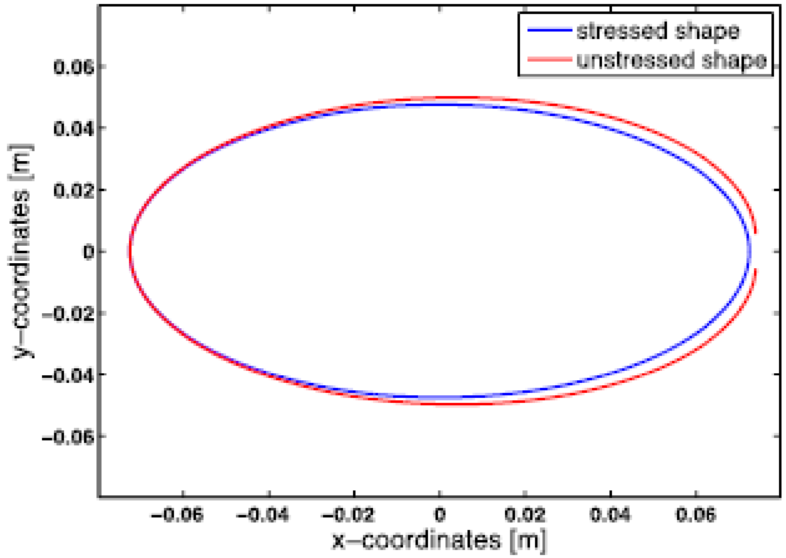


Fig. 1. Plot of the calculated unstressed shape in red versus the bore shape in blue

B. Test setup

1. M-E method (algorithm) validation

mirrored orientation of the disc (to rule out possible random production errors in the disc) for a total of 160 measurements.

Following the same procedure, the test piston ring as defined at the end of section A is measured. The ring is manufactured using laser cutting.

C. Finite Element Validation

In order to further validate the algorithm, 10 more ring geometries are generated for varying parameter sets. The different sets of parameters can be found in the research file [6]. All these geometries are imported in the finite element computing software program COMSOL. The desired uniform contact pressure and body temperature are applied along perimeter. After this the displacement is calculated by COMSOL. The displacement of the last node of each piston ring is then compared to its desired position. Any remaining error is then divided by the total displacement of the

that the accuracy of the algorithm itself might be contributing to this result. The average of all the errors is 15%, which could cause a non-uniform contact pressure. This deviation in the model might be due to the fact that the algorithm is based on simple linear beam theory.

For the beams with a non-zero contact pressure, the boxplot whiskers cover a range of at least 0.15 MPa. Therefore can be concluded that the spread is higher than the measured value.

The lateral forces on the ring, as discussed, may cause this high spread of the measured contact pressure.

V. RECOMMENDATIONS

There are three main issues that should be resolved in further research: the production errors, the lateral friction forces and the error in the algorithm.

The production error caused by the cold-formed steel can be overcome by using a steel plate that is relieved of internal stresses. Furthermore adjustable contact points could be

2. As Blueprint

How to organize Open Spatial Data Infrastructure (SDI) for Smart Cities

Indrajit (2017) AGILE paper Wageningen

In a smart city, an SDI should accommodate not only government entities, but also to academia, private sectors, and citizens. To achieve this, Indonesian SDI follows federated data governance model. Federated data governance is a structure that supports decisions, policies, standards, and information sharing between multiple semi-autonomous entities, such as data domains, committees, business and IT functions, and projects. A federated model will usually have a steering committee that oversees the governance process and addresses issues or needs that can't be addressed at the domain level (Figure 2) which is almost similar to INSPIRE.

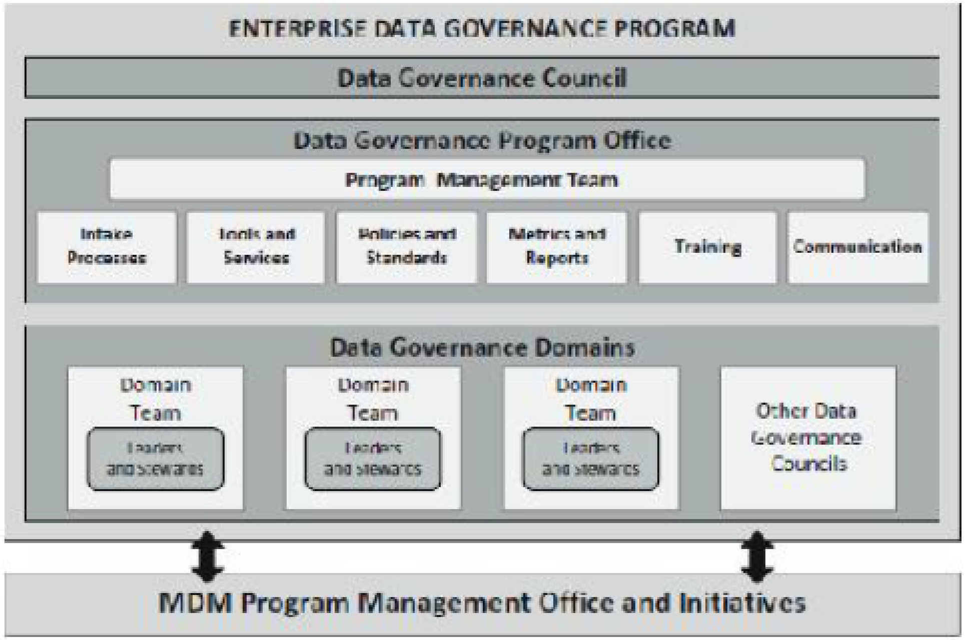


Fig 2: Federated data governance model (Source: Allen & Cervo, 2015)

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3. Helps designers decision making

Keywords
Indoor, irradiance, modeling, performance, PV cells, PV products

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Abstract

This article presents a simple comparative model which has been developed for the estimation of the performance of photovoltaic (PV) products' cells in indoor environments. The model predicts the performance of PV solar cells, as a function of the distance from a spectrum of artificial (fluorescent light, halogen light, and light-emitting diodes) and natural light. It intends to support designers, while creating PV-integrated products for indoor use. For the model's validation, PV cells of 12 commercially available PV-powered products with power ranging from 0.8 to 4 mWp were tested indoors under artificial illumination and natural light. The model is based on the physical measurements of natural and artificial irradiance indoors, along with literature data of PV technologies under low irradiance conditions. The input data of the model are the surface of the solar cell (in m^2), the wavelength-dependent spectral response (SR) of the PV cell, the spectral irradiance indoors, and solar cell's distance from light sources. The model calculates solar cells' efficiency and power produced under the specific indoor conditions. If using the measured SR of a PV cell and the irradiance as measured indoors, the model can predict the performance of a PV product under mixed indoor light with a typical inaccuracy of around 25%, which is sufficient for a design process. Measurements revealed that under mixed indoor lighting of around 20 W/m^2, the efficiency of solar cells in 12 commercially available PV products ranges between 5% and 6% for amorphous silicon (a-Si) cells, 4–6% for multicrystalline silicon (mc-Si) cells, and 5–7% for the monocrystalline silicon (c-Si) cells.

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4. As Instrument in Design Knowledge

Modeling an Angular Accelerometer using Frequency-Response Measurements

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A characterization of an angular accelerometer sensor is performed with a frequency-response experiment. To assess angular accelerometer dynamic properties, a position-based calibration table is utilized to provide the excitation input. The angular accelerometer specifications and calibration table limitations define a constrained test envelope for this particular setup. Measurement are obtained for a number of constant accelerations and varied with frequency. Analysis of the input-output relation in the frequency-domain leads to a frequency-response function model of the angular accelerometer. Time-domain data are used to validate the frequency-response model. A fourth-order structure is then preferred as the transfer-function for the 400 deg/s acceleration, with a 99.02 % fit. Besides representing the angular accelerometer dynamics, the angular accelerometer model is essential for the design of fault-tolerant flight control system.

AIAA SciTech Forum
4-8 January 2016, San Diego, California, USA
AIAA Guidance, Navigation, and Control Conference

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5. Empirical models that support from below

ELSEVIER journal homepage: www.elsevier.com/locate/matlet

A new technique for the characterization of the water leaching behavior of space holding particles in the preparation of biomedical titanium scaffolds

CrossMark

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Keywords:
Water leaching
Titanium
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Space holder

ABSTRACT how to measure?

In this study, a new real-time measurement technique for the characterization of the water leaching behavior of space holding particles from titanium scaffold preform for bone tissue engineering was developed. This technique yielded accurate and reproducible data. Fitting the data acquired into the existing solvent debinding models led to plots that could be used to elucidate the mechanisms operating during the space holder removal process through water leaching, i.e., (i) rapid dissolution, (ii) dissolution and diffusion and (iii) saturation.

"What is a model?"
Family resemblance term
→ How do Engineers' use of "Model"

Model of model

- **Design Engineers use Models for many purposes**
- Predicting; decision making; experimenting; exploring; system control; knowledge acquisition; method justification; approximate calculation of X. As a theory of..: measurement model;
- As way of viewing/calculating; paradigm; perspective
- reliability; approximate theory of artifacts (floating offshore wind turbine)
- Every complicated calculation is even called "model"
- Also as **APPROXIMATE CALCULATION**
- **Should we decide where they use it "appropriately" and where "inappropriately"?**

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THANK YOU FOR YOUR ATTENTION!