"Art without engineering is dreaming;
Engineering without art is calculating."

“T he greatest deception men suffer is
from their own opinions.”

Leonardo da Vinci
Introduction

- Rapid & Turbulent Environment emphasises need for a Rapid & Higher Performing PDP (Product Development Process).
  \[\Rightarrow\text{Virtual PDP a necessity}\]

- CAE toolset
  - the only virtual means of design valuation and verification
  - the most effective and efficient means to rapidly qualify and quantify product expectations and deliverables

However;

- CAE’s functional and domain specific nature.
  \[\Rightarrow\text{impedes efficient PDP knowledge discovery and flow}\]
Introduction

• PDP’s foundation is based on comprehension & availability of product specific knowledge amongst all the stakeholders.

• Comprehension & Availability of Product specific knowledge is via;
  – Acquisition, Processing, Elicitation, Encapsulation, Representation, Validation & Verification

• PDP knowledge is created & established mainly via;
  – Direct engagement & use of every PDP stakeholder specific know-how
  – The acquisition of current and potential future customer needs
  – The direct mapping of all the customer & business needs at all the necessary PDP development layers.

The Problem Focus
What this paper aspires to answer

➢ Current CAE toolset perceived shortcomings;
  – Utilise a small fraction of an enterprises informational asset
  – Specific product requirements can’t be addressed explicitly neither described with high fidelity
    However it has a fundamental impact on CAE assumptions
  – Are not capable to address the social relational process. What drives CAE runs? How these get socialised & reported?
  – Cascaded product requirements have no reliable framework for a traceable decision making process, from which a system, product attribute feature etc. has been derived.
Current PDP Environment
Volatility from Communication failure

The Analysis Process is fundamentally top-down. At each “level” of design we must understand the context which originates from the level above.
Current PDP Environment

Cognition

Development & Maturity

- Customer domain
- Functional domain
- Physical domain
- Process domain

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CAE’s influence within PDP

Knowledge Elicitation

- CNs: Customer Needs; The Benefits / Needs customer seeks from the product
- FRs: A minimum set of Requirements that completely characterise the functional needs of the Design solution in the functional domain
- DPs: The elements of the design solution in the physical domain that are chosen to specify the specific functional requirements
- PVs: The elements in the process domain that characterise the process to produce the product specified in terms of design parameters

Applicable At ALL levels & at each PDP stage Based on valid Assumptions

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CAE’s influence within PDP
Quantification Qualification & Knowledge Utilisation

Nominal Textual
Role Type, Road Type, Weather
Conditions

Nominal Numerical
Frame Size, Rider percentile

Ordinal Textual based on
Definition to Synthesis of axioms
Bright, hot, comfortable

Ordinal Numerical based on
Synthesis of axioms
Hardness, Surface Finish

Ratio, Interval or Measurable;
Physical Axiom Level
Length, weight, angle

Quantification, Qualification
Explicit; Expressed in functions

Ratio, Interval or Measurable;
Physical Axiom Level
Length, weight, angle

Statistical / Probabilistic;
Relationships in functions

Logic & Rule Based;
Conditions for occurrence. If A then B, If A and B then C, If A<B then C etc

Expert Judgment / Input Opinion;
Conditions for occurrence with confidence levels.
If A then usually B, If A and B then possibly C, If A<B then never C etc

Subjective Novice Judgment / Input Opinion;
Conditions for occurrence based on imprecise or unqualified levels.
If A then guess B, If A and B then possibly C, If A<B then usually C etc

CAE’s Influence within PDP
Communication

System Level

Model Level

CAE Pre Level

CAE Post Level

Stock

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CAE Model Interrogation
Cognition Comprehension Communication

Preliminary

- What is Known?
- What is the unknown?
- What is need to be found?
- What is the Understanding!!

Preparatory

- How un-Known is to be found
- How un-Known can be modelled
- How un-Known can be represented
- How Understanding is valid??

The challenges faced by CAE Model

- What one understands
- What one models
- How one chooses to represent such understanding
- What one deduces from the Simulation Output
- What one wants to communicate
- What one communicates (contained message)
- How this message is seen in context
- What one relates to as a conclusion
- What one elicits as information, knowledge & experience

CAE’s Assumptions

A blessing & A curse
CAE Model Interrogation

Comprehension

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Ratio, Interval or Measurable
- Physical Axion Level
- Length, weight, angle

Product Development

Validation Product

Customer Use

PDP Time

Logic & Rule Based
- Conditions for occurrence: If A then B, If A and B then C, If A<B then C etc.

Expert Judgement/Input Opinion
- Conditions for occurrence with confidence levels: If A then usually B, If A and B then possibly C, If A<B then never C etc.

Subjective Novice Judgement/Input Opinion
- Conditions for occurrence based on imprecise or unqualified levels: If A then guess B, If A and B then possibly C, If A<B then usually C etc.

Quantification, Qualification

WHAT we should know in a tangible level if enterprise has in place;
- Tangible and existing data models
- Enterprise specific processes & procedures
- Conventional data bases & vaults (Benchmark data, statistical data etc)
- Conventional product model data (CAD, CAE, Tests etc)

Knowledge discovery then can be achieved via;
- Conventional Data - Knowledge Bases
- Conventional Data Processing
- CAE Modelling (Scenario, Discovery, Cognition)
- Data Mining
- Stakeholder - Social Expert Review

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CAE Model Interrogation

Comprehension – CAEs Domain

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Ratios, Interval or Measurable
- Physical Axiom Level
- Length, weight, angle

Product Requirements
- Marketing
- Design
- Development
- Validation

Explicit: Expressed in functions
- Ratio, Interval or Measurable:
  - Physical Axiom Level
  - Length, weight, angle

Statistical / Probabilistic:
- Relationships in functions

Logic & Rule-Based:
- Conditions for occurrence. If A then B, If A and B then C, If A < B then C etc

Expert Judgement / Input Opinion:
- Conditions for occurrence with confidence levels. If A then usually B, If A and B then possibly C, If A < B then never C etc

Subjective Novice Judgement / Input Opinion:
- Conditions for occurrence based on imprecise or unqualified levels. If A then guess B, If A and B then possibly C, If A < B then usually C etc

WHAT CAE can augment if enterprise has in place;
- Conventional Product Engineering
- Development systems infrastructure
- System Thinking Consortia

Knowledge discovery then can be achieved via the proposed Framework composed from;
- System Experts (PDP Development Panel)
- CAD/Design Expert
- CAE Experts
- PDP Managers / Facilitators
CAE Model Interrogation
Comprehension – Purposeful CAE Model Studies

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Quantification, Qualification

Explicit; Expressed in functions

Ratio, Interval or Measurable; Physical Axiom Level

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Concept Studies
- Factorial Studies
- Optimisation Studies
- Robustness Studies
- Correlation Studies

PDP Time

Knowledge Utilisation

Supported by Systems Engineering

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CAE Model Interrogation
Comprehension – Purposeful CAE Model Data Output

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CAE Model Interrogation

Comprehension – Purposeful CAE Model Data Output

A Set of Runs will yield results
CAE must check these results for validity & meaning

Once CAE physical model & data output proved satisfactory

Data mining begins

CAE Data Mining

Making Sense out of the CAE Model Output

• The challenges faced by the CAE community
  – There is often information ‘hidden’ in the data that is not evident
  – CAE Analysts may take sometimes weeks to discover useful information
  – A great proportion of the data is never analyzed at all

From: R. Grossman, C. Kamath, V. Kumar, "Data Mining for Scientific and Engineering Applications"
CAE output underpins numerous informational augmentations & inferences.

Good CAE practice a well thought combination of factors:

- Concept Studies
- Factorial Studies
- Optimisation Studies
- Robustness Studies
- Correlation Studies

The Journey of deceleration pulse/s
CAE Data Mining
Making Sense out of the CAE Model Output

Post Processing ???
A NEW Pre-Processing > Solving > Post Processing Cycle

From measurable data we **deduce**
- Energy dissipation at tire
- Energy dissipation at spoke
- etc.

From these data we **augment**
- Energy intensity at a specific $\Delta t$
- Inertia effects Vs stiffness
- etc.

Which leads to **infer** knowledge
- Energy intensity at X value corridor; Comfy, Stiff, Unpleasant
- Energy dissipation levels at Y value corridor when Z stiffness; Tire works harder, Fork Durability compromised….
- etc.
CAE Data Mining
Making Sense out of the CAE Model Output

Armed with this information / knowledge
Scripts are written to elicit knowledge - From CAE to PDP stakeholder specific

Simple Graph Representations then are defined
- Colour coding
- Graph clustering & segmentation
- CAE Graph / Vector customisation
- etc

Conclusions

- CAE is underutilised & not well integrated within PDP
- Full CAE toolset potential is unlocked if holistic and conceptual thinking precede them
  - CAE Assumptions, Tangibles, Metrics & Expectations are all defined at those early stages
- CAE is underutilising it’s own data (Analyst Vs Data Ratio)
- CAE has the capacity to become the PDP centre regarding the social relational process by changing CAE output semantics
- CAE has the capacity and the ability to provide a reliable framework for traceable decision making utilising the potential from its immense full mathematical formalism / logic
Questions?