Massachusetts Institute of Technology

Models in Engineering
Glossary

Anchoring bias is the tendency to use an initial piece of information to make subsequent judgments. Once an anchor is set, there is a bias toward interpreting other information around the anchor.

An **attribute** is a decision maker's perceived metric of how well a perceived objective is met.

Automation bias occurs when human operators in partially-automated systems rely excessively on automated solutions or processes without adequate monitoring and verification.

Black box model is a model that can only be viewed in terms of its inputs and outputs (or transfer characteristics), without any knowledge of its internal workings. Its implementation details are "opaque" (black) for the user.

The **change management process** in systems engineering is the process of requesting, planning, implementing, and evaluating changes to a system while supporting the processing and traceability of changes.

Clustering techniques are algorithms that enable the user to data sets into groups of similar traits, beyond that of simple visual exploration.

Confirmation bias is the tendency to only consider what confirms one's beliefs, and to ignore what contradicts one's beliefs.

Cost models are models that evaluate potential design in terms of the resources (mainly cost) required for their realization.

Cyber-physical gaps are the difference between what is happening in real life and what people get as input from systems, or what people perceive is happening in the real world.

A **database query** is a request for information from a database through one of the following three general methods:

- Choosing parameters from a menu: In this method, you choose the parameters from a list which the database system presents. This is perhaps the easiest but the least flexible method.
- Query by example (QBE): In this method, you specify the fields and values that define the query in the blank record presented by database system.
- Query language: In this method, you request information in the form of a stylized query that must be written in a special query language. This is the most complex but also the most powerful method.

A **data model** organizes elements of data and standardizes how data is connected to each other and how they are processed and stored inside the system.

A **decision maker** is a special type of stakeholder who has influence or control over driving the needs and setting up goals for the system.

Decision Matrix Method is a qualitative technique used to make design decisions by ranking possible design alternatives against a set of criteria options which are scored and summed to gain a total score which can then be ranked. It can weighted and unweighted. A weighted decision matrix operates in the same way as the basic decision matrix but introduces the concept of weighting the criteria in order of importance. The resultant scores better reflect the importance to the decision maker of the criteria involved. Refer to the next section for more details on different decision matrix methods.

Design decision is any decision that has an impact on the design or outcome of the end system is a design decision.

Design space is the span of possible alternative solutions to the system design problem, from which one or more could be picked and are under the control of the designer; usually consisting of distinct concepts, architectures, and particular designs.

Design Structure Matrix (DSM) is a simple, compact representation of a system or project in the form of a square matrix. It is the equivalent of an adjacency matrix in graph theory and is used in systems engineering and project management to model the structure of complex systems or processes.

Design-value loop perspective is the problem to solution decision-making approach using three types of models in two categories: evaluative models (performance and cost) and value models, that encourages feedback and explicit separation of objective (e.g. evaluative models) and subjective (e.g. value) considerations. The goal in this perspective is to find alternatives with a design space that best satisfy expectations on the value space.

Design variables are factors within the control of the designer or engineer, an endogenous factor (e.g. parameterizations of a design).

The Design Vector is a Nx1 matrix, where each component N represents degree of freedom in the system.

Development uncertainty is caused during the development of the system, including economic, political, cost, schedule, technology, requirement and constraint uncertainties.

Dominated designs interior points in the trade space such that one can typically find a higher utility design at the same cost, or lower cost at the same utility.

Empirical models are defined by mathematical equations generated by doing a regression analysis on empirical data that we have about the system. These mathematical equations, unlike the governing equations, only explain a system under certain conditions -- the ones for which we have data -- and cannot be used to reliably predict the general behavior of the system.

Enumeration lists the range and steps possible for each design variable (specifying the requirements for the inputs for evaluation models).

Evaluative models take design variables as input and predict performance and cost.

Failure mode and effects analysis (FMEA) is a structured and systematic technique of failure analysis. It helps identify potential failure modes based on experience with similar products and processes—or based on common physics of failure logic. This information can then be used to develop a V&V plan for testing these failure modes.

Fuzzy pareto set designs in the trade space that lie within k% distance from the pareto front. As k increases, the number of designs considered within the trade space increases as well.

Glyph plot is a type of multi-dimensional visualization that enables the designer to view up 7 dimensions including X, Y, Z axes, color, size, transparency and orientation.

An **interface control document (ICD)** in systems engineering describes the interface or interfaces between the systems under consideration. The purpose of the ICD is to communicate all possible inputs to and all potential outputs from a system for some potential or actual user of the system.

In numerical optimization, **Lagrange multipliers** is a method to maximize or minimize functions subject to given equality constraint(s).

An **MBSE critique** is a critical review and assessment of the whole model with a defined rationale.

Measurement scales are used to categorize and/or quantify attributes, variables. And measures. There are four scales of measurement that are commonly used in engineering analysis: nominal, ordinal, interval, and ratio scales. (Refer to next section for detailed discussion on scales.)

A **mode error** is an error where a user mistakes the situation or mode they believe the program or machine to be in and takes an action appropriate the perceived mode, but inappropriate in the real mode. For example, editing what is believed to be a test version of the code, when in fact, the edits are making changes to published code.

Model is a mathematical construct/representation of a system that has the ability to predict the emergence of the system under some specified operating conditions.

Model-Based Engineering (MBE) is an approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle. (Final Report, Model-Based Engineering Subcommittee, NDIA, Feb. 2011)

Model-Based Systems Engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. (INCOSE SE Vision 2020, INCOSE-TP 2004-004-02, Sep 2007)

Model benchmark is the process of validating against the predicted model response such as another validated model or experimental data.

Model credibility is the amount of trust that people have in the model's output to make decisions based upon it.

A **model curator** is a leadership role within an organization who helps organize and classify models. He or she also helps teams pick the right models to help them achieve their end goals and helps set up model configuration related processes for the particular project. Model curators are the go-to people for any modeling-related questions and concerns within the organization.

Model Development Process (MDP) is a rigorous step-by-step method to create a model that is ready for use.

Model fidelity is the quality of the model's output, i.e. the degree to which the model acts as a sufficient representation of the real-world system it is based on.

Model investment bias occurs when the more money and time invested in developing the model, the more people have a false sense of security that whatever the model comes up with must be correct.

A **model owner** is the single point of reference for making decisions for the model. Typically the model owner is the one who understands the cost of building and configuring the model and also has authority to change the model.

Model uncertainty can arise due to system predictions, such as when simulated performance and system performance differ.

Model V&V is a process conducted during the development of a model with the ultimate goal of producing an accurate and credible model. It is a very important step, as generally models are approximate imitations of real-world systems. Due to this, a model should be verified and validated to the degree needed for the model's intended purpose or application.

In a model, a **module** can be defined as a finite group of tightly coupled mathematical relationships that are under the responsibility of a particular individual or organization.

Monte Carlo methods are a class of numerical methods that relies on generating suitable random numbers.

Multi-Attribute Tradespace Exploration (MATE) is a conceptual design methodology that applies decision theory to model and simulation-based design.

Multidisciplinary design optimization (MDO) is a field of engineering that incorporates a number of disciplines while solving optimization design problems. MDO allows designers to incorporate the relevant disciplines simultaneously which can result in a superior design as compared to optimizing each discipline sequentially.

Nominal model covers the basic outcomes from the system without going into detail about the contingencies and emergency conditions.

The **Objective Vector** is a Nx1 matrix, where each component N represents an output of the model.

Operational uncertainty can occur after the system is developed, such as changing political and market conditions, and changes in operational environment.

Parallel coordinate plot is a type of multi-dimensional visualization that plots each dimension as a coordinate with a lowerbound and upperbound, with each design connecting the different coordinates.

Pareto front (or frontier) is the set of non-dominated alternatives (e.g. architectures) within the tradespace analysis.

Performance models evaluate potential design in terms of capabilities or performance they provide to help address the underlying goals and objectives. These are usually related to the behavior of the design, such as top speed, range, efficiency, etc.

Physics-based models are defined by governing equations that have been proven to explain the dynamics of certain systems. The models could be discretized, continuous, or transient.

The **Pugh Concept Selection Method** uses a simple matrix and pre-established criteria to compare design options using subjective opinions to compare alternatives against a baseline (datum), which may be one of the alternatives or current product or service.

Requirement traceability is a discipline concerned with documenting the l requirement and providing bi-directional traceability between various associated requirements through the life of the product.

Sampling is the strategy for selecting a subset of designs to evaluate from the enumerated potential design space (usually taking into account resource constraints in running evaluation models).

Scatter matrix plot is a type of multi-dimensional visualization that enables the designer to view all combinations of 2-D Scatter Plots.

Sensitivity is a measure of the impact on (outcome) metrics caused by a given decision (e.g. an assumption).

A **sensitivity analysis** is a technique used to determine how different values of one or several independent variables impact the dependent variable/s.

Simulation is a process that instantiates a model under a given set of operating conditions for prediction of future behavior.

Stakeholder salience defines the degree to which the stakeholders give priority to competing criteria variables in their decision-making process. In a tradeoff study, stakeholder salience may inform weighing of criteria.

Statistical process control (SPC) is a statistical quality control method applied in order to monitor and control a process. SPC can be applied to any process where the "conforming product" (product meeting specifications) output can be measured. Key tools used in SPC include control charts; a focus on continuous improvement; and the design of experiments. An example of a process where SPC is applied is manufacturing lines.

A **system** is a set of entities and their relationships, whose functionality is greater than the sum of individual entities.

Tradespace is a representation of the outputs of a design model that looks like a two (or more) dimensional plot. The axes of the plot are metrics of interest, such as "performance" and "cost". The points in a tradespace represent potential designs.

Tradespace exploration can be defined as quantitatively exploring the relationships within a large multivariable design space to identify feasible alternatives that satisfy multiple interconnected boundary conditions and objectives, typically in support of designing, selecting, or optimizing a given system.

A **trade study** or **tradeoff study** is the decision-making activity to choose an optimal solution from a set of proposed viable solutions on the basis of benefit to the overall system and its stakeholders.

The **utopia** point is an instance within the tradespace where all analyzed metrics are maximized.

The **"V" Model** is a graphical representation of the systems development life cycle. It summarizes the main steps to be taken in conjunction with the corresponding deliverables within the system validation framework.

Validation is the assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers.

Value is the experienced net benefit at a cost, taking into account importance and scarcity, that will result from the system. Different stakeholders will perceive value differently and it will likely vary over time.

Value metric converts the attributes of a design into a measure of preference(s) of the decision makers, thereby aiding them in choosing between disparate alternatives. Value metrics are quantitative, although it is often dimensionless and may be relative.

Value models assign quantitative scores to potential design in terms of the perceived satisfaction, or benefit at cost, they generate while addressing the underlying goals and objectives.

Verification is the evaluation of whether or not a product, service, or system complies with a regulation, requirement, specification, or imposed condition. It is often an internal process.

Verification and Validation (V&V) are independent procedures that are used together for checking that a product, service, or system meets requirements and specifications, and that it fulfills its intended purpose.

White box model is a model where in addition to the inputs and outputs, the inner components or logic can be viewed but usually cannot be altered. These are the opposite of black box models and are sometimes known as "clear box" or "glass box".