Beyond System Modeling:
Extending SysML for
Goal-driven Generative Design

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Product Manager
Autodesk
Create a specification of an object or a system, intended to accomplish goals in a particular environment, using a set of primitive components, satisfying a set of requirements and subject to constraints.

-Wikipedia
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-Wikipedia
Unlocking Generative Design

INSPIRE → GENERATE → EXPLORE → FABRICATE
Systems Engineering Process
Natural language?

- Colored a light off-white (Fog) or light gray (Platinum)
- Inlaid three-dimensional Apple logo, diamond cut to the exact shape
- Zero-draft enclosures, with no variances in case thickness and perpendicular walls
- Recessed international port identification icons and silk-screened product name badging
- Shallow horizontal and vertical lines, 2 mm wide, 2 mm deep, spaced 10 mm apart on center, which run along any and all of the surfaces of the product, some of which act as vents and setback 30 mm from the front and 4 mm from the back.

...
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Description Logic?

|=(defconcept furniture)
|c| FURNITURE
|=(defconcept office-furniture (?f furniture))
|c| OFFICE-FURNITURE
|=(defconcept desk (?f OFFICE-furniture))
|c| DESK
|=(defconcept color (?c) :=> (member-of ?c (setof green red blue)))
|c| COLOR

...
Model-based Systems Engineering

- **Formalize system modeling for:**
  - Consistency of requirements / specification information
  - Model organization (generalization / specification) and reuse
  - Automated verification and validation

![Diagram of Model-based Systems Engineering](image-url)
SysML Diagrams

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Application examples
Relevance to Goal-driven Generative Design

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Structure
- ibd
- act
- req
- par

Behavior

Requirements
- Rotational Energy
- Air Flow
- Noise Threshold

Solution

INTAKE
COMPRESSION
COMBUSTION
EXHAUST

Air Inlet
Combustion Chambers
Turbine
Cold Section
Hot Section
Example 1: Modeling Lightening Motorcycle Swingarm

THE FUTURE OF MAKING THINGS

LIGHTNING MOTORCYCLE BUILT THE WORLD’S FASTEST PRODUCTION BIKE.

AND IT'S ELECTRIC.
Block Definition Diagram

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Problem Definition
Problem Definition
Problem Definition
Generated Swing Arm
Example 2: Modeling Formula 1 Roll Hoop
ARTICLE 15 : CAR CONSTRUCTION
15.2 Roll structures :
15.2.1 All cars must have two roll structures which are designed to help prevent injury to the driver in the event of the car becoming inverted. The principal structure must be at least 940mm above the reference plane at a point 30mm behind the cockpit entry template. The second structure must be in front of the steering wheel but no more than 250mm forward of the top of the steering wheel rim in any position. is 1050mm in front of the rear of the cockpit.

ARTICLE 17 : ROLL STRUCTURE TESTING
17.2 Principal roll structure test :
A load equivalent to 50kN laterally, 60kN longitudinally in a rearward direction and 90kN vertically, must be applied to the top of the structure through a rigid flat pad which is 200mm in diameter and perpendicular to the loading axis.

...
Requirements – F1 regulations

Step 1: Harvest Requirements

- 100mm behind the rearmost pedal face
- 50mm behind the front roll structure
- Article 14.6.3
- Article 14.6.7
Future Work
Existing SysML Tools

- Magic Draw (No Magic)
- Rational Rose (IBM)
- Enterprise Architect (Sparx Systems)
- SCADE (ANSYS)
- Papyrus (Eclipse community)
Automatic Knowledge Extraction

- Extract relationships between components

NLP + Machine Learning
• Extract component-function knowledge

Motor Controller: Control-Motor
Motor: Generate-Torque
Pump: Pump-Air
Tank: Store-Air
Knowledge extraction - search

Relation Search Engine

Subject  Verb  Object

Search

Example queries:

Subject: turbocharger
(what does a turbocharger do?)

Subject: engine Object: wheel
(what's the relationship between an engine and a wheel?)

Verb: dissipate Object: heat
(which object can / how can we dissipate heat?)
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