SMSWG March Meeting

09 Mar 2021

Greg Garstecki
Principal Consultant

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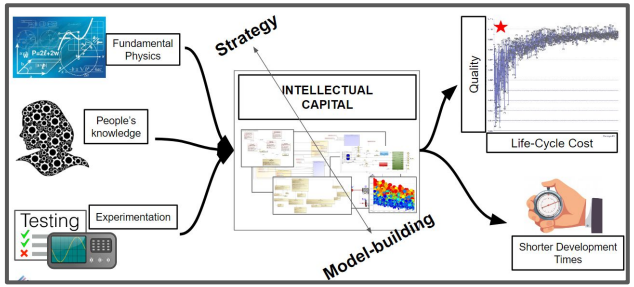
MODELING SOLUTIONS

GMS Founder and Principal Consultant



- 32 years in industry with a focus on performance simulations
- I have always had desire to understand the component or systems in its larger context.
- Career evolution into Systems Engineering
- I want to help other companies realize the benefits of Systems Engineering.

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Requirement Decomposition

Using analytical models to decompose requirements

Main contents

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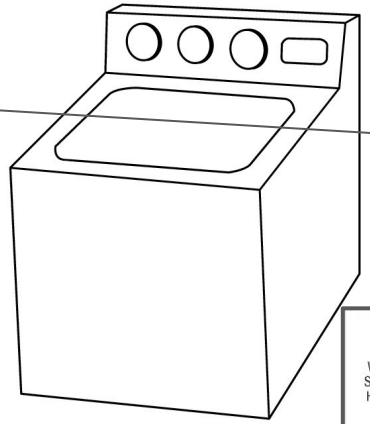
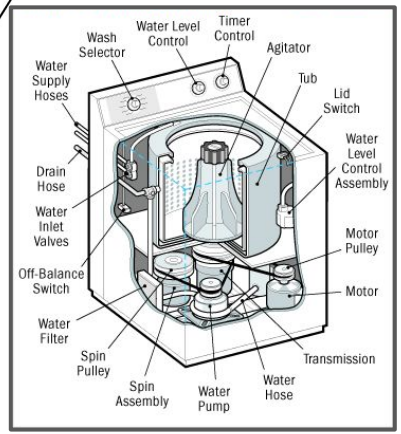
How Do You Specify Requirements for Components?

Usability Requirements

Clean Clothes Requirements



Service Requirements



Energy Requirements

Noise & Vibration Requirements

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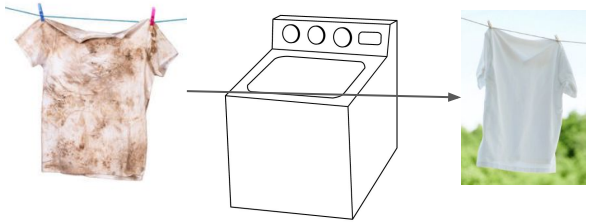
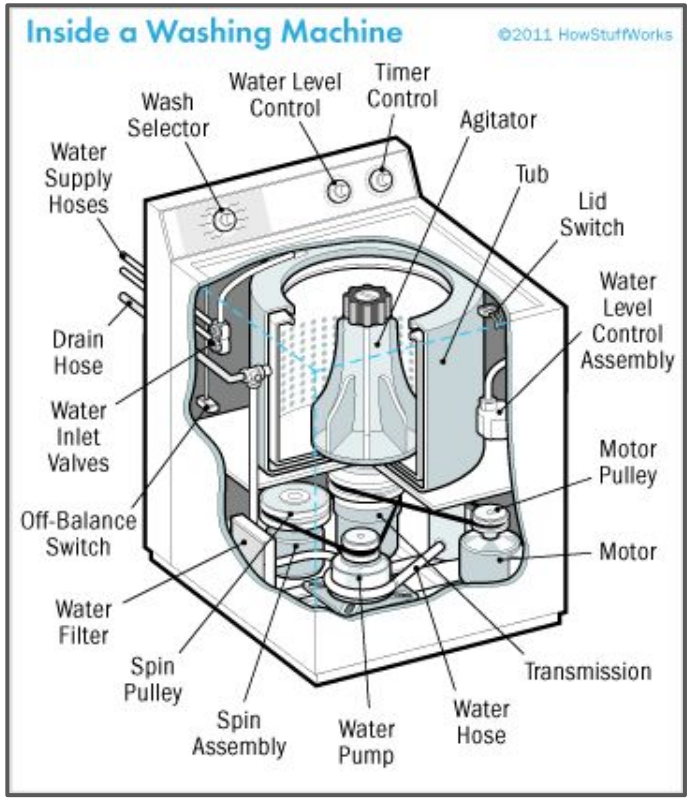
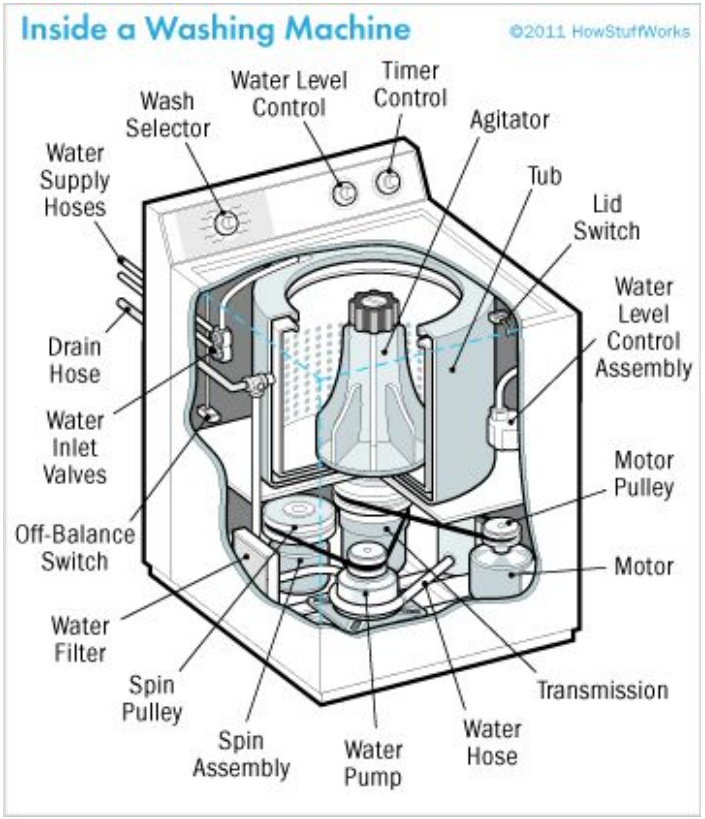
System Requirements Decomposition Focus





System Requirements Decomposition Elements



Stakeholder Needs

Verification test case

Functions

Product Level Requirements

Understanding the product architecture

Parametrics

Analytical Models

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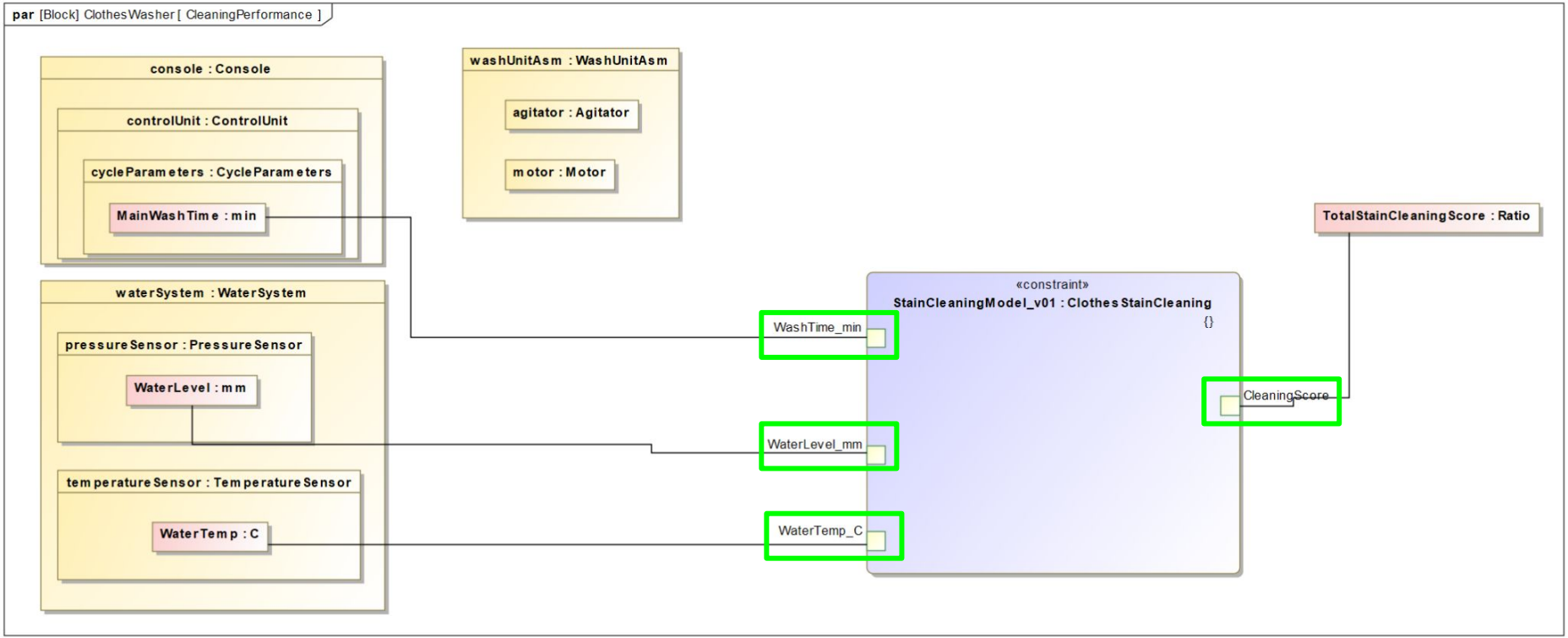
Parametrics - Descriptive to Analytical linkage



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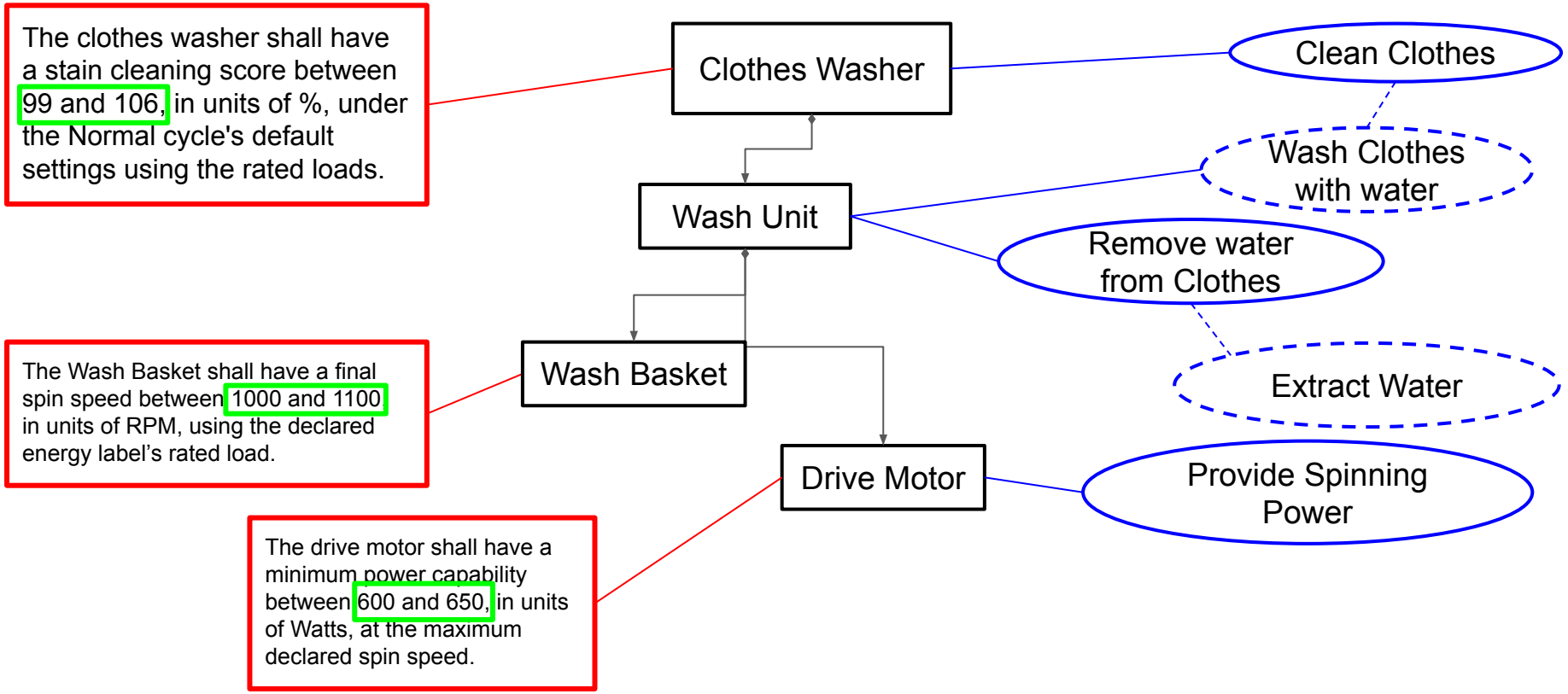
Functions to Requirements Example



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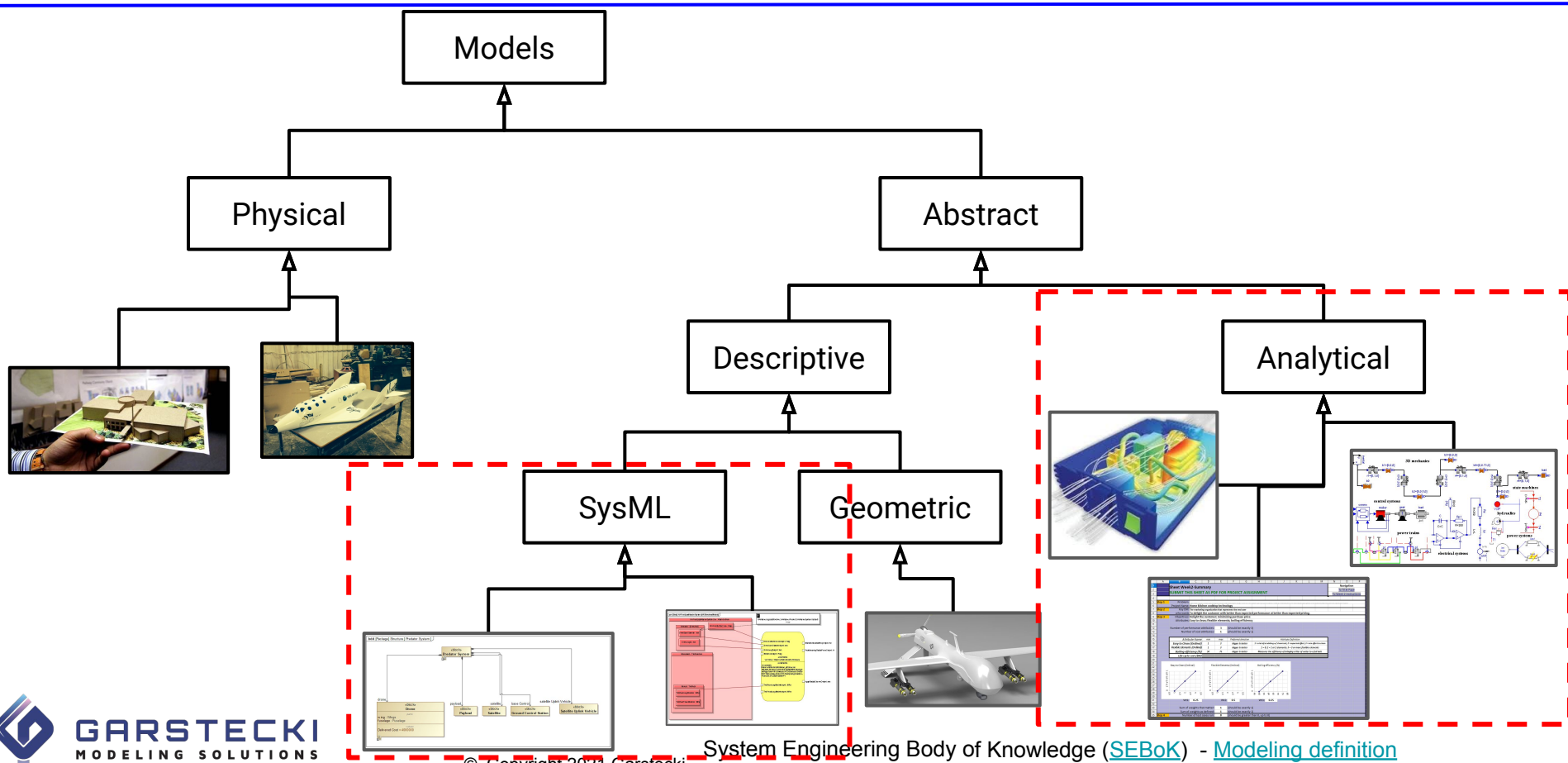
Model Definitions



System Engineering Body of Knowledge (SEBoK) - Modeling definition

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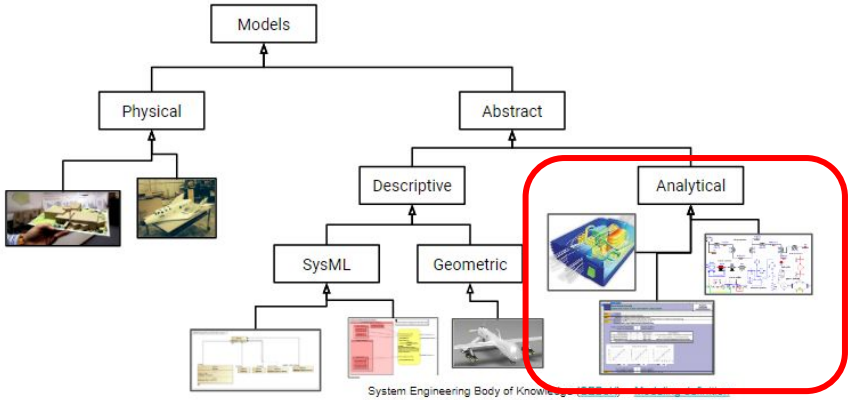
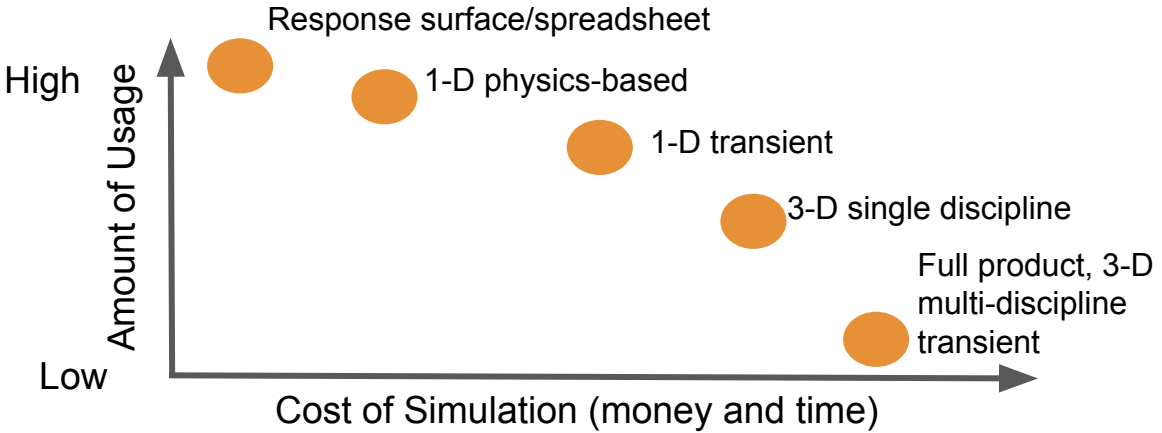
Analytical Modeling Types and Value





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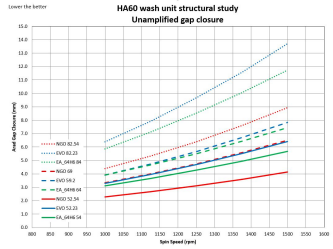
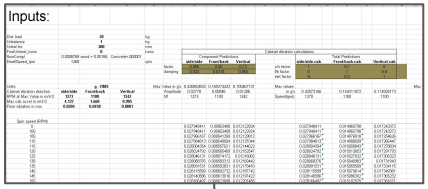
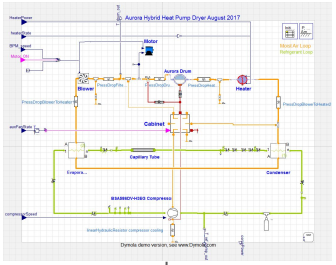
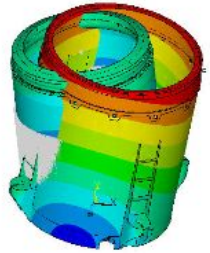
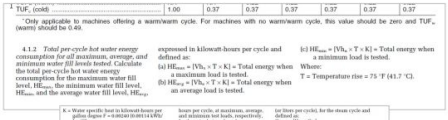
Analytical Modeling Examples

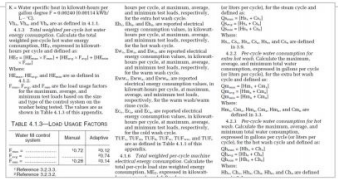


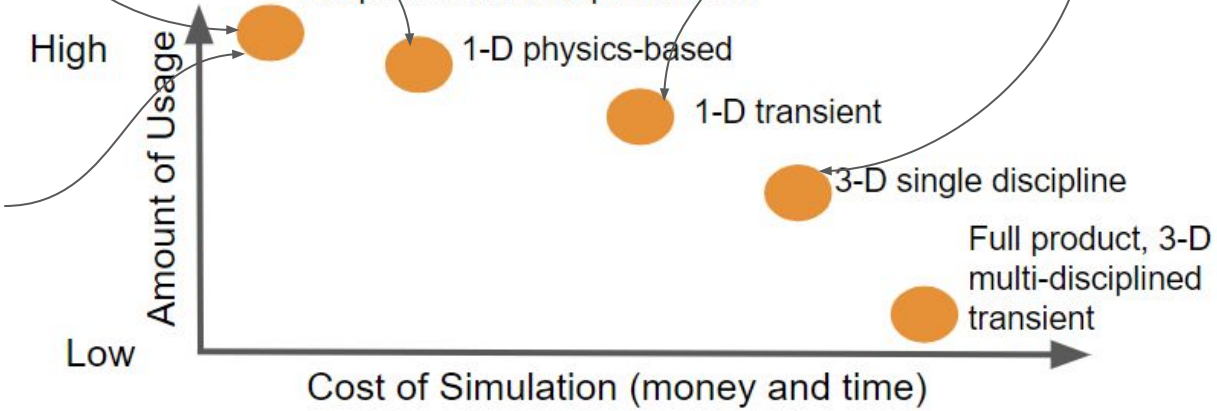












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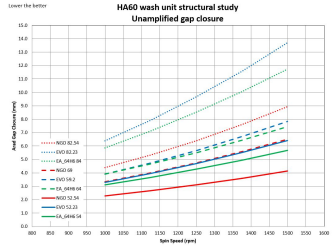
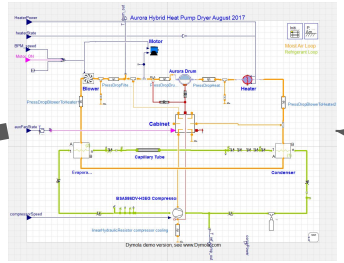
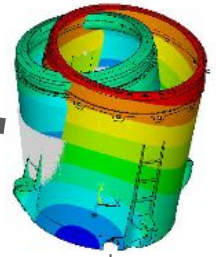
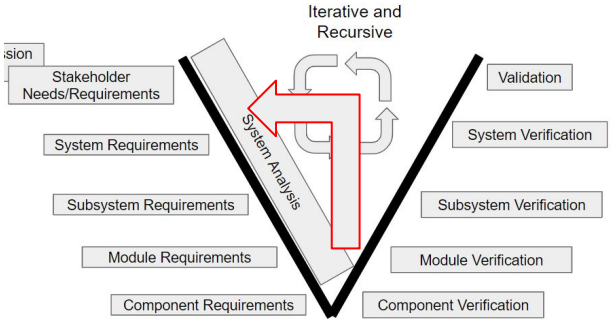
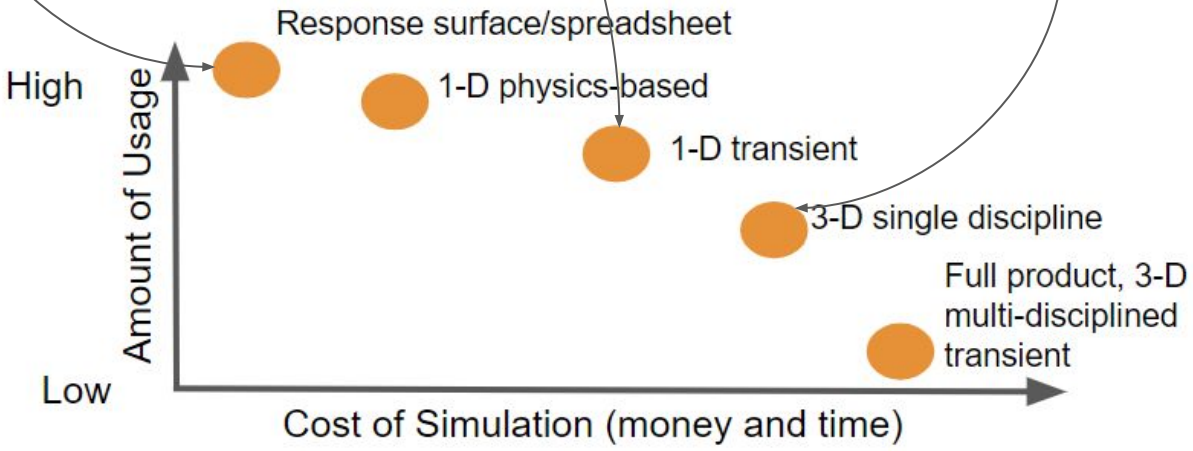
Analytical Modeling “Family”











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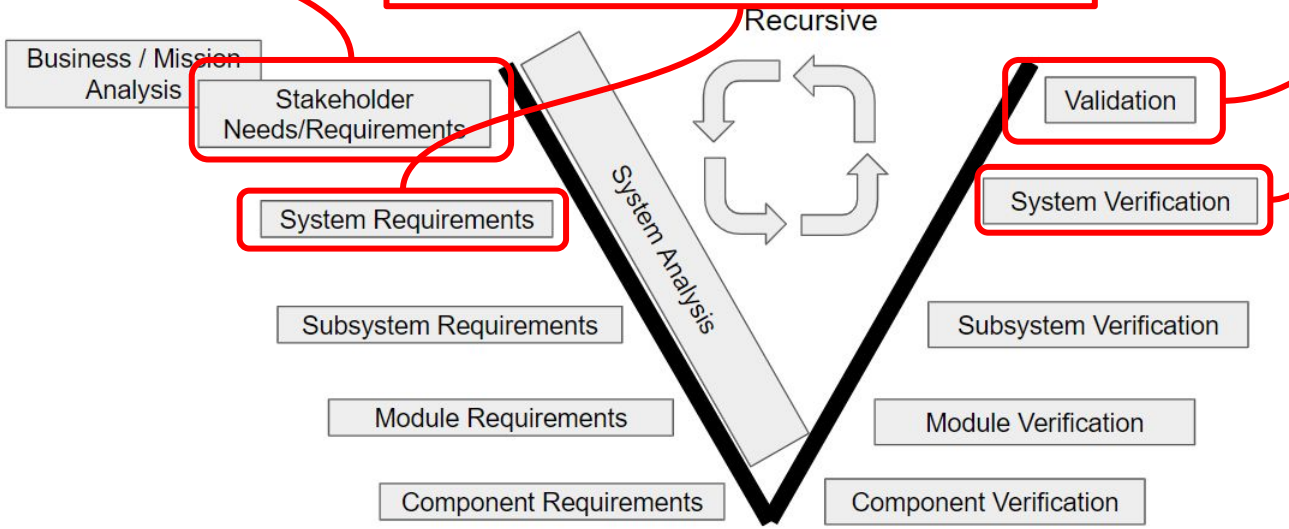
Bringing it all together.

I want to sell a product that has a U.S. Energy Star rating of Tier 3.

The clothes washer system shall have a MEF value between 3.0 and 3.5, in units of cubic foot per kWhr, under the declared Energy cycle's default settings using the rated loads.

U.S. DOE Standard Appliance test procedure 10 CFR430.23(j) Appendix J2



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Requirement Decomposition Insights

TUF_c (cold)	1.00	0.37	0.37	0.37	0.37	0.37	0.37

*Only applicable to machines offering a warm/warm cycle. For machines with no warm/warm cycle, this value should be zero and TUF_w (warm) should be 0.49.

4.1.2 *Total per-cycle hot water energy consumption for all maximum, average, and minimum water fill levels tested.* Calculate the total per-cycle hot water energy consumption for the maximum water fill level, HE_{max}, the minimum water fill level, HE_{min}, and the average water fill level, HE_{avg}, expressed in kilowatt-hours per cycle and defined as:

(a) $HE_{max} = [Vh_s \times T \times K]$ = Total energy when a maximum load is tested.

(b) $HE_{avg} = [Vh_a \times T \times K]$ = Total energy when an average load is tested.

(c) $HE_{min} = [Vh_a \times T \times K]$ = Total energy when a minimum load is tested.

Where:

T = Temperature rise = 75 °F (41.7 °C).

K = Water specific heat in kilowatt-hours per gallon degree F = 0.00240 [0.00114 kWh/L – °C).

Vh_s, Vh_a, and Vh_c are as defined in 4.1.1.

4.1.3 *Total weighted per-cycle hot water energy consumption.* Calculate the total weighted per-cycle hot water energy consumption, HE_T, expressed in kilowatt-hours per cycle and defined as:

$HE_T = [HE_{max} \times F_{max}] + [HE_{avg} \times F_{avg}] + [HE_{min} \times F_{min}]$

Where:

HE_{max}, HE_{avg}, and HE_{min} are as defined in 4.1.2.

F_{max}, F_{avg}, and F_{min} are the load usage factors for the maximum, average, and minimum test loads based on the size and type of the control system on the washer being tested. The values are as shown in Table 4.1.3 of this appendix.

TABLE 4.1.3—LOAD USAGE FACTORS

Water fill control system	Manual	Adaptive
F_{max} =	[1]0.72	[2]0.12
F_{avg} =		[2]0.74
F_{min} =	[1]0.28	[2]0.14

[1] Reference 3.2.3.3.
[2] Reference 3.2.3.2.

hours per cycle, at maximum, average, and minimum test loads, respectively, for the extra hot wash cycle.

Eh_x, Eh_a, and Eh_n are reported electrical energy consumption values, in kilowatt-hours per cycle, at maximum, average, and minimum test loads, respectively, for the hot wash cycle.

Ew_x, Ew_a, and Ew_n are reported electrical energy consumption values, in kilowatt-hours per cycle, at maximum, average, and minimum test loads, respectively, for the warm wash cycle.

Eww_x, Eww_a, and Eww_n are reported electrical energy consumption values, in kilowatt-hours per cycle, at maximum, average, and minimum test loads, respectively, for the warm wash/warm rinse cycle.

Ec_x, Ec_a, and Ec_n are reported electrical energy consumption values, in kilowatt-hours per cycle, at maximum, average, and minimum test loads, respectively, for the cold wash cycle.

TUF_x, TUF_a, TUF_h, TUF_w, TUF_{ww}, and TUF_c are as defined in Table 4.1.1 of this appendix.

4.1.6 *Total weighted per-cycle machine electrical energy consumption.* Calculate the total per-cycle load size weighted energy consumption, ME_T, expressed in kilowatt-hours per cycle (or liters per cycle), for the steam cycle and defined as:

$Qs_{max} = [Hs_x + Cs_x]$
$Qs_{avg} = [Hs_a + Cs_a]$
$Qs_{min} = [Hs_n + Cs_n]$

Where:

Hs_x, Cs_x, Hs_a, Cs_a, Hs_n, and Cs_n are defined in 3.9.

4.2.2 *Per-cycle water consumption for extra hot wash.* Calculate the maximum, average, and minimum total water consumption, expressed in gallons per cycle (or liters per cycle), for the extra hot wash cycle and defined as:

$Qm_{max} = [Hm_x + Cm_x]$
$Qm_{avg} = [Hm_a + Cm_a]$
$Qm_{min} = [Hm_n + Cm_n]$

Where:

Hm_x, Cm_x, Hm_a, Cm_a, Hm_n, and Cm_n are defined in 3.3.

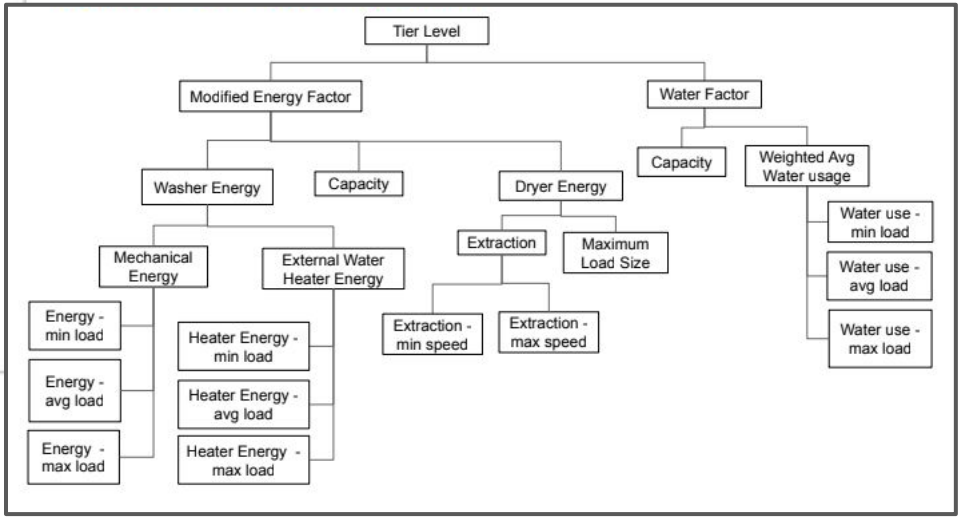
4.2.3 *Per-cycle water consumption for hot wash.* Calculate the maximum, average, and minimum total water consumption, expressed in gallons per cycle (or liters per cycle), for the hot wash cycle and defined as:

$Qh_{max} = [Hh_x + Ch_x]$
$Qh_{avg} = [Hh_a + Ch_a]$
$Qh_{min} = [Hh_n + Ch_n]$

Where:

Hh_x, Ch_x, Hh_a, Ch_a, Hh_n, and Ch_n are defined

U.S. DOE Standard Appliance test procedure 10 CFR430.23(j) Appendix J2



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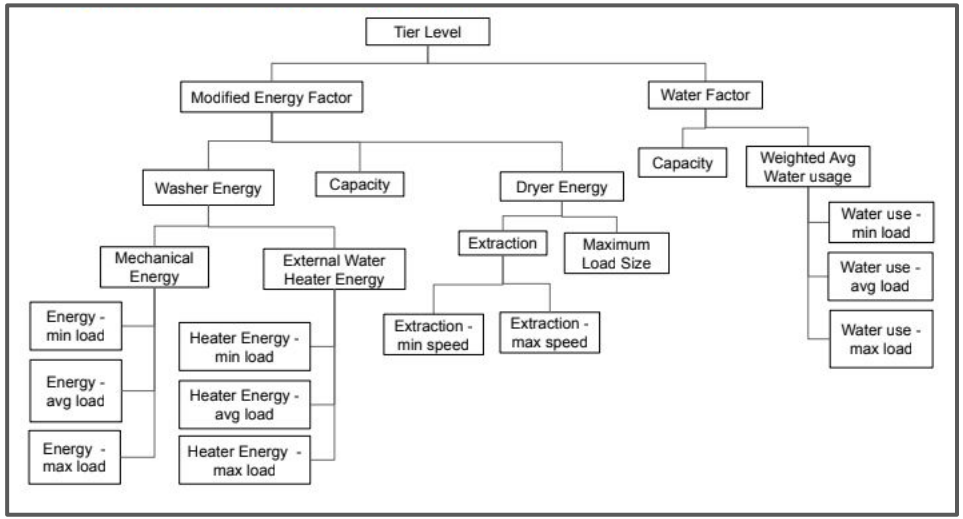
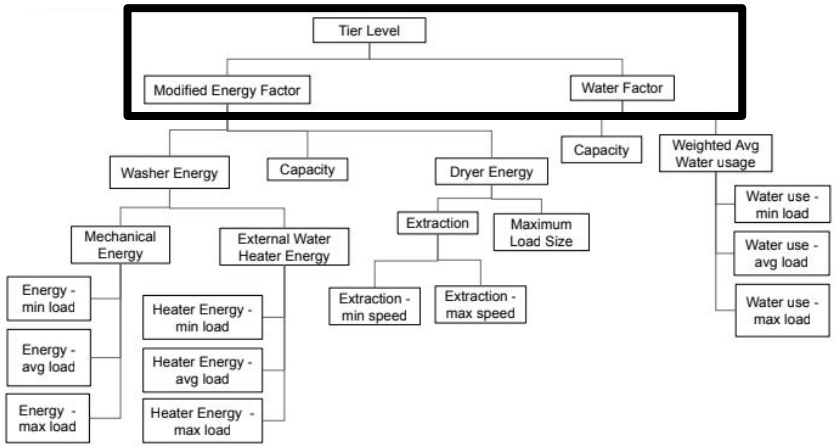
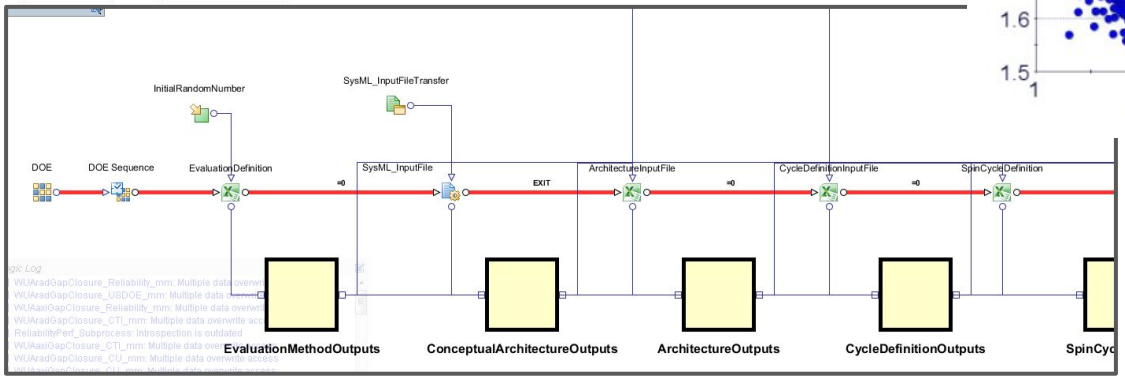
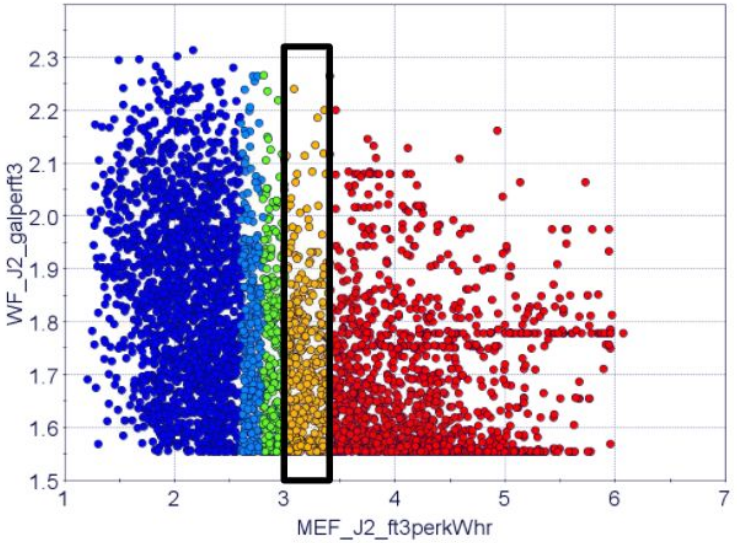
Requirement Verification method

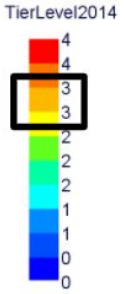


Requirement Decomposition









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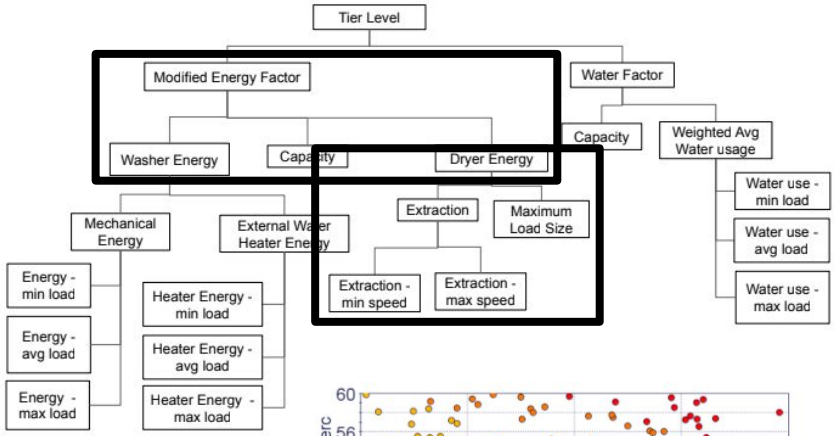
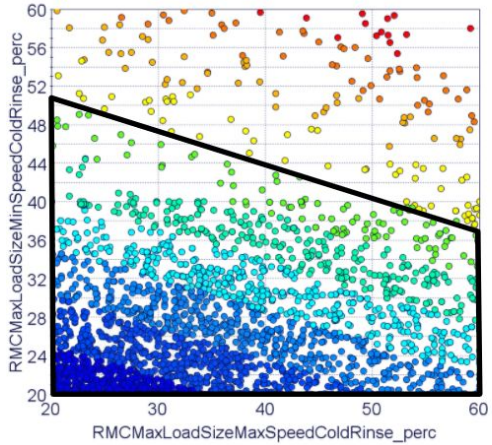
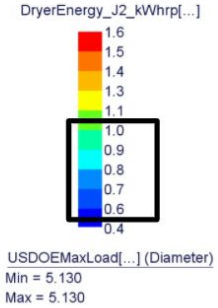
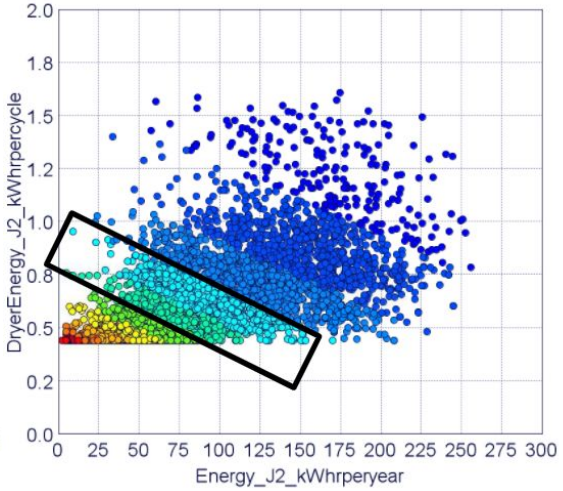
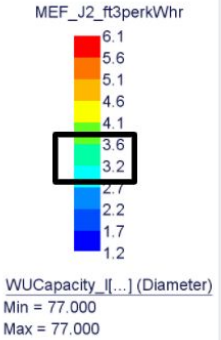
Requirement Decomposition



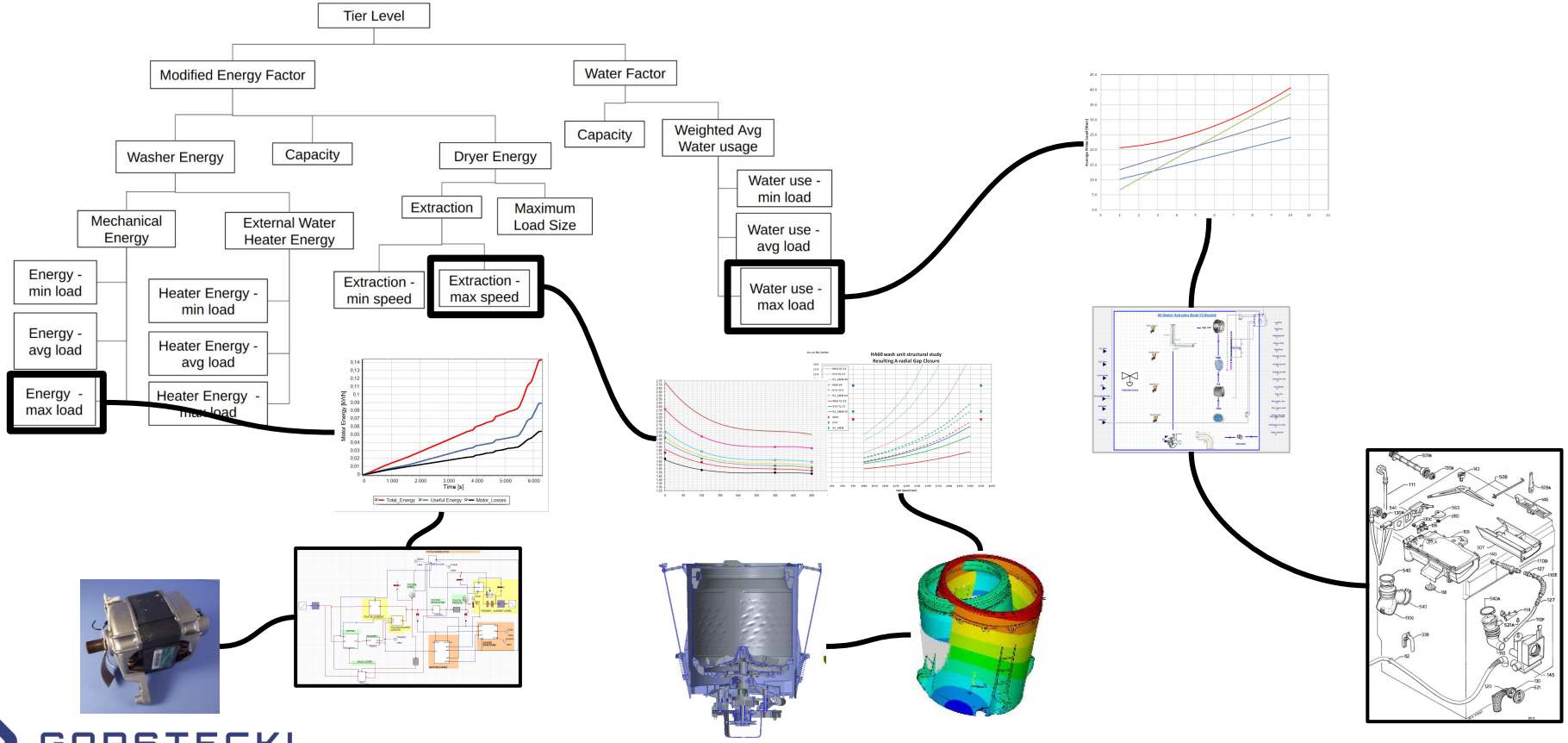




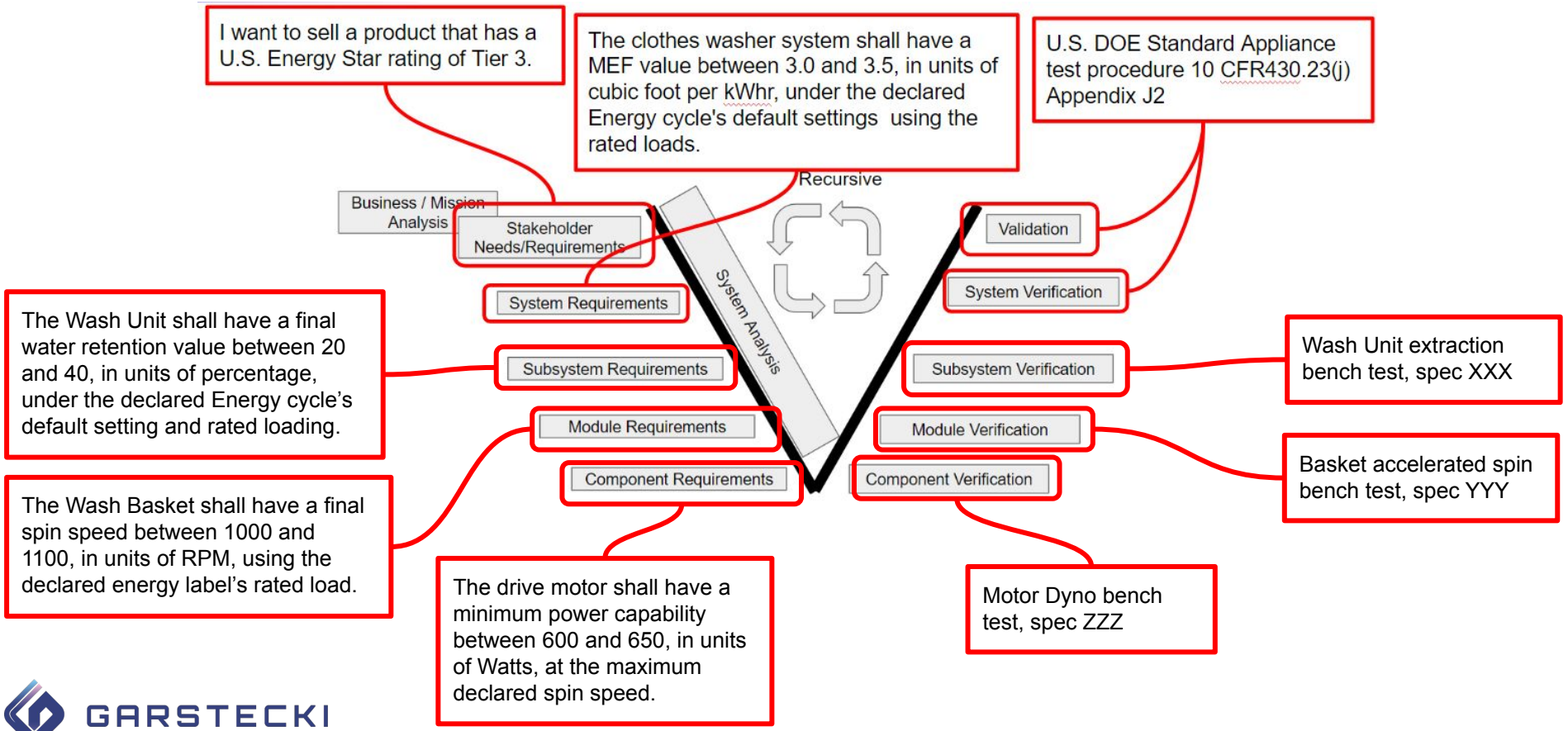




Continuation of the Requirement Decomposition



Resulting Requirement Example



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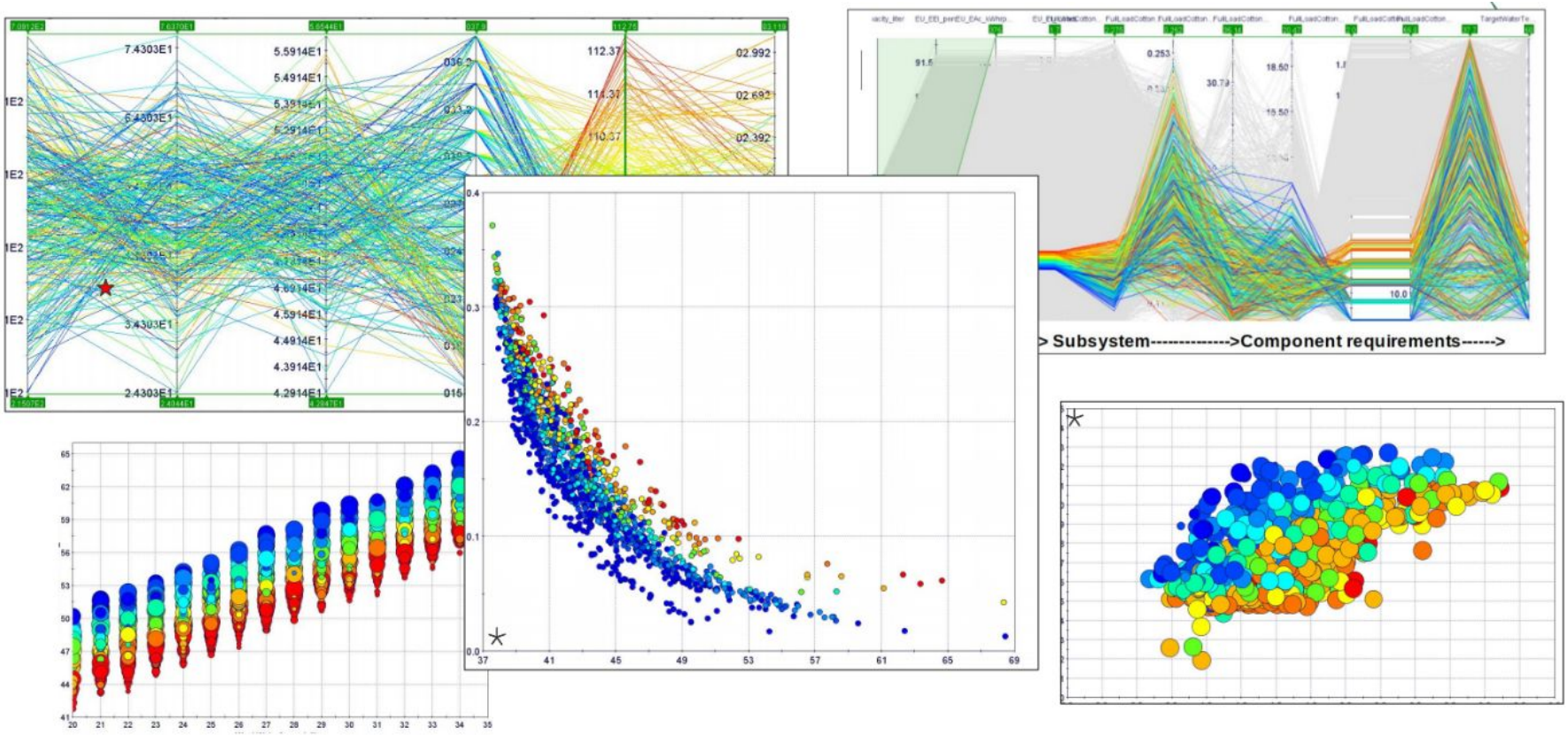
Tradespace and Project Decisions



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THANK YOU!