CAS 741, CES 741 (Development of Scientific Computing Software)

Fall 2019

21 Artifact Generation

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Artifact Generation

- Administrative details
- Questions about MIS?
- Artifact generation (Drasil)

Administrative Details

- For final documentation, make sure you have **addressed and closed** all open issues
- MIS Marking Scheme
  - On Avenue
  - Not all of the spec has to be formal
  - First steps
    - Syntax of access programs
    - State variables?
    - Environment variables?
- Course evaluation
  - Thurs, Nov 21, 10:00 am to Thurs, Dec 5, 11:59 pm
  - https://evals.mcmaster.ca

Administrative Details: Deadlines

MIS	Week 11	Nov 23
Unit VnV or Impl. Present	Week 12, 13	Wed, Nov 28, Dec 5
Unit VnV Plan	Week 13	Dec 3
Final Doc	Week 14	Dec 10

Combine Unit VnV Plan deadline with Final Doc deadline?

Administrative Details: Presentation Schedule

- Unit VnV Plan or Impl. Present
  - Wednesday (Nov 28): Brooks, Vajiheh
  - Wednesday (Dec 5): Olu, Karol
- Can present anything related to the implementation or testing
  - Code
  - Tools used
  - Testing
  - Unit VnV Plan
  - API documentation via doxygen
  - As always it is fine to show work in progress
  - Good to bring questions to the class

Questions?

- Questions about MIS

Abstract

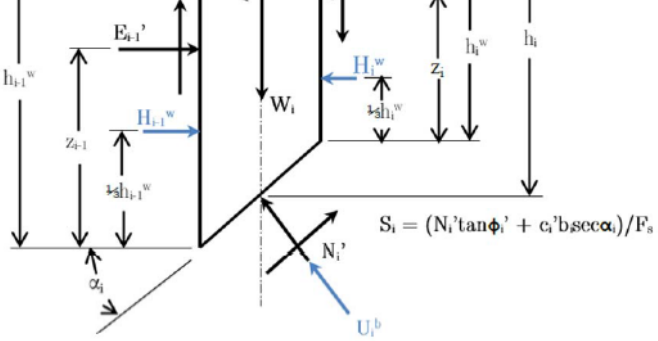
- **Goal** – Improve quality of SCS
- **Idea** – Adapt ideas from SE
- **Document Driven Design**
  - Good – improves quality
  - Bad – "manual" approach is too much work
- **Solution**
  - Capture knowledge
  - Generate all things
  - Avoid duplication
  - Traceability
- **Showing great promise**
  - Significant work yet to do
  - Looking for examples/partners

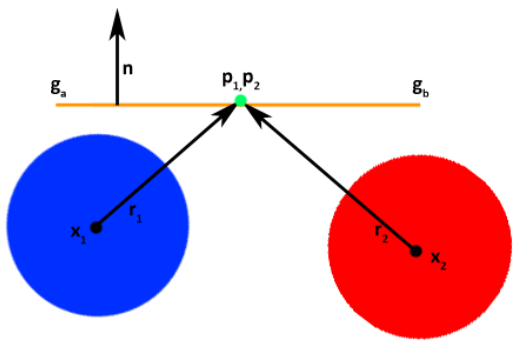
Scope: Large/Multiyear

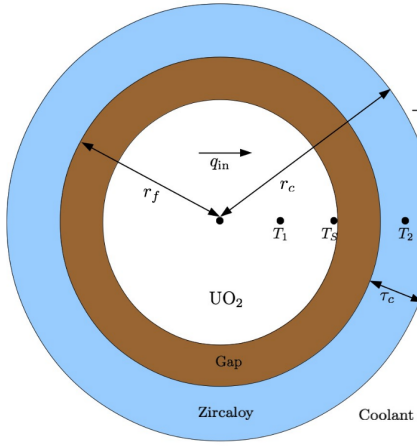
Sc

Scope: End User Developers

Scope


E_{i-1}'
H_{i-1}^w
W_i
H_i^w
z_i
h_i^w
h_i
z_{i-1}
h_{i-1}^w
$\frac{1}{3}h_{i-1}^w$
$\frac{1}{3}h_i^w$
α_i
N_i'
U_i^b
$S_i = (N_i'\tan\phi_i' + c_i'b_i\sec\alpha_i)/F_s$

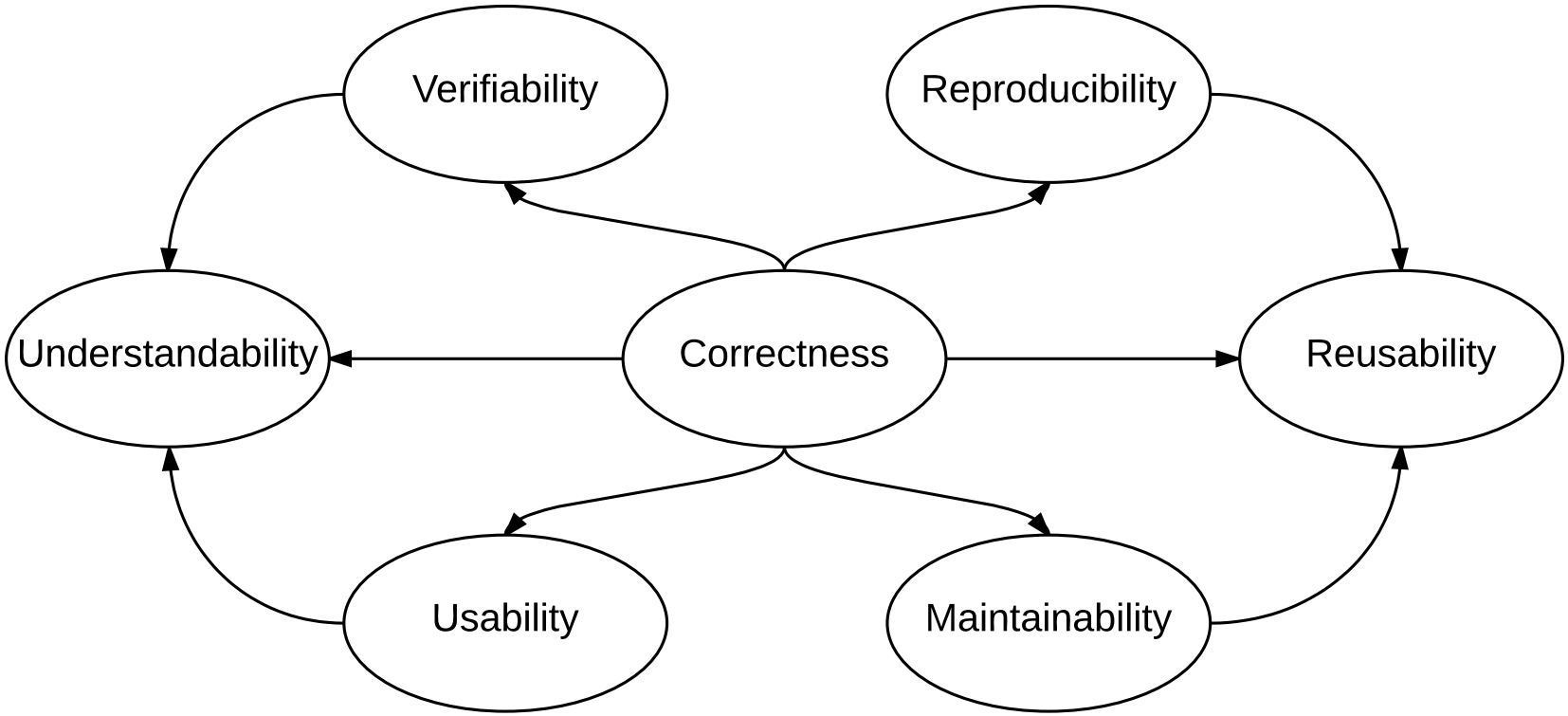

g_a
n
p_1, p_2
g_b
x_1
r_1
r_2
x_2


q_{in}
r_f
r_c
T_1
T_s
T_2
UO_2
τ_c
Gap
Zircaloy
Coolant

Motivation: Safety

Motivation: (Re)certification

Motivation: Improve Quality



Current Approach

- Agile like [**?**]
- Amethododical [**?**]
- Knowledge acquisition driven [**?**]
- Each stage reports counterproductive [**?**]
- Limited tool use [**?**]
- Limited testing of code [**?**]
- Lack of understanding of testing [**?**]
- Missed opportunities for reuse [**?**]
- Emphasis on:
  1. Science [**?**]
  2. Code

Documentation Advantages

- Improves verifiability, reusability, reproducibility, etc.
- From [**?**]
  - easier reuse of old designs
  - better communication about requirements
  - more useful design reviews
  - easier integration of separately written modules
  - more effective code inspection
  - more effective testing
  - more efficient corrections and improvements
- New doc found 27 errors [**?**]
- Developers see advantage [**?**]

Study Of Documentation in SC [?]

1. Select 5 small to medium size SCS
2. Interview code owners
3. Redevelop using Document Driven Design (DDD)
4. Interview code owners
5. Analyze responses

Summary of Case Studies

	LOC	Lng	ND	Ag	SE	Prg	Tst	VC	Bug
SWHS	1000	F77	1	5	✗	✓	✗	✗	✗
Astro	5000	C	2	10	✗	✓	✗	✗	✗
Glass	1300	F90	1	<1	✗	✓	✗	✗	✗
Soil	800	M	1	5	✓	✓	✓	✓	✗
Neuro	1000	M	1	5	✓	✓	✗	✓	✗
Acoust	200	M	4	2.5	✗	✓	✗	✗	✗

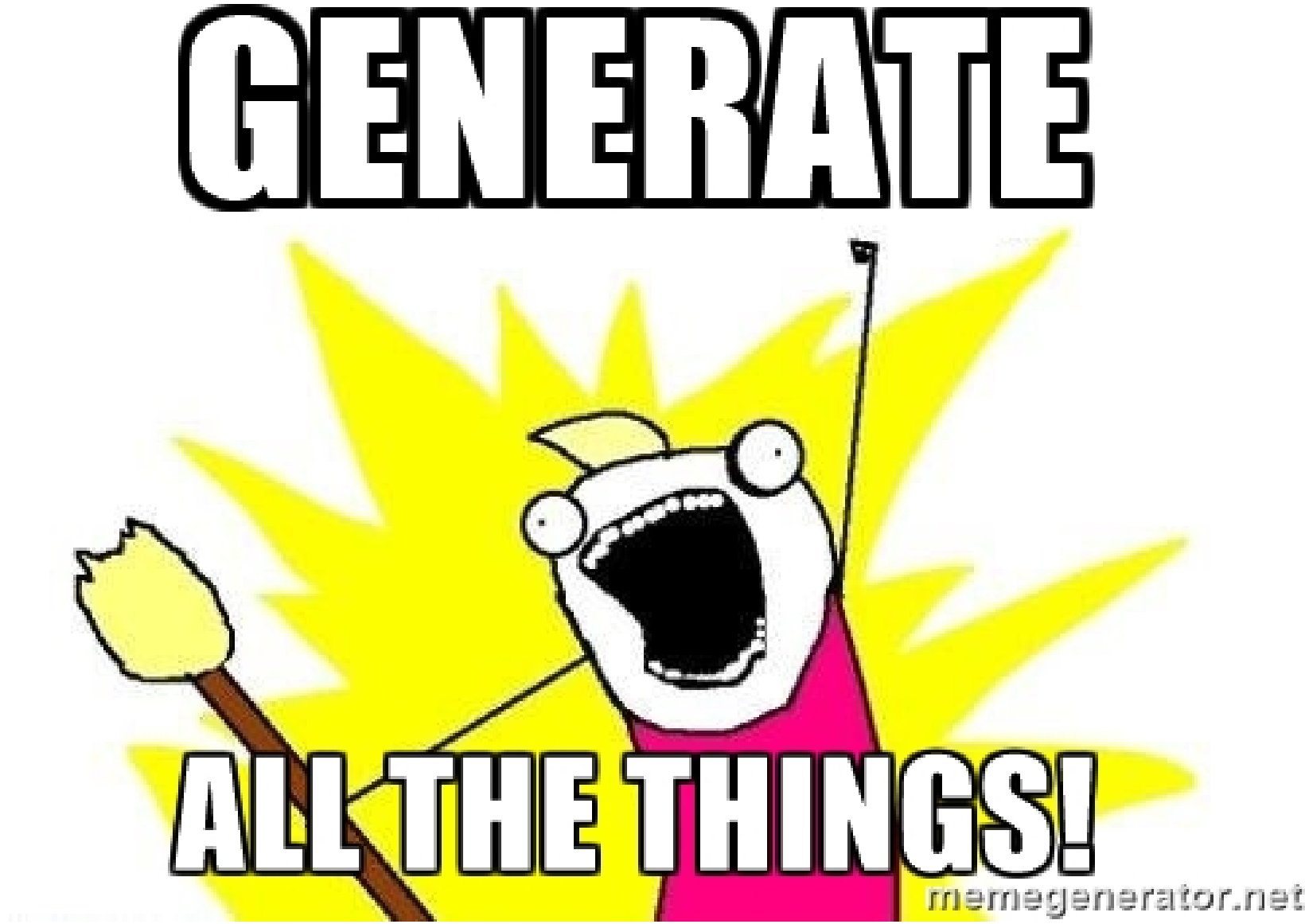
Perceived Advantages from Participants

- Documentation of assumptions
- All variables have explicit units
- SRS helpful with new graduate students
- Modules result in more user friendly code
- Traceability between modules and requirements useful
- Better organized code
- Information sharing on design choices
- Detailed record of knowledge capital
- Code is produced to make testing easier

Disadvantages (Perceived and Real)

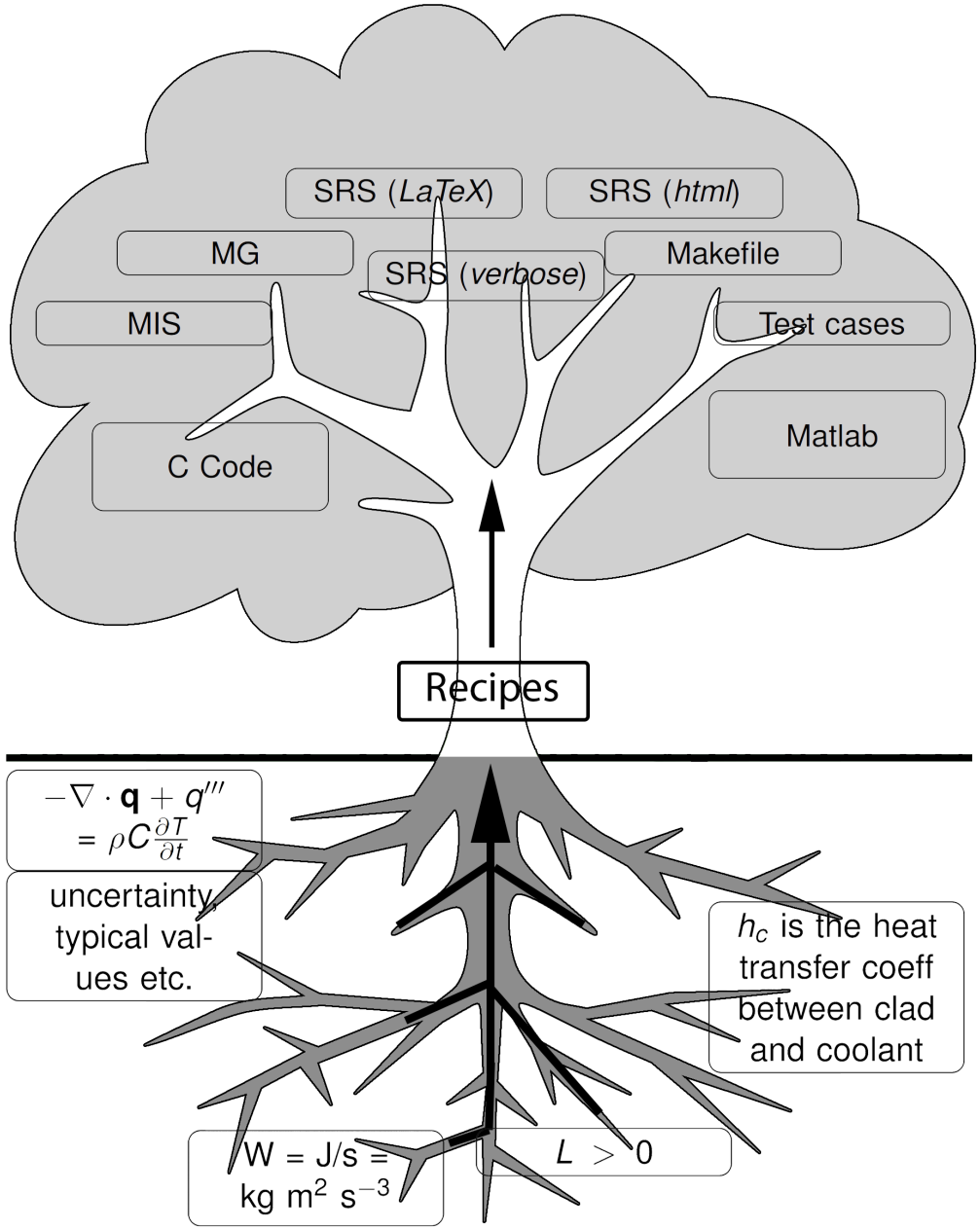
- SRS is too long
- SRS is not necessary
- DDD will not work in reality, since needs upfront requirements
- Too much SE jargon
- Difficult without a team of people
- Too difficult to maintain
- Not amenable to change
- Too tied to waterfall process
- Reports counterproductive [**?**]

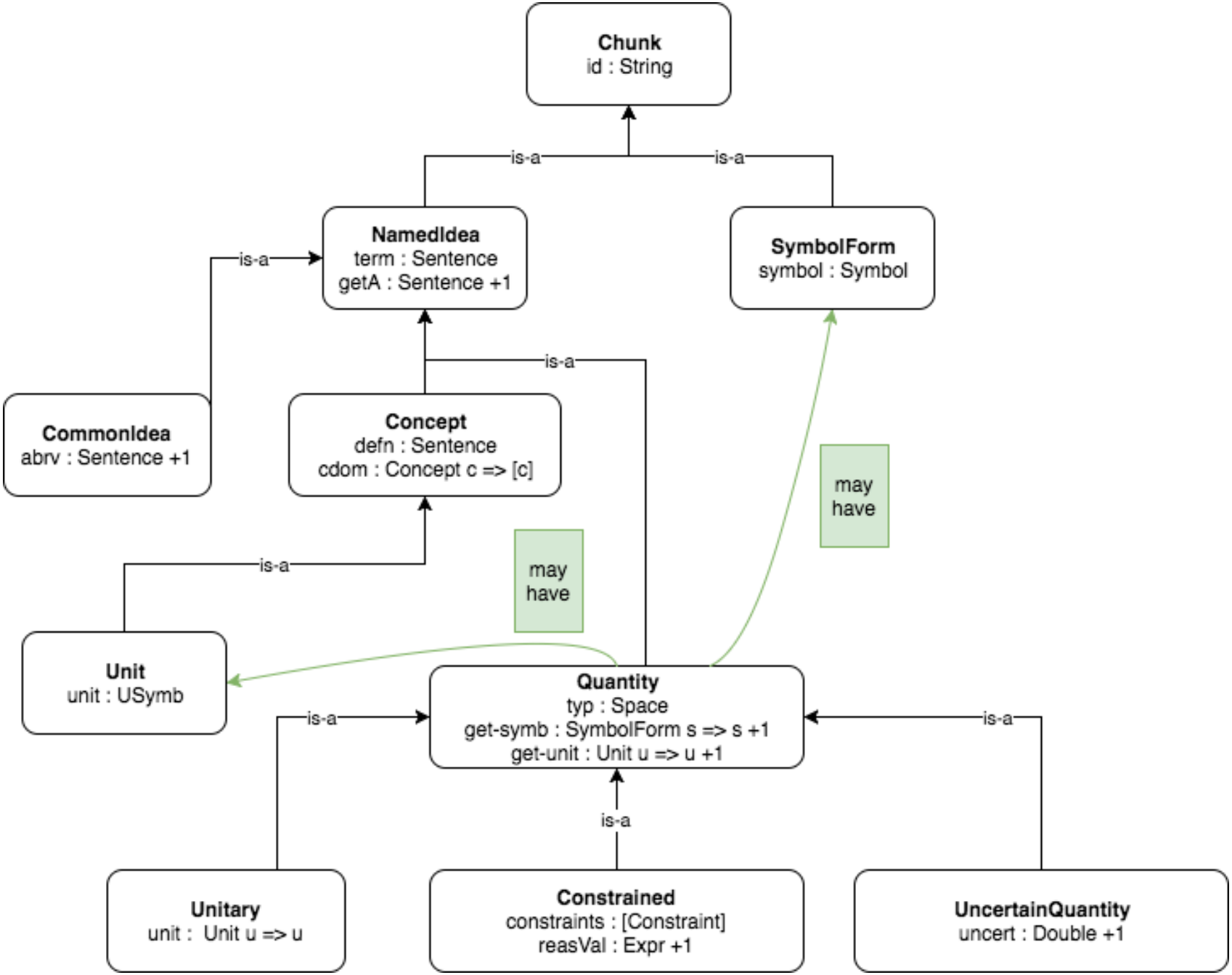
The Solution?


GENERATE
ALL THE THINGS!
memegenerator.net

Knowledge Capture

Drasil


SRS (*LaTeX*)
SRS (*html*)
MG
SRS (*verbose*)
Makefile
MIS
Test cases
Matlab
C Code
Recipes
$-\nabla \cdot \mathbf{q} + q''' = \rho C \frac{\partial T}{\partial t}$
uncertainty, typical values etc.
h_c is the heat transfer coeff between clad and coolant
W = J/s = kg m^2 s^{-3}
$L > 0$


Chunk
id : String
is-a
is-a
NamedIdea
term : Sentence
getA : Sentence +1
SymbolForm
symbol : Symbol
is-a
is-a
CommonIdea
abrv : Sentence +1
Concept
defn : Sentence
cdom : Concept c => [c]
may have
may have
is-a
Unit
unit : USymb
Quantity
typ : Space
get-symb : SymbolForm s => s +1
get-unit : Unit u => u +1
is-a
is-a
is-a
Unitary
unit : Unit u => u
Constrained
constraints : [Constraint]
reasVal : Expr +1
UncertainQuantity
uncert : Double +1

J_{tol} in SRS.pdf

Refname	**DD:sdf.tol**
Label	Stress Distribution Factor (Function) Based on Pbtol
Units	Unitless
Equation	$J_{tol} = \log\left(\log\left(\frac{1}{1-P_{btol}}\right)\frac{\left(\frac{a}{1000}\frac{b}{1000}\right)^{m-1}}{k\left(\left(E\cdot 1000\left(\frac{h}{1000}\right)^2\right)\right)^m \cdot LDF}\right)$
Description	J_{tol} is the stress distribution factor (Function) based on Pbtol P_{btol} is the tolerable probability of breakage a is the plate length (long dimension) (m) b is the plate width (short dimension) (m) m is the surface flaw parameter ($\frac{\mathrm{m}^{12}}{\mathrm{N}^7}$) k is the surface flaw parameter ($\frac{\mathrm{m}^{12}}{\mathrm{N}^7}$) E is the modulus of elasticity of glass (Pa) h is the actual thickness (m) LDF is the load duration factor

J_{tol} in SRS.tex

```
\noindent \begin{minipage}{\textwidth}
\begin{tabular}{p{0.2\textwidth} p{0.73\textwidth}}
\toprule \textbf{Refname} & \textbf{DD:sdf.tol}
\phantomsection
\label{DD:sdf.tol}
\\ \midrule \\
Label & $J_{tol}$
\\ \midrule \\
Units &
\\ \midrule \\
Equation & $J_{tol}$ =
           $\log\left(\log\left(\frac{1}{1-P_{btol
              }}\right)\frac{\left(\frac{a}{1000}\
              frac{b}{1000}\right)^{m-1}}{k\left(\
              left(E*1000\right)\left(\frac{h
              }{1000}\right)^{2}\right)^{m}*LDF}\
              right)$
\\ \midrule \\
Description & $J_{tol}$ is the stress distribution
    factor (Function) based on
```

J_{tol} in SRS.html

```
<a id="">
<div class="equation">
<em>J<sub>tol</sub></em> = log(log(<div class="
    fraction">
<span class="fup">
1
</span>
<span class="fdn">
1 &minus; <em>P<sub>btol</sub></em>
</span>
</div>)<div class="fraction">
<span class="fup">
(<div class="fraction">
<span class="fup">
<em>a</em>
</span>
<span class="fdn">
1000
</span>
```

J_{tol} in Python

```
def calc_j_tol(inparams):
    j_tol = math.log((math.log(1.0 / (1.0 - inparams
        .pbtol))) * ((((inparams.a / 1000.0) * (
        inparams.b / 1000.0)) ** (inparams.m - 1.0))
        / ((inparams.k * (((inparams.E * 1000.0) * ((
        inparams.h / 1000.0) ** 2.0)) ** inparams.m))
         * inparams.ldf)))
    return j_tol
```

J_{tol} in Java

```
public static double calc_j_tol(InputParameters
    inparams) {
        double j_tol = Math.log((Math.log(1.0 / (1.0
            - inparams.pbtol))) * ((Math.pow((
           inparams.a / 1000.0) * (inparams.b /
           1000.0), inparams.m - 1.0)) / ((inparams.
           k * (Math.pow((inparams.E * 1000.0) * (
           Math.pow(inparams.h / 1000.0, 2.0)),
           inparams.m))) * inparams.ldf)));
        return j_tol;
    }
```

J_{tol} in Drasil (Haskell)

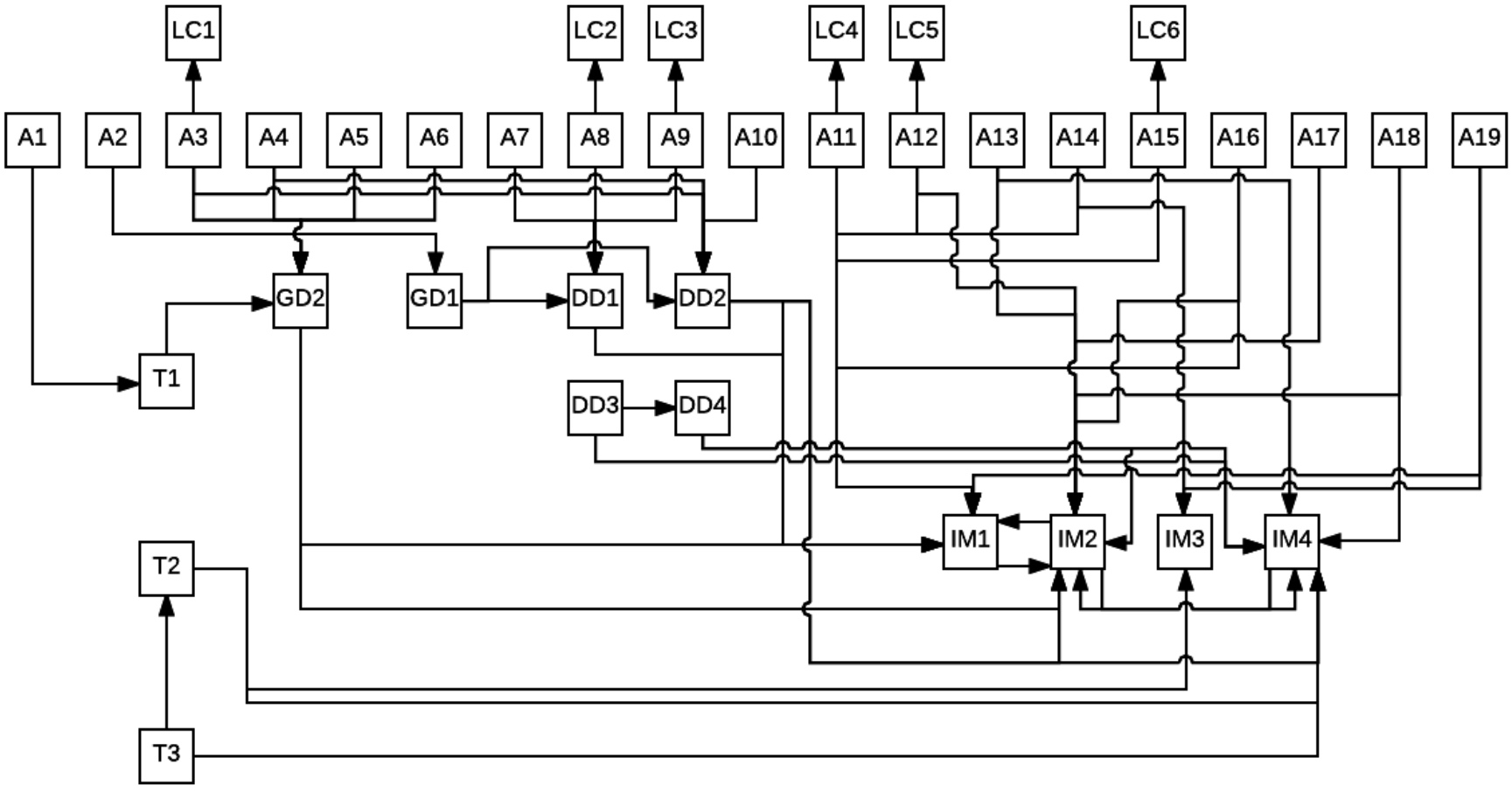
```
stressDistFac = makeVC "stressDistFac" (nounPhraseSP
  $ "stress distribution" ++ " factor (Function)")
      cJ
sdf_tol = makeVC "sdf_tol" (nounPhraseSP $
  "stress distribution" ++
  " factor (Function) based on Pbtol")
  (sub (eqSymb stressDistFac) (Atomic "tol"))

tolStrDisFac_eq :: Expr
tolStrDisFac_eq = log (log ((1)/((1) - (C pb_tol)))
  * ((Grouping (((C plate_len) / (1000)) * ((C
      plate_width) / (1000)))) :^
  ((C sflawParamM) - (1)) / ((C sflawParamK) *
  (Grouping (Grouping ((C mod_elas * 1000) *
  (square (Grouping ((C act_thick) / (1000)))))) :^
  (C sflawParamM) * (C lDurFac)))))
tolStrDisFac :: QDefinition
tolStrDisFac = mkDataDef' sdf_tol tolStrDisFac_eq
  (aGrtrThanB +:+ hRef +:+ ldfRef +:+ pbTolUsr)
```

J_{tol} without Unit Conversion

```
tolStrDisFac_eq :: Expr
tolStrDisFac_eq = log (log ((1)/((1) - (C pb_tol)))
  * ((Grouping ((C plate_len) * (C plate_width)) :^
  ((C sflawParamM) - (1)) / ((C sflawParamK) *
  (Grouping (Grouping ((C mod_elas * 1000) *
  (square (Grouping (C act_thick))))) :^
  (C sflawParamM) * (C lDurFac))))))
```

Traceability Graph



Maintainability

A1: The only form of energy that is relevant for this problem is thermal energy. All other forms of energy, such as mechanical energy, are assumed to be negligible [T1].

A2: All heat transfer coefficients are constant over time [GD1].

A3: The water in the tank is fully mixed, so the temperature is the same throughout the entire tank [GD2, DD2].

A4: The PCM has the same temperature throughout [GD2, DD2, LC1].

A5: etc.

Verifiability

Var	Constraints	Typical Value	Uncertainty
L	$L > 0$	1.5 m	10%
ρ_P	$\rho_P > 0$	1007 kg/m^3	10%

$$E_W = \int_0^t h_C A_C (T_C - T_W(t))dt - \int_0^t h_P A_P (T_W(t) - T_P(t))dt$$

- If wrong, wrong everywhere
- Sanity checks captured and reused
- Generate guards against invalid input
- Generate test cases
- Generate view suitable for inspection
- Traceability for verification of change

Reusability

Num.	**T1**
Label	**Conservation of energy**
Eq	$-\nabla \cdot \mathbf{q} + q''' = \rho C \frac{\partial T}{\partial t}$
Descrip	The above equation gives the conservation of energy for time varying heat transfer in a material of specific heat capacity C and density ρ, where $\mathbf{q}$ is the thermal flux vector, q''' is the volumetric heat generation, T is the temperature, ∇ is the del operator and t is the time.

Reusability

- De-embed knowledge
- Reuse throughout document
  - Units
  - Symbols
  - Descriptions
  - Traceability information
- Reuse between documents
  - SRS
  - MIS
  - Code
  - Test cases
- Reuse between projects
  - Knowledge reuse
  - A family of related models, or reuse of pieces
  - Conservation of thermal energy
  - Interpolation, Etc.

Reproducibility

- Usual emphasis is on reproducing code execution
- However, [**?**] show reproducibility challenges due to undocumented:
  - Assumptions
  - Modifications
  - Hacks
- Shouldn't it be easier to independently replicate the work of others?
- Require theory, assumptions, equations, etc.
- Drasil can potentially check for completeness and consistency

Smith and Koothoor (2016) [?]

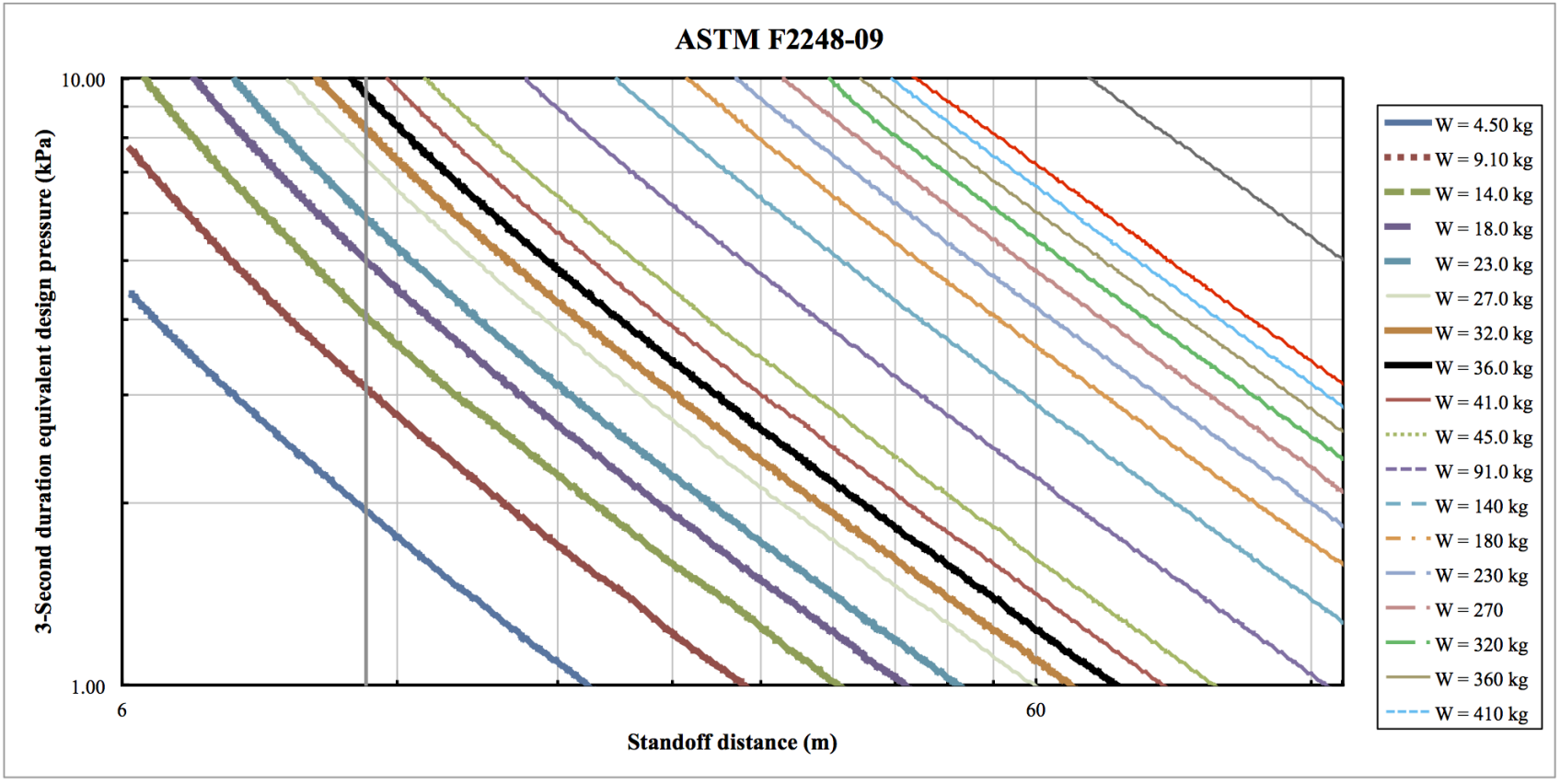
$$R_1^{\text{code}} = \frac{f}{8\pi k_{\text{AV}}} + \frac{1}{2\pi r_f h_g} \tag{1}$$

$$R_1^{\text{manual}} = \frac{f}{8\pi k_{\text{AV}}} + \frac{1}{2\pi r_f h_g} + \frac{\tau_c}{4\pi r_f k_c} \tag{2}$$

- Uncovered 27 issues with the previous documentation
  - Incompleteness (R_{gap})
  - Inconsistency(r, r_0, h_g)
  - Verifiability problems (R_1)
  - Lack of traceability (circuit analogy)
- Advantages of proposed approach
  - Abstract to concrete
  - Separation of concerns
  - Every equation, assumption, definition, model, derivation, source and traceability between them

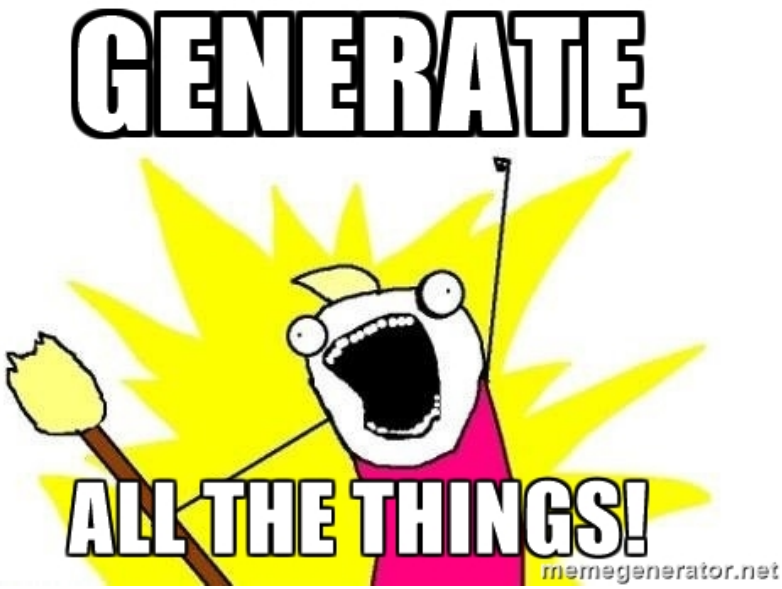
NO

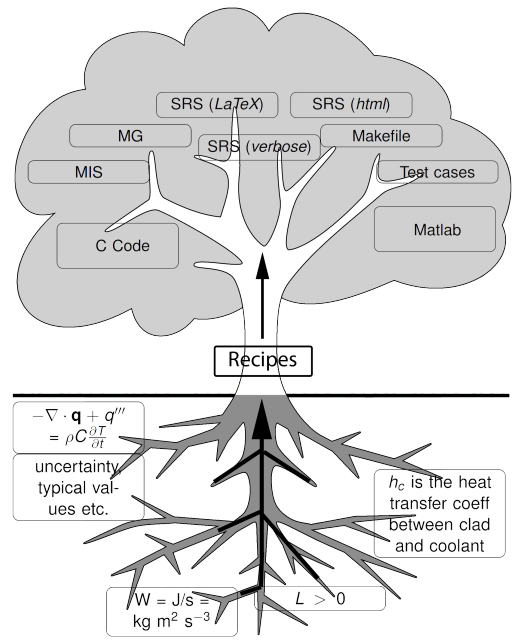
Future Work


ASTM F2248-09
10.00
1.00
3-Second duration equivalent design pressure (kPa)
6
60
Standoff distance (m)
W = 4.50 kg
W = 9.10 kg
W = 14.0 kg
W = 18.0 kg
W = 23.0 kg
W = 27.0 kg
W = 32.0 kg
W = 36.0 kg
W = 41.0 kg
W = 45.0 kg
W = 91.0 kg
W = 140 kg
W = 180 kg
W = 230 kg
W = 270
W = 320 kg
W = 360 kg
W = 410 kg

Drasil Framework for LSS

- SCS has the opportunity to lead other software fields
- Document driven design is feasible
- Requires an investment of time
- Documentation does not have to be painful
- Develop/refactor via practical case studies
- Ontology may naturally emerge
- Open source Drasil here





References I