

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

**Fall 2020**

**Artifact Generation**

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November 23, 2020



# Artifact Generation

- Start recording
- Administrative details
- Artifact generation (Drasil)

# Administrative Details

- Upcoming classes
  - ▶ L20 - Artifact Generation (Today)
  - ▶ L21 - Drasil Demos
  - ▶ L22 – L24 - Implementation and testing presentations

# Administrative Details

- For final documentation, make sure you have **addressed and closed** all open issues
- MIS marking scheme on Avenue
- Course evaluation
  - ▶ Wed, Nov 25, 10:00 am to Wed, Dec 9, 11:59 pm
  - ▶ <https://evals.mcmaster.ca>
- MG/MIS Reviews
  - ▶ Assign issues to your domain expert and secondary reviewer
  - ▶ Due two days after assignment (but we can be flexible on this)
- Further Deliverable Reviews
  - ▶ Not part of marking scheme for course
  - ▶ Encouraged to do anyway, maybe as a quid pro quo?

# Administrative Details: Report Deadlines

**MG + MIS (Traditional)** Nov 23

**Drasil Code and Report (Drasil)** Nov 23

Final Documentation Dec 9

- The written deliverables will be graded based on the repo contents as of 11:59 pm of the due date
- If you need an extension for a written deliverable, please ask
- You should inform your primary and secondary reviewers of the extension
- Two days after each major deliverable, your GitHub issues will be due

# Admin Details: Presentation Schedule

- Drasil Project Present (20 min each)
  - ▶ Thurs, Nov 26: Andrea, Naveen, Ting-Yu
- Test or Impl. Present (15 min each)
  - ▶ Mon, Nov 30: John, Salah, Liz, Xingzhi, Leila
  - ▶ Thurs, Dec 3: Shayan, Naveen, Sid, Gaby, Seyed
  - ▶ Mon, Dec 7: Ting-Yu, Xuanming, Mohamed, Andrea, Tiago
- 4 presentations each
- If you will miss a presentation, please trade with someone else

# Implementation and Testing Presentations

You can present anything related to implementation or testing

- Show off your code, or as much of it as you have completed
- Unit VnV Plan
- Test case report
- Verification/validation activities
- Demonstrate technology
  - ▶ Continuous integration
  - ▶ Valgrind
  - ▶ Doxygen for API documentation
  - ▶ Etc.
- Drasil presentations - emphasize testing
- Fine to show work in progress
- Good to ask the audience for advice, feedback
- Other ideas are likely fine

# Questions?

- Questions on administrative details?
- Questions about Module Guide?
- Questions about upcoming presentation?
- Questions about MIS?
- Other questions?

# Implementing Your MIS

- The mapping between the MIS and the code is generally not “term” by “term”
- You do not need to use the mathematical type listed in the spec
- Consider A2 (Allocation to Engineering Programs) for set types
  - ▶ Problem Description
  - ▶ Source Code

# Abstract for Artifact Generation Talk

- **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

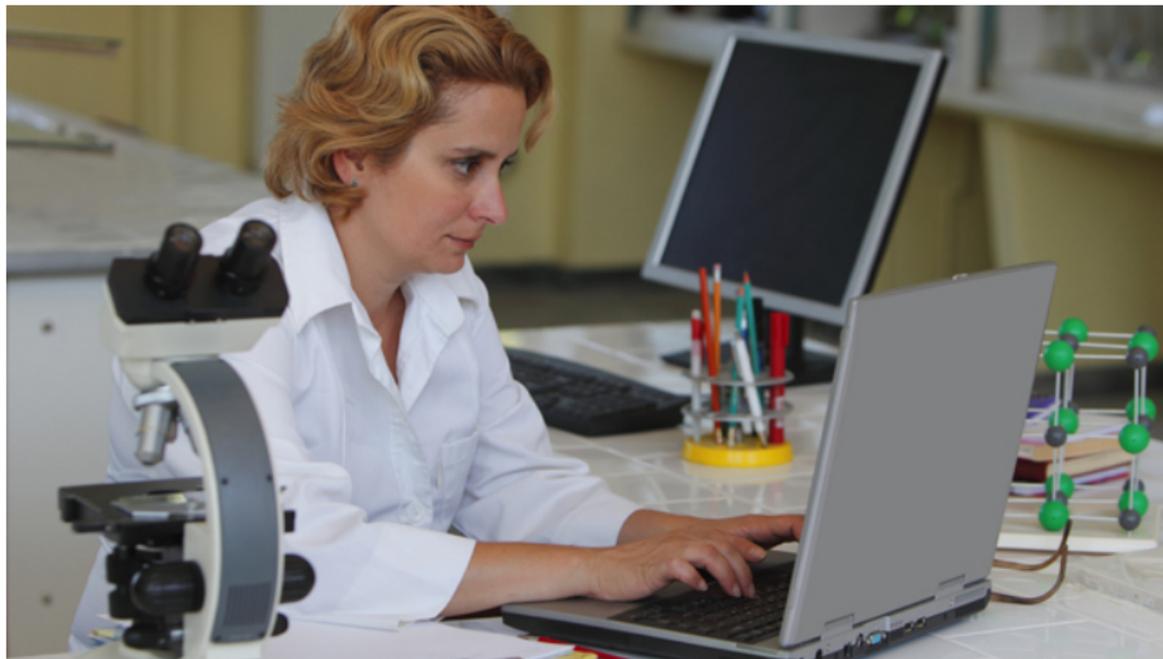
Scope: Large/Multiyear



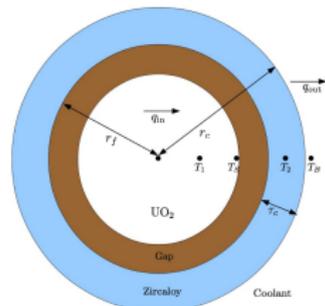
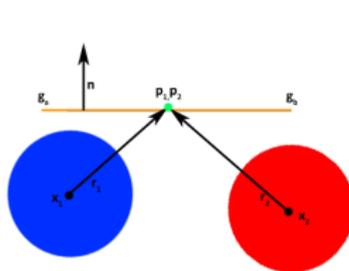
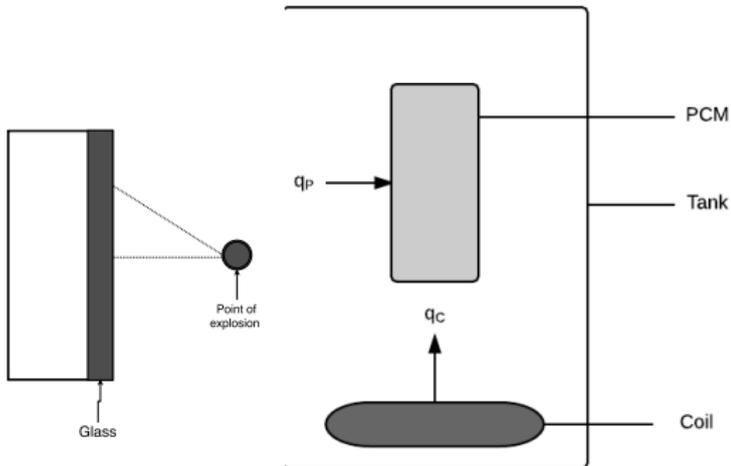
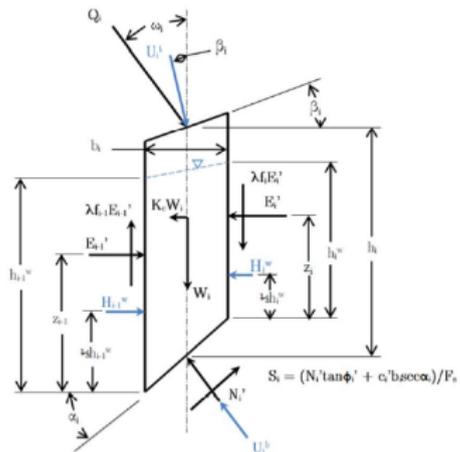
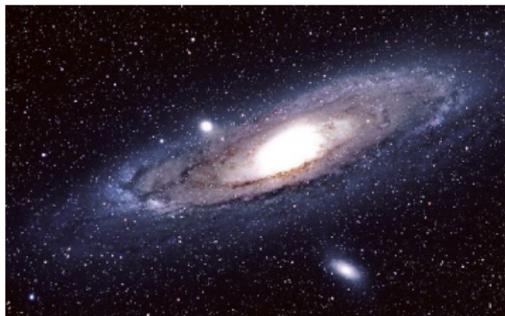
# Scope: Program Families



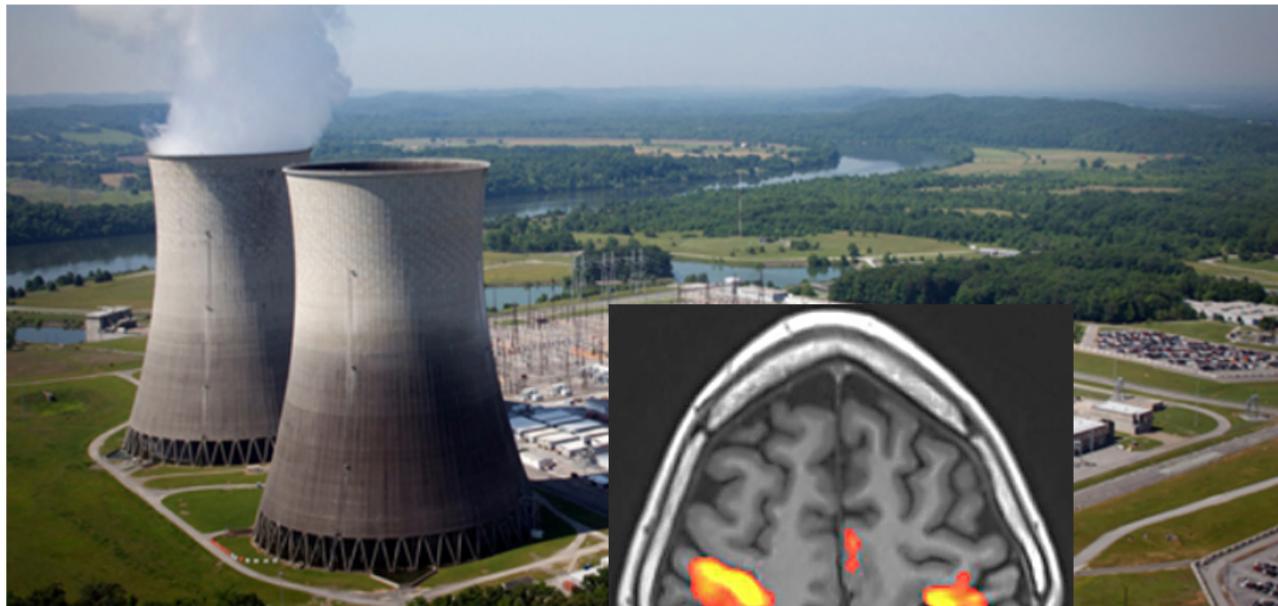
## Scope: End User Developers



# Scope: Physical Science



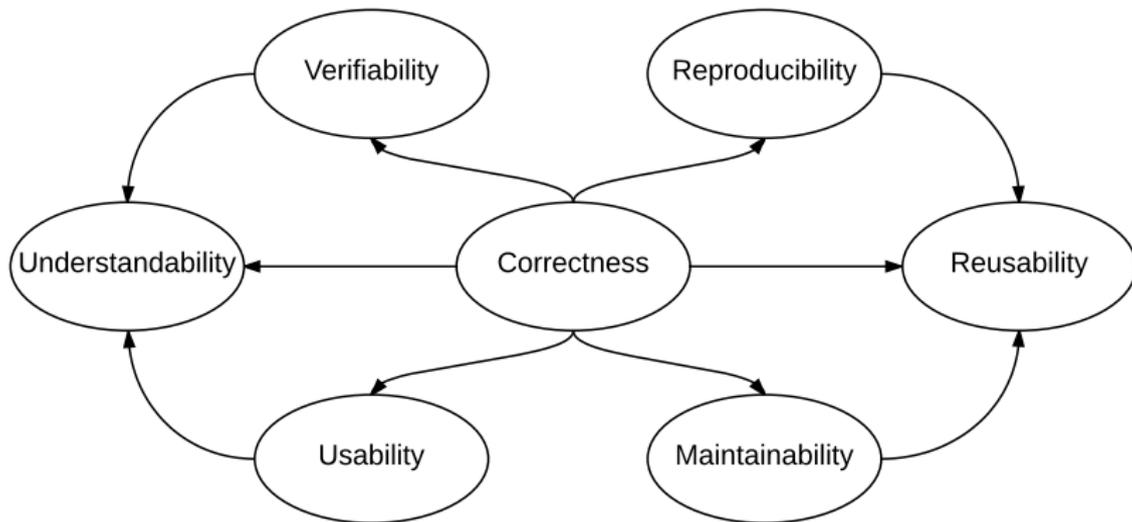
# Motivation: Safety



Motivation: (Re)certification



# Motivation: Improve Quality



# Current Approach

- Agile like [1]
- Amethododical [3]
- Knowledge acquisition driven [4]
- Each stage reports counterproductive [10]
- Limited tool use [13]
- Limited testing of code [5]
- Lack of understanding of testing [7]
- Missed opportunities for reuse [8]
- Emphasis on:
  1. Science [6]
  2. Code

# Documentation Advantages

- Improves verifiability, reusability, reproducibility, etc.
- From [9]
  - ▶ 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 [12]
- Developers see advantage [11]

# Study Of Documentation in SC [11]

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
<b>SWHS</b>	1000	F77	1	5	✗	✓	✗	✗	✗
<b>Astro</b>	5000	C	2	10	✗	✓	✗	✗	✗
<b>Glass</b>	1300	F90	1	<1	✗	✓	✗	✗	✗
<b>Soil</b>	800	M	1	5	✓	✓	✓	✓	✗
<b>Neuro</b>	1000	M	1	5	✓	✓	✗	✓	✗
<b>Acoust</b>	200	M	4	2.5	✗	✓	✗	✗	✗

# Perceived Advantages from Participants

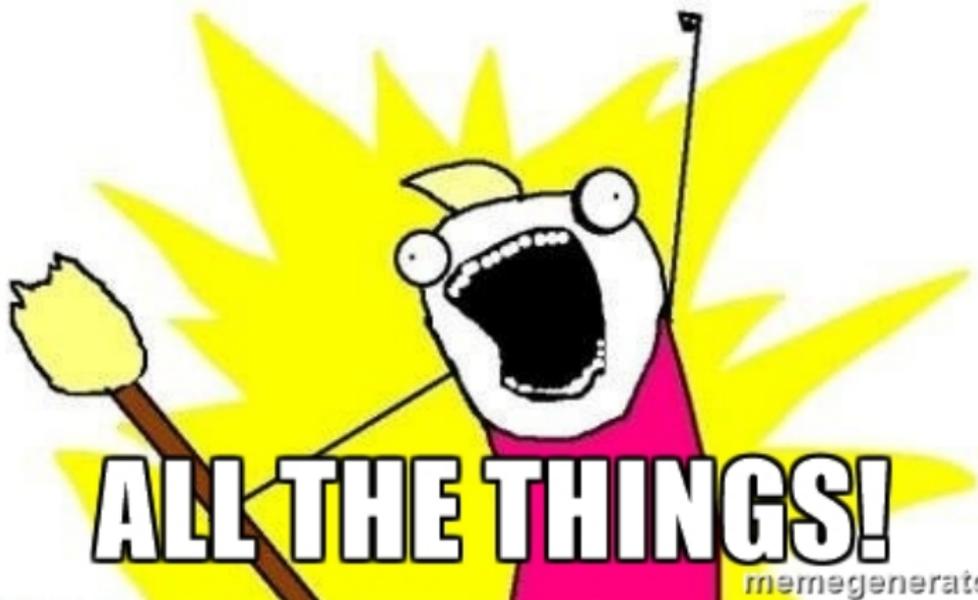
- Documentation of assumptions
- All variables have explicit units
- SRS helpful with new graduate students
- Modules result in more user friendly code
- Traceability between modules and requirements useful
- Better organized code
- Information sharing on design choices
- Detailed record of knowledge 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 [10]

## The Solution?

# GENERATE

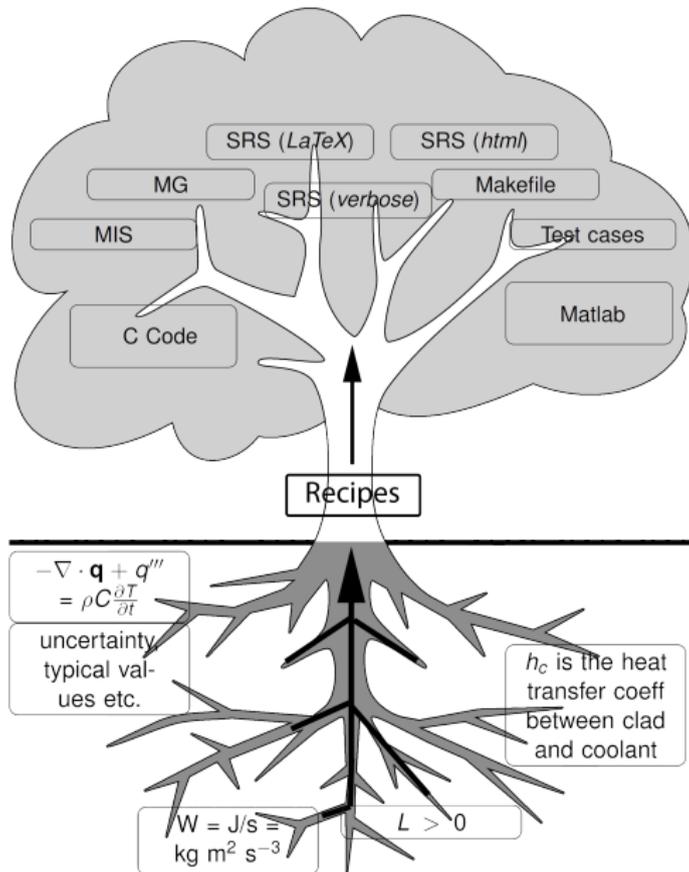


[meme-generator.net](http://meme-generator.net)

# Knowledge Capture



# Brasil





# $J_{tol}$ in SRS.pdf

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

## $J_{tol}$ 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 &  $J_{tol} =$ 

$$\frac{\log\left(\log\left(\frac{1}{1-P_{btol}}\right)\right)}{\frac{\left(\frac{a}{1000}\right)\frac{b}{1000}}{\left(E*1000\right)\left(\frac{h}{1000}\right)^2}}^{m-1} \left(\frac{h}{1000}\right)^{2m} * LDF$$

\\ \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>
</div>)
```

## $J_{tol}$ 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.ldr)))
    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)

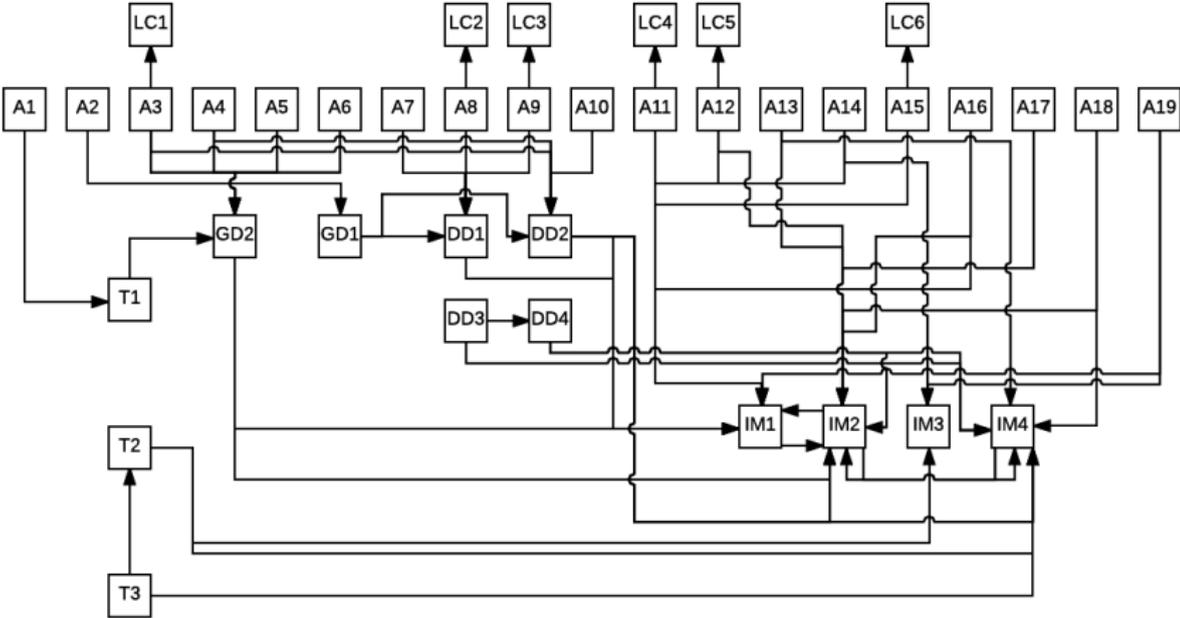
```
stressDistFac = makeVC "stressDistFac" (nounPhraseSP
  $ "stress distribution" ++ " factor (Function)")
  cJ
sdf_tol = makeVC "sdf_tol" (nounPhraseSP $
  "stress distribution" ++
  " factor (Function) based on Pbtol")
  (sub (eqSymb stressDistFac) (Atomic "tol"))

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%
$\rho_P$	$\rho_P > 0$	1007 kg/m <sup>3</sup>	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  $\rho$ , where  $\mathbf{q}$  is the thermal flux vector,  $q'''$  is the volumetric heat generation,  $T$  is the temperature,  $\nabla$  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, [2] 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) [12]

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

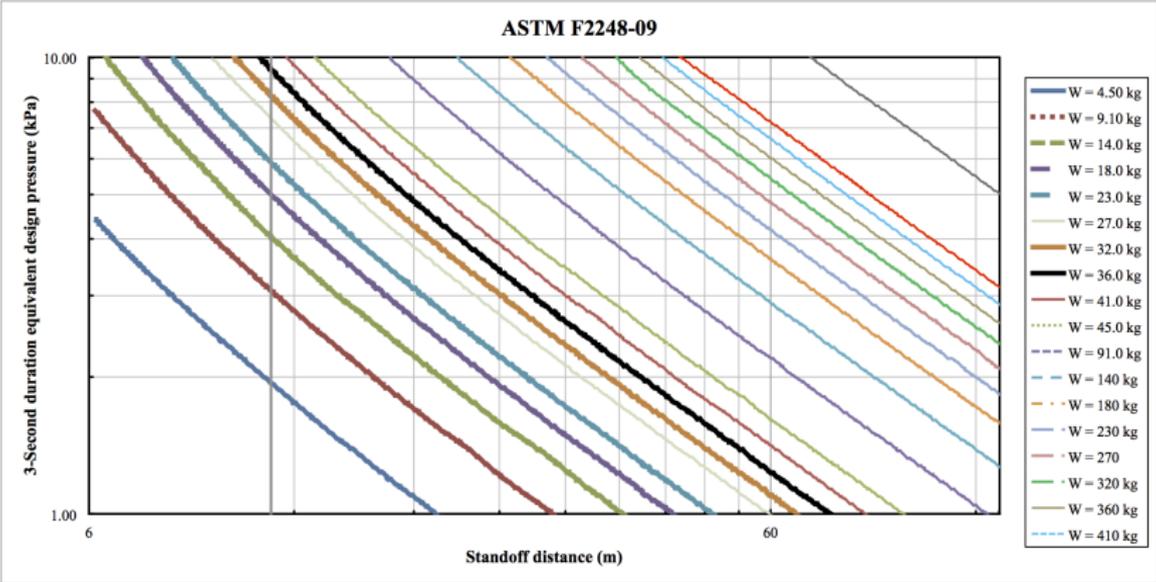
$$R_1^{\text{manual}} = \frac{f}{8\pi k_{AV}} + \frac{1}{2\pi r_f h_g} + \frac{\tau_c}{4\pi r_f k_c} \quad (2)$$

- Uncovered 27 issues with the previous documentation
  - ▶ Incompleteness ( $R_{\text{gap}}$ )
  - ▶ 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**

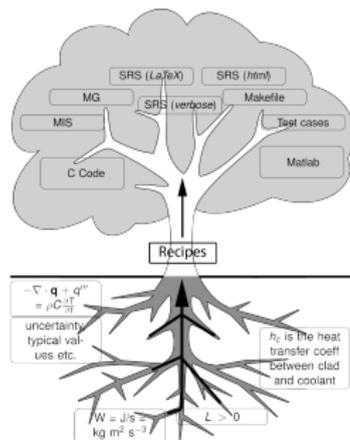
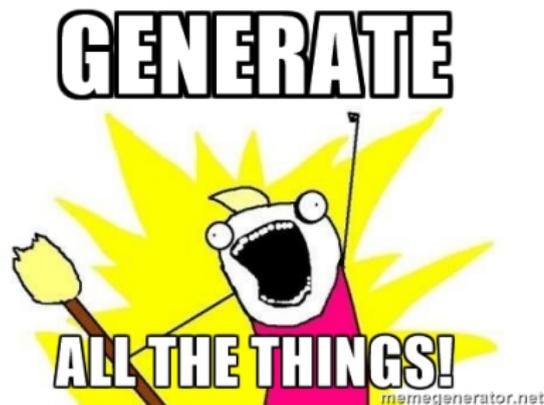


# Future Work



# 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](#)



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