

*Towards Analysis Led Design –
Collaboration of CAE tools for fluid system design*

Computational Sciences Experts Group
September 2011

WE ARE CSEG

*We don't sell software. We bring our modeling expertise
and make your CAE software do
advanced stuff.*

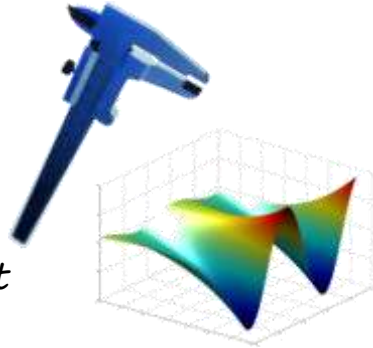
*The stuff you bought the
software to do to begin with.*

CSEEG Services



1. Calibrate:

We build accurate simulation models and calibrate them with test data



2. Integrate:

We integrate various simulation tools for a specific problem to reduce error and improve accuracy



4. Optimize:

We build optimization tools or integrate with existing ones to optimize key variables in the system



3. Interface:

We build simplified interfaces for complex models to enable faster and wider use of simulation models



The Speaker



Sudhi Uppuluri, Principal Investigator

Sudhi has over 14 years of experience in the simulation industry. He worked as a consulting engineer and sales manager at Flowmaster USA for 8 years where he worked on various advanced fluid system modeling in Automotive and Aerospace fields.

He has various technical publications on related subjects in SAE and AIAA journals. He holds a Masters in Aerospace Engineering from the University of Illinois at Urbana-Champaign and a Certificate in Strategy and Innovation from the MIT Sloan School of business.

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Full Profile on Linked in: [Sudhindra Uppuluri](#)

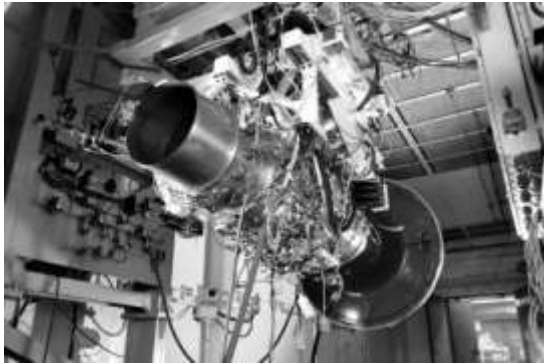
Analysis Led Design

Are we there yet?

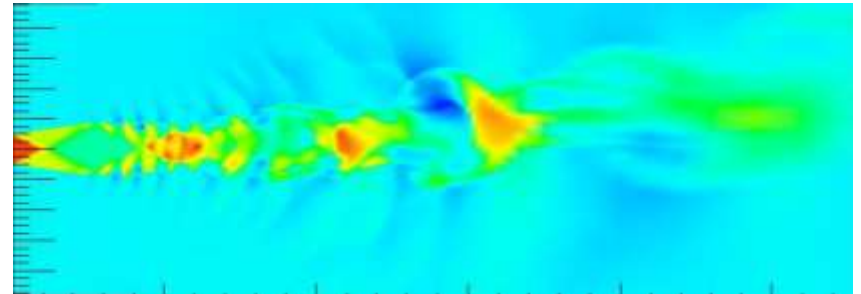
Engineers would love to for analysis to come up with the
Initial design

...towards Analysis Led Design

“What key improvements would you like to make?”



testing



simulation

“I want to improve the predictability and fidelity of my simulation”

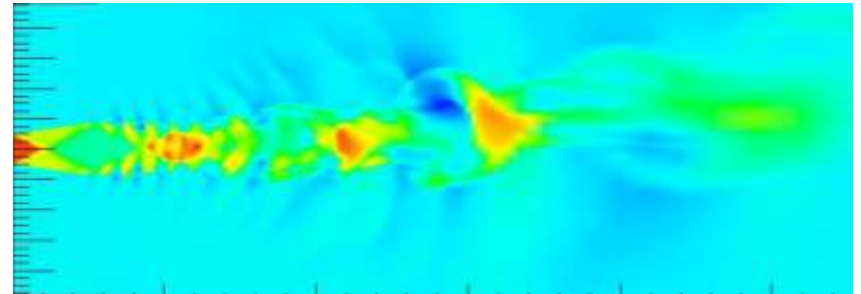
Are we *really* doing analysis work
before the prototype?

not really!

...towards Analysis Led Design

“We don’t have any test data!”

*Without initial
prototype*

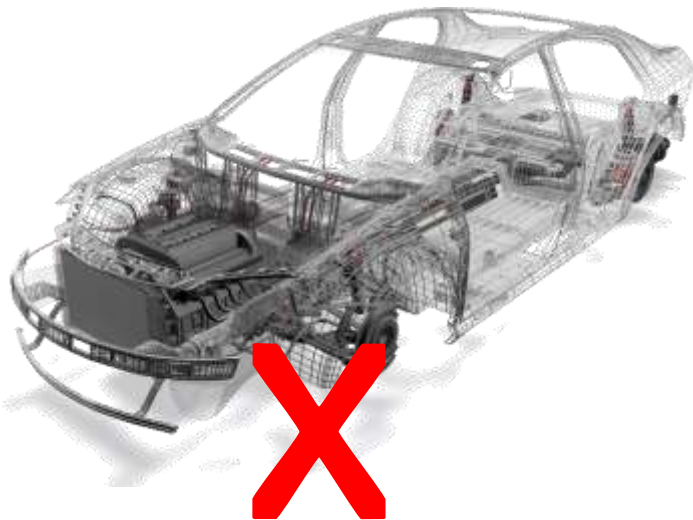


simulation

*Simulation is used today more for troubleshooting
and optimization and less for initial product
design*

...towards Analysis Led Design

Reduce the number of initial prototypes



We all have a
bunch of tools

Range of CAE tools

Overall Vehicle Model

Control System

External Aero

S/W integrity
and standards
testing

Multiple System Integration

Internal
component
specific codes

System
Optimization

Overall System Modeling (1D)

CFD (3D)

FEA

Combustion

Internal
component
specific codes

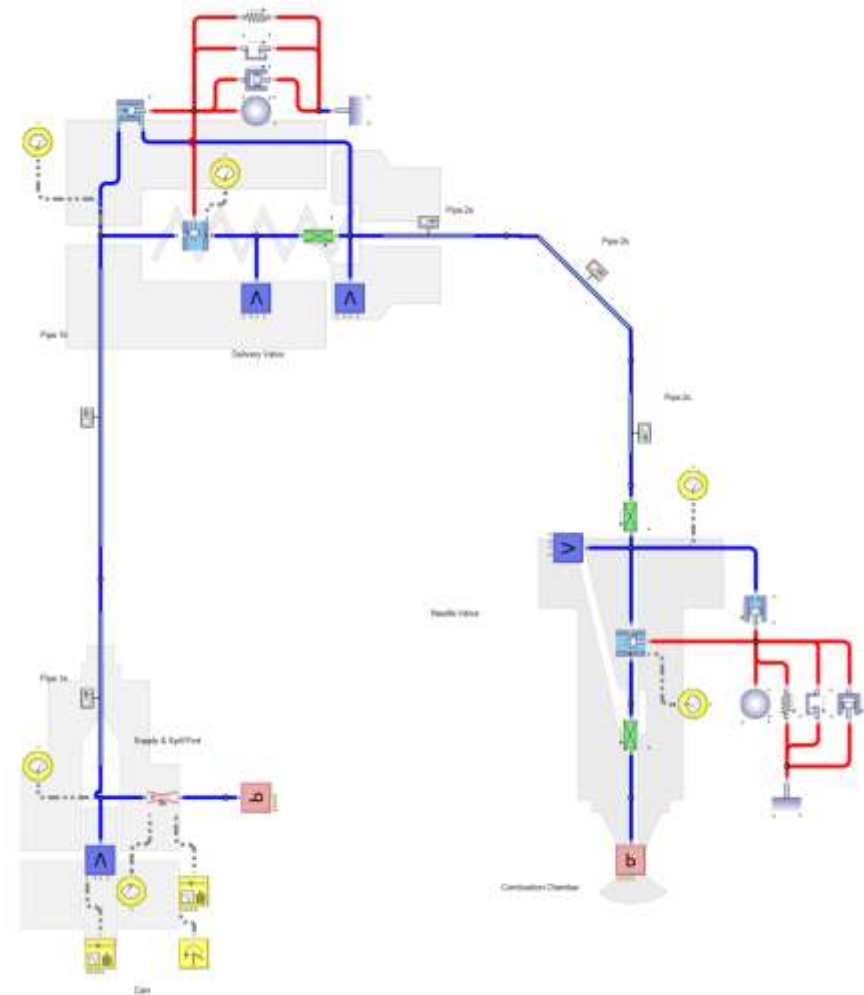
1D

(or zero D)

Wow, could we go any lower?

What does a typical 1D fluid system look like?

- Overall system laid out with individual components
- ✓ Evaluates overall system performance
- Study of components primarily at their boundary conditions

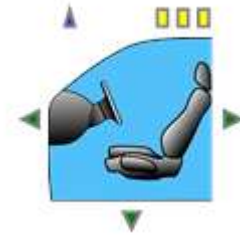
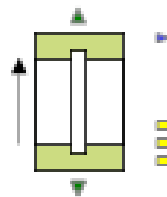
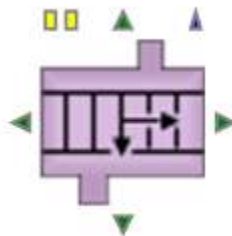


What is 1D physics?

- 1D is physics along 1 axis – e.g., flow through a pipe

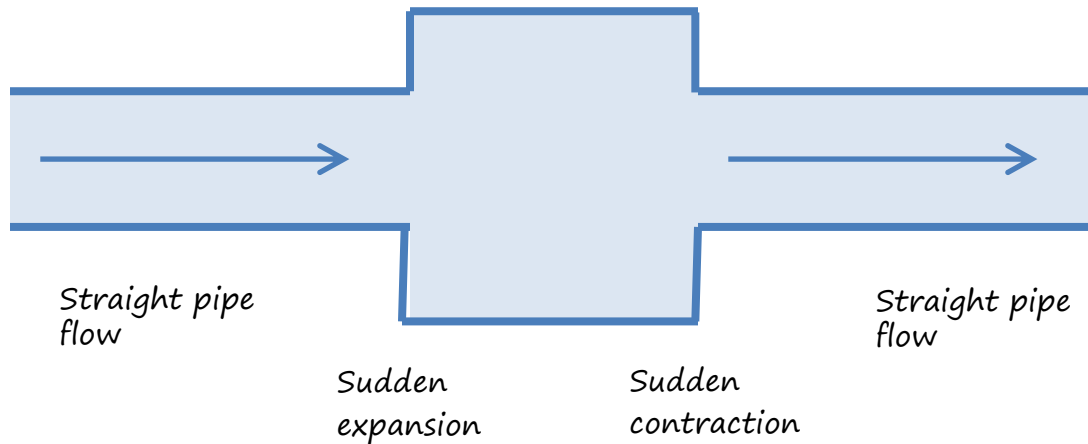


- Generally accepted meaning also encompasses components that can be fully defined via boundary conditions (lumped parameter)



Example of 1D physics

- Pipe and junction analysis



$$P_2 - P_1 = \frac{fL}{d} \frac{\dot{m}_1 |\dot{m}_1|}{2\rho A^2}$$

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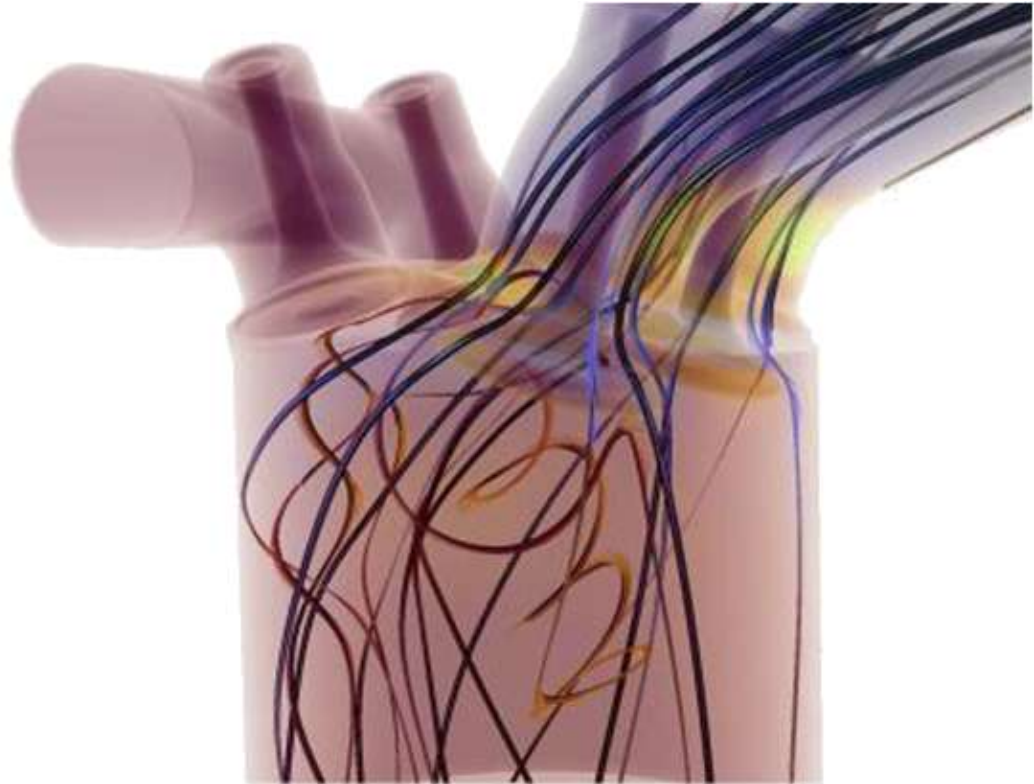
$$P_1 - P_2 = \frac{I_c K}{2\rho A_1^2} \dot{m}_2 |\dot{m}_2|$$

3D

We love these colorful pictures!

3D physics

- 3D CFD – Solving Navier-Stokes equation for complex flows
- Simplified 3D models for airflow through overlapping airside heat exchangers
- ✓ Can provide initial performance data based on CAD model



Internal codes

By the people who really know what they are talking about.

Component specific codes

- Heat Exchanger

$$(m\bar{c}_p)_H(T_{Hi} - T_{Ho}) + m \left(\frac{P_1}{\rho_1} - \frac{P_2}{\rho_2} \right) = (m\bar{c}_p)_C(T_{Ci} - T_{Co}) + m \left(\frac{P_3}{\rho_3} - \frac{P_4}{\rho_4} \right)$$

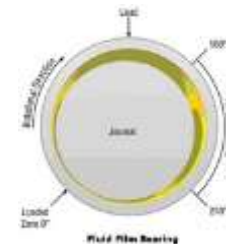
$$P_1 - P_2 = \frac{Km_2 |m_2|}{2A^2 \rho}$$



- Journal bearing

$$Q_p^* = \pi \frac{1 + 1.5 \varepsilon^2}{3 \left(\frac{b - b_n}{D} \right)}$$

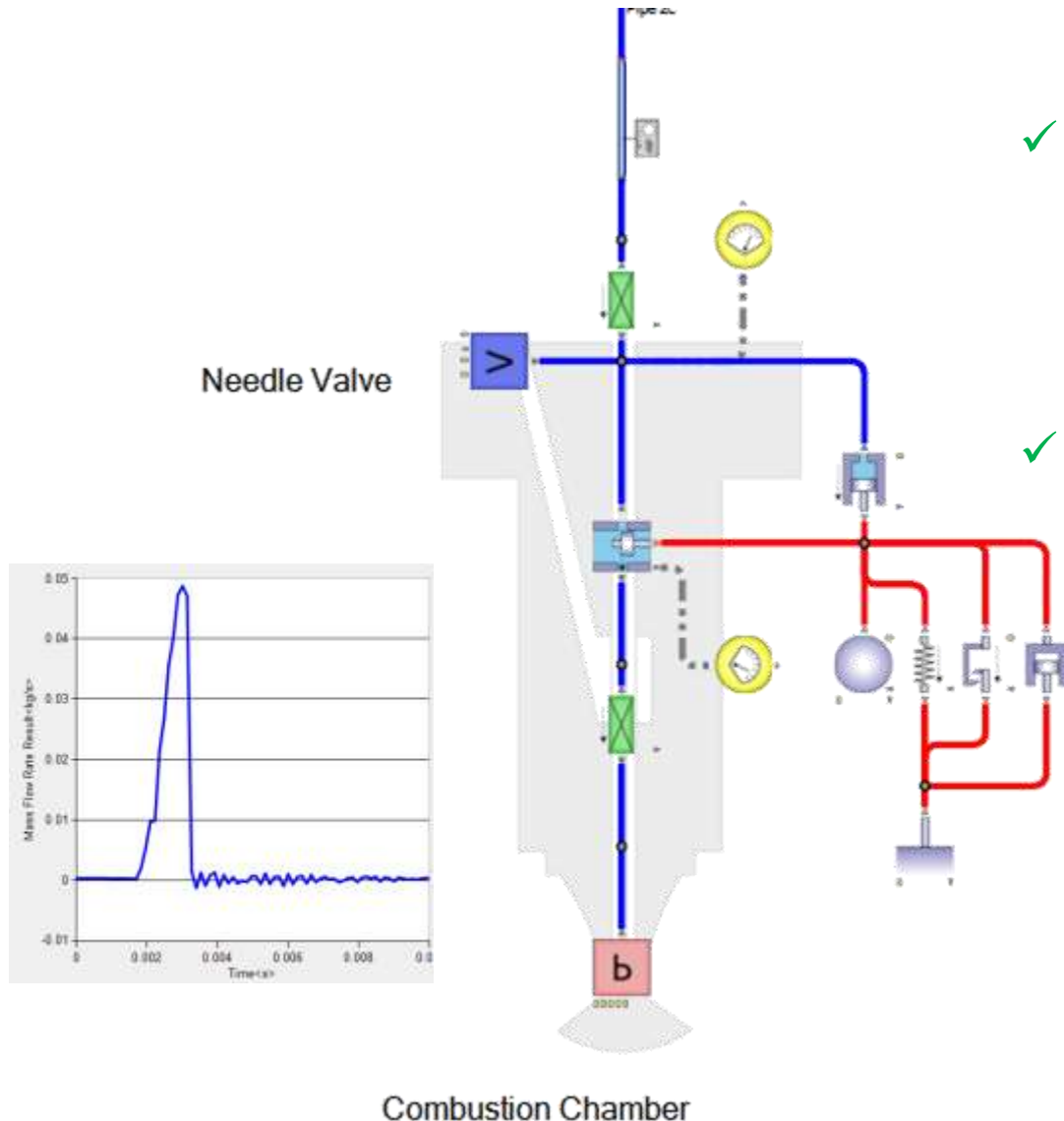
$$Q_d = \frac{D^3 \psi |\omega|}{4} \left[\frac{b}{d} - 0.223 \left(\frac{b}{d} \right)^3 \right] \varepsilon$$



*Many different approaches to this flow calculation exist

*But can all these tools start to do
predictive work?*

1D physics – 1D Fluid and 1D Mechanical system interaction

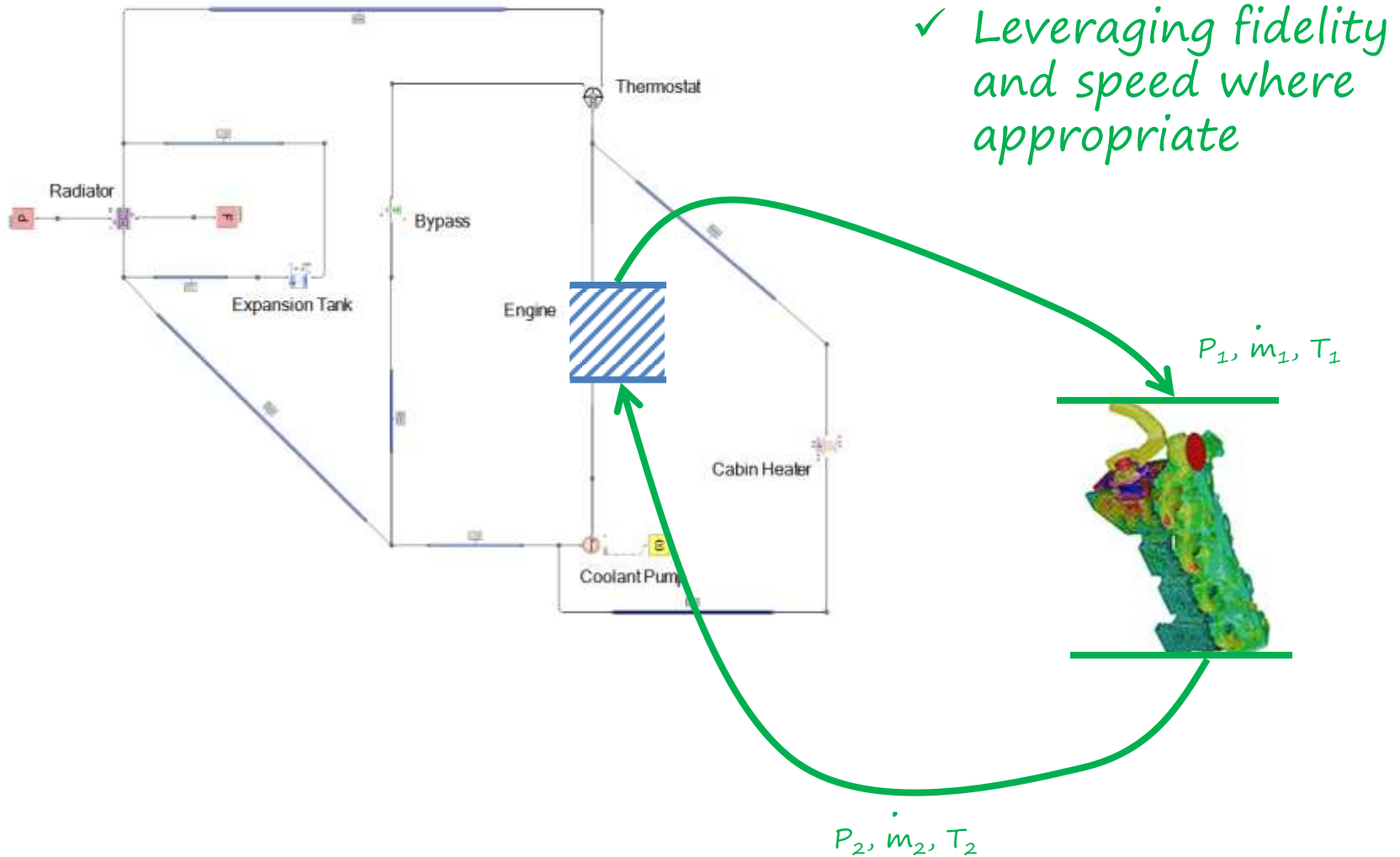


✓ Enables study of interaction of components' physical movements with fluid dynamics

✓ Real time or faster transient analysis with system responses

*1D and 3D get married and
get more predictive.*

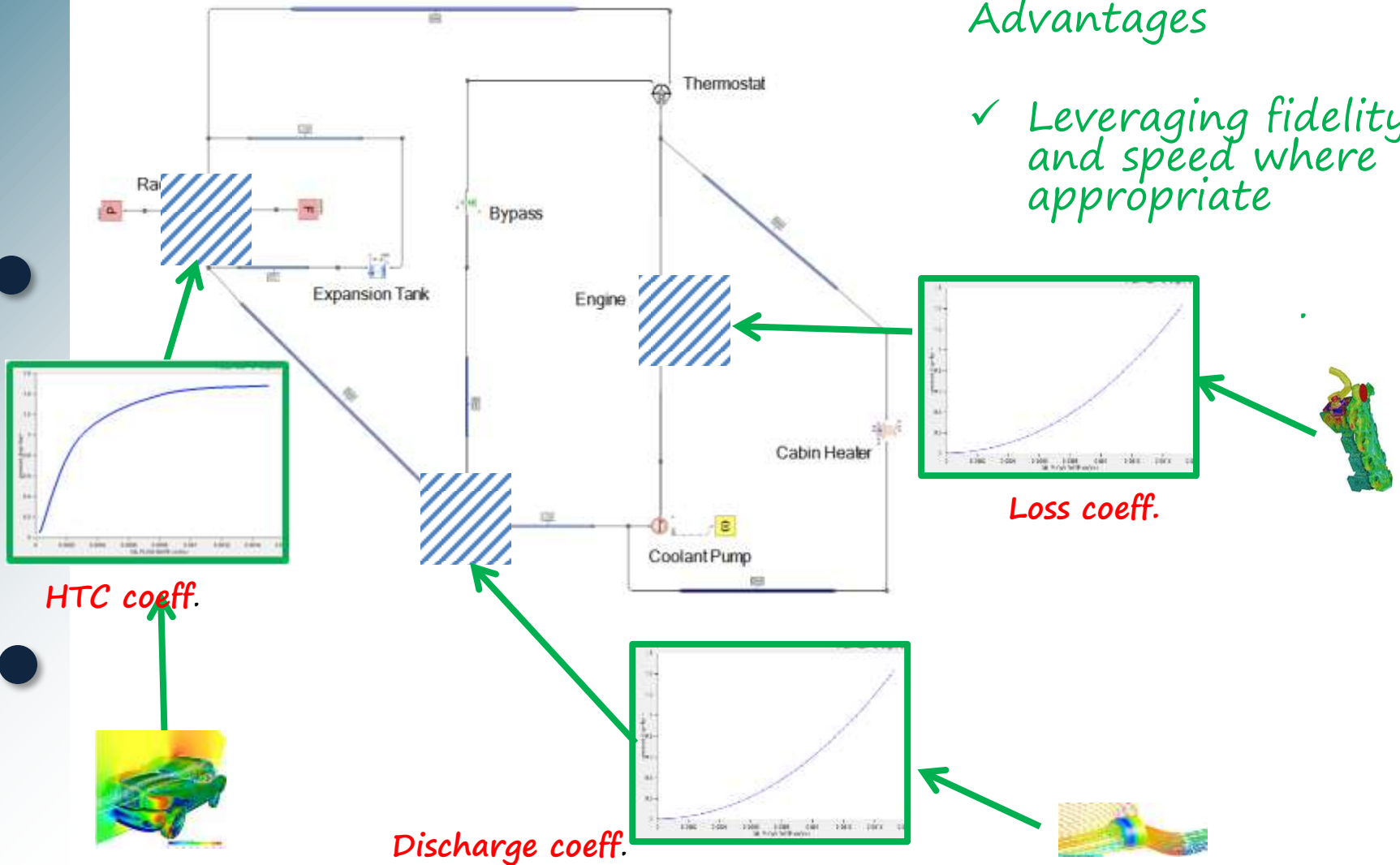
Leveraging best of 1D & 3D (co-simulation)



Leveraging best of 1D & 3D (collaboration)

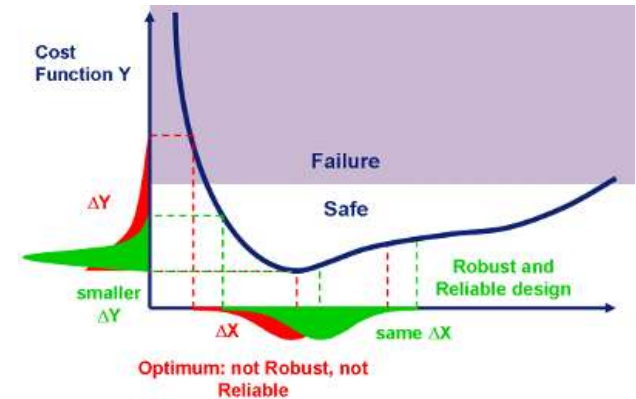
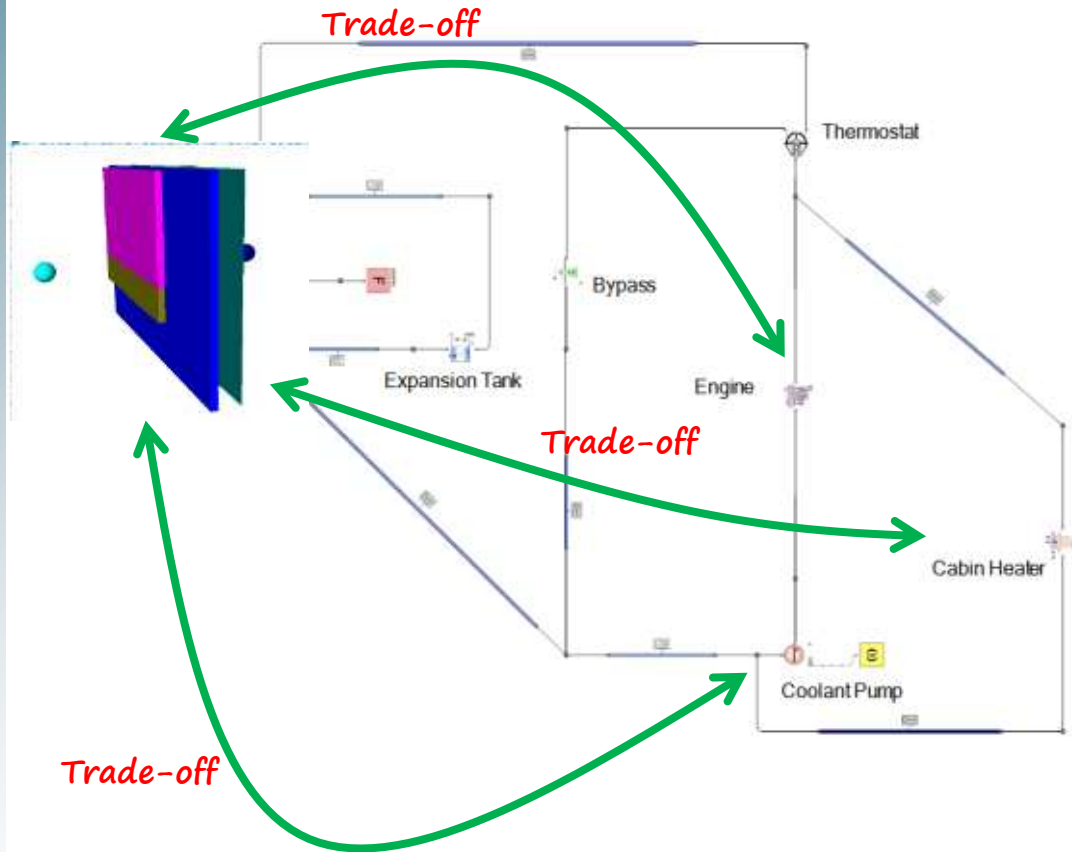
Advantages

- ✓ Leveraging fidelity and speed where appropriate



*Does that radiator really have to
be that big?*

Optimization and Robust design



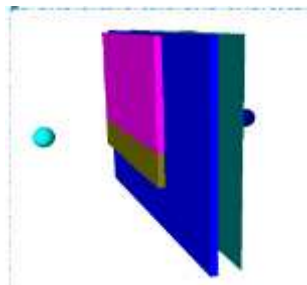
- ✓ Enables optimization of the system by trading off for the most important variables

These systems don't work alone.

They act in groups!

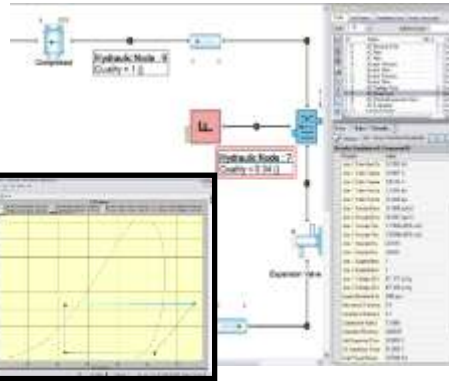
(we knew that)

Integrating multiple fluid systems

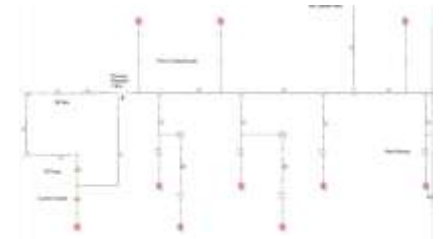


Cooling Pack

Effect of
condenser
placement



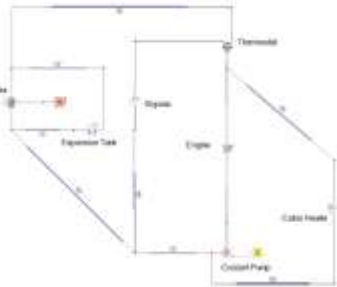
AC System



Lubrication
System

Accurate
heat input
by drive
cycle

Radiator
performance



Cooling
System

Oil cooler
performance



Combustion

Accurate heat input
by drive cycle

1D Fluid & Mechanical system integration with control systems

Engine Control (Simulink)

Cylinder firing
Timing, Voltages

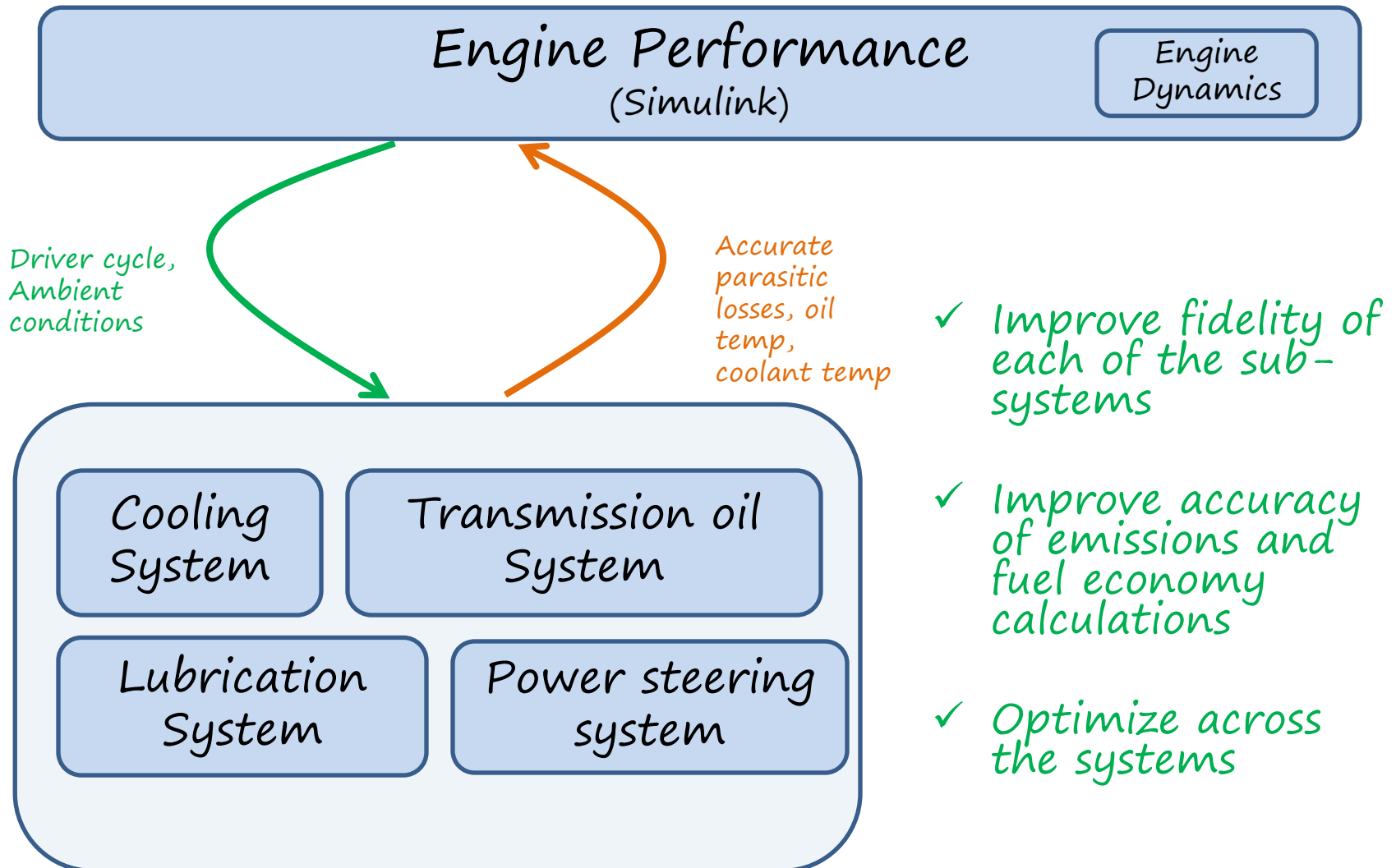
Fuel
consumption



- ✓ Integrate with engine control to evaluate and optimize fuel consumption
- ✓ Enable usage by control systems users with minimal fluid system experience

*And they can help us
Use less gas.*

Optimizing across all engine fluid systems

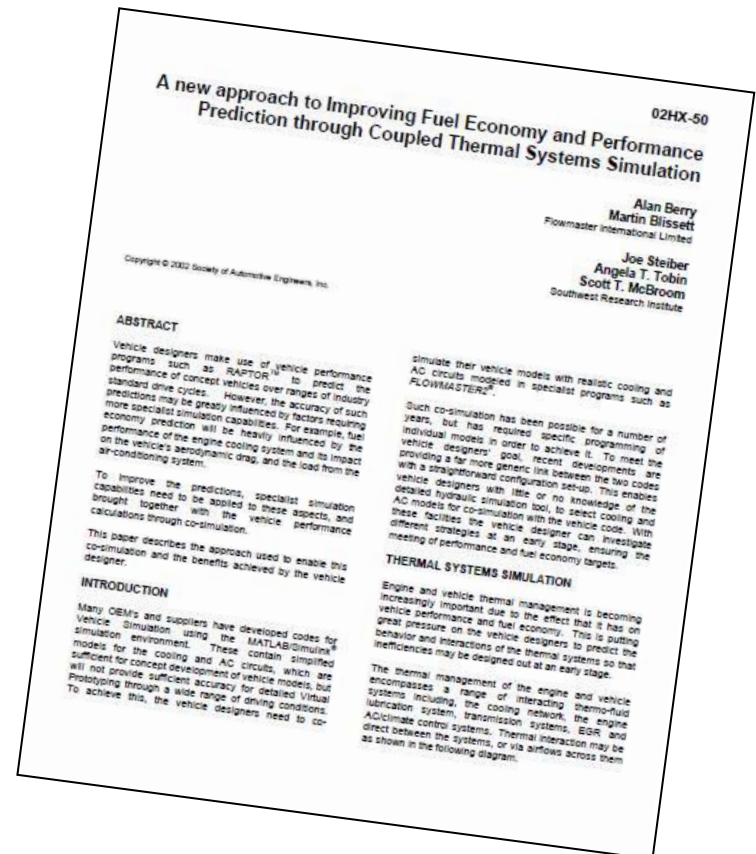


Really!
Other people have done it.

Fuel economy improvements

- Numerous fuel economy improvement avenues exist when coupling and optimizing systems

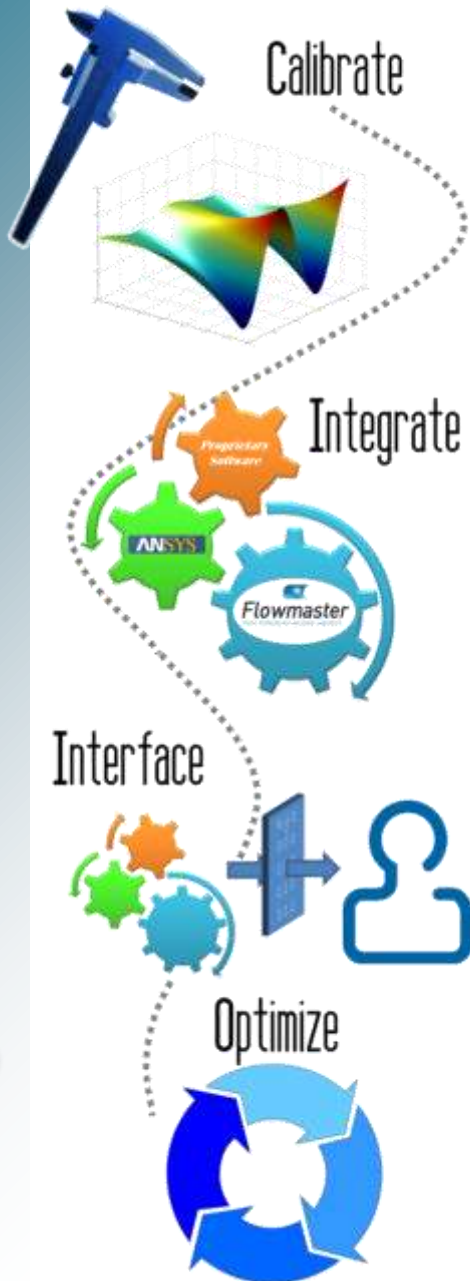
- ✓ Reduced parasitic loads
- ✓ Achieving optimum oil and coolant temperatures
- ✓ Accurate control strategies



Observations



- *Collaboration between CAE tools (e.g., 3D and 1D) reduces dependence on test data making simulation more predictive*
- *Extensive integration between CAE tools enables optimization across systems and help meet stricter fuel economy goals*



Discussion

Contact us to find out how CSEG can help you improve your analysis.

Sudhi Uppuluri

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Upcoming webinars



- Key modeling considerations while modeling a 1D passenger car cooling system – *October 2011*
- Key modeling considerations while modeling 1D lubrication systems for diesel engines – *December 2011*

To sign-up to receive WebEx invitations of future technical webinars, please send an email with your contact information to webinars@cseg.us

DID I MENTION THAT...

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and make your CAE software do
advanced stuff.*

*The stuff you bought the
software to do to begin with.*