CENTER FOR COMPACT AND EFFICIENT FLUID POWER

A National Science Foundation Engineering Research Center

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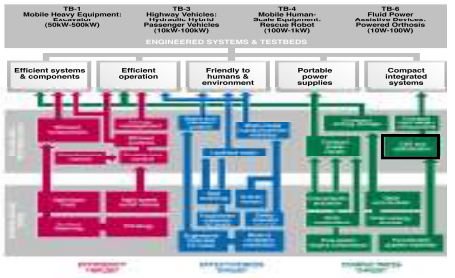
CCEFP Project 2E



Project 2E: Component Integration for Compact Fluid Power Systems

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What fluid power-related question is being answered?

- ***How can one most effectively represent design knowledge about fluid power systems?***
- Can one significantly reduce the time and effort required to formulate and solve fluid power design problems through composition and re-use of synthesis and analysis models?
- How can one capture analysis knowledge about fluid power components from multiple disciplinary perspectives and at multiple levels of abstraction?
- How can one use fluid power models at different levels of fidelity to search the system design space most efficiently?

How does this fit into the Center's overall strategy?

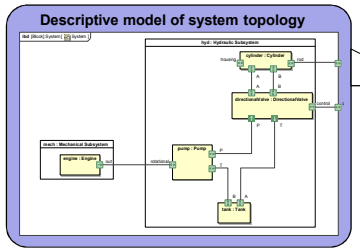
- Enable designers to make efficient and effective comparisons of different system architectures relative to their preferences for system-level trade-offs → Efficient Systems and Compact Integrated Systems
- Enable the evaluation of the impact of introducing new component technologies → Efficient Components
- Enable the fluid-power industry to predict the impact of technology trends on overall system performance → Efficient Systems and Compact Integrated Systems

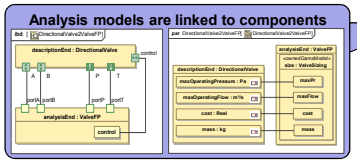
On which test bed will it be demonstrated?

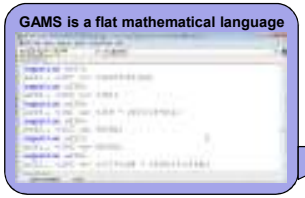
- The model-based systems engineering approach for fluid-power systems will be used to perform a thorough exploration of the space of system architectures for both **TB1 (Excavator)** and **TB3 (Hydraulic Hybrid Passenger Vehicle)**

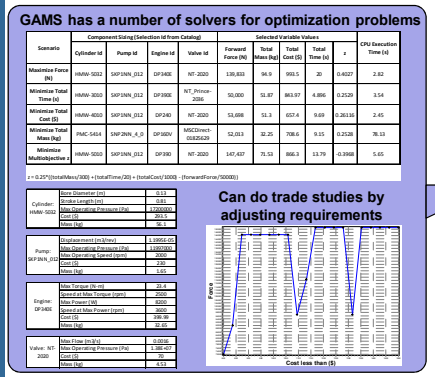
Main idea: Formally define models that capture knowledge about fluid power systems.

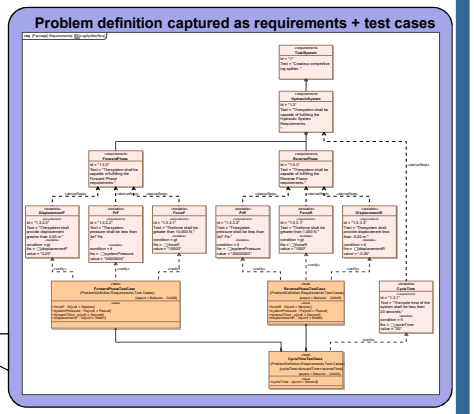
- Formal models of system, requirements, and test cases
- Models represented in a general purpose modeling language: OMG SysML™
- Model Transformations automatically generate additional models
  - Descriptive and Analytical Models
- GAMS (General Algebraic Modeling Language) for:
  - Cost, Mass, and Steady-State Analysis Models

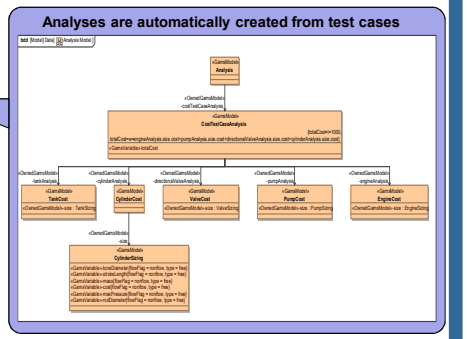


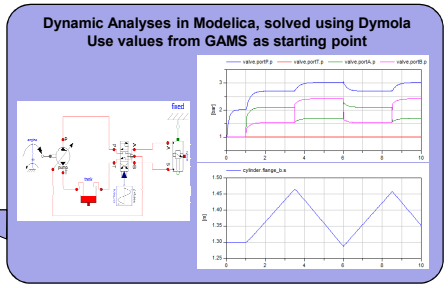






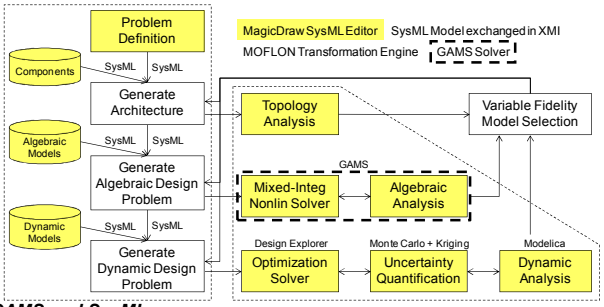






What progress has been made?

- ***ModelCenter Framework***



GAMS and SysML

- Defined a method for formulating hydraulic systems in terms of declarative algebraic models
- Acausal Mathematical Programming approach instead of imperative Simulation-based Optimization

Hydraulic Hybrid Vehicle (TB3)

- Formulated dynamic model of TB3 as a Mathematical Programming problem
- Approximated differential equations with algebraic differences
- Initial results using MINLP solvers are promising
- Need to develop complete model, much larger than typical MINLP problems

Value of Information Variable-Fidelity Modeling Framework

- Defined a method for incorporating multiple models into a Gaussian process surrogate model
- Proposed using of Value of Information to determine design sites of interest during exploration

Publications

- Kerzhner A.A., and C.J.J. Paredis, "Using Domain Specific Languages to Capture Design Synthesis Knowledge for Model-Based Systems Engineering," in *Proceedings of IDETC/CIE 2009*, San Diego, CA, 2009.
- Malak R.J. Jr, L. Tucker, and C.J.J. Paredis, "Compositional Modeling of Fluid Power Systems using Predictive Tradeoff Models," *International Journal of Fluid Power*, 10(2) p.45-56, 2009.
- Malak R.J. Jr, and C.J.J. Paredis, "Using Support Vector Machines to Formalize the Valid Input Domain of Predictive Models for Systems Design Problems," in *Journal of Mechanical Design*, Accepted pending revisions.
- Shah, A. A., C. J. J. Paredis, Burkhart, R., and Schaefer, D., "Combining Mathematical Programming and SysML for Component Sizing of Hydraulic Systems," *Proceedings of IDETC/CIE 2010*. Montreal, Quebec, Canada, 2010.
- Shah, A.A., D. Schaefer, and C.J.J. Paredis, "Enabling Multi-View Modeling with SysML Profiles and Model Transformations," in *Proceedings of the 6th International Conference on Product Lifecycle Management*, Bath, UK, July 6-8, 2009.

Who are the industry and university collaborators?

Industry	**University**
Deere & Co.,Sauer-Danfoss, Lockheed Martin, No Magic Inc., Phoenix Integration	Linköping University, Univ. of Darmstadt, Univ. of Stuttgart, Univ. of Bath