Development of an Exhaust Energy Recovery System Model

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Development of an Exhaust Energy Recovery System Model

- Background
- System Architecture
- Technology Development
- Model Development
  - Structure
  - Two-Phase Model
  - Model Validation
- Continuing Development
  - System Model
  - Modeling Tools

Background
System Goals and Solution

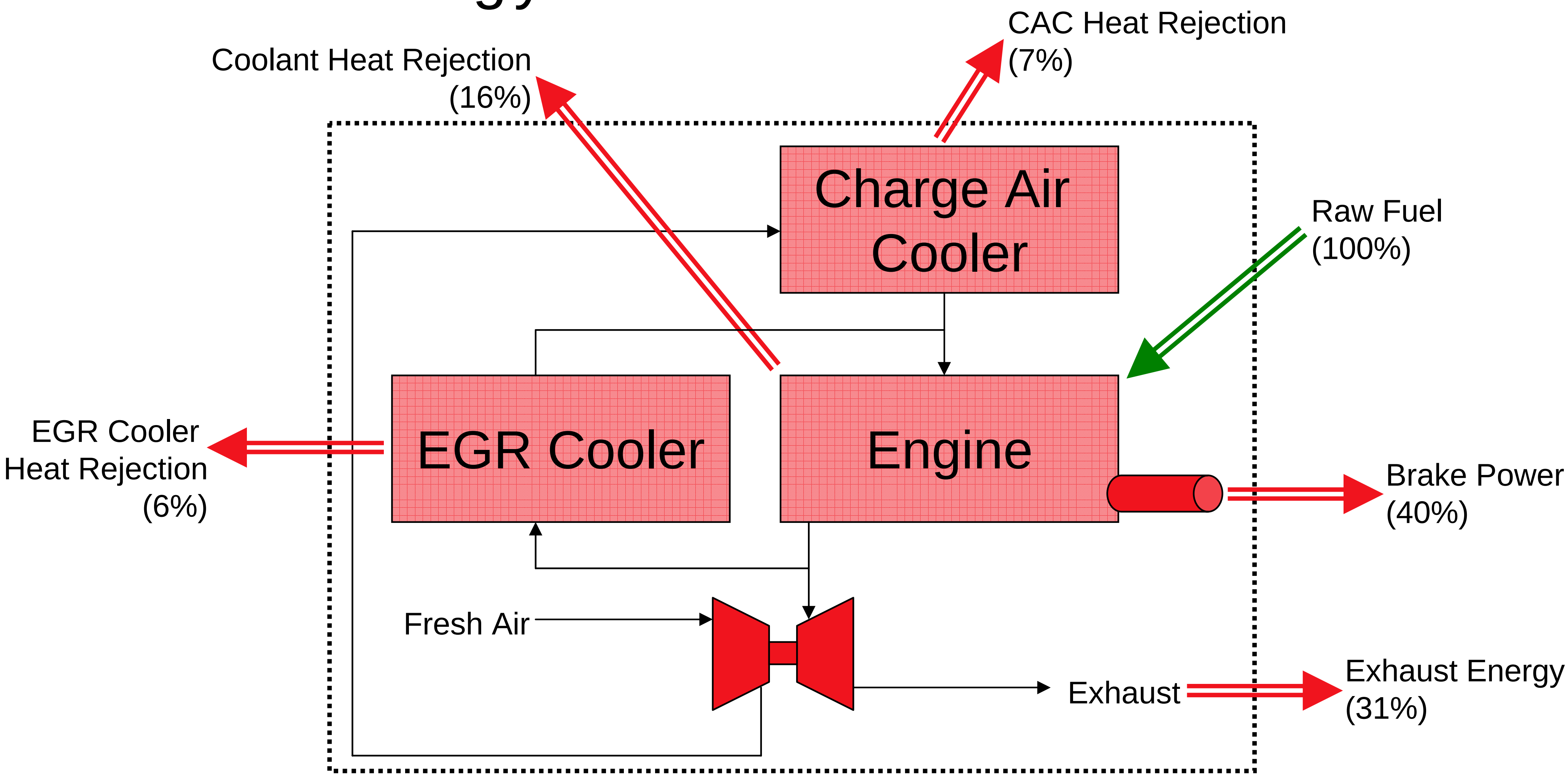
Goals

- Improve fuel efficiency by 10% on a 2010 engine
- Reduce the need for additional heat rejection capacity

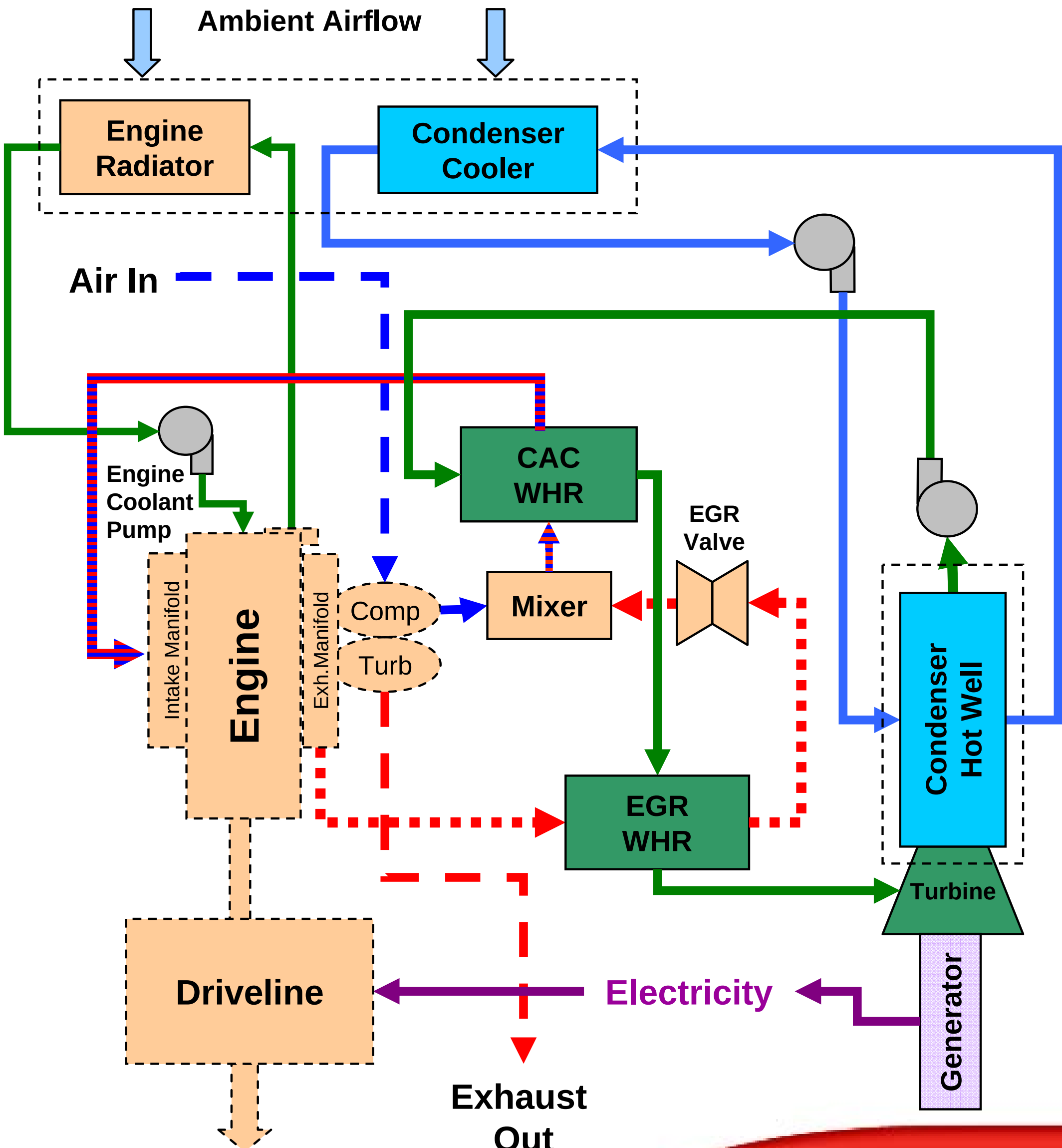
Solution

- Integrate a Rankine cycle with a diesel engine
- Recover heat from charge air cooler and EGR cooler

Background
Fuel Energy Distribution



System Architecture



Working fluid:

- Honeywell R245fa
- Steam

Technology Development

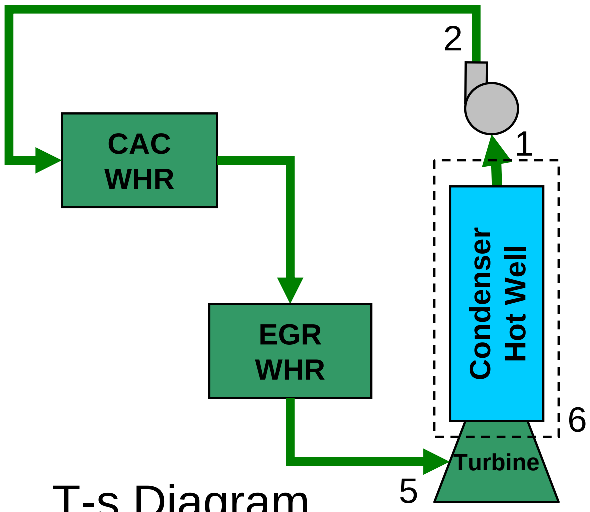
- Choose the right tool
  - Previous analysis in EES
  - Need detailed model for component sizing and dynamic system model for controls development
- GT-SUITE
  - GT-POWER does not currently have the ability to model two-phase flow
  - New simplified model developed to circumvent this issue

Model Development Structure

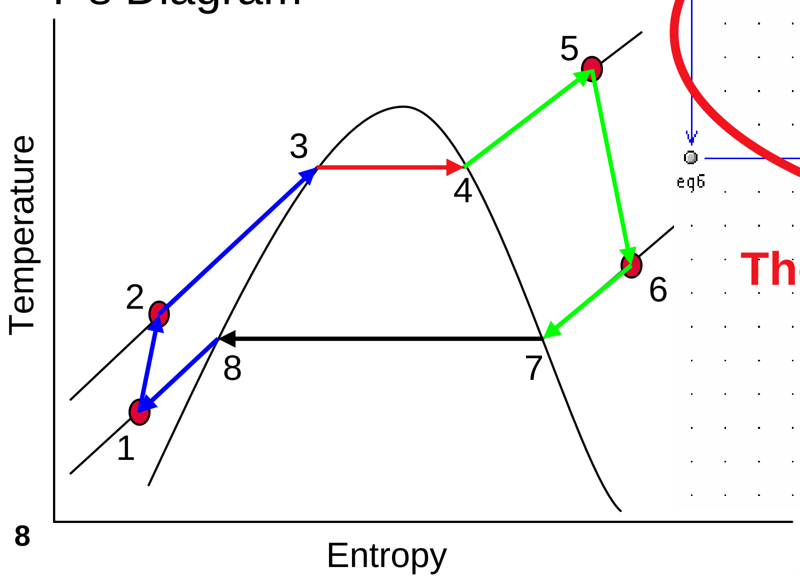
- Independent flow paths for liquid and vapor
- Link flow paths with thermodynamic equations (implemented by sensors and actuators)

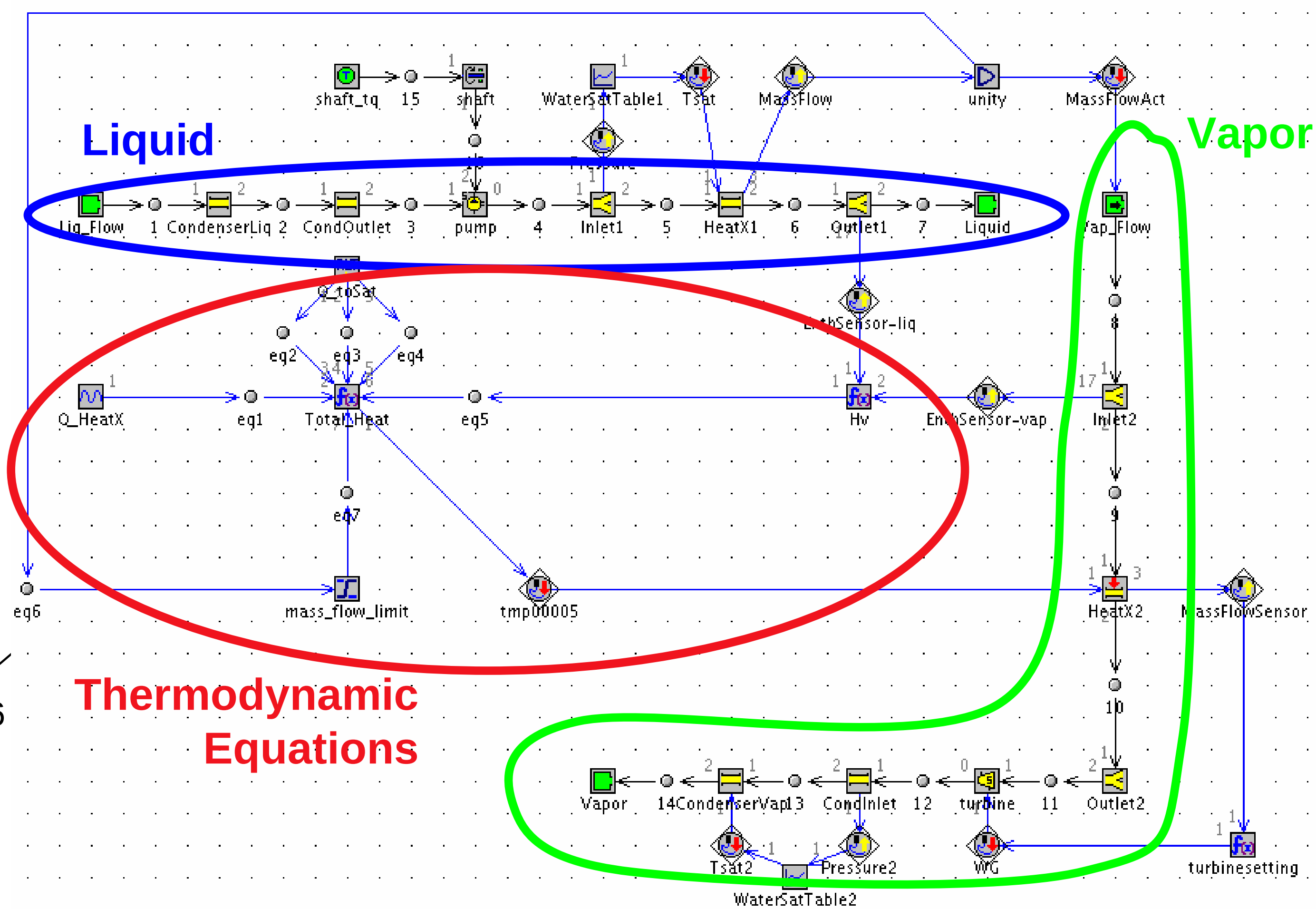
- Assumptions
  - Two independent flow paths
  - There can be no operating state within the two phase region
  - Constant pressure phase change
  - All heat input is transferred to the working fluid

Model Development
Two-Phase Model



T-s Diagram





Model Development
Two-Phase Model: Thermodynamics

- Use the following equations to determine heat addition

q_{HX} : Heat transfer from heat exchanger (input from engine model)

q_{sat} : Heat required to reach saturation temperature (from GT-SUITE)

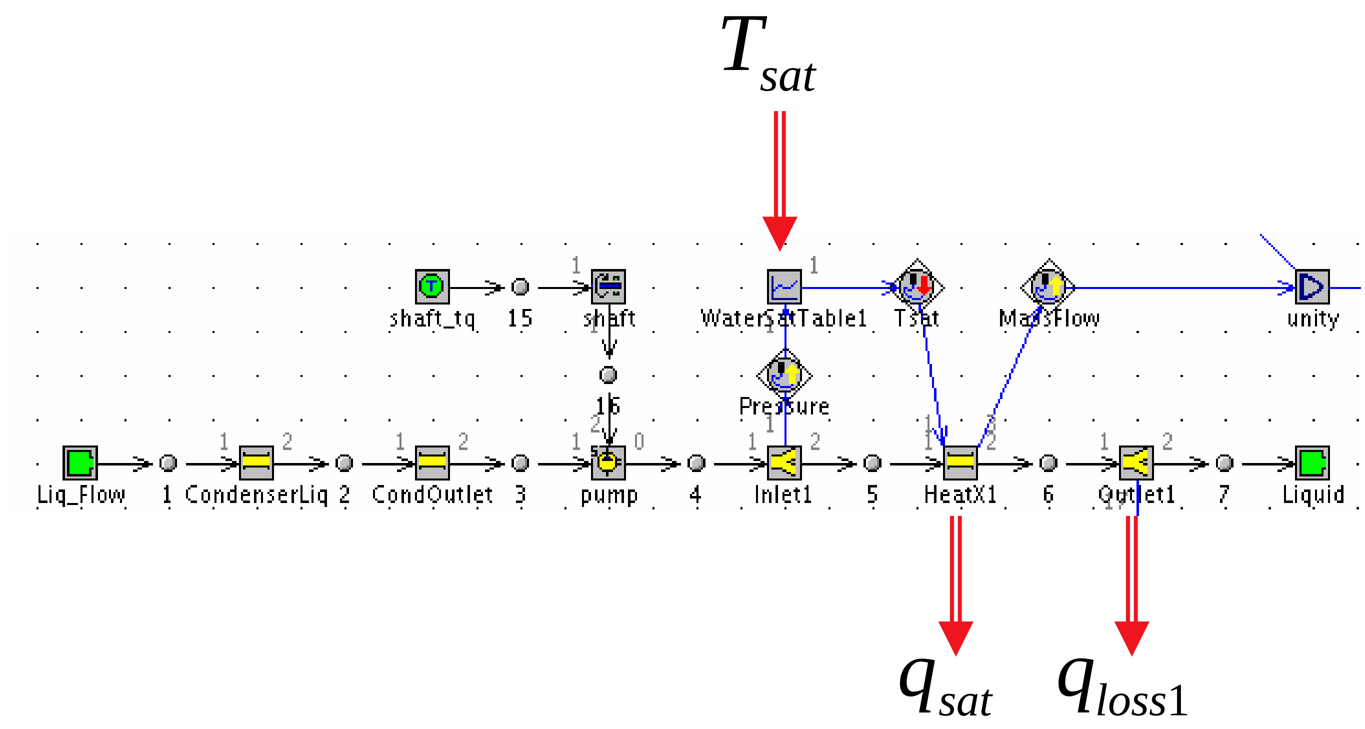
q_{loss1} : Heat lost in HX1 outlet (from GT-SUITE)

q_{loss2} : Heat lost in HX2 inlet (from GT-SUITE)

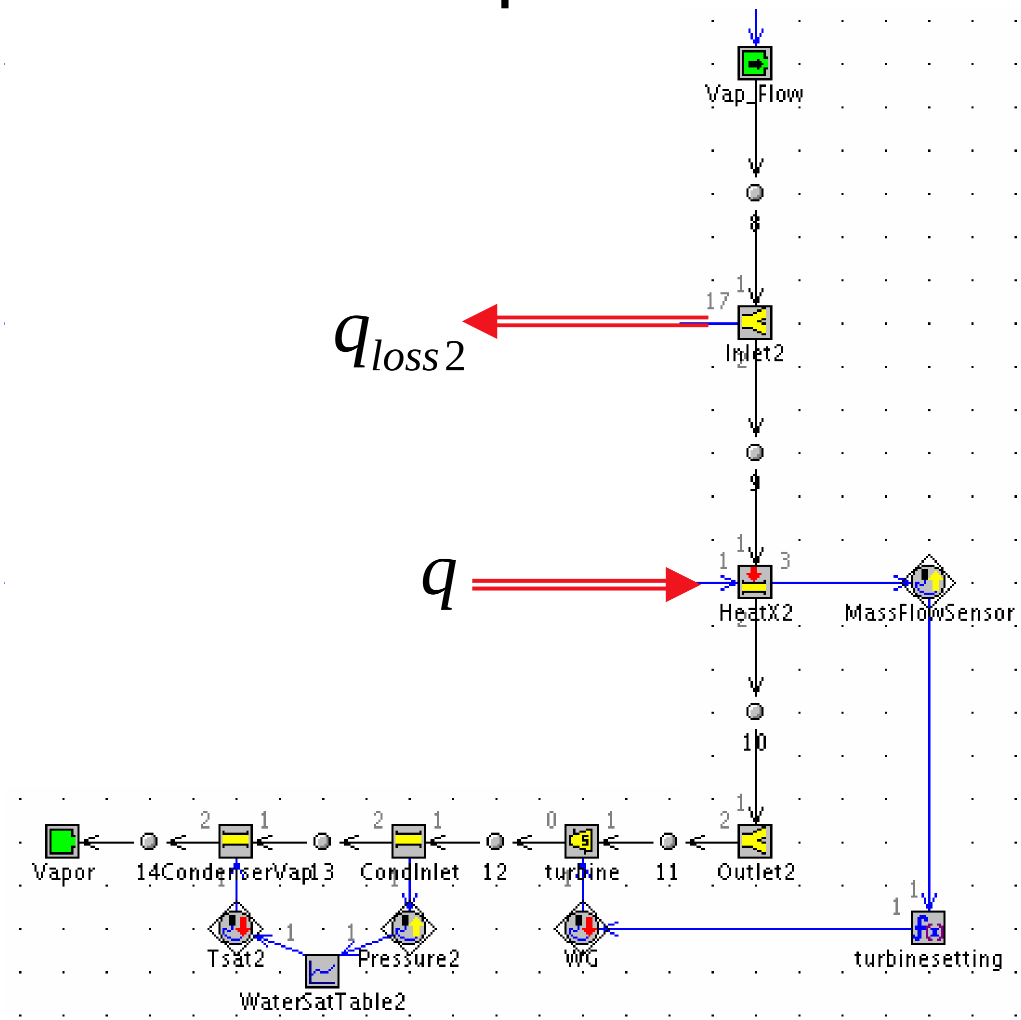
$$T_{wall\_HX1} = T_{sat}$$

$$q = q_{HX} - q_{sat} - q_{loss1} - q_{loss2} - H_v \dot{m}$$

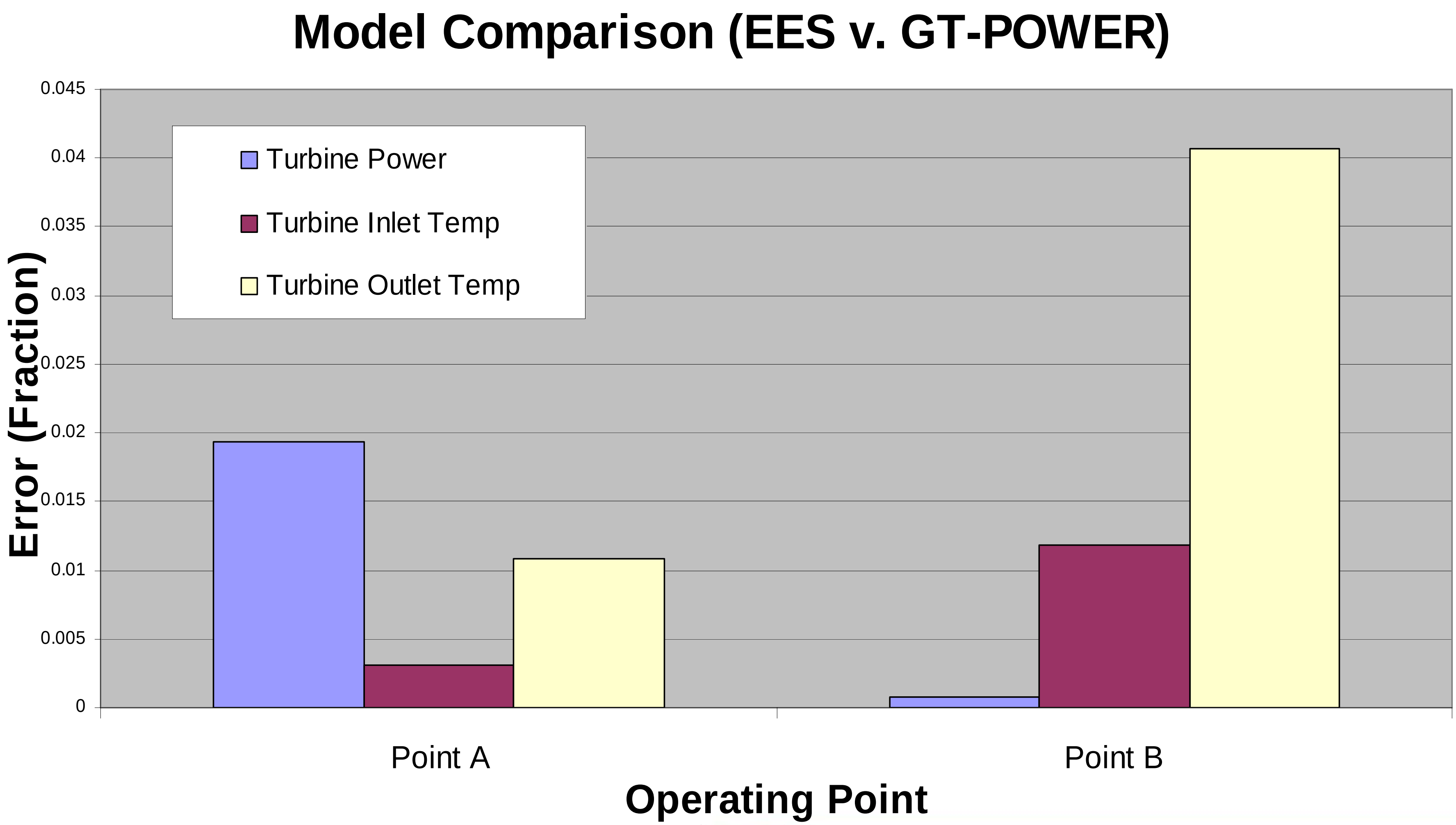
Model Development
Two-Phase Model: Liquid Flow Path



Model Development
Two-Phase Model: Vapor Flow Path



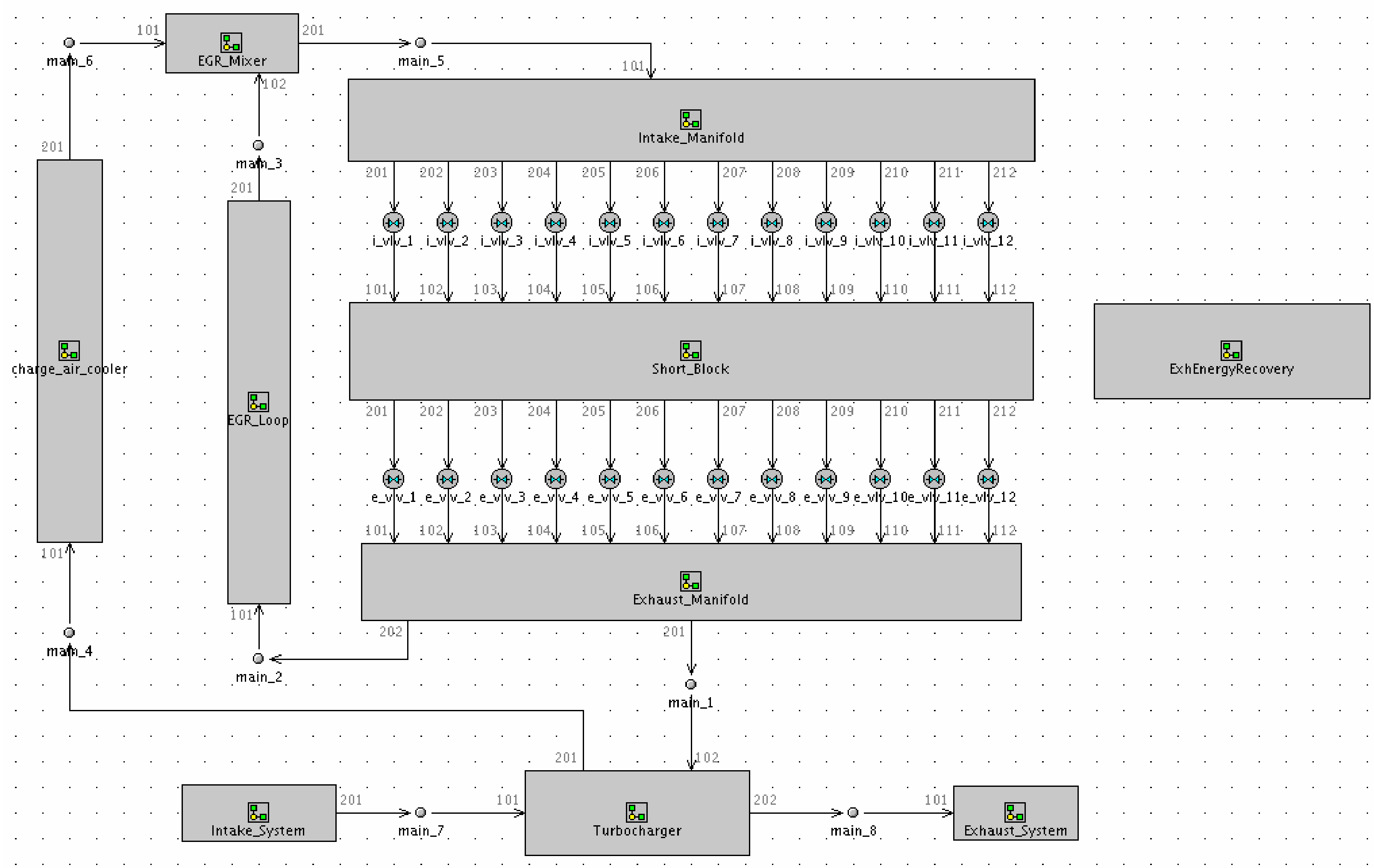
Model Development
Model Validation



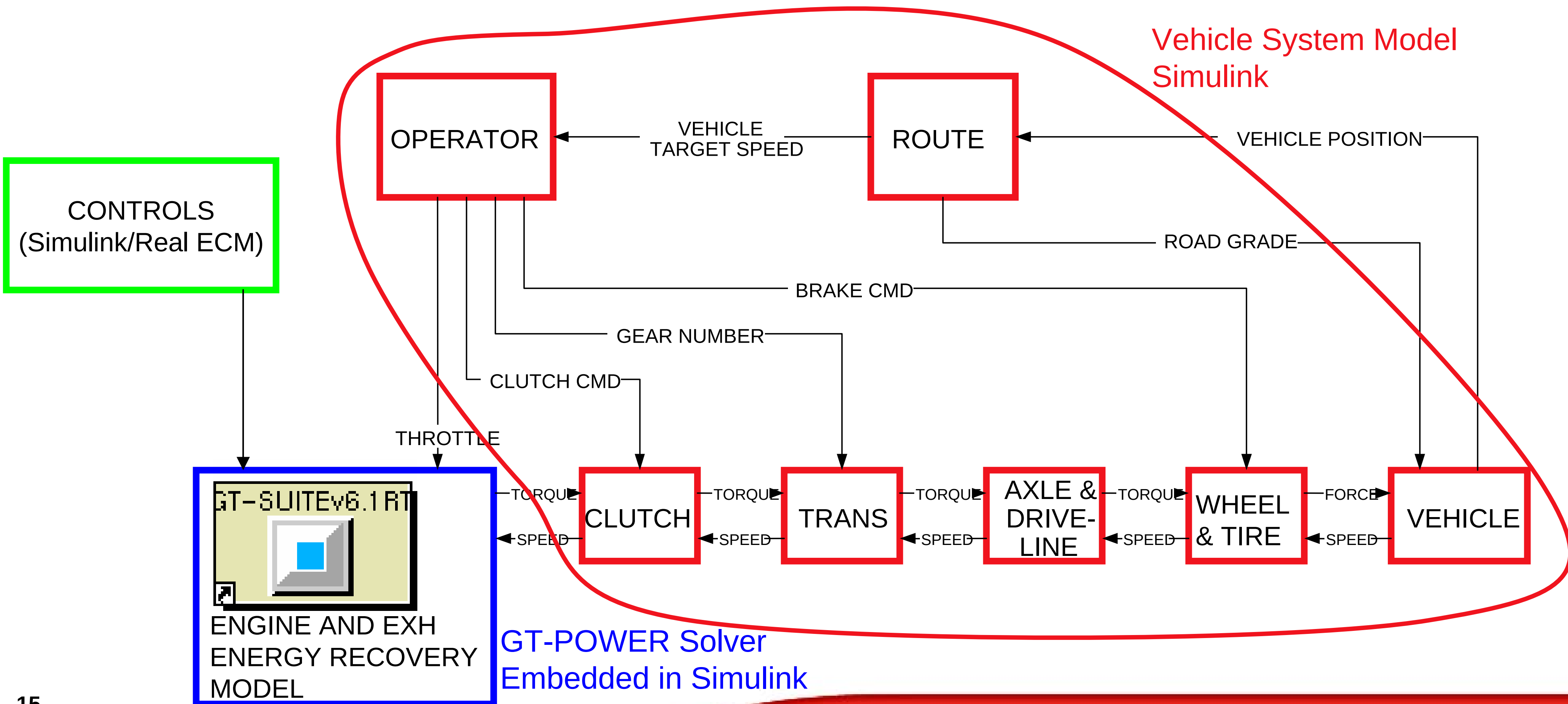
Continuing Development
System Model

- Integrate the exhaust energy recovery Rankine cycle system model with an engine model
  - More detailed heat exchanger models (Master/slave, effectiveness)
- Analyze time step constraints
  - Push development of real time model for dynamic system model

Continuing Development
System Model



Continuing Development
Dynamic System Model



Continuing Development Modeling Tools

- GT-SUITE
  - Ability to model two-phase flow
  - Ability to develop stable real time capable engine and exhaust energy recovery model

Questions?