KULI DRIVE

3rd KULI User Meeting
17th – 18th Oct 2001

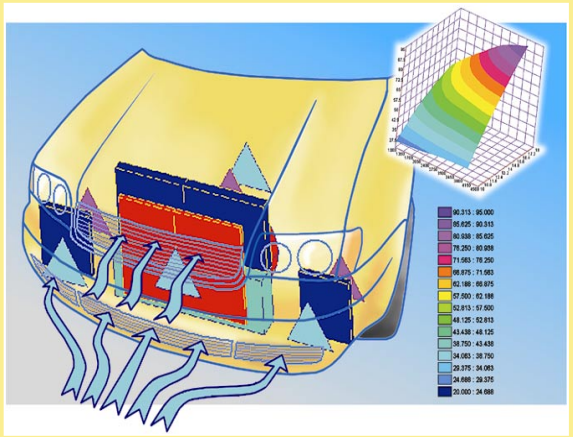
Simulation of transient processes for real driving cycles

Th. Gumpoldsberger, ECS, Steyr

KULI MODULES

KULI ADVANCED

KULI 5.0



KULI AC

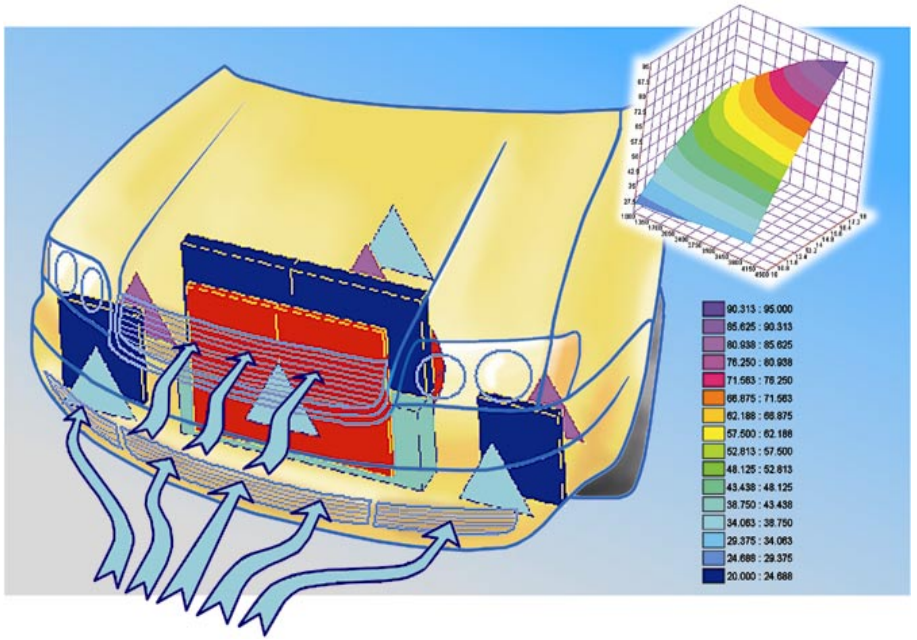
KULI DRIVE

KULI HEATSIM

KULI DRIVE

Content:

- Overview
- Examples
- Requirements
- Measurement
- Data Analysis
- Preferred KULI Model
- Balanced Model



KULI DRIVE - Overview

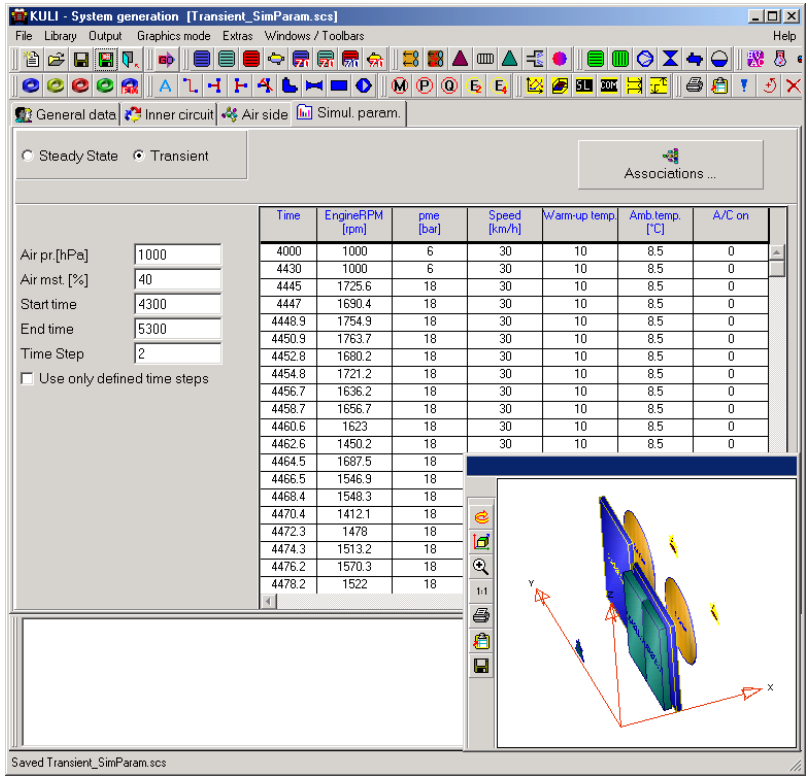
Simulation Targets

- **Heating-Up**
  (steady boundary conditions)
- **Driving Cycle Simulation**
  (unsteady boundary conditions)
- **Parameter Determination**
  (thermostat opening, fan activation, ...)

KULI DRIVE - Overview

➢ Time Dependent Variables in KULI

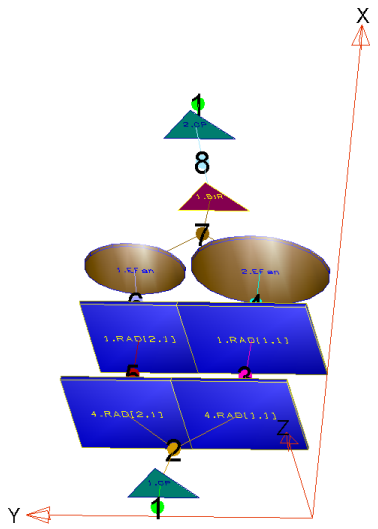
- Driving Speed
- Engine RPM
- Effective Mean Pressure
  - fan speed
  - top hose temperatures
  - rejected heat
  - mass flow rate
- Ambient Parameters
- E-Fan Stages

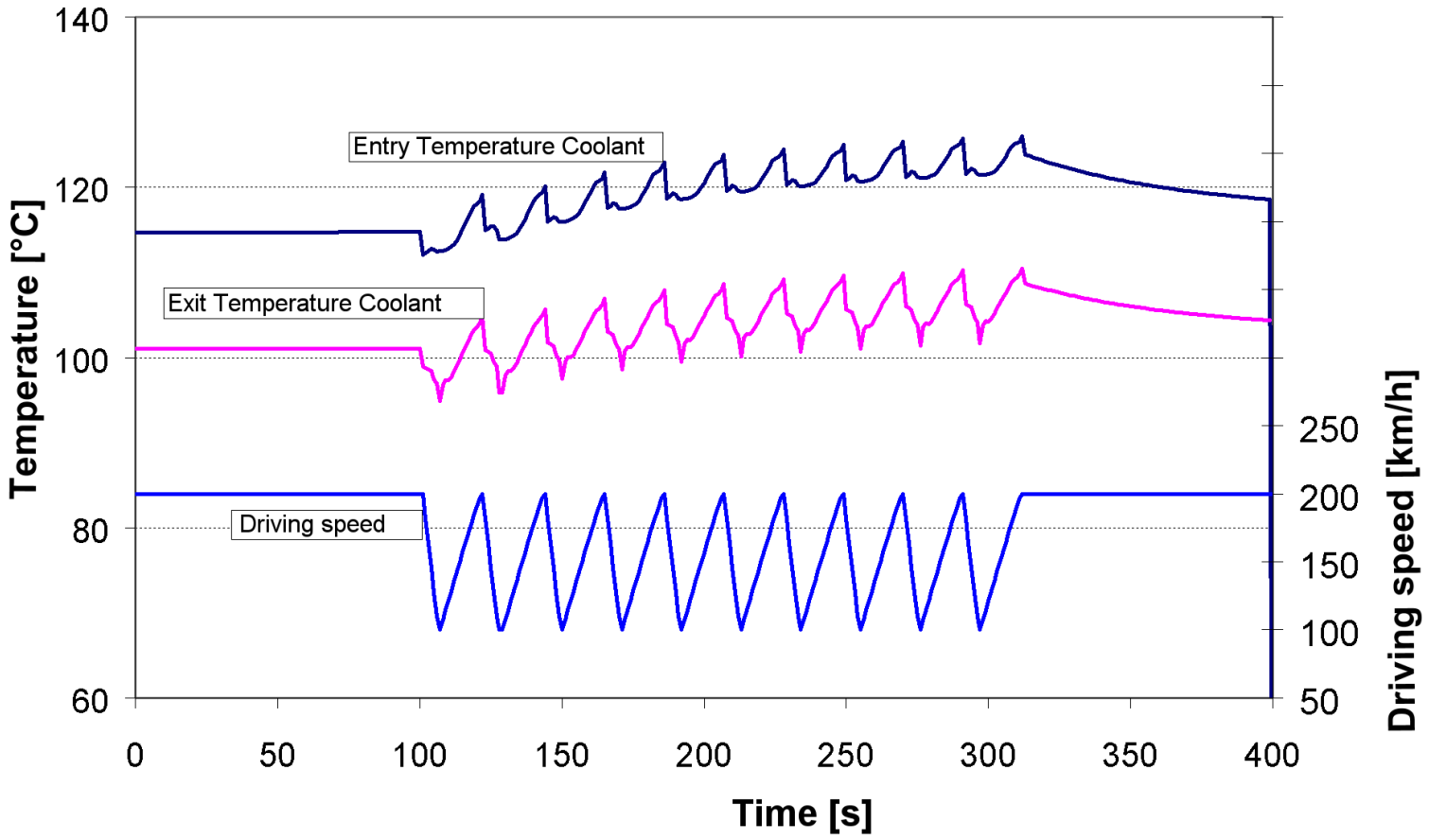


➢ Sensor Dependent Actuator Values

KULI DRIVE - Examples

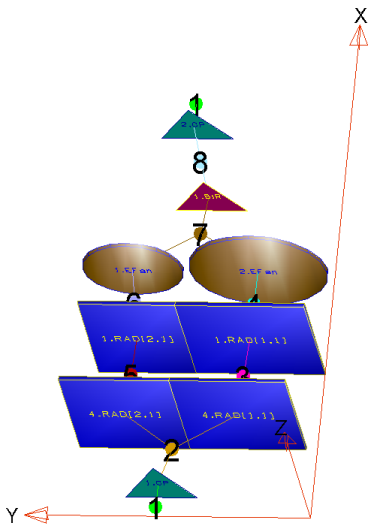
Transient Analysis – Synthetic Driving Cycle

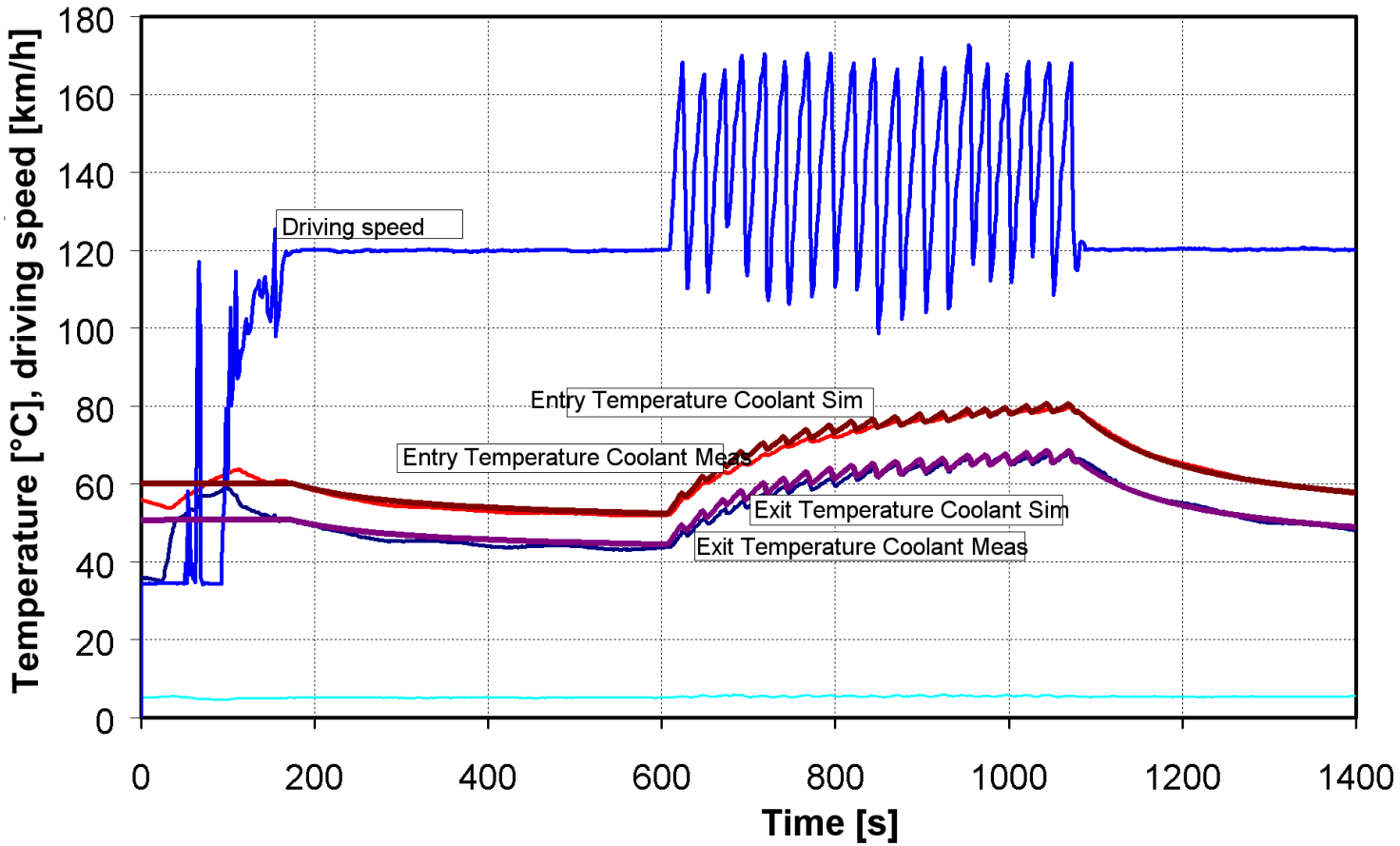




KULI DRIVE - Examples

Transient Analysis – Real Driving Cycle





KULI DRIVE - Requirements

Transient Analysis – Required Data

➢ Steady State Balanced Cooling System

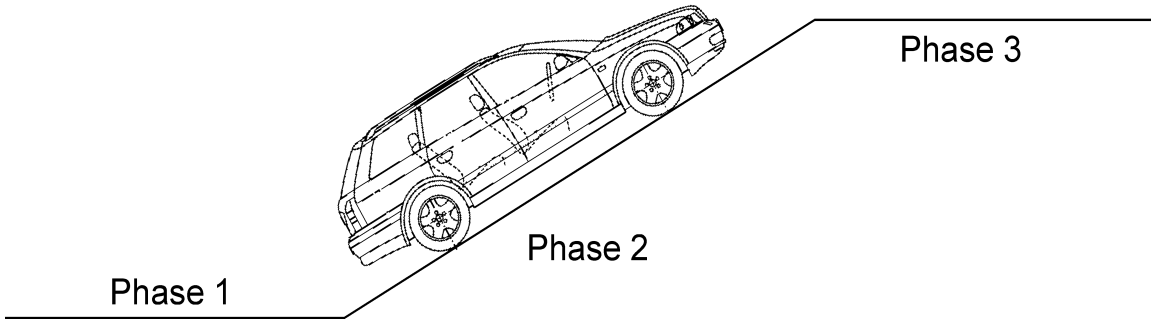
- Heat Map of the Engine
- Mass Flows
- Built-In Resistance
- Media Temperatures
- ...

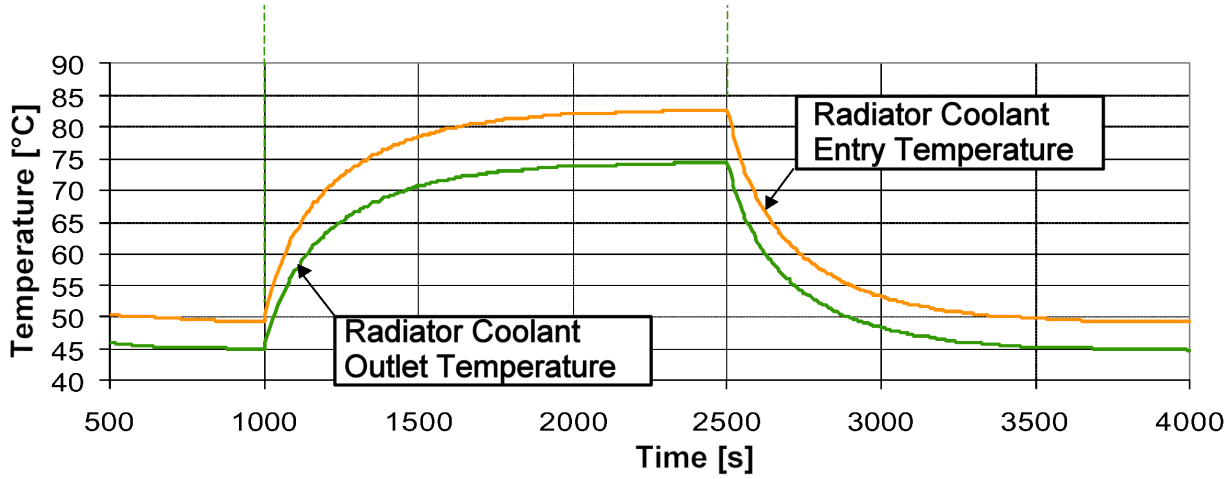
➢ Transient Balanced Cooling System

- Coolant Temperatures vs. Time
- Fan speed vs. Time
- Engine Load and Speed vs. Time

KULI DRIVE - Measurement

Transient Analysis – Measurement





KULI DRIVE - Data Analysis

Transient Analysis – Measurement Analysis

- **Automatic Balancing**

  Use of the **HEATSIM Engine**

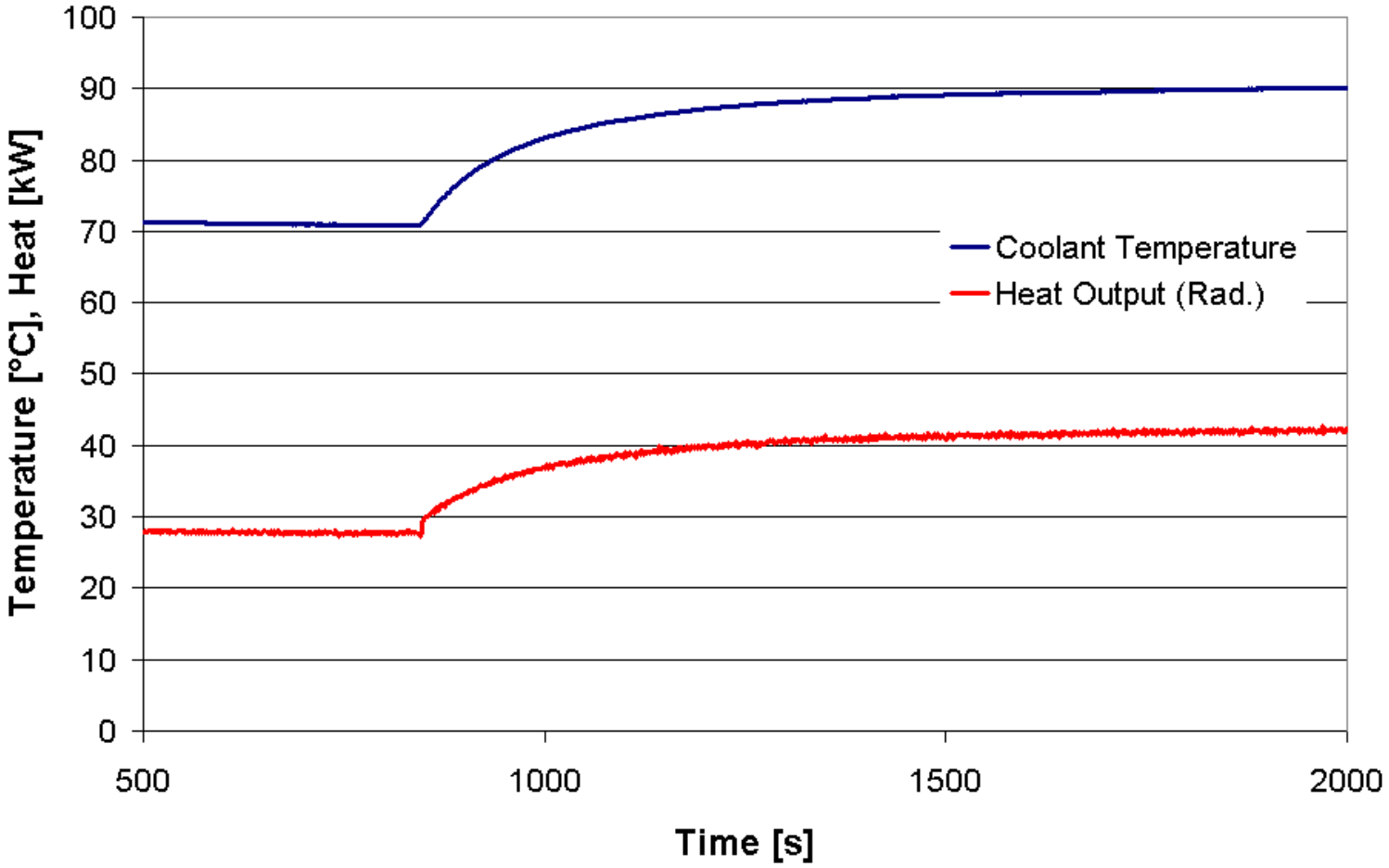
- **Manual Balancing**

  Analysis of the **Measurement Data**

  - Heat Input
  - Heat Output
  - Change of temperatures

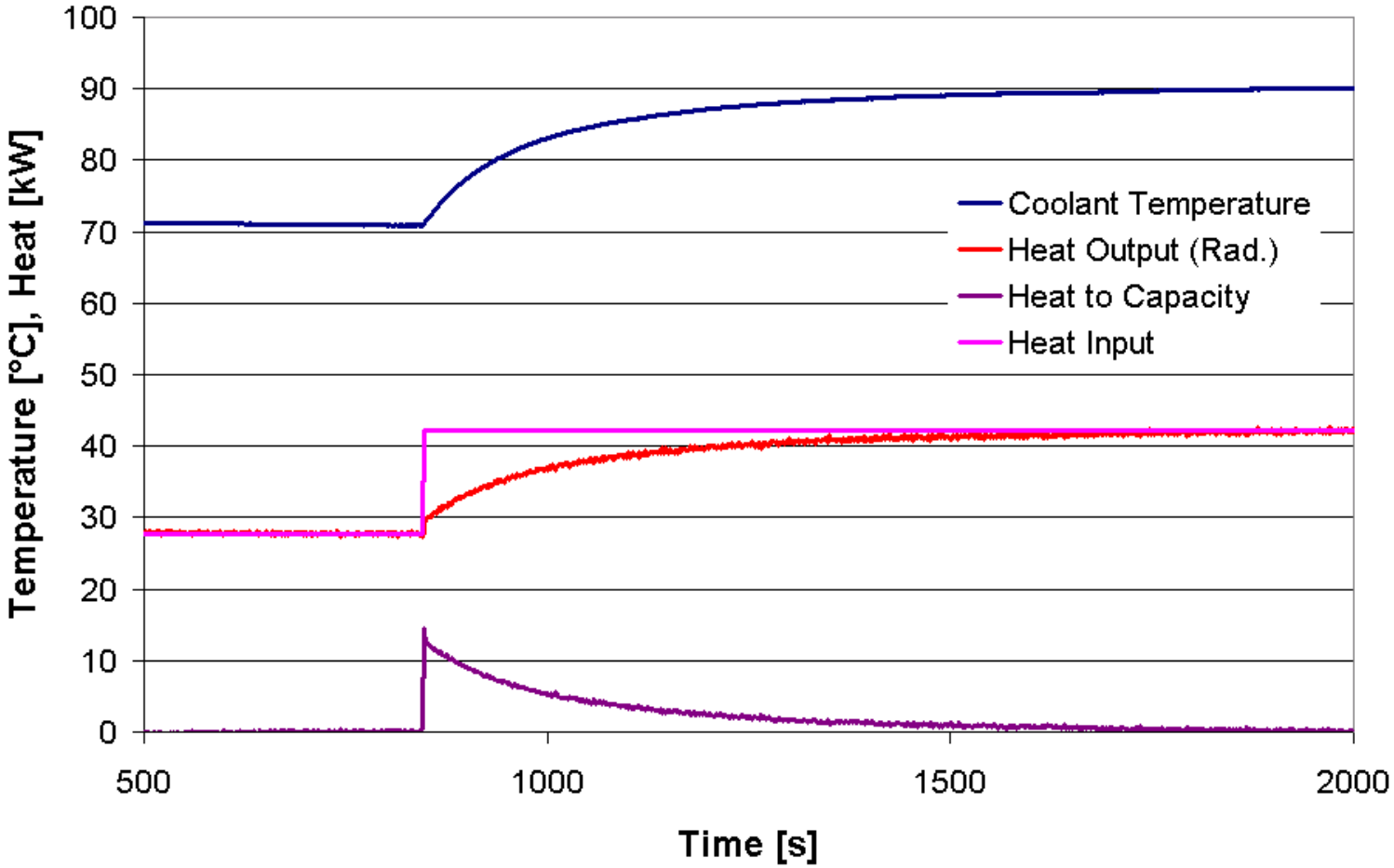
KULI DRIVE - Data Analysis

➢ Manual Balancing



KULI DRIVE - Data Analysis

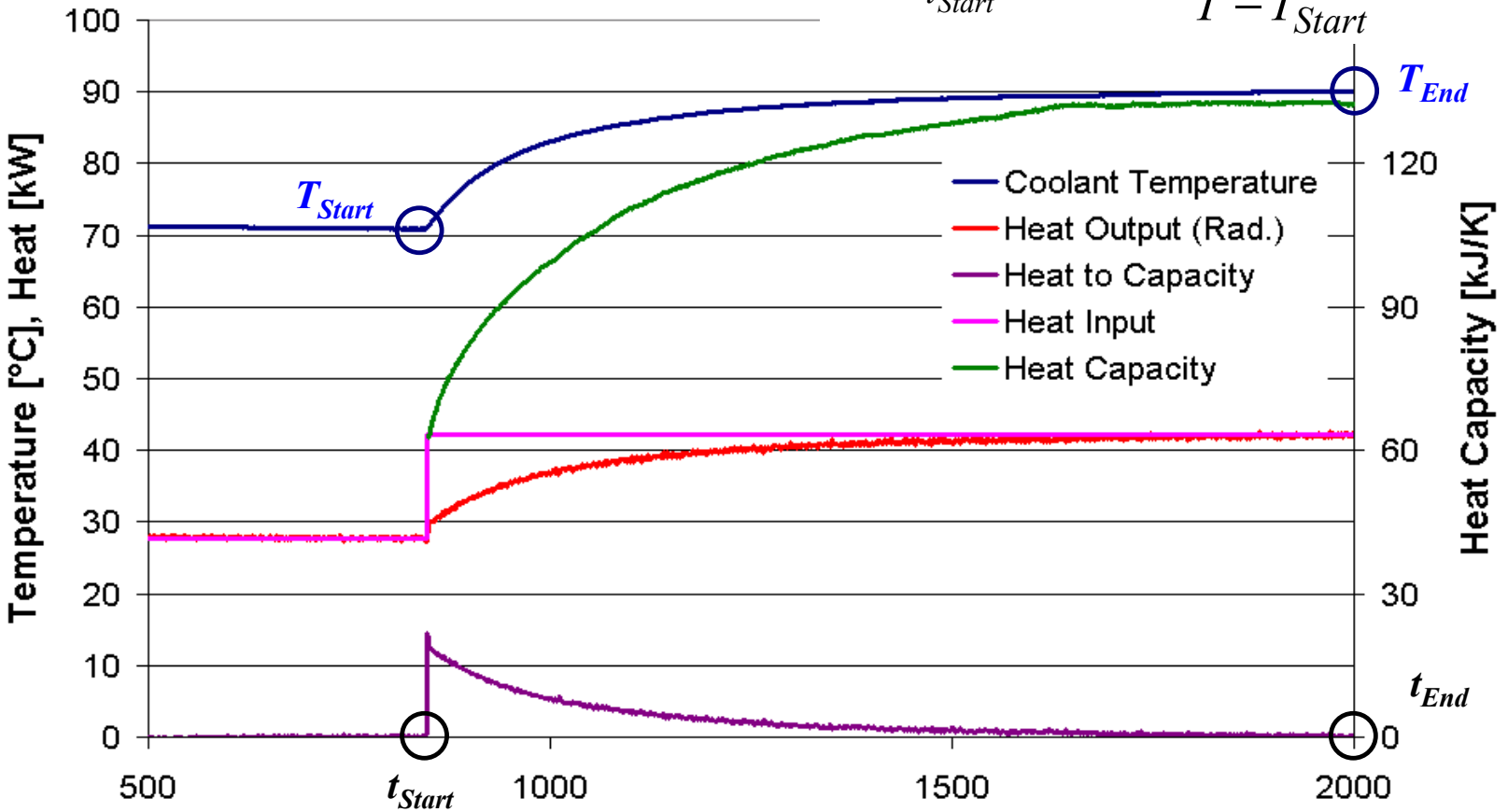
➢ Manual Balancing



KULI DRIVE - Data Analysis

➢ Manual Balancing

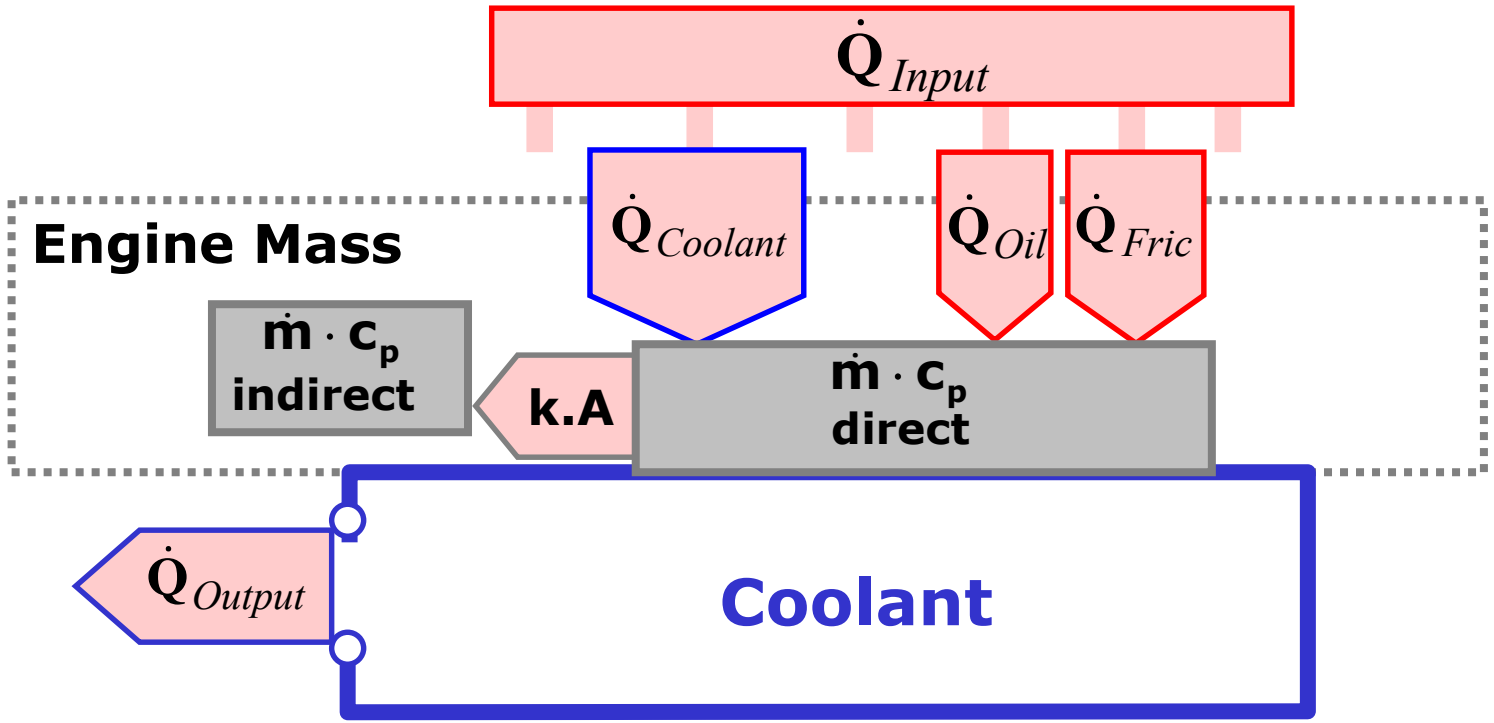
$$Mcp\Big|_{t_{Start}}^{t} = \frac{\int_{t_{Start}}^{t} \left(\dot{Q}_{Input} - \dot{Q}_{Output}\right) \cdot dt}{T - T_{Start}}$$



$$W = \int \dot{Q} \cdot dt = Mcp \cdot \Delta T$$

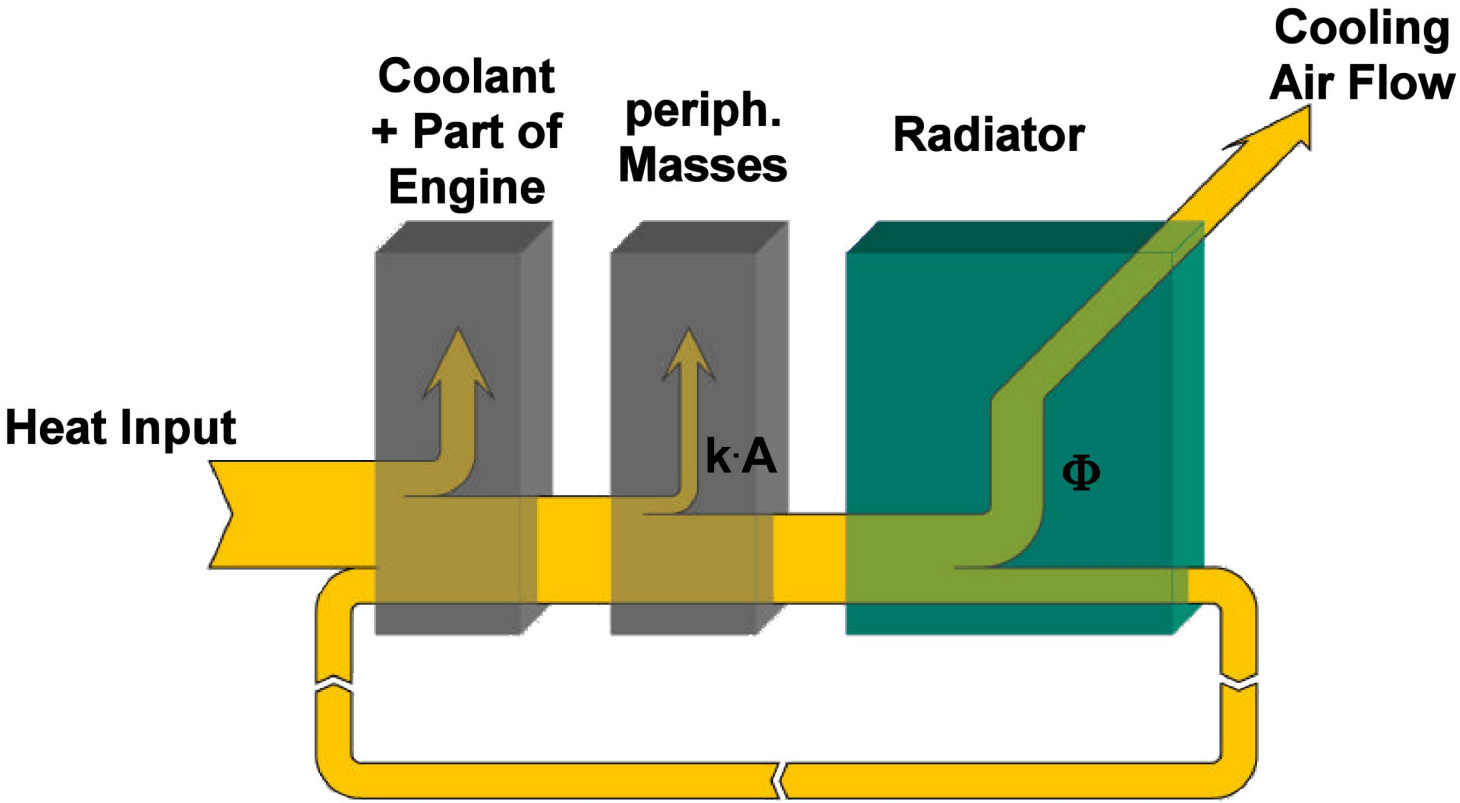
KULI DRIVE – Preferred KULI Model

➢ Engine Model



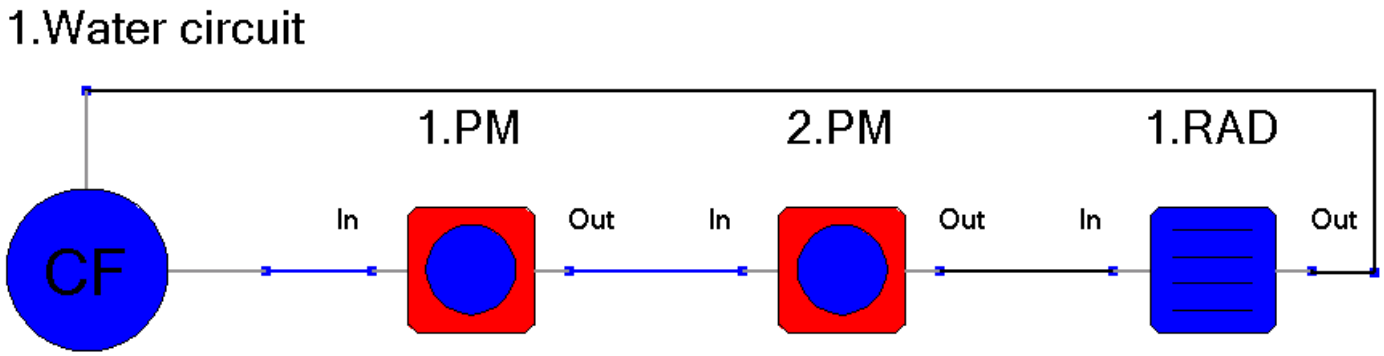
KULI DRIVE – Preferred KULI Model

➢ Engine Model: Heat Flow Diagram



KULI DRIVE – Preferred KULI Model

➢ Engine Model: KULI



1.PM: Direct Heated Masses

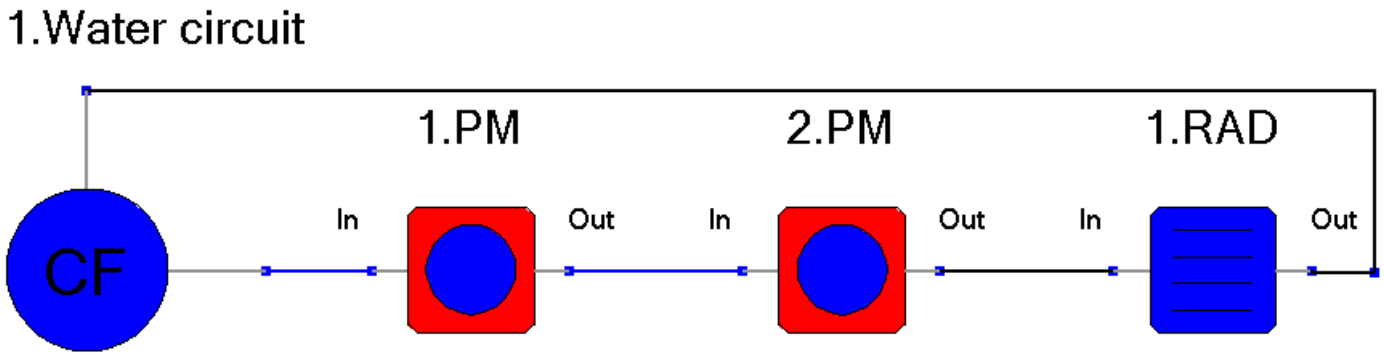
Heat Transfer Area * Heat Transfer Coefficient is very high

2.PM: Indirect Heated Masses

Heat Transfer Area * Heat Transfer Coefficient of the Balancing

KULI DRIVE – Preferred KULI Model

➢ Engine Model KULI: Balancing Parameters



1.PM: Direct Heated Masses

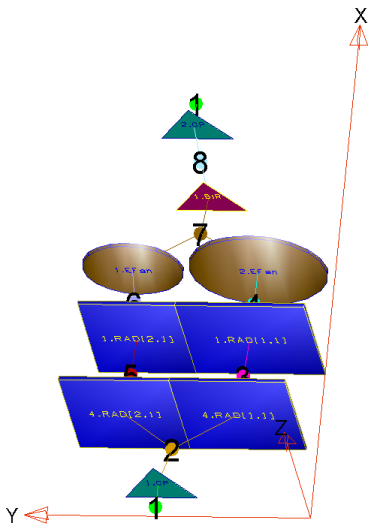
Heat Capacity -> Of Data Analysis

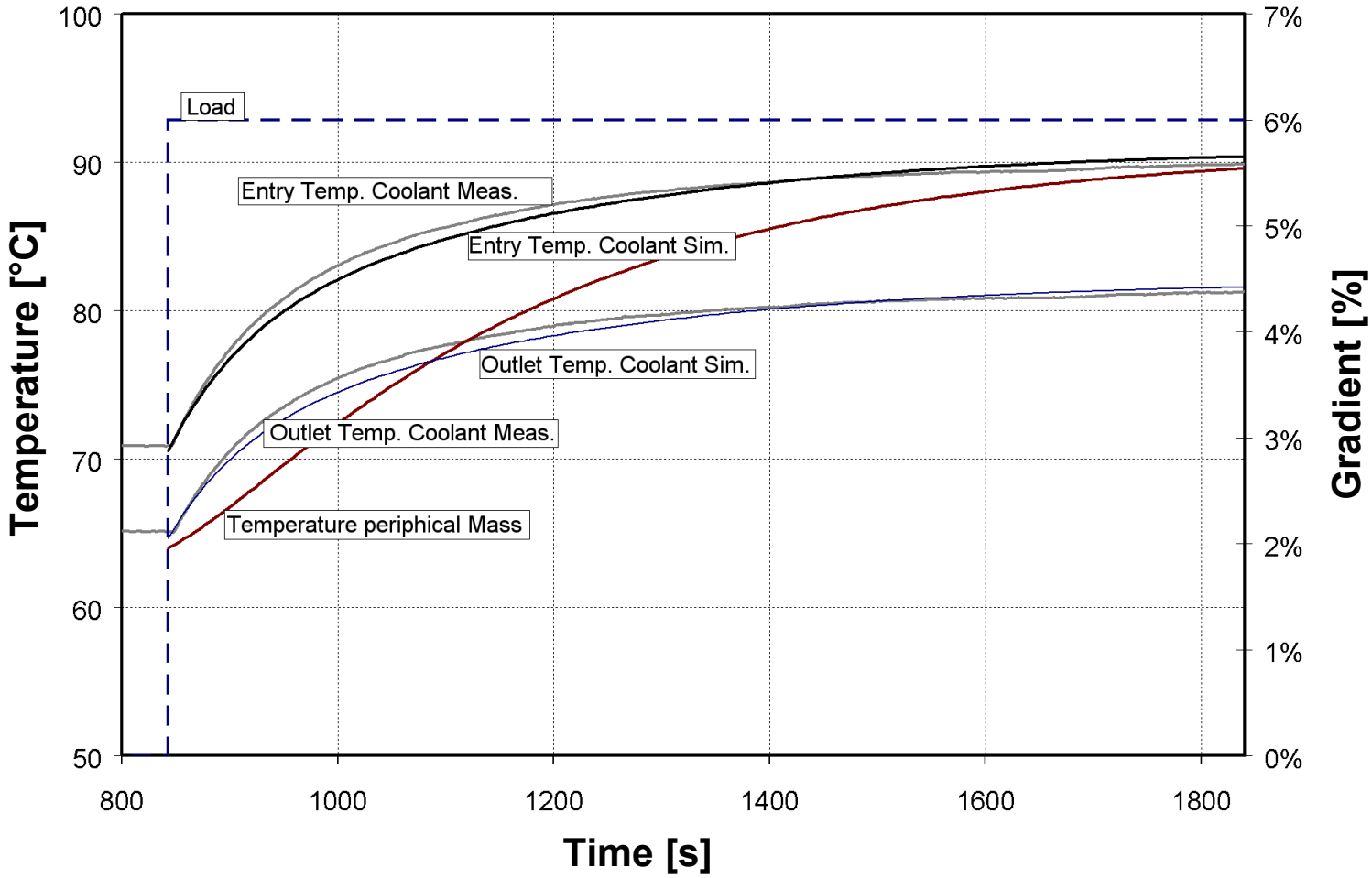
2.PM: Indirect Heated Masses

Heat Capacity -> Of Data Analysis

Heat Transfer -> Of Equalization

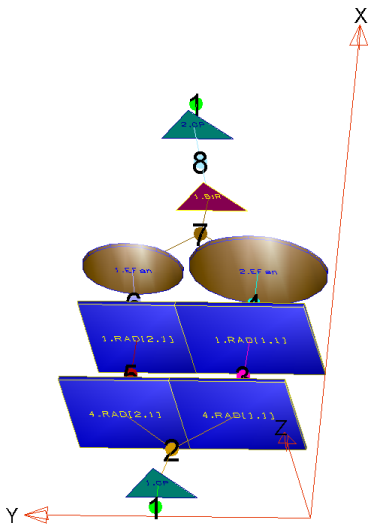
KULI DRIVE – Balanced Model

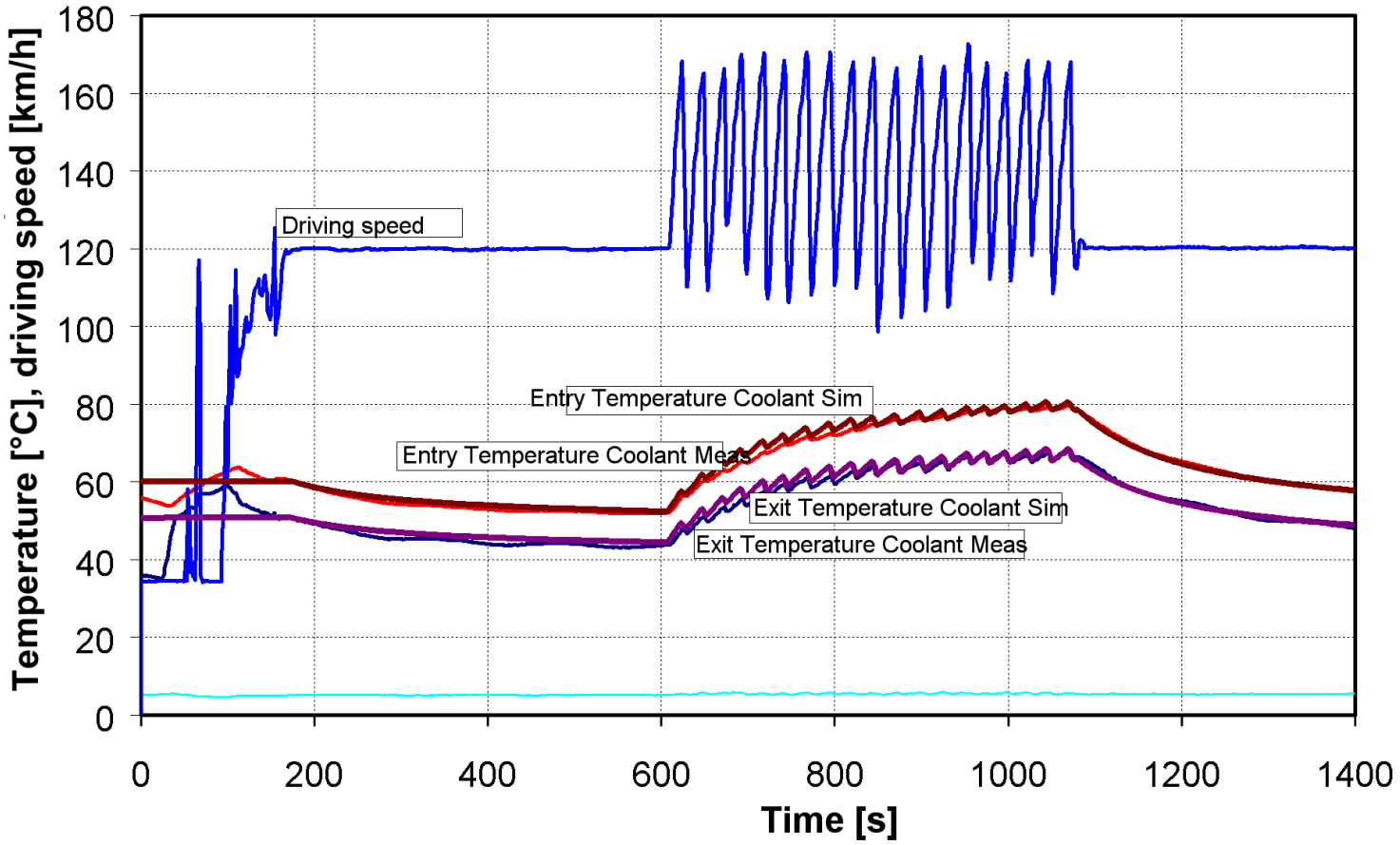




KULI DRIVE - Examples

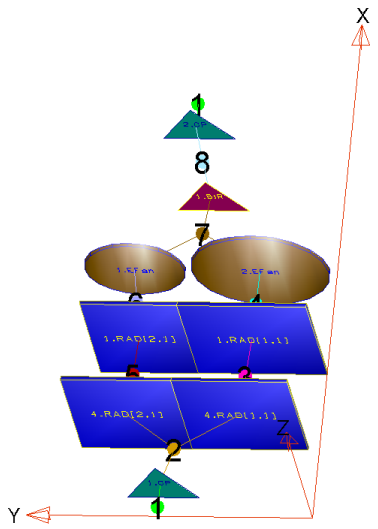
Transient Analysis – Real Driving Cycle

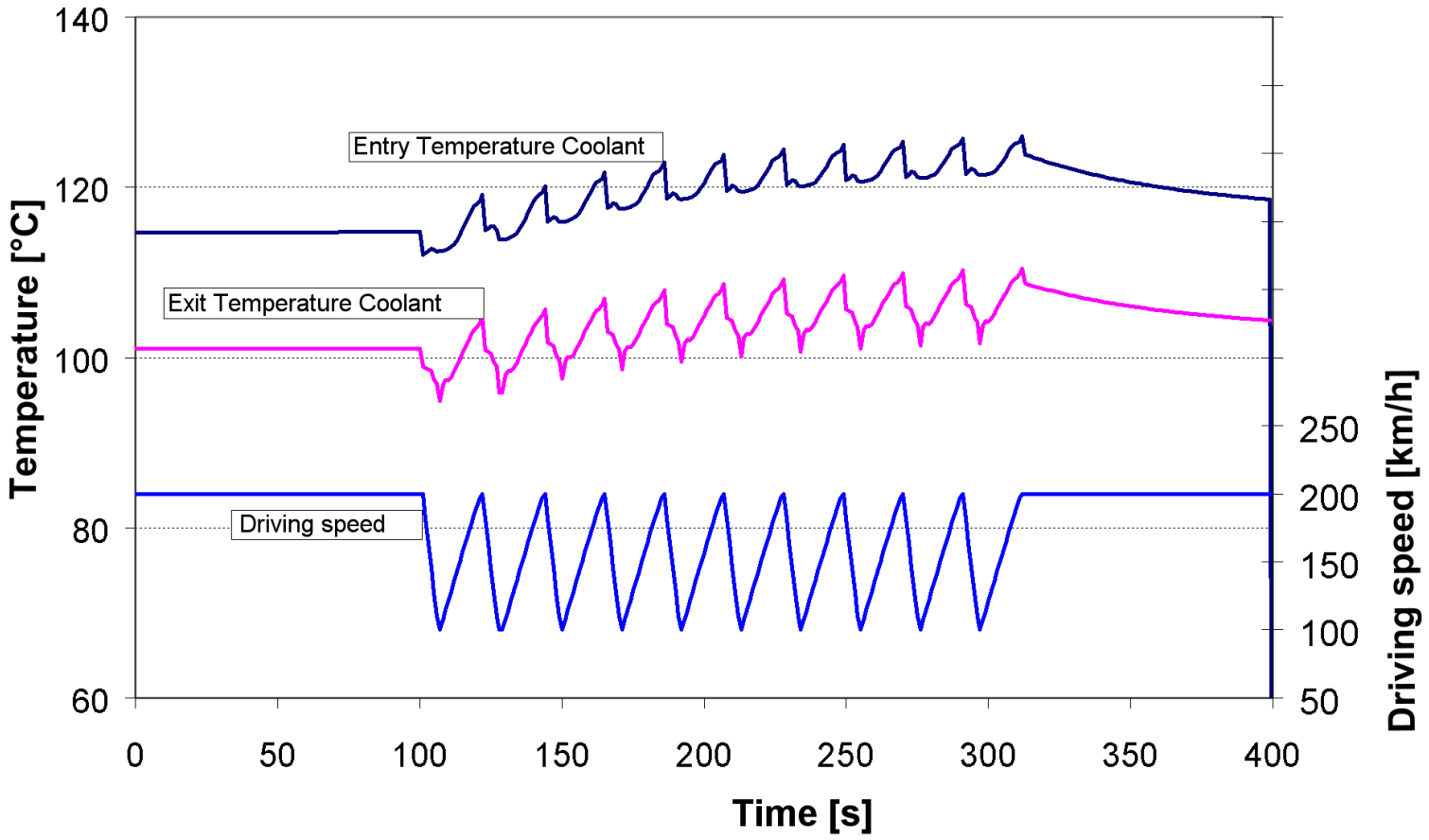




KULI DRIVE - Examples

Transient Analysis – Synthetic Driving Cycle





Summary – DRIVE Transient

➢ Driving Cycle

- Accurate prediction
- Low effort
- Verification of steady state designed systems for transient driving cycles

➢ Parameter Determination

- Thermostat opening
- Strategy for fan activation
- Fuel reduction for high coolant temperatures
- Development of emergency strategies

Future Development KULI – DRIVE Transient

➢ Downgraded HEATSIM-Engine

- 2-mass Model (Coolant Circuit)
- 4-mass Model (Coolant and Oil Circuit)
- Automatic Balancing
- Internal Heat Transfer in the Engine (Oil to Coolant)

➢ Integrated Driving Simulation

- Road Profile
- Gearbox
- Resistances
- Engine data
- Vehicle data

The End

Thank You For Your Attention

Thomas Gumpoldsberger,

and the ECS-Steyr KULI Team