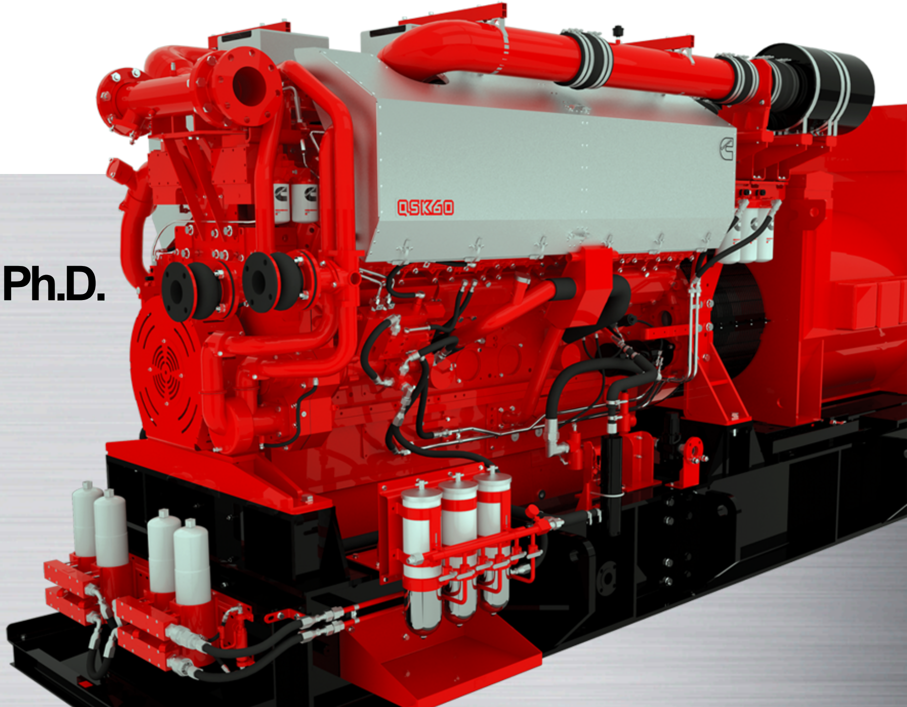
Marine Keel Cooler Optimization Tool

EML 4551C Senior Design



Sponsored by **Frank Ruggiero**

Faculty Advisor **Steven W. Van Sciver, Ph.D.**

Instructor **Nikhil Gupta, Ph.D.**

Team 3

Melissa Allende *Grady Beasley* *Stanko Gutalj*

James Haga *Jacob Ross*

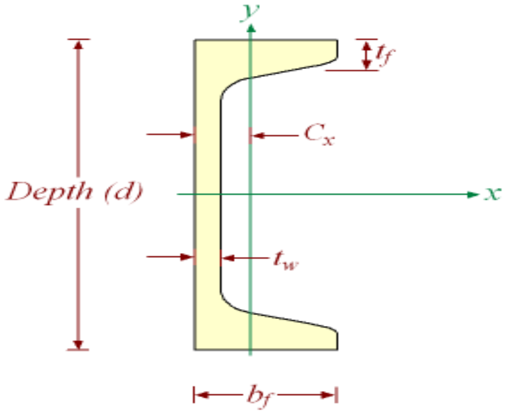
Presented 19 November 2015

Overview

- What is a Keel Cooler
- Background and Theory
- Problem Statement and Goal
- Project Scope
- Software
- Hardware
- Scheduling and Resource Allocation
- Results
- Conclusion

What is a Keel Cooler?

- A heat exchanger used to cool marine engines that is located on the hull of a boat

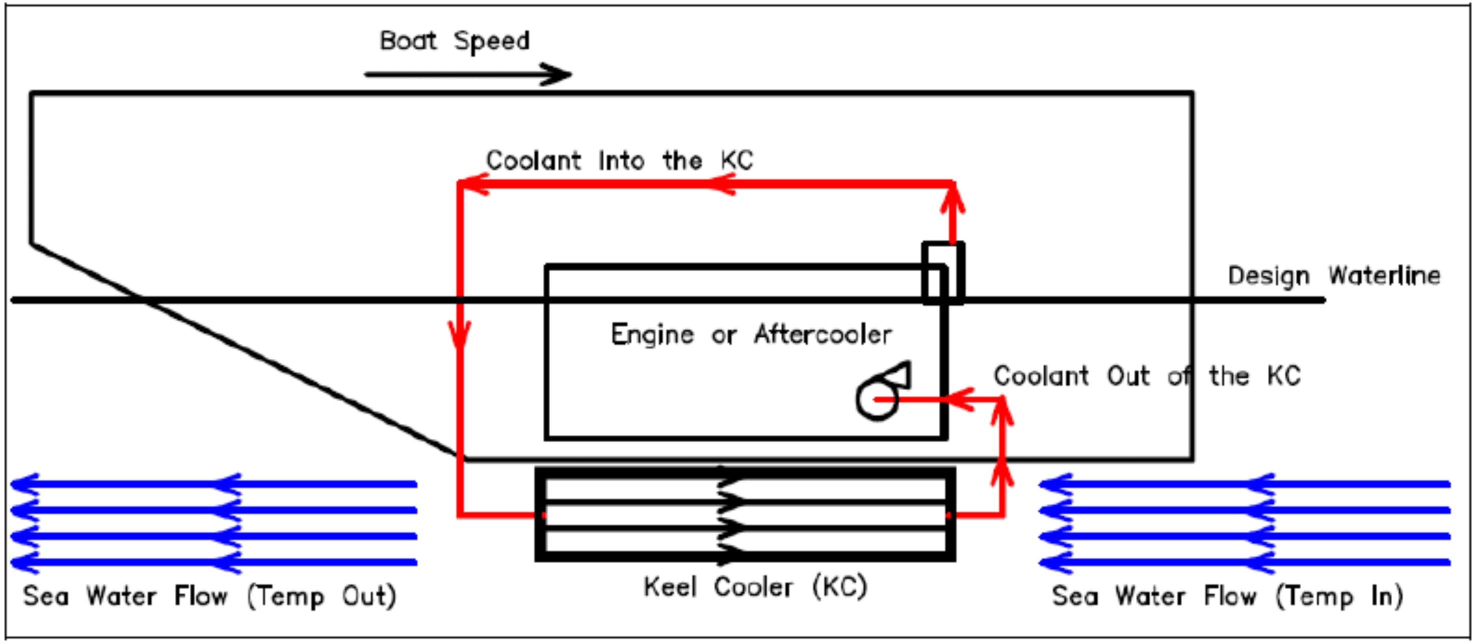


Cross-section of standard c-channel

Background and Theory

- Since cooling of engine is not possible to thoroughly rely on charged air circulation, an alternate system must be used
- Keel cooling is a cooling system which utilizes a group of tubes, pipes or channels attached to the outside of the hull below the waterline
- A properly designed and installed cooling system is essential for satisfactory engine life and performance
- Cummins Marine one of the Markets within Cummins Inc. is specialized in diesel engines outfitted to provide power in marine vessel applications

Background and Theory



Problem Statement & Goal

- Problem Statement:

  "The current Cummins Keel Cooler Tool provides no feedback on a particular design and is limited in its capability"

- Project Goal:

  "Design a more versatile design tool which generates feedback and provides a more user friendly interface"

Project Scope

- The current design has no customer feedback
- Only provides user an output of “Pass/Fail” on design
- Needs to provide recommendations for design improvement
- Current tool is outdated and not user friendly
- The device needs to be able to evaluate the design of the keel cooler through the use of different materials (Currently only evaluates steel)

House of Quality (HOQ)

Technical Requirements / Customer Priority		Programming language	Minimize coding lines	Shareable	Use equations	Range of inputs	Testability
Uses Multiple materials	4	1	1	1	4	4	4
Define optimal size	5	1	1	1	4	2	2
User friendly	4	4	4	4	1	2	2
Suggest alternatives	3	2	1	1	1	2	1
Accurate	5	1	2	1	4	1	4
Interactive feedback	4	2	2	1	1	4	2
Raw Score		44	46	37	67	61	65
Rank order		5	4	6	1	3	2

Technical Rank scale:
4 Highest
2 Medium
1 lowest

Customer Priority:
Ranks from 1 to 5 where 5 is the highest

Design and Analysis

- Choosing a Coding Language
  - *C, Java, Matlab*
  - *Judging criteria*
    - ✓ *Knowledge*
    - ✓ *Structure*
    - ✓ *Aesthetics*
    - ✓ *Relevance*

Table 1: Decision Matrix

Program:	Knowledge	Structure	Aesthetics	Relevance	Total:
C	9	10	1	10	8.5
Java	2	7	8	8	4.2
Matlab	8	1	8	6	6.4

C was chosen due to Team Member familiarity and ease to convert to other languages if necessary

Current Validation Tool

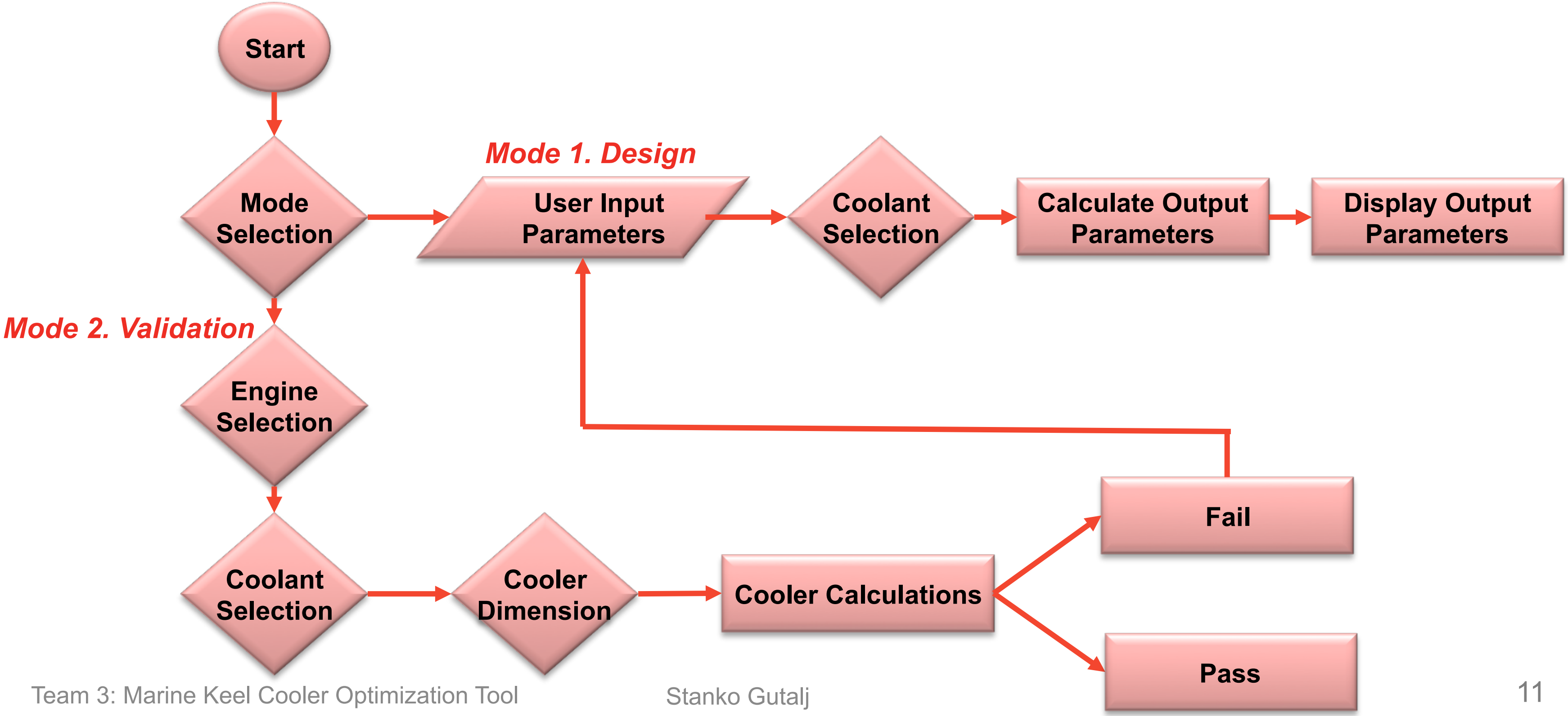
Current Program Specification Sheet

Engine Data		
Engine Model		
Engine Brake Horsepower	[BHP]	
Engine Speed	[rpm]	
Select a Cooling Circuit Type		
Total Circuit Heat Rejection	[BTU/min]	
Coolant Flow to Keel Cooler	[gpm]	
Engine Coolant Capacity	[gallons]	
Coolant Type (50/50 glycol or Water/DCA)		Make a Selection
Maximum Sea Water Temperature	[deg F]	85
Design Speed	[knots]	
Keel Cooler Data		
Standard Channel Size		Make a Selection
Channel Width	[inches]	
Channel Height	[inches]	
Web Thickness	[inches]	
Cross Sectional (Web) Area	[sq. inches]	
Coolant Velocity	[ft/sec]	
Channel Material		Steel
Total Installed Keel Cooler Length	[feet]	
Thermal conductivity "k"	[BTU/hr-F-ft]	26.5
Number of Flow Paths		
Results		
Actual KC Exterior Area	[sq. feet]	
Calculated Exterior Area	[sq. feet]	
Minimum Keel Cooler Length	[feet]	
Minimum Expansion Tank Capacity	[gallons]	
Passing Criteria	**[Pass / Fail]**	

Stanko Gutalj

Design and Analysis

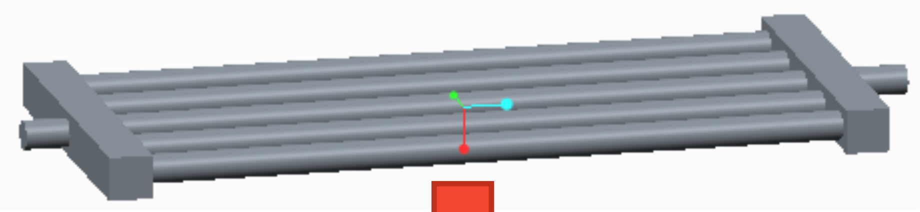
- Program Structure

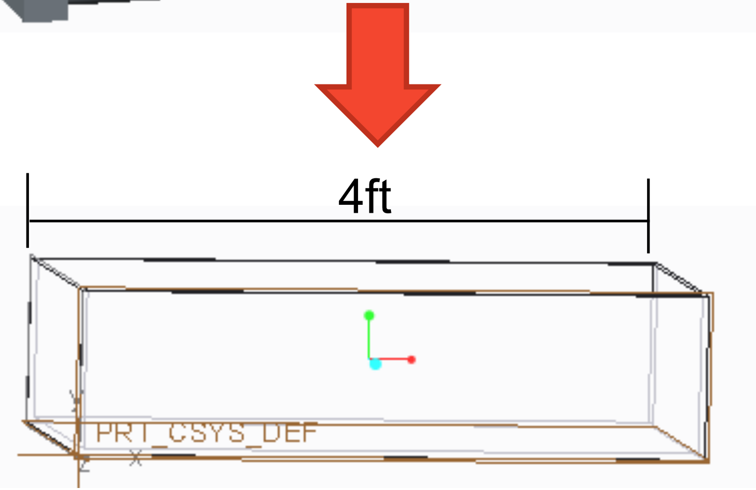


Hardware | *Keel Cooler Simulation*

- The team is designing a testing apparatus to simulate various keel cooler configurations
  - Number of flow paths
  - Surface Area
- Device must allow various measurements
  - Heat Dissipation
  - Mass Flow Rate
- The team reviewed 3 designs

Hardware | *Design 1*





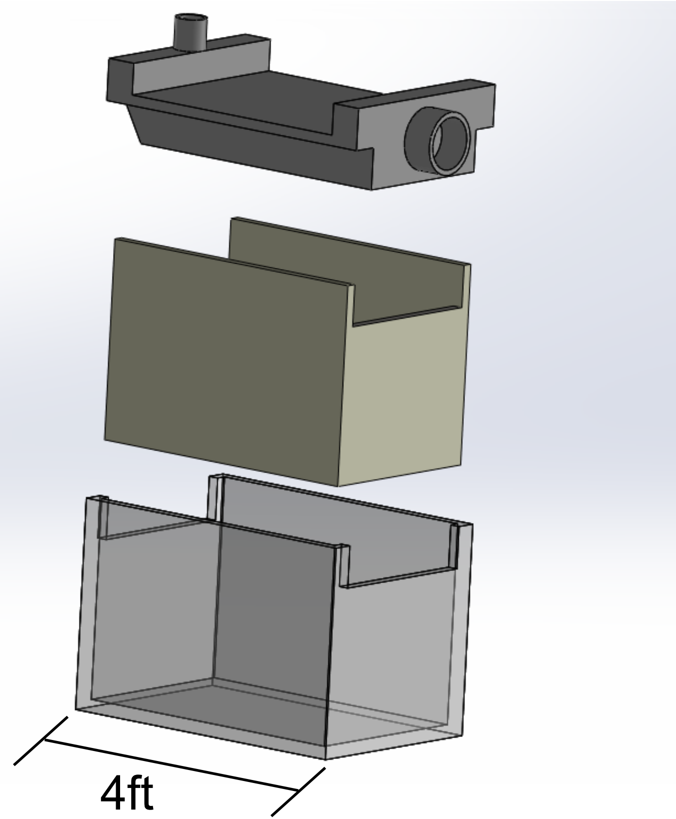
- **Advantages**

1. Cheap
2. Small
3. Easy to design/ machine

- **Disadvantages**

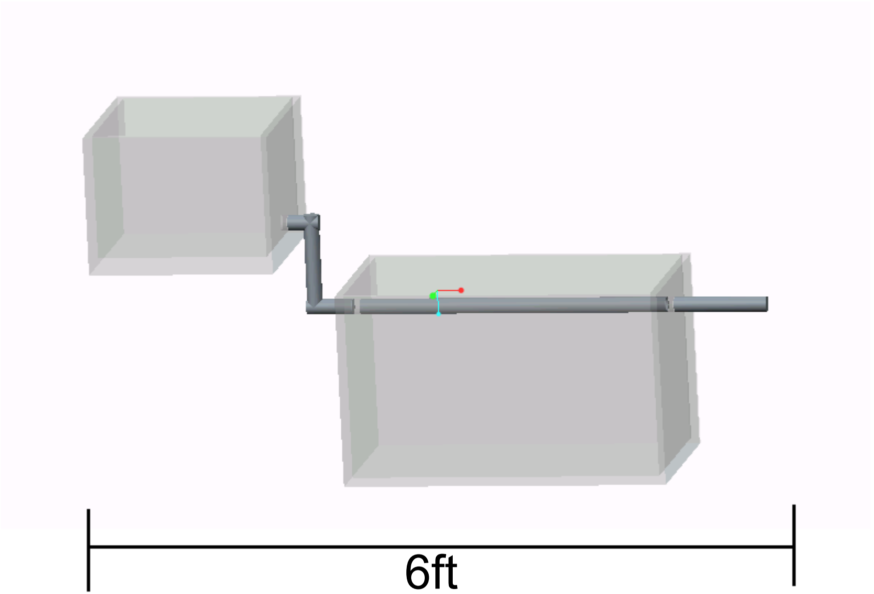
1. Not made of C channels

Hardware | *Design 2*



- **Advantages**
  1. C-channel design
  2. Simulates larger keel coolers
- **Disadvantages**
  1. Manufacturability
  2. Expensive

Hardware | *Design 3*



Advantages

1. Very basic and cost effective
2. Easy to construct and deconstruct

Disadvantages

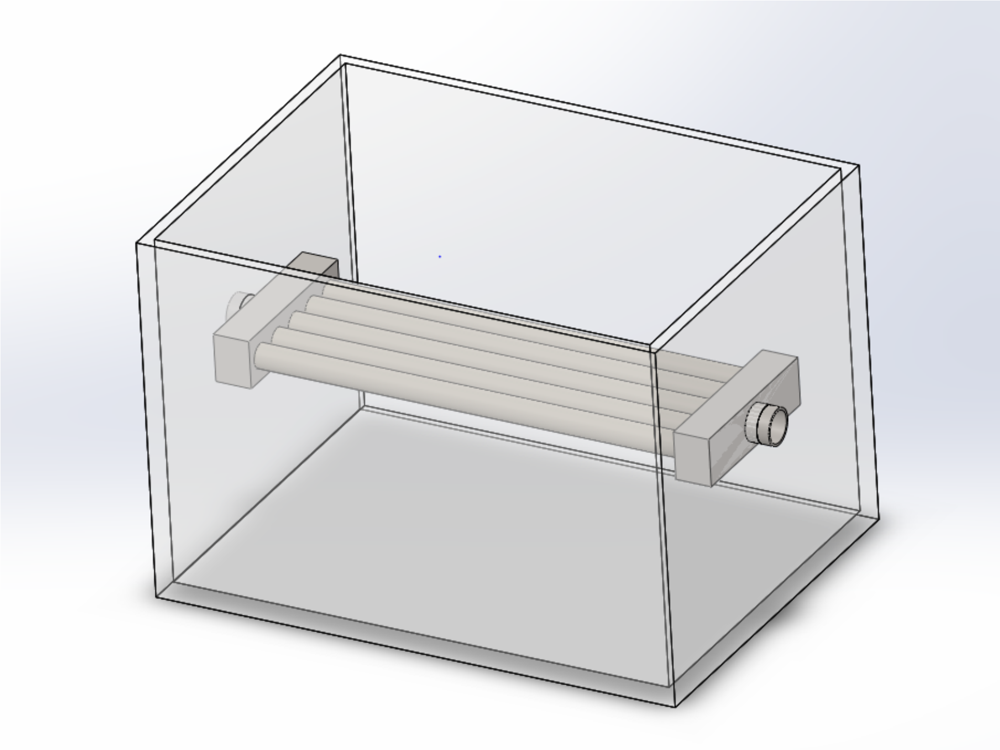
1. No multi-tube configuration

Hardware | *Design Evaluation*

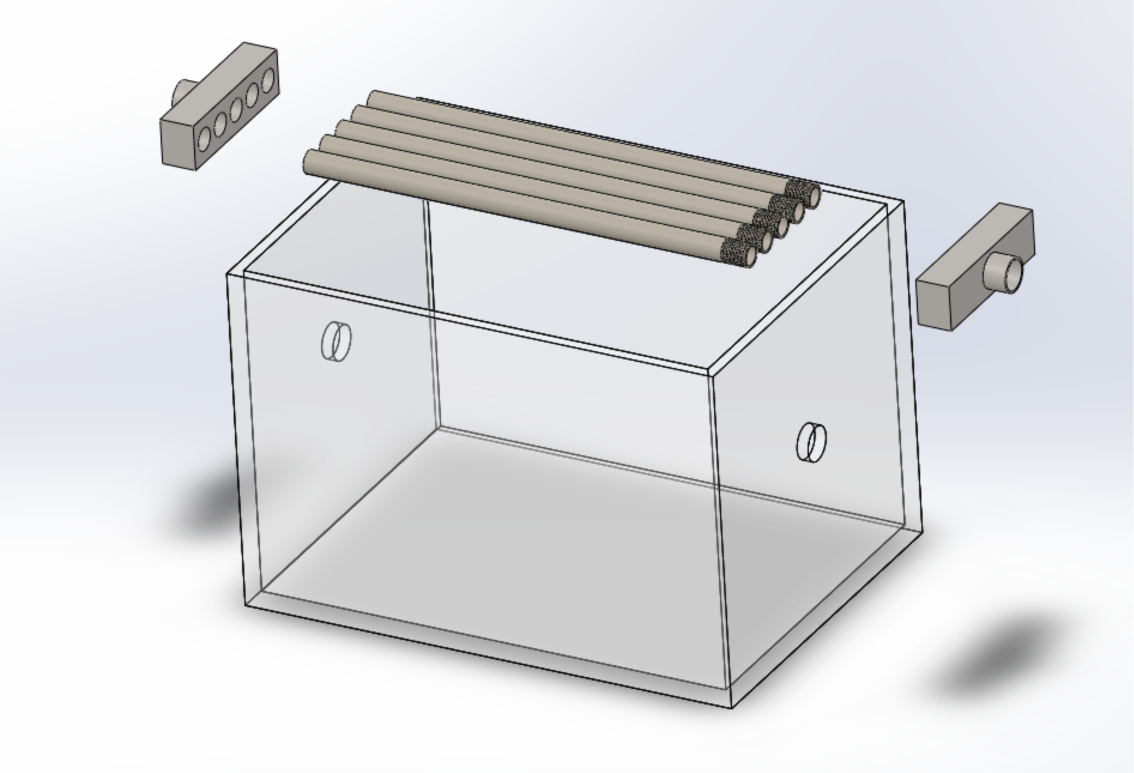
- Categories ranked from 1 to 10
- Averaged to attain final score

Design	Manufacturability	Cost	Adaptability	Total
1	7	6	10	7.7
2	4	4	6	4.7
3	9	8	2	6.3

Hardware | *Selected Concept Assembled View*



Hardware | *Selected Concept Exploded View*



Scheduling and Resource Allocation

- **Team visit to facilities**
  - Trip to Cummins Marine Integration Center facilities – *Scheduled Spring 2016*
  - Team expected to visit production facility – *Scheduled Spring 2016*
  - Gain general assessment of keel cooler system:
    - ✓ Application
    - ✓ Functionality
    - ✓ Dimensions/specifications

Scheduling and Resource Allocation

- **Work Breakdown**
  - *Program:*
    - ✓ Stage 1: Catalog constant values in program
    - Stage 2: Incorporate thermodynamic formulae
    - Stage 3: Test/Debug
    - Stage 4: Add functionality for multiple materials
    - Stage 5: Test/Debug

Scheduling and Resource Allocation

- **Work Breakdown**
  - *Testing Apparatus*:
    - ✓ Propose three design concepts
    - ✓ Decision matrix for selection
    - Finalize design
    - Order materials
    - Build
    - Troubleshoot problems
    - Use to validate engineering principles

Scheduling and Resource Allocation

- **Cost Breakdown**
  - *Program:*
    - Coded using free software available to team
  - *Testing Apparatus*:
    - Round metal tubing: steel ~$5 ft, aluminum ~$6.50 ft
    - Pump: $100-500
    - Flanges: $2-50 (dependent on material, size, intricacy, etc.)
    - Fasteners/elbows: <$500
    - Thermocouples: ~$70

Risks

- **Possible Risks in Product Testing**

Program

- No risk associated with program testing phase

Testing Hardware

- Building the testing apparatus
- Proper keel cooler connections
- Burns caused by piping and heating element

Facilities

- Engine coolant burns – *at Cummins facility*
- Engine overheating – *at Cummins facility ($$$)*

Risks

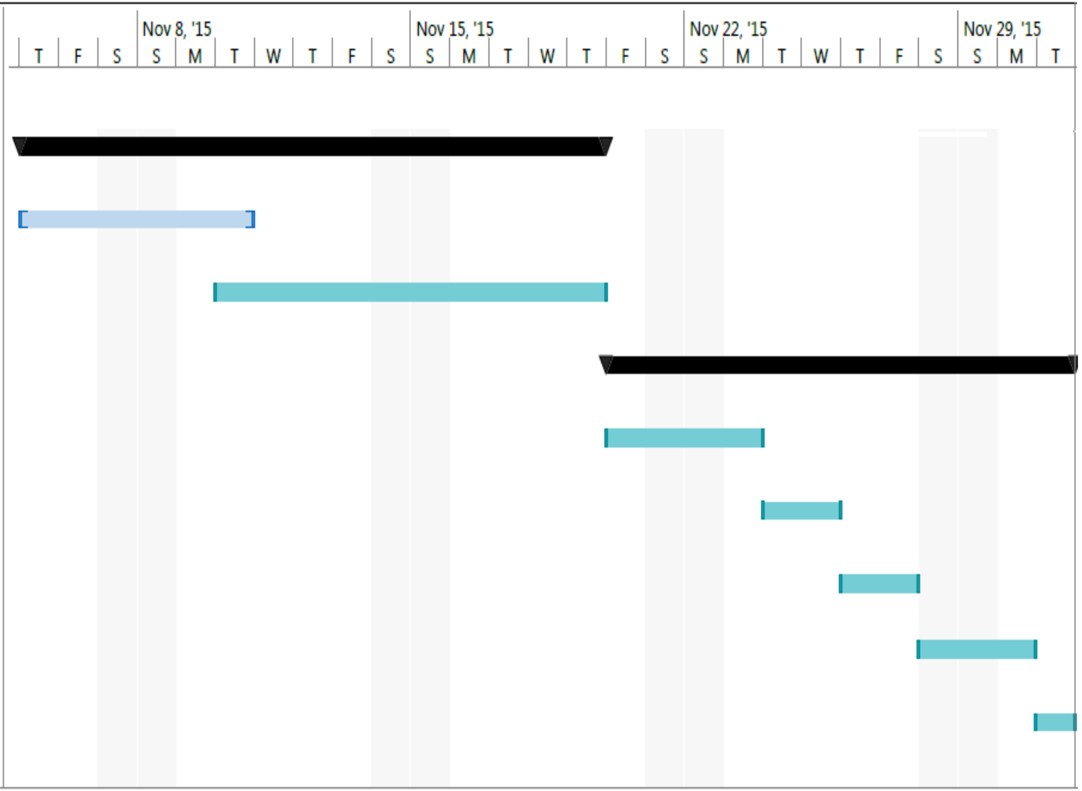
- **Possible Risks in Product Implementation**
  - Product is inaccurate
  - Engine failure
  - Tarnished reputation
- **Risk Analysis**
  - **Concept Generation (No Risk)**
  - **Product Assembly (Low Risk)**
  - **Product Testing (Medium Risk)**
  - **Product Implementation (High Risk)**

Project Outlook

- Current/next Week:
  - *Put equations into program*
  - *Finalize hardware design*
- Following Weeks:
  - *Continue work on program*
  - *Order materials*
  - *Update sponsor/advisor*
  - *Plan for future*

Project Outlook

product architecture	11 days	Tue 10/20/15	Tue 11/3/15
Flow Chart	11 days	Tue 10/20/15	Tue 11/3/15
configuration design	11 days	Thu 11/5/15	Thu 11/19/15
material selection	4 days	Thu 11/5/15	Tue 11/10/15
Modeling parts	8 days	Tue 11/10/15	Thu 11/19/15
parametric design	8 days	Fri 11/20/15	Tue 12/1/15
Robust Design	2 days	Fri 11/20/15	Mon 11/23/1
Tolerences	2 days	Tue 11/24/15	Wed 11/25/1
Final Dimensions	2 days	Thu 11/26/15	Fri 11/27/15
DFM	2 days	Sat 11/28/15	Mon 11/30/1
Final Report	1 day	Tue 12/1/15	Tue 12/1/15



Questions

Melissa Allende Grady Beasley Stanko Gutalj
James Haga Jacob Ross