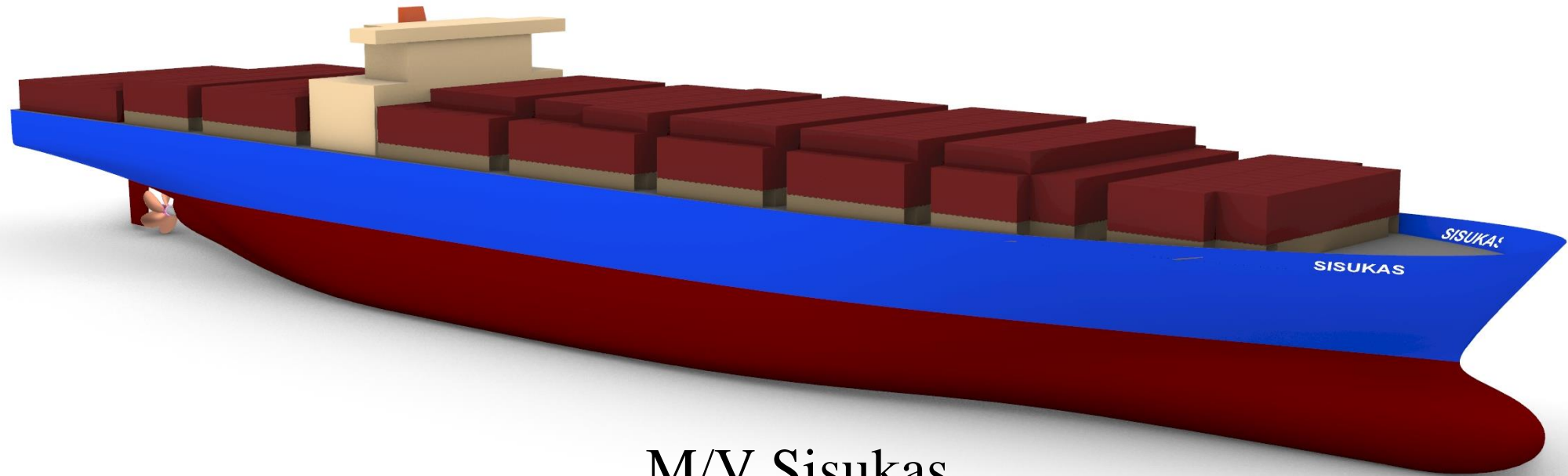# Emergent Design Failure: Lurking Dangers of Regression-Based Design

-Michael Biek, NAME '21 (Honors Capstone)
Advisor: Prof. David Singer, NAME



M/V Sisukas

# Project Goals

- To understand emergence of design failures through the evaluation of my NA 470 senior ship design project
  - Emergent design failures are characterized by rework, design churn, and/or failure to integrate the design
- The steps for the project were to: (1) Learn about advance design theory, (2) Evaluate NA 470 design and determine what emergent design failures existed, and (3) evaluate what design decisions created the emergence and why / how they were made.
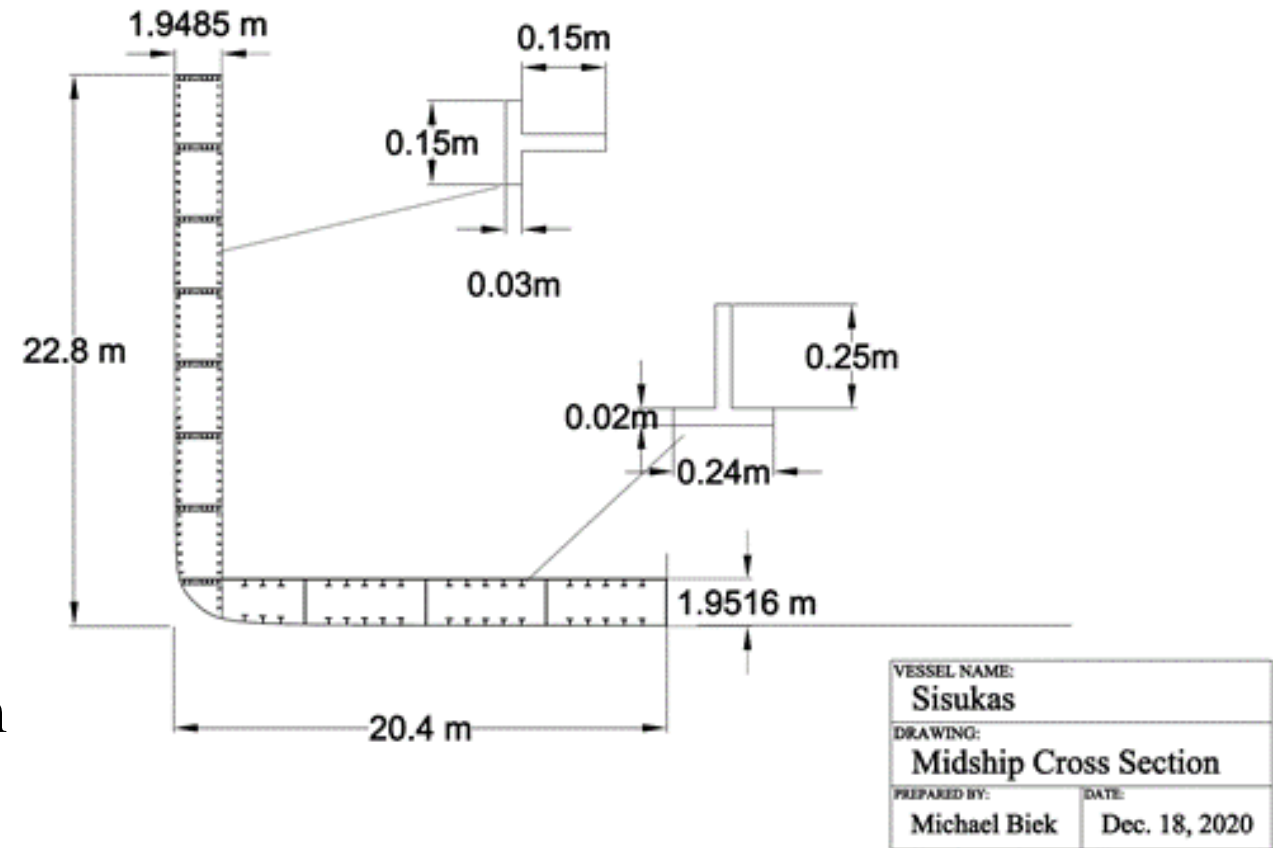
# Summary of Determined Emergence

- Rework – The ship's width had to be changed several times, weights had to be redistributed for stability

- Design Churn – The design of the midship cross section took much longer than normally expected

- Failure to Integrate – n/a


- After creating the list, I picked the midship structural cross section for further study.

# The Midship Structural Cross Section

- The midship cross section provides structural strength for the ship

- Midship is the location of greatest concentration of structural stresses along the length of a ship

- Cross section must meet area moment requirements based on size and weight

- While the tall height made satisfying the overall moment requirement easy, it was very difficult to meet the deck and bottom section modulus requirements (danger of deck and bottom plates buckling)



1.9485 m

0.15m

0.15m

0.03m

22.8 m

0.25m

0.02m

0.24m

1.9516 m

20.4 m

VESSEL NAME:
**Sisukas**
DRAWING:
**Midship Cross Section**
PREPARED BY:          DATE:
**Michael Biek**       Dec. 18, 2020

**NAVAL ARCHITECTURE & MARINE ENGINEERING**
UNIVERSITY OF MICHIGAN

**ENGINEERING HONORS PROGRAM**
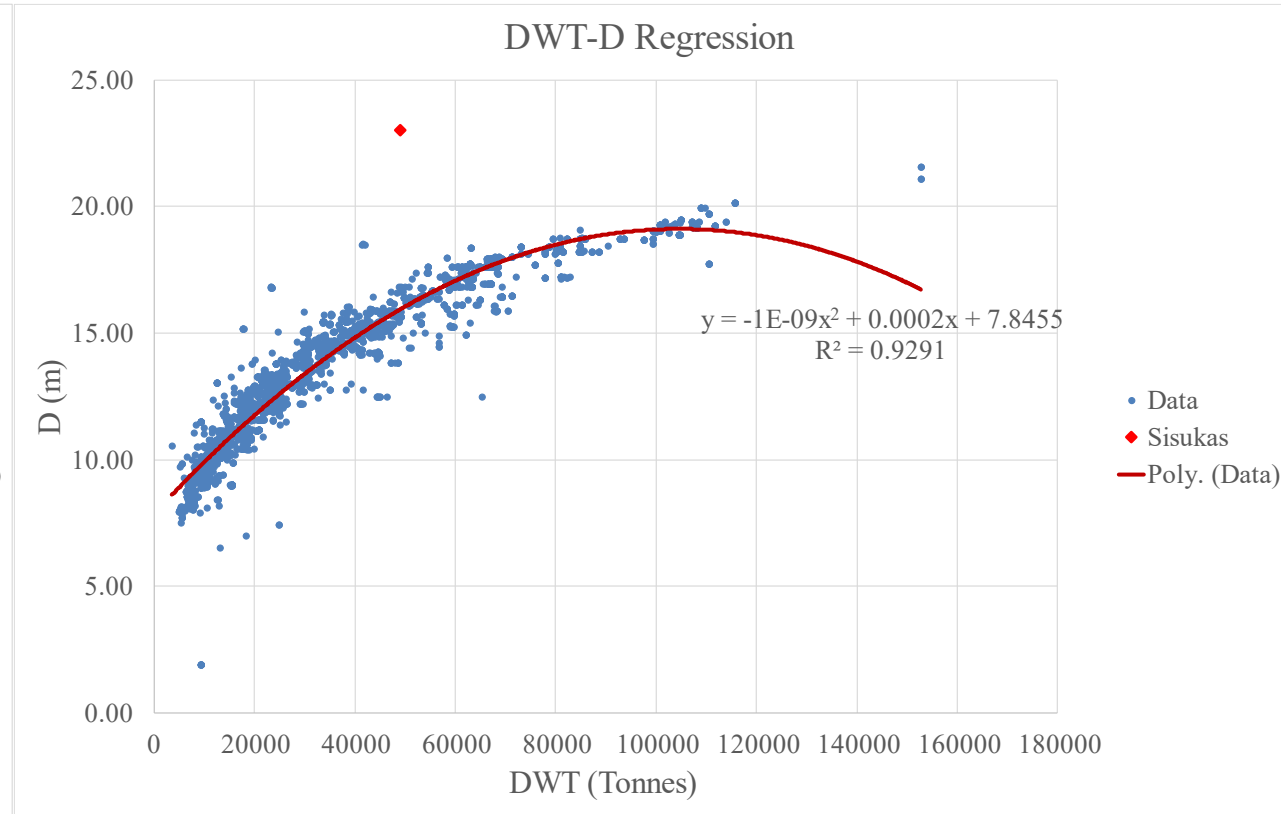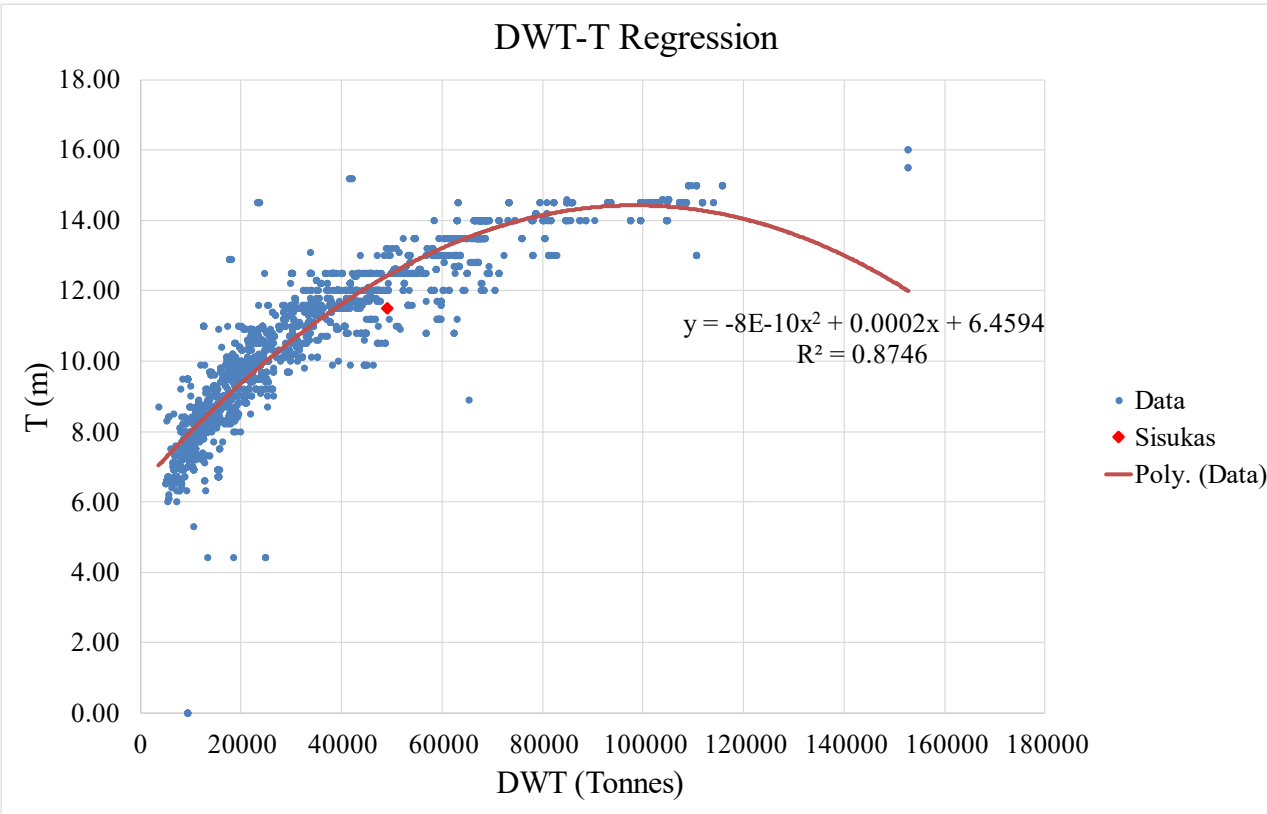UNIVERSITY OF MICHIGAN

# Design Decision leading to Emergent Path

- Vessel size was estimated using regression analysis of a provided dataset of existing ships
- Dataset included vessels' **Draft**, **T** but not **Depth**, **D**
- NA 470 project guidelines never included any assessment of depth
- Regression resulted in a depth allowing for stacks of eight cargo containers, and was not changed any further
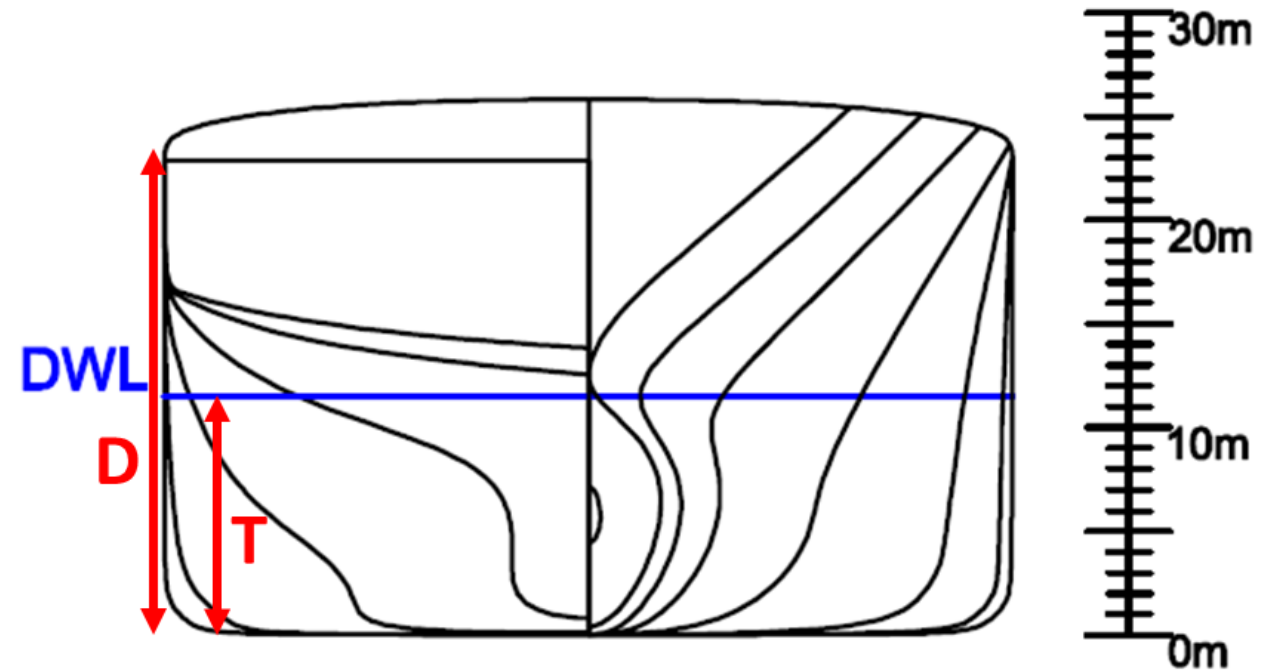
# Original regression analysis based on **draft, T,** looked good…

## …but subsequent estimation of **depth, D**, from original data reveals extreme departure



### DWT-T Regression

$y = -8E\text{-}10x^2 + 0.0002x + 6.4594$

$R^2 = 0.8746$

- Data
- Sisukas
- Poly. (Data)

### DWT-D Regression

$y = -1E\text{-}09x^2 + 0.0002x + 7.8455$

$R^2 = 0.9291$

- Data
- Sisukas
- Poly. (Data)

NAVAL ARCHITECTURE & MARINE ENGINEERING
UNIVERSITY OF MICHIGAN

ENGINEERING HONORS PROGRAM
UNIVERSITY OF MICHIGAN

# How Depth Decision Resulted in Design Failure

- Large depth led to difficulty satisfying deck girder section modulus

- This was due to large distance from deck girder to area centroid

- Required many iterations of cross-section design to meet the requirement

| | | | | |
|---|---|---|---|---|
| **SM_min** | **360813.88** | **cm^2-m** | | |
| | | | | |
| **ABS 3-2-1/3.7.2 - Hull Girder Moment of Inertia** | | | | |
| **I_required:** | **2708812.9** | **cm^2-m^2** | | |
| | 270.88129 | m^4 | | |
| | | | | |
| | | | | |
| **Deck and Bottom SM** | | | | |
| | | | | |
| Calculated area moment about the Centroid | | | 549.984 | m^4 |
| | | | | |
| **Deck** | | | | |
| Distance from NA to deck | 15.099 | m | | |
| Area moment | 549.984 | m^4 | | |
| Deck SM | 364251.94 | cm^2-m | | |
| | | | | |
| **Bottom** | | | | |
| Distance from NA to BL | 7.766 | m | | |
| Area moment | 549.984 | m^4 | | |
| Bottom SM | 708194.69 | cm^2-m | | |

# Conclusions

- Regression analysis difficult when many complex, combining factors are present
- Emergent design failure at such an early phase of design (day 1) compromised many later parts of the design