Systems, Rockets & Nippons

Professor Dianne DeTurris

Summer Camp 2019

INTRODUCTION

- People and Stars
- People and Rockets
- People and Systems
- People

People are Fascinated with the Stars

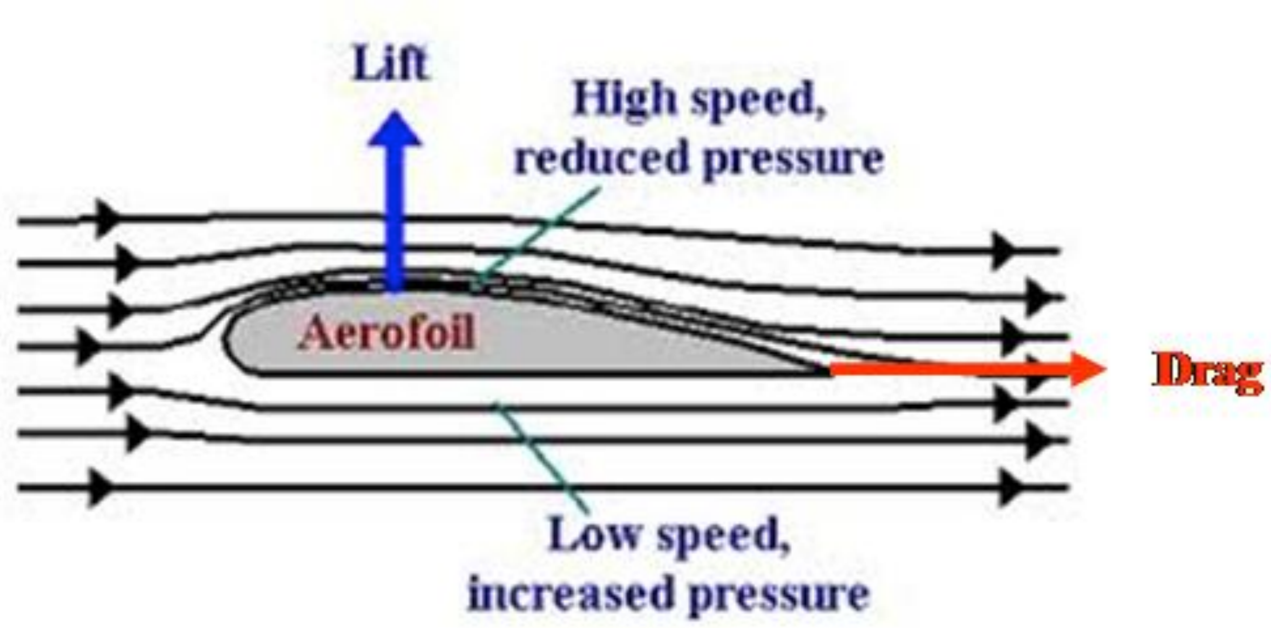
- History of flight goes back to the beginning of recorded history
- Many traditions have stories and myths about flight, where gods come down from the heavens
- Arrows start flying
- Then fireworks (without safety helmets)

People Start Trying to Fly

- People actually flying starts with tower jumping
  - wearing a big cloak does not work
- Then comes the connections between birds and fish (da Vinci)
  - velocity and pressure are related

Flying: Science Fiction to Science Fact

- Understand the laws of physics (Newton)
- Apply aerodynamics (Bernoulli, Cayley)
- Achieve heavier than air powered flight (Wrights)



People Pioneering Space Flight

The Exploration of Cosmic Space by Means of Reaction Device, 1903

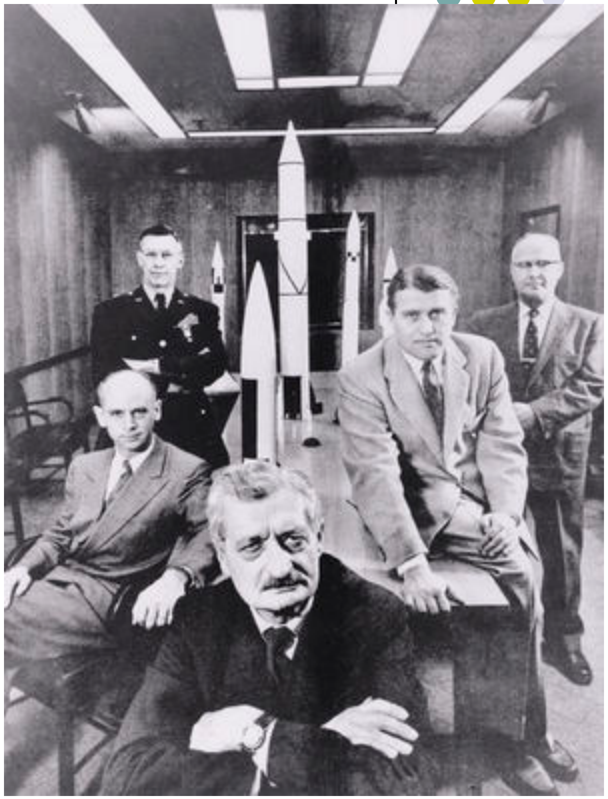
Konstantin Tsiolkovsky

- the first serious scientific work on space travel

A Method of Reaching Extreme Altitudes, 1919

Robert Goddard

- the first serious work on using rockets in space travel
- world's first liquid-fueled rocket



The Rocket into Planetary Space, 1923 Hermann Oberth

- an early member of the "Society for Space Travel“
- von Braun’s mentor

Rockets go into Space

- Imagining space flight (Tsiolkovsky)
- Flying to space from German perspective (Oberth, von Braun)
- Flying to space today is still the same

http://www.v2rocket.com

https://global.jaxa.jp/projects/rockets/h2/index.html

Rockets go into Space

- Routine spaceflight without people
- Routine spaceflight with people
- How about we are dedicated to studying spaceflight?
- Laboratory of Spacecraft Environment Interaction Engineering
  - Space Engineering International Course

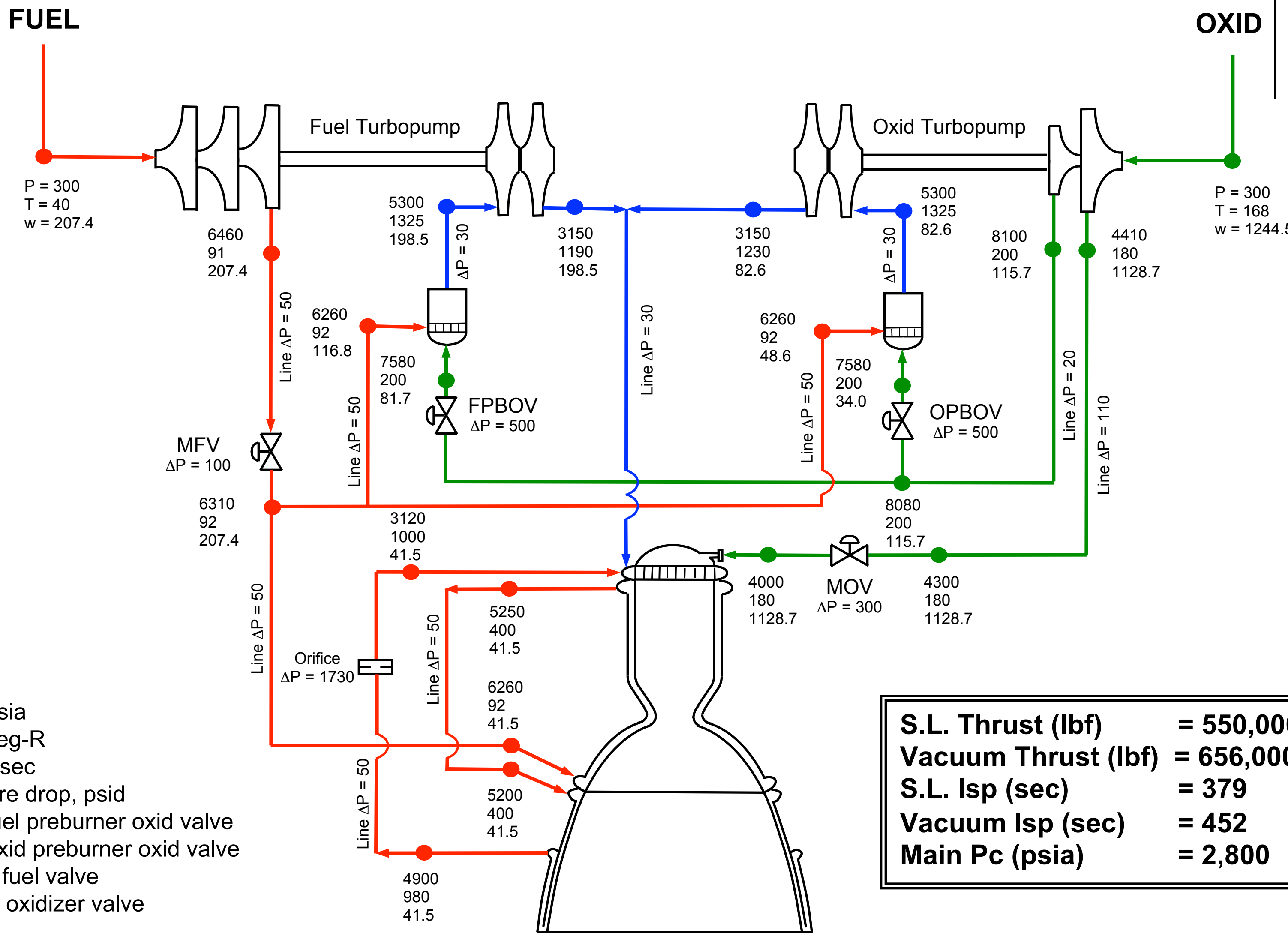
Rocket System Development

- Systems engineering was developed to make rockets reliable
  - from 80% failure to 80% success in 10 years
  - read the book "The Secret of Apollo" by Stephen Johnson

- Systems engineering helps show a system level perspective

- What does a rocket system level perspective look like?

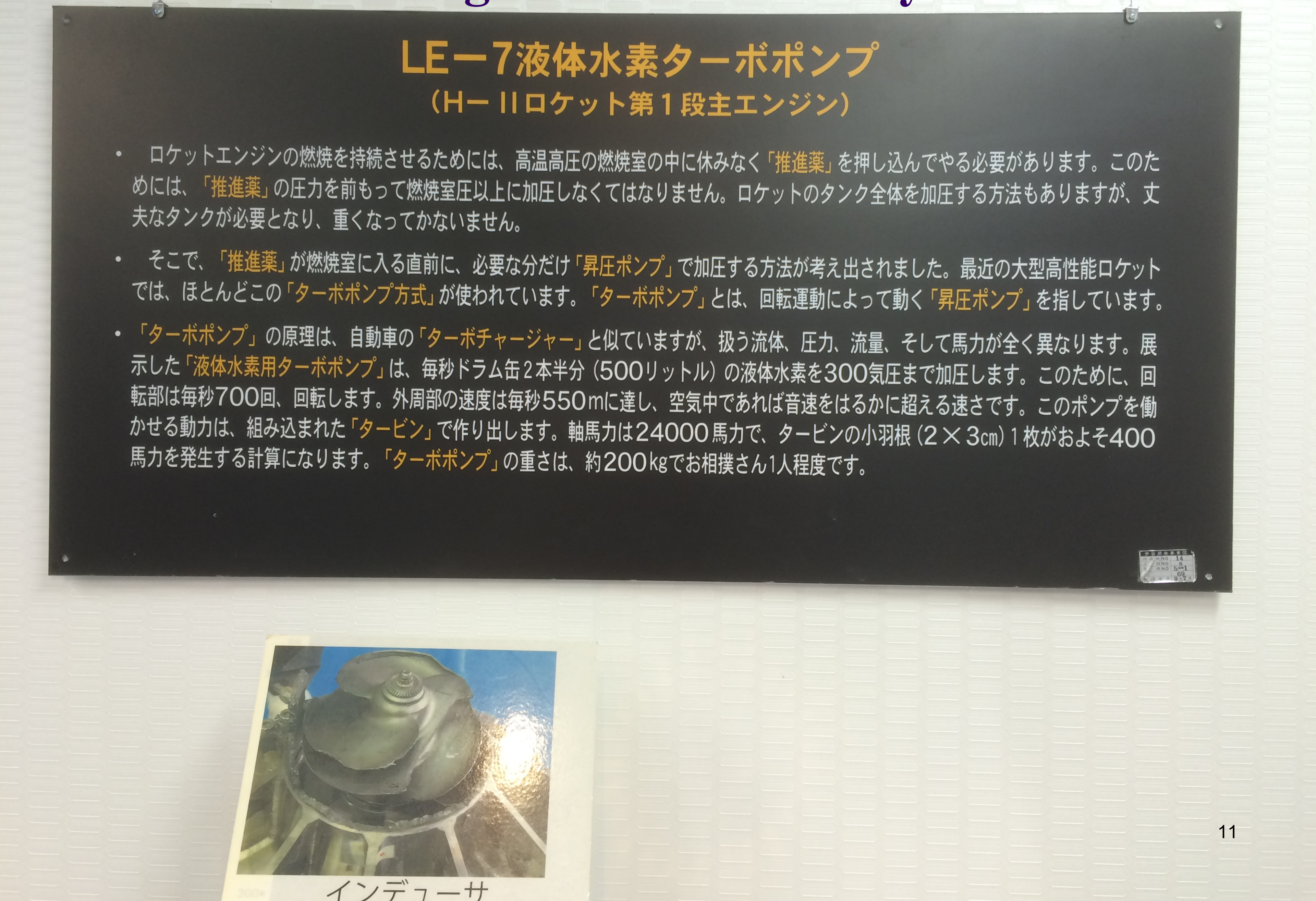
Sample Staged-Combustion Cycle Engine Balance



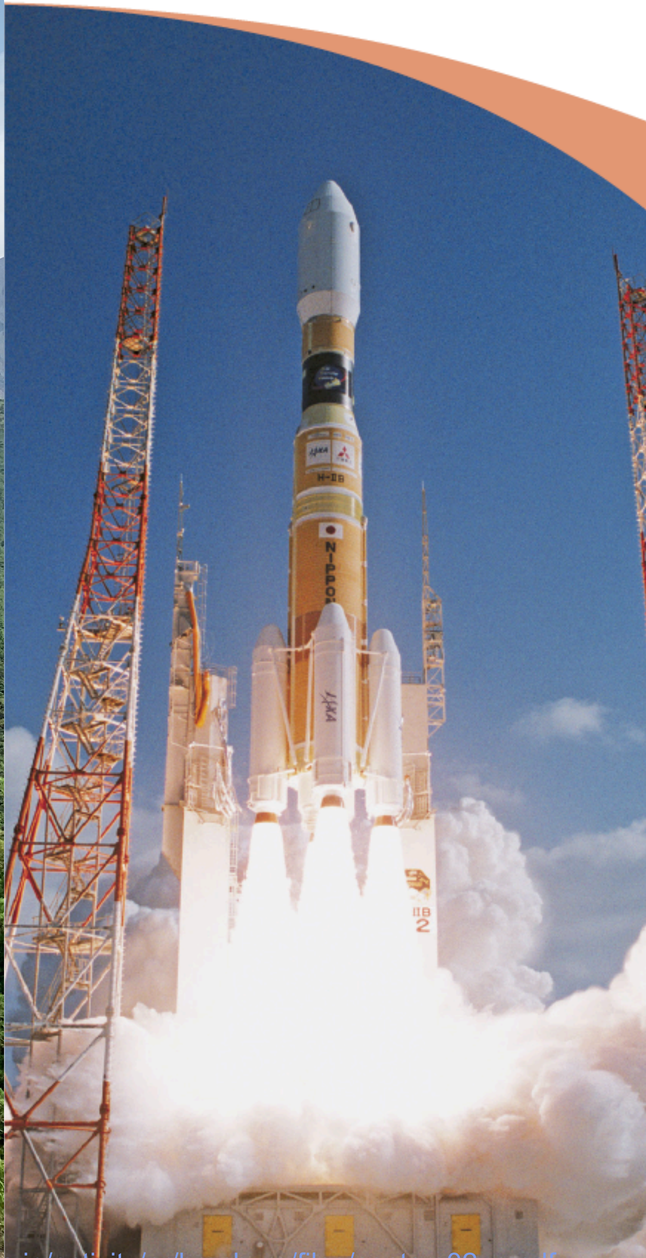
P = Press, psia
T = Temp, deg-R
w = Flow, lb/sec
ΔP = Pressure drop, psid
FPBOV = Fuel preburner oxid valve
OPBOV = Oxid preburner oxid valve
MFV = Main fuel valve
MOV = Main oxidizer valve

S.L. Thrust (lbf)	**= 550,000**
Vacuum Thrust (lbf)	**= 656,000**
S.L. Isp (sec)	**= 379**
Vacuum Isp (sec)	**= 452**
Main Pc (psia)	**= 2,800**

LE-7A Staged Combustion Cycle



Tanegashima
Space Center



https://global.jaxa.jp/activity/pr/brochure/files/centers02_e.pdf

Thinking in Systems

- A way to see systems development holistically

- The system is more than the sum of its parts (synergy)
  - Thinking about internal and external interconnections

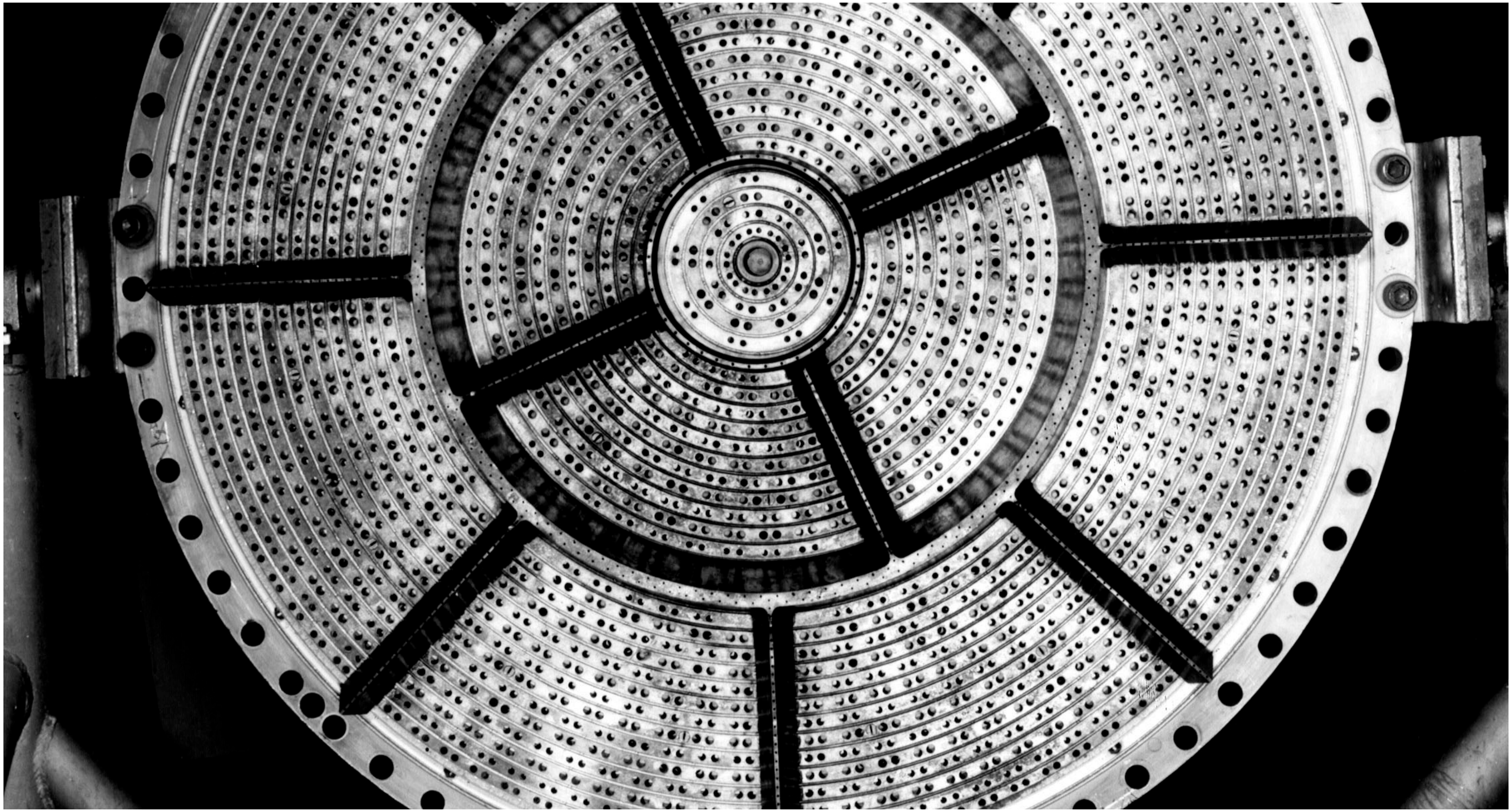
- More than technology development or systems engineering
  - includes system behavior
  - viewpoints of people involved in lifecycle of product
  - zoom in and zoom out to see the forest and the trees

- The system, in this case, is a rocket that goes to space

This is a Holistic System

F-1 Rocket Fuel Injector (from Saturn V)

Notice that the injectors are not uniform
Injector design is part art, part science
Design is important to prevent combustion instability and explosion

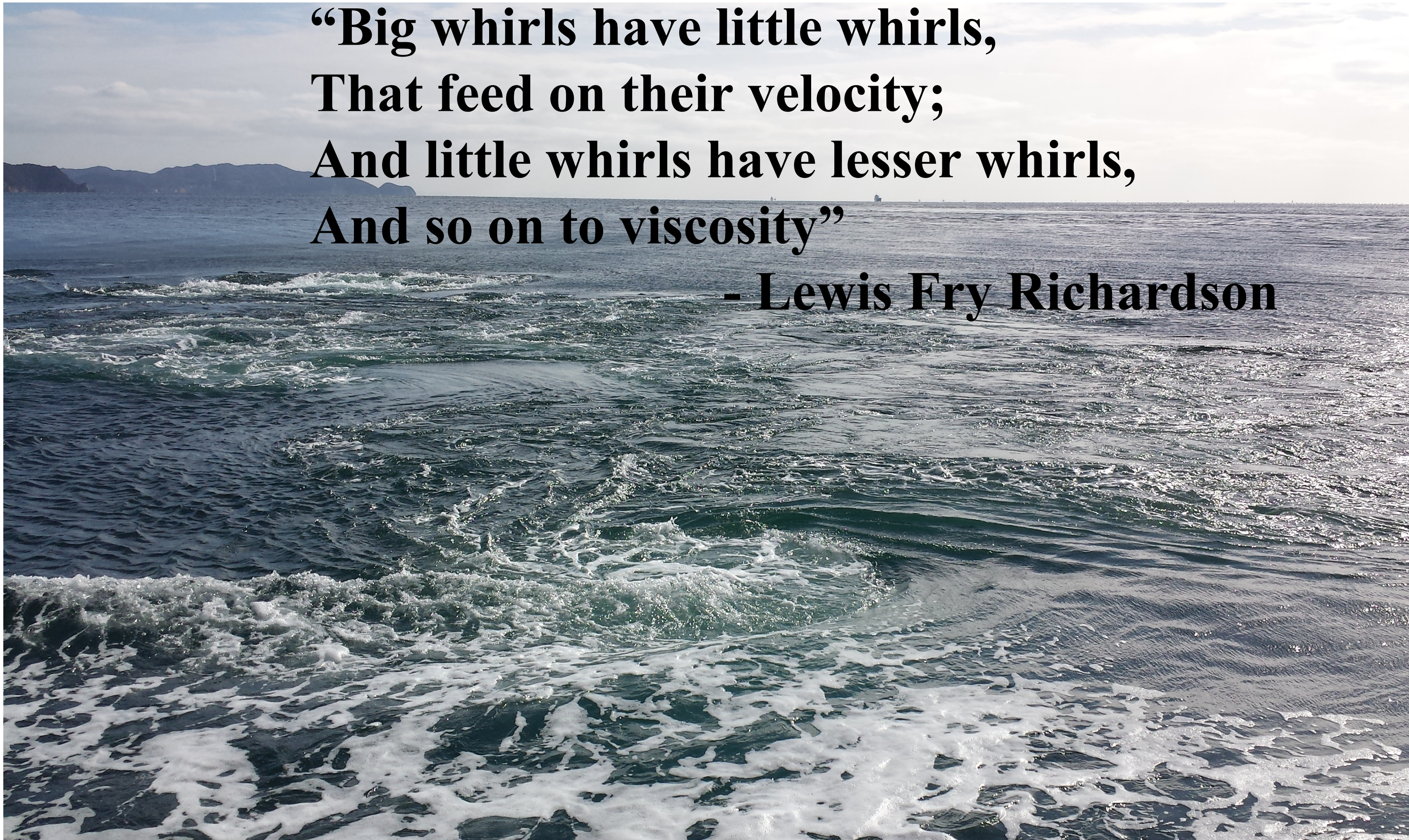


http://heroicrelics.org/info/f-1/f-1-injector.html


±0.0
WT
REC
SHARP

It’s All About the System Boundaries

- is everything interconnected, or isn’t it?

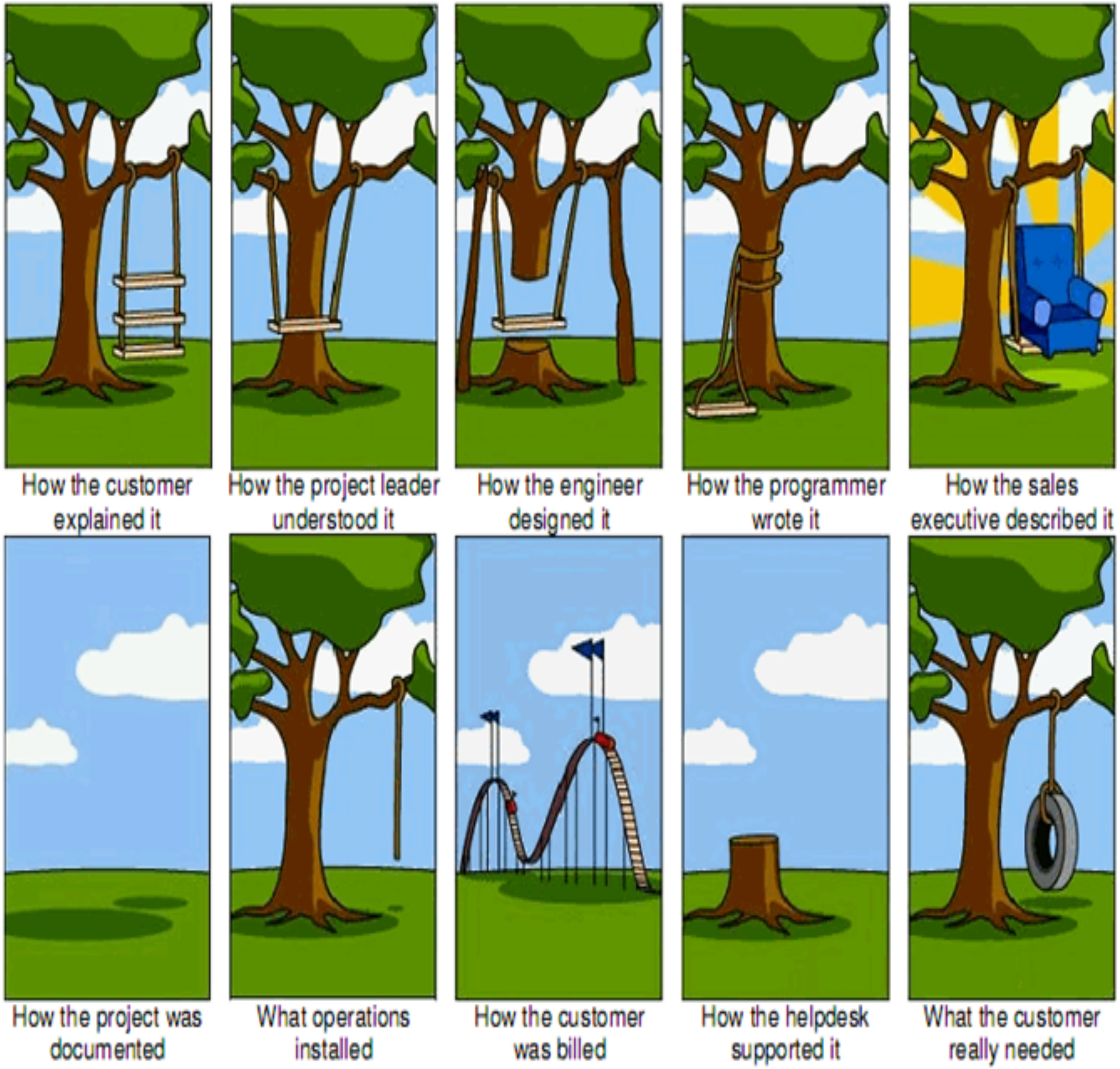


Onaruto Bridge Whirlpools

The Engineering Process Needs Interpreters

- People have intuition and judgment that the process doesn't have
  - People can zoom in and zoom out
  - People can have a holistic view of uncertainty, risk and their implications in decision making
  - People can see interconnections between the parts
  - People can collaborate
  - People have different perspectives

Perspectives Vary...



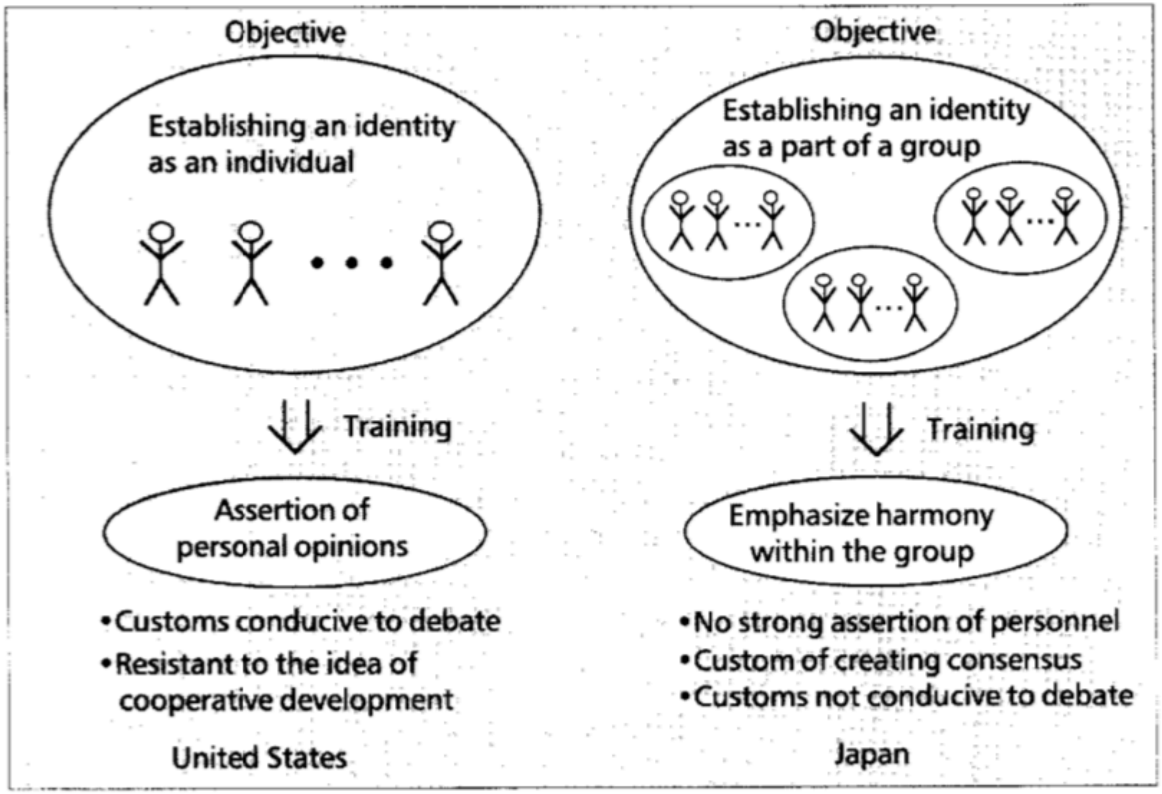
Collaborative Systems Thinking

- MIT model developed for aerospace systems
- Emergent behavior of teams resulting from the interactions of team members
- Utilizes a variety of thinking styles, design processes, tools, and communication media
- Considers systems attributes, interrelationships, context and dynamics towards executing systems design

- A recommendation for engineering education

Collaborative Systems Thinking: An exploration of the mechanisms enabling team systems thinking, C. Lamb, MIT, 2009. PhD

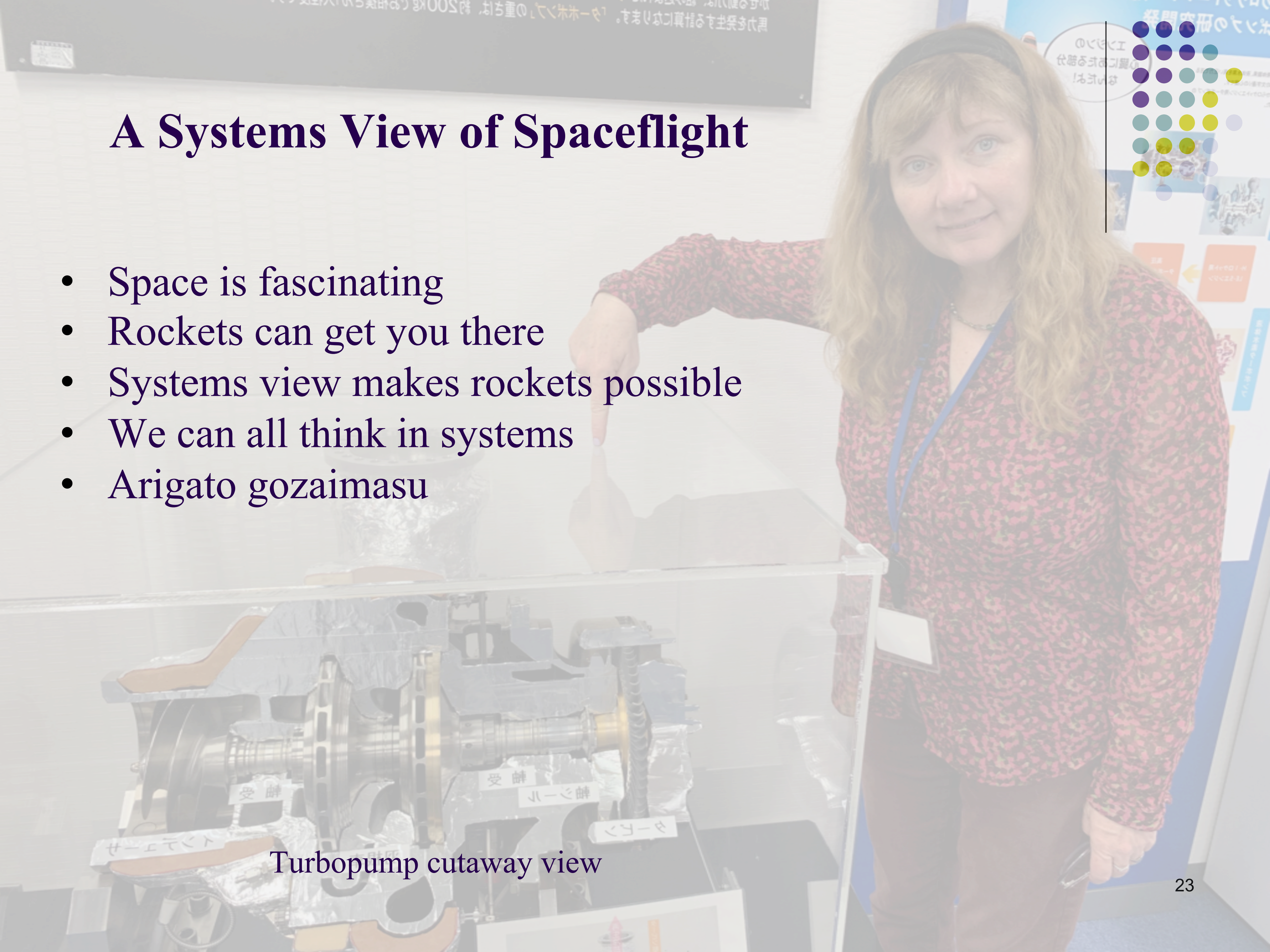
IEEE Article on Engineering Education, 1992



■ **Figure 2.** *Fundamental goals of American and Japanese societies since World War II.*

A Systems View of Spaceflight

- Space is fascinating
- Rockets can get you there
- Systems view makes rockets possible
- We can all think in systems
- Arigato gozaimasu



Turbopump cutaway view