

# IBEHS 4C03: Statistical Methods in Biomedical Engineering

## Probability

Carol Bassim , DMD, MHS  
Assistant Professor, CLA  
Division of Education and Innovation  
Department Of Medicine

location: MDCL  
phone: (905) 525-9140  
email: [bassimc@mcmaster.ca](mailto:bassimc@mcmaster.ca)  
web: <http://ibiomed.mcmaster.ca>

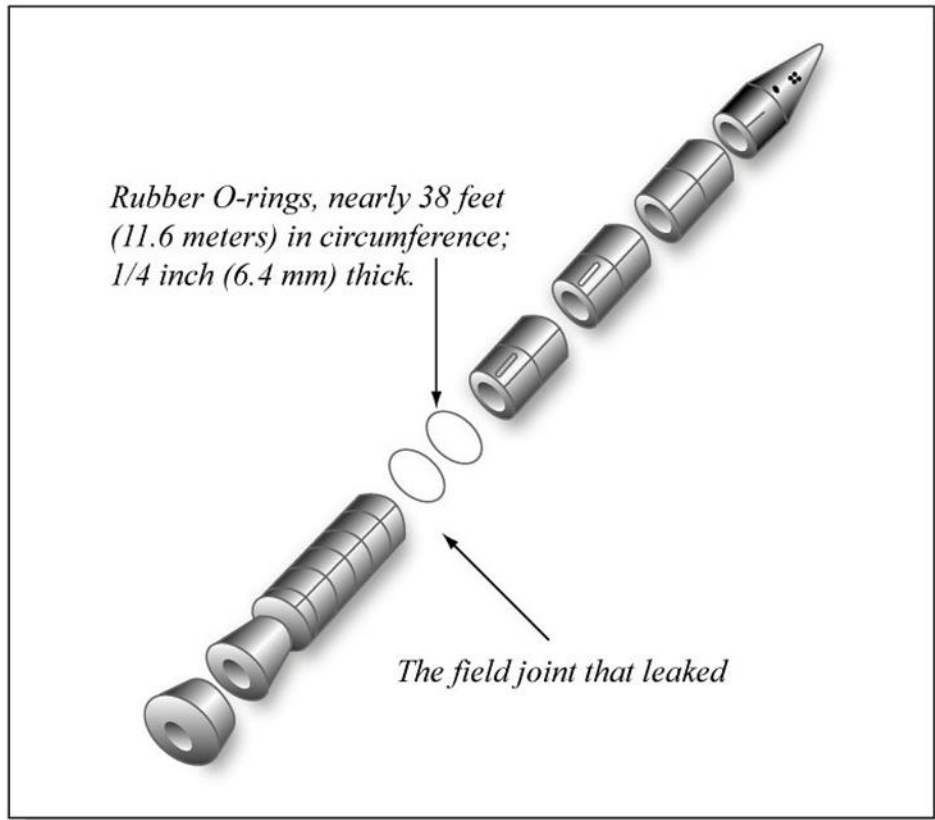


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**BRIGHTER WORLD**

# Probability of O-ring failure for the Challenger Space Shuttle

- Challenger space shuttle exploded in 1986 due to a failure of the solid rocket booster O-rings

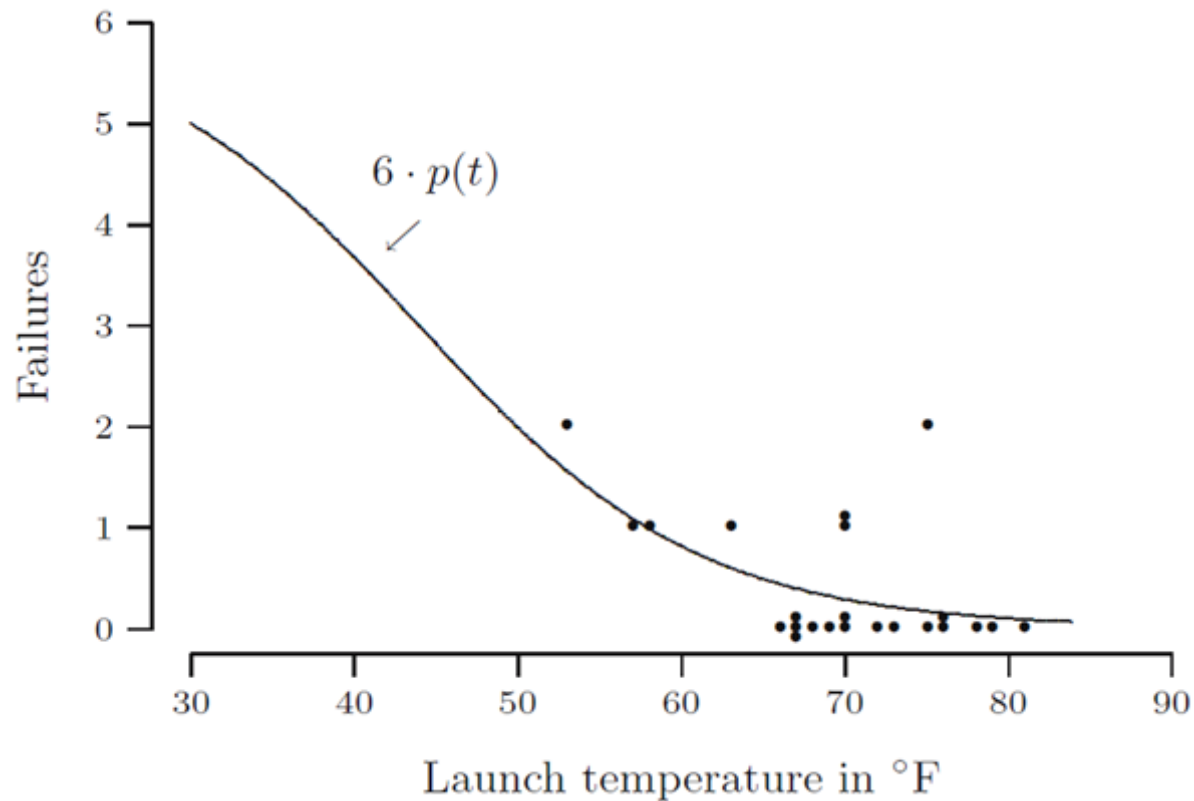


Experts have estimated that the probability that an individual O-ring joint would function properly under the conditions on the day of the launch was 0.977.

There were 6 of these O-rings.

What is the probability of failure?

# Probability of O-ring failure for the Challenger Space Shuttle



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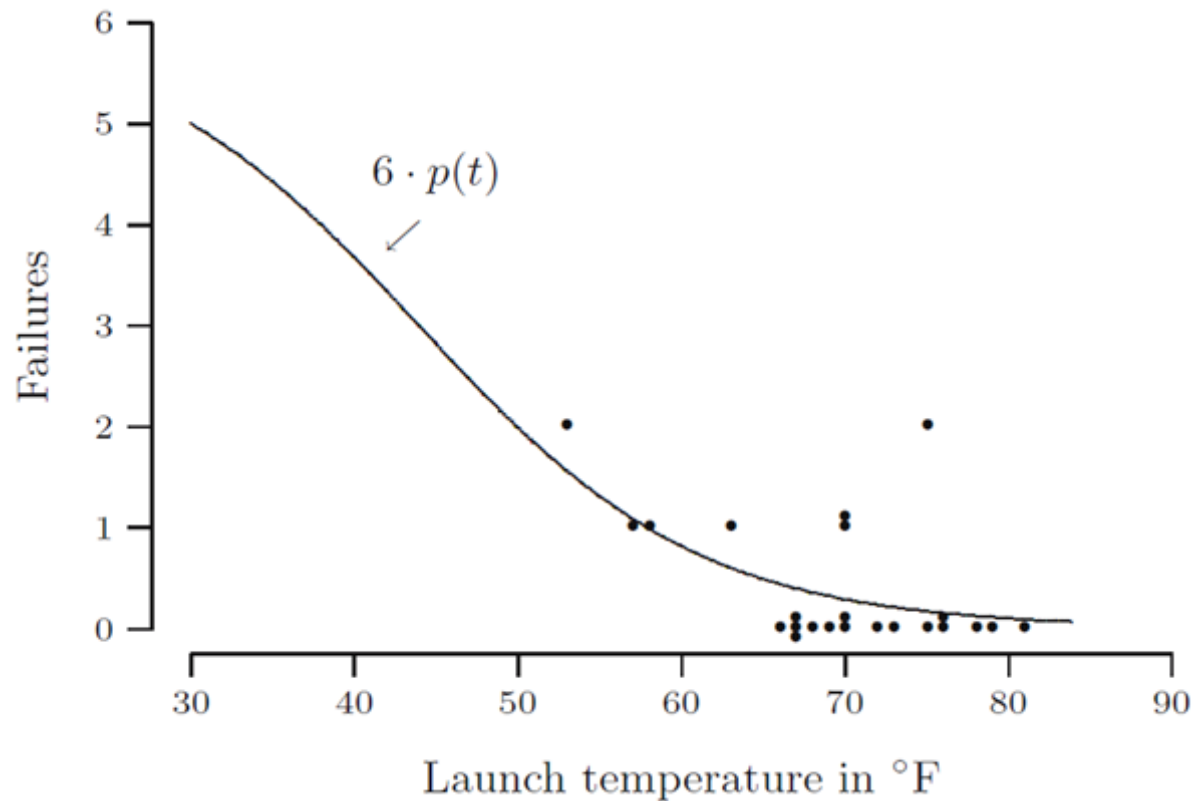
Probability that shuttle would launch safely:

Assume that the O-ring joints succeed or fail independently; each with  $P(\text{success}) = 0.977$  and  $P(\text{failure}) = 0.023$

All 6 O-rings successful:

$$(0.977) \cdot (0.977) \cdot (0.977) \cdot (0.977) \cdot (0.977) \cdot (0.977) = (0.977)^6 = 0.870$$

# Probability of O-ring failure for the Challenger Space Shuttle



Experts have estimated that the probability that an individual O-ring joint would function properly under the cold conditions on the day of the launch was 0.977.

There were 6 of these O-rings.

Probability that shuttle would NOT launch successfully:

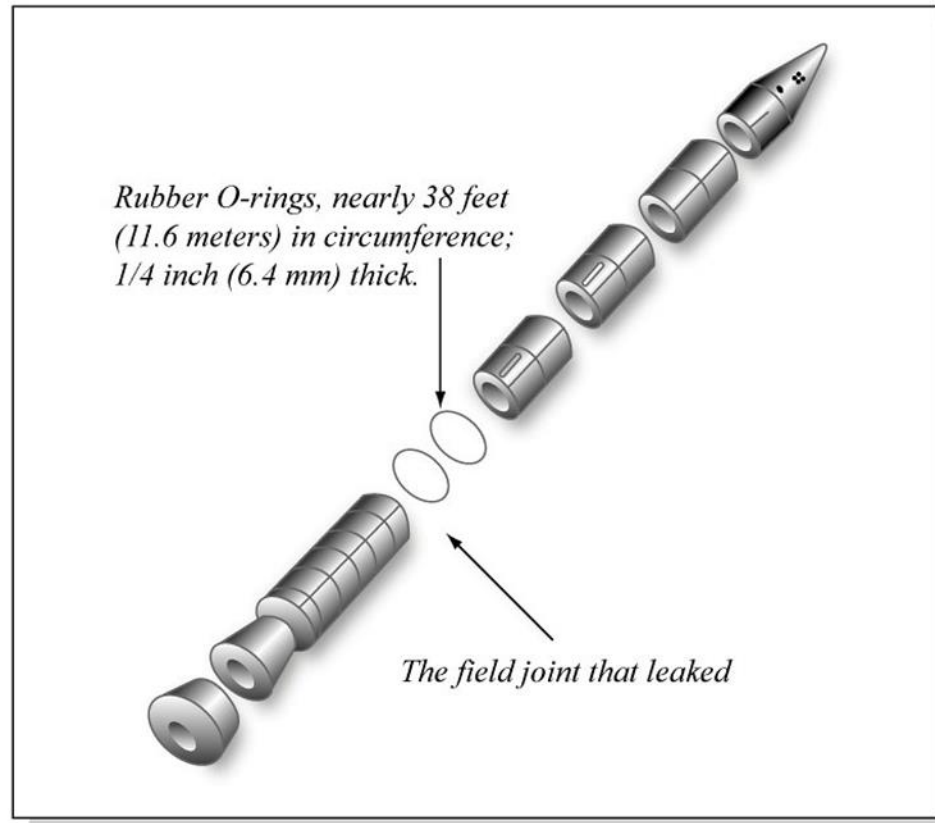
One or more failures (any or all of 1,2,3,4,5,6 O-rings fail)

$P(\text{failure} \geq 1) = 1 - P(\text{zero failures}) =$

$1 - (0.977^6) = 0.130$

# Probability of O-ring failure for the Challenger Space Shuttle

- Challenger space shuttle exploded in 1986 due to a failure of the solid rocket booster O-rings
- Given launch conditions, probability of failure was about 13%



Dalal, Siddhartha & Fowlkes, Edward & Hoadley, Bruce. (1989). Risk Analysis of the Space Shuttle: Pre-Challenger Prediction of Failure. Journal of The American Statistical Association - J AMER STATIST ASSN. 84. 945-957. 10.1080/01621459.1989.10478858.

# Probability of O-ring failure for the Challenger Space Shuttle

- Space Shuttle Challenger and NASA operating under severe budget pressures
- Launch was a media event
- 24 previous successes
- Shuttle had been reclassified from developmental to operational (i.e., safe)
- Groupthink at NASA
  - Is Morton-Thiokol (contractor for booster rockets) with or against us?
  - NASA's sense of invulnerability, unanimity, security, mission, and specialness
  - Single groups with singular knowledge
  - Hierarchy and conformity
  - No devil's advocate and no final second-guessing done for protocol
- Morton-Thiokol concerned about future booster contracts
- Desire to launch: remember you can be wrong!