ETHICS LECTURES

The Space Shuttle Challenger Tragedy – An Overview

MAE 175a

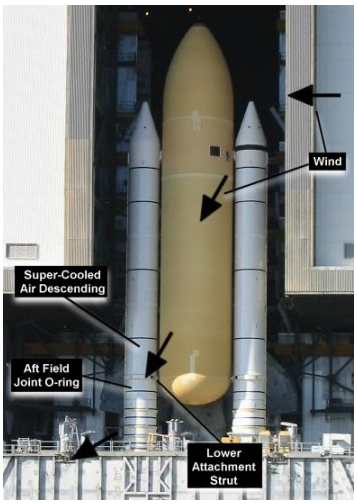
2nd ethics lecture

Sources: http://www.tsgc.utexas.edu/archive/general/ethics/shuttle.html
http://www.engineering.com
Presidential commission report
http://www.aerospaceweb.org
http://onlineethics.org/moral/boisjoly/RB-intro.html

UCSD Jacobs | Mechanical and Aerospace Engineering

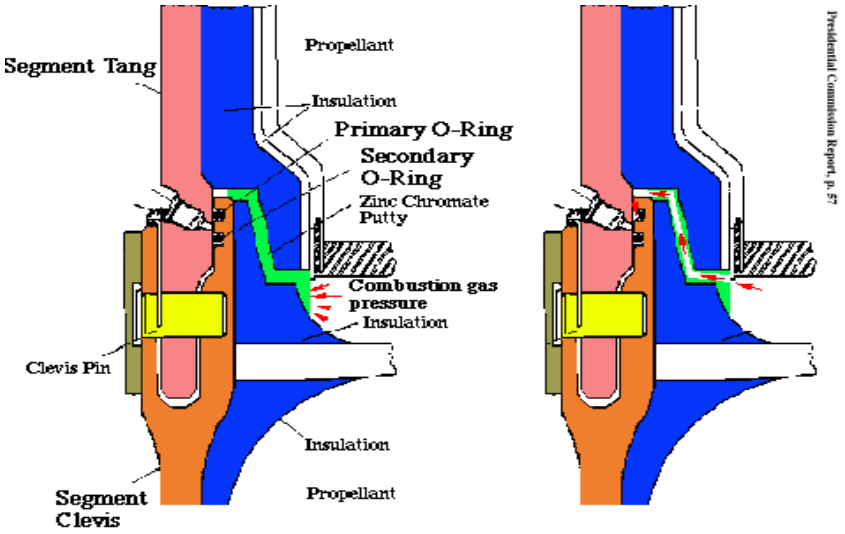
Analysis after the launch: O-rings crucial part of the seal between segments of the solid rocket boosters

- **Each of the white solid rocket boosters is 149 feet long and 12 feet in diameter**
- **Weight of each booster before firing: 2 million lbs.!**
- **Manufacturing requires building in sections**
- **Purpose of O-rings is to keep the high pressure (~10 Mpa = 100 atm.) high-temperature (~2800 °C) gases contained**



UCSD Jacobs | Mechanical and Aerospace Engineering

Diagram of the O-ring assembly



UCSD Jacobs | Mechanical and Aerospace Engineering

Engineers were well-aware of the O-ring problem

- **Problem had been first observed in 1977**
- **Redesign effort was launched in 1985**
- **Senior ("Level-1") NASA management had been briefed on the problem in August 1985**

UCSD Jacobs | Mechanical and Aerospace Engineering

Previous experience with the O-ring seals

- **The seals are subject to *dynamic loading* – i.e. each of the joints flexes during the *stress* of take-off**
- **The O-ring seals had been tested by Morton Thiokol, the manufacturer, down to12˚C (53 ºF), and were deemed safe to that temperature**
- **The rubber elastomer of the seals becomes brittle as the temperature gets colder**
  - This could cause the o-ring to respond more slowly to the vehicle dynamics, temporarily opening a gap where hot gases could flow through
- **Previous flights (e.g. launch at 11˚ C (51 ºF) in 1985) had shown significant (up to 70%) erosion of the o-rings**

UCSD Jacobs | Mechanical and Aerospace Engineering

The people / organizations involved (before we show 2nd video)

- **Marshall Space Flight Center - in charge of booster rocket development**
- **Larry Mulloy - challenged the engineers' decision not to launch**
- **Morton Thiokol - Contracted by NASA to build the solid rocket booster**
- **Alan McDonald - Director of the Solid Rocket Motors project**
- **Bob Lund - Engineering Vice President**
- **Robert Ebeling - Engineer who worked under McDonald**
- **Roger Boisjoly - Engineer who worked under McDonald**
- **Joe Kilminster - Engineer in a management position**
- **Jerald Mason - Senior executive who encouraged Lund to reassess his decision not to launch.**

UCSD Jacobs | Mechanical and Aerospace Engineering

Ethics lecture focus: Challenger Disaster, Mission-51L

Showing of 2nd video

UCSD Jacobs | Mechanical and Aerospace Engineering

Ethics lecture focus: Challenger Disaster, Mission-51L

Wrap up after 2nd video

UCSD Jacobs | Mechanical and Aerospace Engineering

"All Systems Go"

- **Despite warnings about the weather, NASA declared the launch a "go" for January 28th.**
- **This prompted Alan McDonald, director of the Solid Rocket Motors Project at Thiokol, to ask his engineers to present a briefing about the O-rings to NASA engineers**
- **With a few hours to prepare, Robert Ebeling, Roger Boisjoly, and Arnie Thomson prepared a convincing argument that the problem of joint rotation and O-ring seating would be exaggerated by the cold weather.**
  - Night-time teleconference Jan. 27th with Thiokol (Utah), Marshall SFC (Alabama), and Kennedy SFC (Florida)

UCSD Jacobs | Mechanical and Aerospace Engineering

Conclusions from the Thiokol Engineers (Bob Lund, engineering VP)

- **We have no test data below 12˚C (53 ºF)**
- **Data we have at low temperatures shows erosion**
- **Temperatures are predicted to be much below 53 ºF at the launch time**
- **Since we have no data below 53 ºF, *we cannot prove* that the Shuttle will be unsafe at these temperatures, but *we recommend* a delayed launch until the temperatures are at least within the database**

UCSD Jacobs | Mechanical and Aerospace Engineering

Debate and confusion

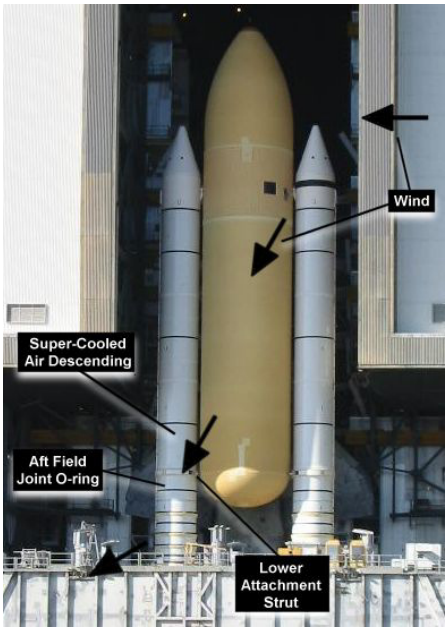
- **NASA managers: *design specifications* were for boosters to be operational at 0˚C (31 ºF)?**
  - (Thiokol had thought this was the specified storage temperature)
- **Marshall solid rocket booster project manager Larry Mulloy: Data are inconclusive**
  - Sparked heated debate with engineers
- **Mulloy bypasses engineers to ask Joe Kilminster – a Thiokol engineer in a management position – for input**
  - Kilminster stands by the recommendations of the Thiokol Engineers
- **Several other managers at Marshall expressed doubt and dismay about the recommendation to not launch**
- **Kilminster asks for a meeting off-line to review data**

What next?

- **Upper management gets into the act**
  - Jerald Mason, senior executive at Thiokol, notes that o-rings were expected to seal even when 30% eroded
  - Previous data showed little correlation of erosion with temperature
  - Mason finally turned to Bob Lund and said, "Take off your engineering hat and put on your management hat."
- **Kilminster writes a revised statement**
- **The new recommendation stated:**
  - Cold was still a safety concern
  - Thiokol had found that the original data was indeed inconclusive and their "engineering assessment" was that launch was recommended
  - EVEN THOUGH the engineers had no part in writing the new recommendation and refused to sign it!

Again: "All systems go"

- **Alan McDonald, director of the Thiokol Solid Rocket Motor Project, who was with NASA personnel in Florida, is astounded by the new recommendation**
  - Tries to persuade NASA to cancel launch
- **NASA overrides the safety concerns and declares the solid rocket boosters safe and the launch a "go"**

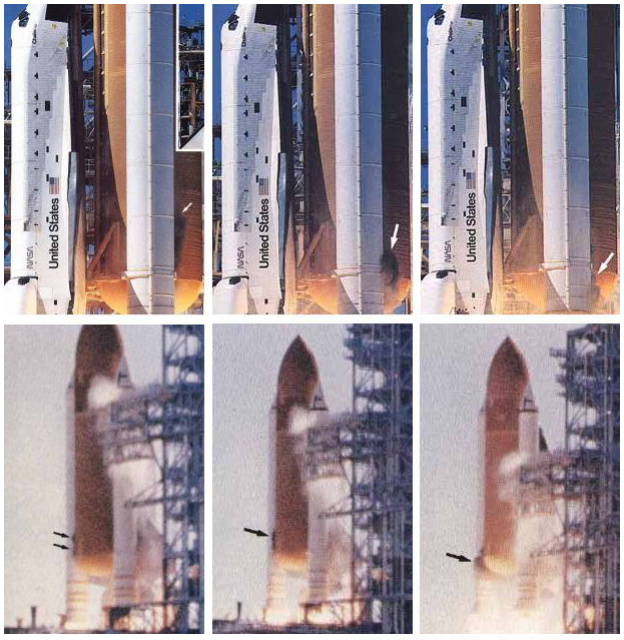


The Launch

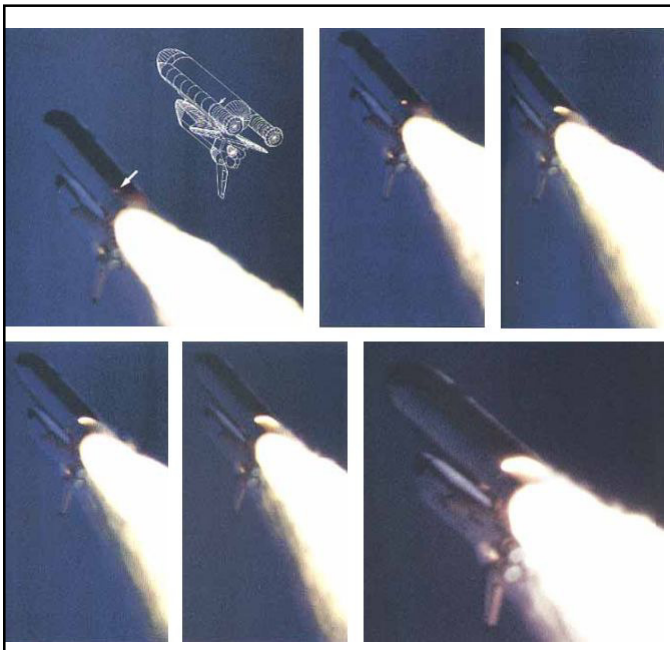
- **Wind blowing down and along liquid hydrogen tank is very cold**
- **Engineers at launch point thermal imaging camera at aft field joint, measure temperature of -13˚C (8º F)**
- **Ice inspection team also concerned**
- **These people were unaware of previous night's teleconference**

Partial failure during launch

- Black puffs of smoke from right aft SRB joint
- Sealed up with Al_2O_3 after a very short leak



UCSD Jacobs | Mechanical and Aerospace Engineering



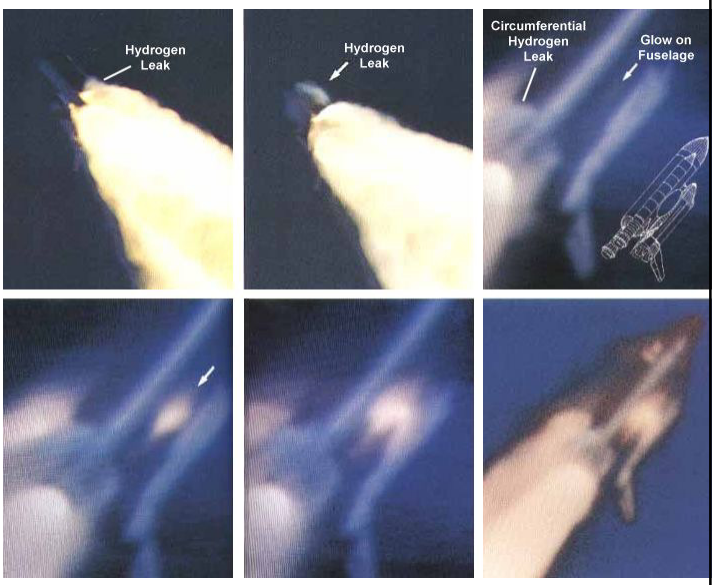
Excessive wind shear dooms mission

- Highest wind shear ever recorded ~ 1 minute into flight
- Attitude control and wind lurch vehicle
- Seals re-open, allowing flame to jet from SRB

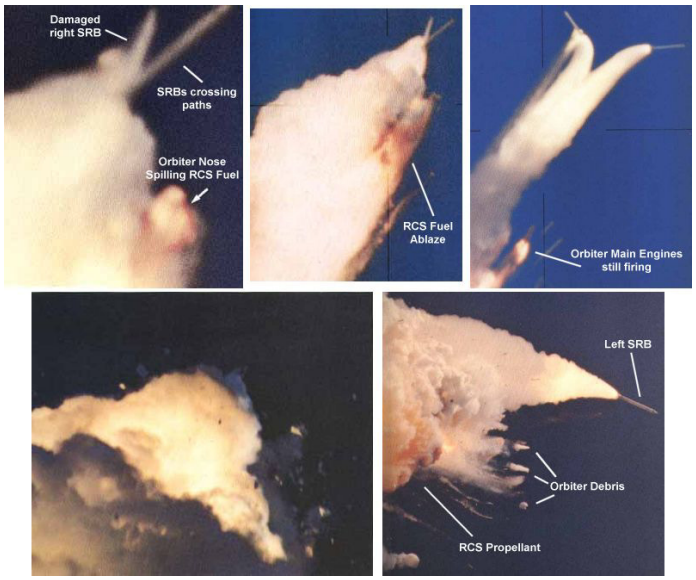
UCSD Jacobs | Mechanical and Aerospace Engineering

Hot gases impinge on H_2 tank

- Tank melts, liquid H_2 vaporizes
- O_2 tank fails, orbiter engulfed in flame
- Orbiter spins, loading causes structural failure



UCSD Jacobs | Mechanical and Aerospace Engineering



UCSD Jacobs | Mechanical and Aerospace Engineering

The ethical dilemma

- **What could NASA management have done differently?**
- **What, if anything, could their subordinates have done differently?**
- **Does it change your opinion to know that NASA was considering a new vendor for the SRBs (and Morton Thiokol knew this)?**
- **What should Roger Boisjoly have done differently (if anything)? In answering this question, keep in mind that, at his age, the prospect of finding a new job if he was fired was slim. He also had a family to support.**
- **What do you (the students) see as your future engineering professional responsibilities in relation to both being loyal to management and protecting the public welfare?**

UCSD Jacobs | Mechanical and Aerospace Engineering

Reflections

- **Role of the engineer**
- **Role of the manager-engineer (important)**
  - Can sometimes best translate engineering judgment and experience into decisions
- **NASA management decision to proceed due to LACK of data (and possibly lack of judgment?)**
  - Reversal of older cautionary procedures

Bibiography
(to go with suggested references at the beginning)

- Feynman, Richard Phillips. *What Do You Care What Other People Think: Further Adventures of a Curious Character*. Bantam Doubleday Dell Pub, ISBN 0553347845, Dec 1992. Reference added by request of Sharath Bulusu, as being pertinent and excellent reading - 8-25-00.
- Lewis, Richard S.*Challenger: The Final Voyage*. New York: Columbia University Press, 1988.
- McConnell, Malcolm.*Challenger: A Major Malfunction.* Garden City: Doubleday, 1987.
- Trento, Joseph J.*Prescription for Disaster*, New York: Crown, c1987.
- United States Congress House Committee on Science and Technology.*Investigation of the Challenger Accident: Hearings before the Committee on Science and Technology, US House of Representatives, Ninety-Ninth Congress, Second session ....* Washington: US G.P.O., 1986.
- United States Congress House Committee on Science and Technology.*Investigation of the Challenger Accident: Report of the Committee on Science and Technology, House of Representatives, Ninety-Ninth Congress, Second session.* Washington: US G.P.O., 1986.
- United States Congress House Committee on Science, Space, and Technology. *NASA's Response to the Committee's Investigation of the "Challenger" Accident: Hearing before the Committee on Science, Space, and Technology, U.S. House of Representatives, One Hundredth Congress, First session, February 26, 1987.* Washington: US G.P.O., 1987.
- United States Congress Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science, Technology, and Space. *Space Shuttle Accident: Hearings before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate, Ninety-Ninth Congress, Second session, on space shuttle accident and the Rogers Commission report, February 18, June 10, and 17, 1986.* Washington: US G.P.O., 1986.

UCSD Jacobs | Mechanical and Aerospace Engineering