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Engineering Failure Analysis - A Review

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ISO 9001:2000

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Hubble Space Telescope

- **Background**
  - Designed in the 1970's and launched 1990
  - The first major orbiting space based observatory
- **Problem**
  - The curve to which the primary mirror was ground was incorrect, causing "spherical aberration"
  - The flaw resulted in a fuzzy focus image
- **Impact**
  - 4 costly servicing missions in 1993-2002
  - More than $3 billion spent to date

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TITAN IV B-27/INERTIAL UPPER STAGE-21/DSP-19

- **Background**
  - -Mission: Place DSP satellite into geosynchronous orbit

- **Problem**
  - - IUS stage 1 to IUS stage 2 interface connector failed to separate
  - - Inexperienced technicians, inadequate engineering and assembly drawings led to improper application of thermal tape at connector separation plane
  - - Inadequate failure modes and effects analysis on connect

- **Impact**
  - -Spacecraft failed to achieve proper orbit greatly reducing operational capability

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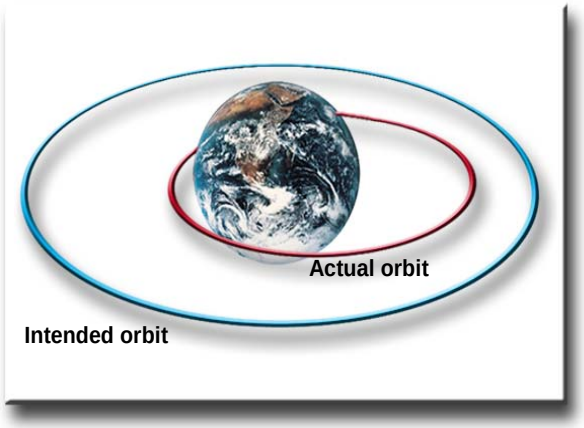
TITAN IV B-32/CENTAUR TC-14/MILSTAR-3

- **Background**

  - The mission was to place MILSTAR communications satellite into geosynchronous orbit

  - Titan IVB core vehicle nominal

  -Centaur upper stage separated from Titan vehicle



- **Problem**

  - Flight software was not used for data validation

  -Error in the manual entry of a roll rate filter

    - Correct value -1.992476
    - Value manually entered by technician -0.1992476

  - Second Centaur burn failed to achieve correct orbit, resulted in low orbit

- **Impact**

  - Greatly reduced mission capability

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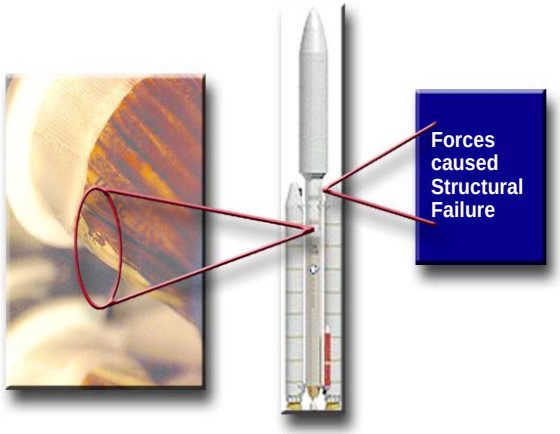
Titan IV A-20/Centaur/NRO

- **Background**
  - Mission: Place NRO payload into orbit
- **Problem**
  - 40 seconds after launch shorted wires caused the guidance system to reset and the vehicle to pitch and yaw beyond design loads
  - Likely harness damage occurred before launch possibly due to a combination of inadequate design, faulty workmanship, rework or shipping
- **Impact**
  - Resulted in structural failure and destruction of vehicle



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GALAXY 601

- **Background**
  - August 27, 2000 spacecraft used for cable and broadcast television, national and regional radio transmission, and data relay.
- **Problem**
  - Conformal coating (prevents tin whisker growth) used to cover tin surfaces electronics was improperly applied and thus allowed tin whiskers to bridge a relay terminal causing an electrical short
- **Impact**
  - Satellite lost
  - Cost: $500M

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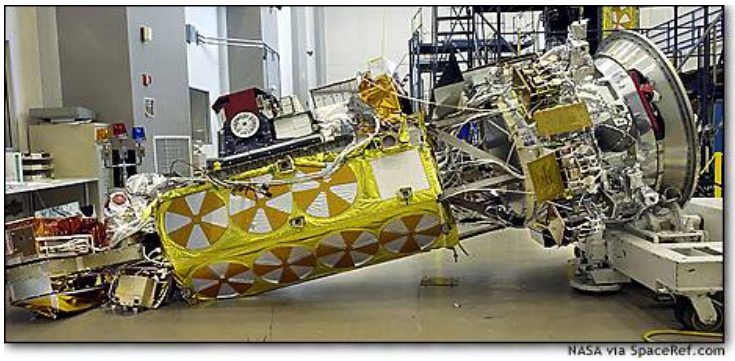
NOAA-N PRIME WEATHER SATELLITE

- **Background**
  - Television Infrared Observation Satellite (TIROS)
  - TIROS spacecraft is a polar-orbiting meteorological satellite.
- **Problem**
  - Bolts securing the satellite to a turnover cart were removed -Satellite toppled from its platform during tilting operation
  - The causes were identified as a lack of discipline, not following procedures – Responsible Test Engineer (RTE), Production Quality Control (PQC), and Production Assurance (PA) were identified as the offices of primary responsibility.
- **Impact**
  - Complete loss: $239 Million



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MARS POLAR LANDER MARS CLIMATE ORBITER

- **Background**
  - The failures of the Mars Climate Orbiter (MCO) and Mars Polar Lander (MPL) in 1999.
- **Problem**
  - The 'root cause' of the MCO failure was the use of data in English units that were thought to be in metric units within a segment of ground-based, navigation-related mission software.
  - The loss of MPL has been traced to premature shutdown of the descent engines, resulting from a vulnerability of the software to transient signals.
  - End-to-End testing, "…inadequate checks and balances that permitted an incomplete systems test and allowed a significant software design flaw to go undetected."
- **Impact**
  - Loss of both missions ($327M)

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DELTA III 259/GALAXY-X

- **Background**
  - -The Mission was to deliver commercial Satellite into orbit
  - -Inaugural flight of Delta III

- **Problem**
  - - Conscious deviation from normal, proven space design analysis
  - -The control system tried to correct a slow natural oscillating roll that developed during the first minute of flight. The control system expended all the hydraulic fluid in the thrust vector control system
  - -Frequency would have been discovered if more thorough standard analysis was performed and filtered
- **Impact**
  - - Lost vehicle and payload
  - - Significant damage to product line

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DELTA III 269/ORION-3

- **Background**
  - 2nd flight of commercially developed Delta III
  - The RL10B-2 engine abruptly shut down followed by tumbling of the stage
- **Problem**
  - Second-stage engine stopped due to a combustion chamber breach
  - Combustion chamber breach was a result of defective brazing due to poor manufacturing process controls
  - Inspection results were not recognized as nonconforming because of improper translation of braze coverage design requirements to the acceptance criteria used by quality assurance procedures.
- **Impact**
  - Spacecraft separation occurred placing the Orion-3 satellite in useless orbit
  - No customer for the third Delta III flight
  - Delta III program cancellation after third flight

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SPACE SHUTTLE PROGRAM AUTOMATED CHECK-OUT & LAUNCH CONTROL SYSTEM

- **Background**
  - Primary objective: to reduce cost, increase performance and increase efficiency over legacy system
  - CLCS was intended to provide ground support equipment control

  - Began 1997 and canceled 2002
- **Problem**
  - Lack of disciplined software development resulted in cost growth, schedule slippage and reduced functionality
- **Impact**
  - Cost estimate increase from $207M to $533M
  - Cancellation of program after $300M spent

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EUROPEAN SPACE LAUNCHER – ARIANE 5

- **Background**
  - First launch, after a decade of development costing $7 billion.
  - Designed to lift 10,000 kg into geo orbits

- **Problem**
  - Launch failure caused by complete loss of guidance and attitude information 30 seconds after lift-off
  - Specification and design errors in the software of the inertial reference system.
  - Reuse of Ariane 4 software and values.

- **Impact**
  - The destroyed rocket and its cargo were valued at $500 million.
  - Loss of future launch contracts

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CHINESE SPACE LAUNCH FAILURE

- **Background**
  - CZ-3B was China's most powerful launch vehicle.
  - It had a payload of 5,000kg, and four liquid-fuel boosters strapped onto the core stage.
  - 1996-1998
- **Problem**
  - The CZ-3B began to veer off course two seconds after liftoff.
  - A gold-aluminum solder joint in one of the gyro servo loops failed.
  - Malfunction of the inertial guidance system
  - The vehicle and its payload hit the ground and exploded
- **Impact**
  - Crashed and devastated a village causing death and injuries
  - Cost: $125 million dollars

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BRAZIL SPACE PROGRAM'S SATELLITE LAUNCH VEHICLE (VLS)

- **Background**
  - Brazil attempting to develop a satellite launch vehicle
  - Four-stage rocket using solid propellants
  - Much of the technology for the VLS was derived from early Brazilian Sonda-class sounding rockets.
- **Problem**
  - Program plagued by quality problems and successive launch failures (1997-2004):
    - First Launch - Rocket off course and destroyed.
    - Second Launch -destroyed in-flight when the rocket again veered off course.
    - Third Launch - Explosion on launch pad during launch preparation
- **Impact**
  - Third Launch - 21 Lives lost
  - Processing facilities and launch pad destroyed

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Space Shuttle

- **Background**
  - Shuttles Developed in early 1970s
  - First flight April 1981
- **Problem**
  - Challenger loss caused by a failure in the joint between the two lower segments of the right Solid Rocket Motor.
  - Columbia loss caused by a breach in the Thermal Protection System on the leading edge of the left wing.
  - Combination of design and manufacturing flaws coupled with management failures lead to both accidents.
- **Impact**
  - Destruction of Challenger and Columbia and loss of life

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FIRESTONE TIRE RECALL

- **Background**
  - Wilderness All Terrain tires on Ford Explores manufactured at Decatur Illinois plant
  - Recalled in 2000 for tread separation
- **Problem**
  - Manufacturing equipment malfunctions
    - Lead to air void between tread and steel belt
    - Lower cohesion levels between belt and tread
  - Design defects
    - Design creates excessive stress between belt and tread
  - Inadequate testing
- **Impact**
  - Loss of life

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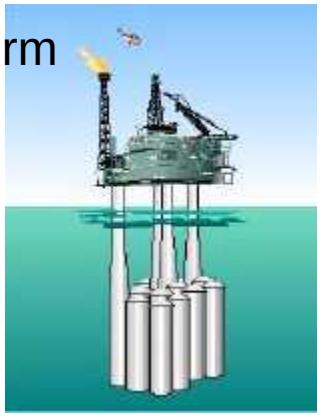
SLEIPNER NORTH SEA OIL PLATFORM

- **Background**
  - Statoil (Norwegian Oil Co.), August 1991
  - Platform supported by four elongated concrete cells, one of which sank during a standard blasting operation
- **Problem**
  - Inaccurate finite element analysis performed on concrete support structure.
  - Shear stresses underestimated by 47%
  - Concrete structure failed.
- **Impact**
  - $1B
  - Loss of platform



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BRAZILIAN OIL COMPANY PETROBAS OIL PLATFORM

- **Background**
  - Oil platform inaugurated in 2000
  - Located in Campos Basin, 80 miles off the coast of Rio de Janeiro
  - Supplies 5% of Brazil's total oil output
- **Problem**
  - Ignored daily bulletin advisories about valve and pump failures
    - Pressurization in platform vent system
    - Build up of Hydrocarbons
    - Rupture of tanks resulting in fire
  - Damage to flotation tower due to rupture of tanks
    - Resulting in collapse of platform
- **Impact**
  - Loss of 10 lives
  - $500M structural loss
  - $41.5M increase in insurance premiums

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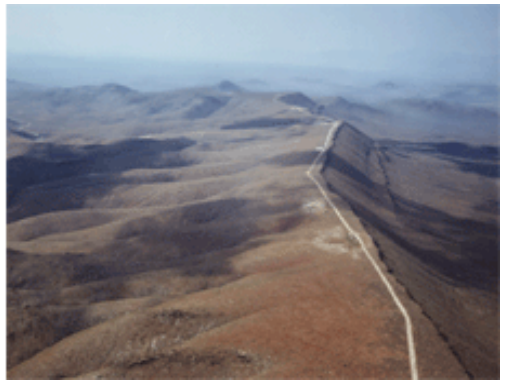
NUCLEAR WASTE REPOSITORY AT YUCCA MOUNTAIN

- **Background**
  - First long-term geologic repository for spent nuclear fuel and high-level radioactive waste.
  - NRC requires nuclear facilities to develop a quality assurance program
- **Problem**
  - DOE auditors identified significant problems with data sources, validation of scientific models, and software development.
    - Data sets could not be traced back to their original sources
    - No standardized process to develop scientific models needed to simulate geological events
    - No process for ensuring that software being developed to support the models would work
- **Impact**

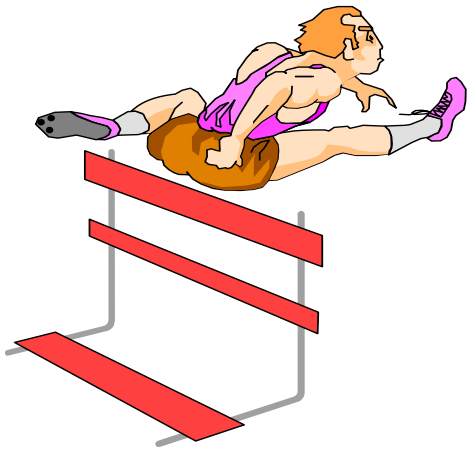
  - Continuing delay of repository licensing, operation and stockpiling of spent fuel



Thank you

Product Development
•Failure Analysis
•Finite Element Analysis
•Prototyping

(ISO 9001 : 2000)



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