I recently came across a uncensored report on the ill-fated spacecraft and crew of seven astronauts. It was April 1985 when Challenger was destroyed several miles high shortly after lift-off.

This report is far larger than the report posted on NASA's file servers - at 450 pages.

One of the areas of focus is the right booster rocket. Below is a excerpt on just how badly engineered this booster was from the beginning of the shuttle program. This is report is unedited and a real eye-opener. Extracts from the report are shown in italics, comments to text are shown in bold-italic font. Remember that this report was written after Challenger's final flight.

We will skip boilerplate text and begin at page 61 of the report:

Recommendations

1. NASA should write and issue a new and more accurate performance specification which would cover the full range of thermal and structural requirements for the Solid Rocket Motors, with an adequate factor of safety for unusually low temperatures.

2. The Committee concurs with the Rogers Commission Report Recommendations on new joint design, but believes it is more appropriate to be more explicit in identifying the weaknesses in the joint design that need correction.

3. The field joints of the Solid Rocket Motors should be redesigned to account for the following features while providing a significant factor of safety:

- *a. Movement in the joint;*
- *b. Proper spacing between tang and clevis;*
- *c. Seals made to withstand high and low temperatures under all dynamic thermal and structural loadings;*
- *d. Adequate sealing without the use of putty;*
- *e. Protection against insulation debonding and propellant cracking.*

Note that PUTTY was used. Everyone has heard about the badly designed O-ring seals and abnormally cold temperatures, but not about the putty. More info about the putty will follow.

Discussion
This section is a summary of Section VII, Casing Joint Design.
For details and substantiation of the statements made in this summary, refer to Section VII.
The evidence, consisting of recovered pieces of the right Solid Rocket Motor casings, photographs of smoke and flame emanating from the right Solid Rocket Motor and telemetry data transmitted from STS 51-L back to Mission Control at the Johnson Space Center verify the failure of the aft field joint of the motor.

Aft joint refers to rear field joint, a joint created at Kennedy Space Center during final assembly of the booster.

As mentioned earlier, NASA's performance specifications did not anticipate operations at temperatures below 31 degrees, a temperature that might occur in Florida during the winter months. The design of the joint was unsatisfactory to provide for the low temperatures or water in the joints that existed on January 28. While it was based on an existing similar rocket casing joint design that had been successful, the design was changed to accommodate the manufacturing requirements of the larger sized shuttle rocket motors.

Larger boosters were added later.

There were even some features of the revised design that indicated the changes were an improvement. It was easier to assemble in the field and it had a second O-ring.

The designers thought if the first O-ring failed, the second would surely hold the propellant gases. The casing joints, as described in the Introduction, have to withstand various structural loads, which change dramatically as the shuttle is assembled, through launch operations, separation of the Solid Rocket Booster and retrieval from the ocean. The joint is dynamic; the components move under these loads.

Note - putty was used despite knowing components move under these loads.

The loads carried by the aft field joint are different from those carried by other joints. The design, based on these loads and 24 successful missions, appeared satisfactory.

One of the loads, however, that of the propellant gas pressure, was not adequately accommodated. The zinc chromate putty, intended to protect the O-rings from this high temperature and relatively high pressure gas, frequently failed and permitted the gas to erode the primary O-rings.

Instead of redesigning the joint, NASA and Thiokol persisted in trying to fix the problem by changing leak-test pressures, changing the size of the O-rings, and trying to control proper spacing between the tang and clevis where the O-rings were located. Complicating this problem, two of the materials used in the joint, the putty and the fluorocarbon elastomer O-rings, were not suited to the task of containing the propellant gas under the full span of Shuttle operating conditions. The behavior of the fluorocarbon elastomer O-rings was something of a mystery to NASA and its contractor.

In other words, no laboratory tests were performed to verify O-ring

properties.

The material was "proprietary," meaning that the constituents used were known only to the manufacturer. Fluorocarbons are expensive, so fillers are frequently added to reduce the cost of the material. These materials behave unlike most other materials. The particular material used in the manufacture of the shuttle O-rings was the wrong material to use at low temperatures. Nitrile or silicon based materials would have demonstrated better performance characteristics.

It became necessary to find a new putty when the original supplier, Fuller O'Brien, stopped making it because it contained asbestos. The characteristics of the new putty changed substantially in response to the quantity of water in the air and it was difficult to apply in both the dry climate of Utah and the dampness of Florida. Its performance in use was highly unpredictable. Again, NASA and its contractor tried to make up for the unsatisfactory material by storing it under refrigeration prior to application in Florida.

*After ignition of the solid propellant in the SRM [**booster casing]** It was learned that the O-ring could be seated by the motor's gas pressure yet still suffer erosion as the hot gases came in contact with it. As mentioned, O-ring erosion was noted after various flights and tests. Also seen was damage given the name "blow-by", a condition where erosion was not necessarily present but where there was evidence that the propellant gas had bypassed the primary O-ring. But rather than identify this condition as a joint that didn't seal, that is, a joint that had already failed, NASA elected to regard a certain degree of erosion or blow-by as "acceptable." To make matters worse, confidence was mistakenly obtained from a mathematical model which suggested that if the erosion did not exceed a specific depth, the O-ring would still seal that joint. In cases where the erosion did exceed the maximum predicted by the model, NASA expanded its experience base to cover this increased damage. As the joint seals continued to exhibit erosion or blow-by or both, more research illustrated the importance of maintaining proper gap spacing between the tang part of the joint and the O-ring **face** of the inner clevis leg. Too little space, and the O-rings would not seal. Too much space, and again the seals would fail. Since the joint opens, or "rotates," when the Solid Rocket Motor is ignited, maintaining proper spacing was difficult if not impossible. The maintenance of such close tolerances in spacing, on the order of 20 thousandths of an inch, while joining 300,000 lb. segments that have been bent during shipment, was not sufficiently provided for in the design.*

Worth repeating: "The maintenance of such close tolerances in spacing, on the order of 20 thousandths of an inch, while joining

300,000 lb. segments <u>that have been bent during shipment,</u>
<u>was not sufficiently provided for in the design.”</u>
This author learned first-hand from a NASA engineer that the mechanical tolerance allowed for assembling the shuttle to the boosters and tank was .200”.

Months passed until, in 1985, engineers at NASA recognized that the design was unsatisfactory. In fact, NASA had written to several other contractors soliciting help with the joint problems. Unfortunately, in the quest to meet schedule and budget, the warnings of the engineers were not heeded.

Money was more important than saving lives.

Based on the above conditions and the evidence, the Committee has endeavored to determine the way in which the joint failed; recognizing that such a determination is difficult, if not impossible, to make with 100% certainty.

The following is the most probable sequence of the joint failure:

1. The failure occured in the lower assembly joint near a strut that connects the Solid Rocket Booster to the External Tank.
2. At that location, the spacing between the two casings was too small to facilitate a tight seal.
3. Also, at that location, there probably existed a hole through the insulating putty, which would act as a conduit concentrating the hot propellant gas on the primary O-ring.
4*. The freezing temperatures reduced the capability of the 0-rings to seal. Worse, at this particular location, near the connecting strut, the joint was made even colder by the further loss of heat caused by the direct connection to the liquid hydrogen fuel, at 423 degrees below zero, in the external tank.*
5. When the Solid Rocket Motors were ignited, the pressure from the motor changed the spacing between the casings. Among other effects, this can prevent the secondary O-ring from sealing.
6. Seven inches of rain fell while the shuttle was being prepared for launch. Water very likely penetrated the joints and froze. Ice in the joints could have dislodged the secondary O-ring even if the change in spacing, coupled with a cold and stiff O-ring, did not.
7. Smoke at ignition occurred at a location near the connecting strut to the external tank. At that location, the primary O-ring was either unseated or eroded and the secondary O-ring was unseated.
8. The primary O-ring was sealed at other locations around the motor casings.
9. The breach in the primary O-ring clogged with burned char and aluminum oxide from the pro-pellant in less than ***3*** *seconds, causing the smoke to stop.*
10. At 37 seconds, 45 seconds and 58 seconds into the flight, the

Space Shuttle encountered heavy turbulence, which forced the steering controls to cycle through changes more severe than previous flights.
11. After throttling back to 65% power as planned, at 57 seconds, power was increased to 104%.

(11) Note that throttling applies only to main shuttle liquid fueled engines.
Boosters have nozzle direction control but no throttling control.
Once the boosters are ignited, nothing can stop them until fuel is exhausted.

12. The combined effect of the turbulence and the increase in power caused the material which clogged the joint to break free, reopening the joint.

(12) can only be speculation that the joint "re-opened."

13. A flame from the right Solid Rocket Motor was seen at the location near the connecting strut.
14. This flame burned through the external tank and caused the destruction of the shuttle.

(14) may be questionable. There is a self-destruct strip which passes vertically near this area.

Considerable attention was paid to the design of the casings because they were larger than seen on any previous Solid Rocket Motor, because this Solid Rocket Motor would be used on a manned flight system, and because these particular motors would be brought back, refurbished and reused.

Given this background, the testing of the joint was included in static firing tests. While there were no special tests conducted to confirm and certify the joint as a separate item, analysis was performed to assure that the joint was adequate. Later, during the operation of the Solid Rocket Motor, it was discovered that the performance of the joint was unsatisfactory.

No one needs to be a rocket scientist to recognize that a horizontal fixed engine test, bolted down to concrete on the desert floor in Utah where the boosters were made, is not like the vertical twisting and strain which occurs during a real launch. Statement above admits NASA prior knowledge; they knew it was "unsatisfactory" but ignored it.
Any "analysis" performed can yield far different results than a actual test.

MANUFACTURE

In manufacture, either new steel casings or previously used casings are employed. The first step is to apply the rubber insulation liner around the inside of the casings. The insulation is removed from a roll and spread around the inside of the casings with special tooling. After application it is cured in place in an autoclave. After the casings have been insulated, they are *placed in a casting pit. The propellant is then poured into the casings under vacuum. The propellant is then cured and the casings are removed from the pit. There is no indication that there were any manufacturing defects that contributed to the loss of the Challenger.*

Rubber burns at 216F to 316F. According to documentation, internal booster temperatures exceed 5,000F. So why was RUBBER used?

Let's look at Morton Thiokol, which perhaps should not have been awarded a booster design contract in 1973:

November 19, 1973.-In its report to NASA Administrator James C. Fletcher, the Solid Rocket Motor Source Evaluation Board (SEB) evaluated the proposals generated by the Solid Rocket Motor RFP. Thiokol scored ***124*** *out of a possible 200 points for its motor design, the lowest score among the four competitors. The only design strength identified by the Board: "Case joint leak-check capability increases reliability and improves checkout operations."*

"RFP" is government jargon for Request For Proposal. Notice how Morton Thiokol had the LOWEST score among the four competitors. Why did it get the contract? TWELVE years before the Challenger disaster?

December 12, 1973. - NASA Administrator James C. Fletcher announced selection of Morton Thiokol as contractor for Design, Development, Test and Evaluation (DDT&E) of the Solid Rocket Motors. In the source selection statement, "Selection of Contractor for Space Shuttle Program, Solid Rocket Motors," a statement was included that indicates that Thiokol ranked fourth *out of the four bidders in the design category (See Appendix V-A). NASA, however, placed greater importance on cost reduction and Thiokol had an attractive cost proposal.*

Above text shows price was why Morton Thiokol won - they were fourth. Contract officers at NASA either did not understand the dangers involved or just ignored them. Usually contract officers use feedback from engineers and scientists who review the technical portion of proposals. Technical people should also share some of the blame.

Contrary to what the public has believed since the eighties, there is abundant proof that the lethal booster design dates back to the beginning of the shuttle program. It is incredible more astronauts were not killed.

Dr. Wernher von Braun was the First Director of NASA, from July 1, 1960 to Jan. 27, 1970. When the public watched John Glenn and others go into space, almost no one outside of NASA knew a former Nazi was the director of the space program.

February 2, 1979.-Mr. Eudy and Mr. Ray of NASA visited the Parker Seal Company. A trip report was sent to Messrs. Hardy/ Rice/McCool of NASA which contained the following statement "Parker experts would make no official statements concerning reliability and potential risk factors associated with the present design however, their first thought was that the O-ring was being asked to perform beyond its intended design and that a different type of seal should be considered. The need for additional testing of the present design was also discussed and it was agreed that tests which more closely simulated actual conditions should be done." This report also referred to the O-ring extrusion gap being larger than Parker had previously experienced. (See Appendix `V-I.`*)*

Double quotes shown above were not added and are shown in the NASA report.

Report documents several years of O-ring failure discussions:

November 12, 1981.-During STS-2, the second Shuttle flight, erosion of the primary O-ring was discovered in the 90 degree location of the aft field joint of the right hand Solid Rocket Motor. The 0.053 inch erosion was not discussed in the STS-3 Flight Readiness review. This was the deepest O-ring erosion that would be discovered in any case field joint.

February 25, 1983. -Employees of Thiokol discussed joint "gap size" and "O-ring compression" at a briefing at the Marshall Space Flight Center.

March 17, 1983.-Mr. Lawrence Mulloy, MSFC Solid Rocket Booster (SRB) Project Manager, informed NASA Level 1 (meaning the Associate Administrator for Space Flight), of the pending change in criticality from 1R to 1, which meant that a single seal failure could result in the loss of the Shuttle and crew. That change was approved on March 28, 1983.

April 4, 1983.-STS-6 was the first flight to use the "lightweight case." It was also the first flight where a criticality factor of 1, instead of lR, was assigned to the joint. After the flight, "blowholes" in the nozzle to case joints, not the case field joints, were found in both the left and right Solid Rocket Motors. These observations were not discussed in the Flight Readiness Reviews for STS-7.

Despite changes to the O-ring design in March 1983, blow-holes were found in BOTH solid rockets a month later - after the flight of STS-6. Challenger's final flight came almost exactly a TWO YEARS LATER because nothing was done about the design flaw.

That still wasn't the end of problems with seals and replacement putty:

December 6, 1983 -An internal Marshall Space Flight Center (MSFC) memo from Mr. Miller to Mr. Horton highlighted the seal leak detection and zinc chromate putty problems.

February 22, 1984 -Marshall Space Flight Center memorandum from Ben Powers to Horton requested that post-flight and post-static firing inspection on specific joints be made. The memo expressed concern about adhesion life of the zinc chromate sealant after installation on the SRM.

March 2, 1984 -Thiokol personnel described the erosion discovered in the 351 degree location of the left Solid Rocket Motor forward field joint of STS-41B at a Flight Readiness Review. The erosion extended over three inches with a maximum depth of 0.040 inches. This was the first time the subject of O-ring erosion sustained on flights STS-2 and STS-6 was discussed as a technical issue at a Flight Readiness Review.'

March 8, 1984 -The notion of ACCEPTABLE EROSION was mentioned at a meeting of the Shuttle Projects Office Board for STS-41-C. Even though the joint was now classified as Criticality 1, which meant that failure of the joint could lead to the loss of the Shuttle and crew, the concept of "maximum possible" erosion, 0.090 inches, was accepted as an absolute value based on a computer program which was supported by limited data. Furthermore, the 0.090 inch value was based on the concept that the O-ring would seal at 3 times the actual motor pressure even if the erosion extended to 0.095 inches thereby giving comfort in continuing with a known problem.

April 6, 1984.-Heat degradation of the O-ring in the left SRM aft field joint of STS41-C was found, along with "blowholes" in the putty.

April 12, 1984 -In an internal Marshall Space Flight Center memorandum, John Q. Miller told Mr. Horton that "stacking difficulties and observed O-ring anomalies" were increasing with the use of Randolph putty. The former supplier, Fuller O'Brien, had discontinued producing the putty previously used in the Shuttle program. Accordingly, putty was ordered from Randolph Products. The memo requested expedited development of a putty with the characteristics of the Fuller O'Brien putty used prior to STS-8.

May 4, 1984 -Morton Thiokol prepared a Program Plan for the protection of Space Shuttle SRM primary motor seals. Thiokol's objective was to isolate the joint problem and to eliminate damage to the motor seals, the O-rings. The plan called for analysis and testing of O-rings, putty and associated lubricants.

A year later in April 1985 Challenger was destroyed, despite the documented engineering history over many years how a seal failure will result in loss of the vehicle and crew.

We can easily conclude from this section of NASA's report:

1. ***NASA was well aware of serious design issues with the boosters. Several years BEFORE Challenger was destroyed***
2. ***Booster design, test and manufacturing contract award to Thiokol should not have been made***
3. ***Thiokol contract award was based on price, not performance***
4. ***Nothing was done to ensure hot gas leakage could not occur***

Finally, Section E: SABOTAGE

Issue
foreign covert action?

Finding
The Committee is convinced that there is no evidence to support sabotage, terrorism or foreign covert action in the loss of the Challenger.

Another big fat lie. It was the data collection system inside the launch pad which monitored the pad that was sabotaged.
Read my account of how the sabotage took place here.

This essay ends at PDF page 54 of the report. Otherwise, the evidence would continue for several hundred pages.

In spite of all this, no one was held accountable.

Ted Twietmeyer

The complete 450 page ”Investigation of the Challenger Accident” can be read here in PDF format.