THE REDUCTION OF COMPLEXITY IN DISASTERS

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Introduction

January 28th 1986, the space shuttle Challenger disintegrated 73 seconds into its flight. The direct cause was a leaking O-ring in the right solid rocket motor allowing hot gasses to escape. These gasses hit the central liquid fuel tank of the shuttle causing the fuel inside to combust, ripping the Challenger apart. A terrible tragedy with a clearly defined cause. It sounds simple, but in reality the disaster was much more complex. There were many contributing factors, from the sharp end causes like the design of the solid rocket booster itself to the blunt end causes like the organizational structure of NASA. All of these factors contributed to the disaster. You can easily get lost in the details of the story. So how does one perceive the complexity of an event like this? Research done by Feltovich (1994, 2004) shows that people have trouble understanding complexity.

The first ones to struggle with the complexity of the Challenger disaster were of course the accident investigators at the time. According to Lundberg (2009) accident investigation is done according to the what-you-look-for-is-what-you-find and what-you-find-is-what-you-fix principles, suggesting that the conclusions of the accident report are highly dependent on what the accident investigators were looking for.

In his research Lundberg (2010) shows that accident investigation is subject to many forms of bias: *Author bias,* a reluctance to accept findings from other people's investigations; *Confirmation bias*, a tendency to confirm preconceived causes; *Frequency bias*, a tendency to classify causes in common categories; *Political bias*, where the status of an individual gives him or her undue influence on the attribution of causes; *Sponsor bias*, where the attribution of causes risk damaging the reputation of the investigator's own organization; *Professional bias*, where causes that are most acceptable to colleagues are chosen.

Lundberg (2010) also found that Engineers tended to attribute more causes to human factors than to technical errors and that the purpose of the investigation also had a major impact. This is show in the fact that for example legal analyses tended to blame individuals more often, whereas an analysis based on the accident evolution and barrier method instead pointed at other factors.

Research done by Cedergren & Petersen (2011) shows that in accident investigation the emphasis is mainly on physical processes, actor activities and equipment (microlevel). Less attention is paid to organizational factors (mesolevel) and conditions related to regulators, associations and government (macrolevel). They also found that investigators focus on areas of their own expertise. This shows that the original accident report is subject to bias and the outcome is highly dependent on the accident investigator who wrote it. So an accident investigation report is a possibly biased and distorted report of an even more complex reality.

All this means that the official accident investigation reports (Like the *Report of the Presidential Commission on the Space Shuttle Challenger Accident (1986), more commonly referred to as the Roger report*) might not be as reliable as one might think. We can see that early accident investigation work (before the Challenger disaster) focused on line managers and sharp end operators. Over time, due to disasters like the Challenger's, the investigation focus changed towards regulatory agencies at the blunt end of operations. Later, even conditions for operations such as economy and less well-defined notions such as safety culture and safety climate was taken into account (Lundberg, 2010).

But the accident investigation report is not the only document published about the Challenger disaster. Many other news articles and scientific articles were also written. These authors did not have nearly as much resources as the accident investigators did to investigate the disaster. So how did they cope with its complexity?

According to Bartlett (1932) people remember by having schemata. A schema is an idea or script which paint a certain expectation of the event and outline rules of what to do. When remembering people call upon these schemata to logically fill in missing information, rather than perfectly reproducing everything. Memory is therefore reconstructive and not reproductive. Bartlett (1932) shows in his research that when a listener is unfamiliar with a story and elements of the story fail to fit the schemata of the listener they are omitted from recollection or transformed into more familiar forms. An illogical unfamiliar story will be transformed into a story that makes more sense to the listener.

Another key finding of Bartlett's (1932) research is that when people pass on stories to each other, the stories get shorter and get rationalized in a way that makes more sense to the storyteller. This is especially the case when a story is unfamiliar and does not fit in the storyteller's schemata. In the results of his research Bartlett observed condensation, elaboration, invention, simplification, integration towards greater coherence and omission of qualifications in memories. Even though writing does not rely solely on memory, it is possible that the effects Bartlett describes are present in written descriptions of the Challenger disaster as well. It also raises the question if stories that are written later, and perhaps formed from more retellings, are more deformed than stories written earlier.

Thorndyke (1977) suggests stories are organized in memory by grammar, representing of the abstract and structural components of the plot. Subjects recall facts corresponding to high-level organizational story elements rather than lower-level details. Summarizations from memory tend to emphasize general structural characteristics rather than specific content. A story will be remembered roughly in this form:

Story = setting + theme + plot + resolution (Where the plot consists of multiple episodes.)

It is possible written descriptions of the Challenger disaster will have a similar story grammar. This grammar can then be used to compare different written descriptions, where descriptions containing more elements of Thorndyke's story grammar are considered to be more complete than others with less elements.

Besides these simplifications, in a complex story like the Challenger's there is also the possibility of bias. Research done by Harris (1979) shows that authors have a tendency to make experimental evidence conform with their favorite theories, so instead of reading and citing the complete story as described by the Rogers report, authors might selectively pick elements of the disaster that conforms with their theories and citing and referring to those. A cognitive engineer will be more likely to write about the human factors aspects of the disaster, while a mechanical engineer would most likely write about the mechanical aspects of the disaster.

Another way to cope with the complexity of the Challenger disaster is by citing other literature. While this is a very common practice, especially for scientific articles, Vicente & Brewer (1993) found that errors are commonly made when citing literature. They observe four kind of error; *attribution error* where the theory or experiment is attributed incorrectly, *method error* where the method is cited incorrectly, *result error* where the results are cited incorrectly and *gist error* where the gist of the findings is cited incorrectly. A *gist error* is the most serious type of error, but also the rarest. While the impact of an incorrect citation might not be large at first, as others cite the erroneous article the amount and severity of the error increases over time.

Vicente & Brewer show that when citing research done by de Groot (1946, 1965), researchers used the erroneous reports of Chase & Simon (1973a, 1973b), instead of citing original de Groot studies, ultimately resulting in error and misconceptions. This begs the question; before referring to the space shuttle Challenger disaster in their article, did people read the original Rogers report, or do they read and cite second hand sources on the Challenger disaster like the research done by Vaughan (1996)? Does citing second hand sources on the space shuttle Challenger disaster effect the reliability of an article?

Research done by Feltovich (2004) shows that when a learner is confronted with a complex situation, they often deal with complexity through oversimplification. This is especially true when:

• Events are dynamic, simultaneous and parallel, and organic (evolving, emergent) rather than governed by simple cause and effect

• Event parameters are continuous and highly interactive

• Events involve heterogeneous components or explanatory principles, nonlinear dynamics, and multiple context-dependencies

• Events can be understood by multiple representations
• Cases show asymmetries and irregularities
• Key principles are abstract and nonobvious

In such cases,
• Learners and practitioners tend to interpret situations as though they were characterized by simpler alternatives
• Their understandings tend to be reductive—that is, they tend to simplify
• They tend to try to defend their simple understandings when confronted with facts that suggest that the situation is more complex than what they suppose
• Overcoming these defenses requires practice, experience, and mental effort

Feltovich's research suggests that the extremely complex reality of a disaster will be too complex to understand so when trying to understand it people will have to make reductions.

Of course this reductive tendency described by Feltovich applies to everyone, so even the Rogers report will be a reduction of a more complex reality and articles citing this Rogers report will most likely reduce the complexity even further. The articles referring to the Challenger disaster will most likely contain error and some forms of reduction. To understand the effect of reductive tendency written descriptions of the space shuttle Challenger disaster were studied. This study aims to answer, among others, the following questions:

-What is the level of complexity in written descriptions of the space shuttle Challenger disaster?

These short disaster descriptions will almost be per definition a reduction of complexity compared to the original Rogers report, but what is the level of complexity? How many causes will be mentioned and will these short descriptions contain story grammar in the way Thorndyke (1977) described it? Can a reduction in the amount of words be seen like Bartlett (1932) suggests?

-How does the complexity of articles on the space shuttle Challenger disaster change over time?

Research done by Bartlett (1932) suggests that over time stories get simpler and shorter. Vicente & Brewer (1993) suggest that over time the amount of error and severity of error increases, so we expect to see shorter less complex and less accurate descriptions of the disaster in younger articles.

-Is there a significant difference in complexity between scientific and non-scientific articles referring to the Challenger disaster?

Another factor that may be of influence on reductive tendency is the nature of the written article. Because scientific articles are written according to the scientific method and are therefore as accurate and unbiased as possible it would be likely that scientific articles are closer to reality and therefore more complex. However, Harris (1979) shows in his research that scientific authors have a tendency to make experimental evidence conform with their favorite theories, so it is also possible that this is not the case.

Method

Eligibility of articles

For selecting articles on the space shuttle challenger there are a few criteria the articles need to meet. First, the article needs to contain a description of the disaster of between around 50 words and around 500 words. Just mentioning the space shuttle disaster or using it in a theory without mentioning the disaster itself is not enough. The article cannot solely be about the Challenger disaster, unless there is a 50-500 word description of the disaster and the rest of the article is not relevant to the disaster itself. The articles also need to be written in English after 1986 and need to have a known author and date.

The articles themselves will be either scientific or non-scientific. Scientific is defined as having been published in a peer reviewed journal, a conference or dissertation. Non-scientific, for the purposes of the present study, is defined as everything else.

Article collection

Google Scholar was used as a search engine. The search query ‘challenger disaster’ in Google Scholar yielded approximately 22.500 hits, the search query ‘challenger explosion’ yielded approximately 17.800 hits, the search query ‘challenger accident’ 23.600 hits, and the search query ‘challenger tragedy’ 16.100 hits. For each of these queries the first twenty pages were searched. This because the chance of finding a relevant article after page twenty is slim. The articles found were filtered on previous criteria and availability. The articles that matched the criteria and had the full text available were included in this research.

Fifty articles were found, but on closer inspection 12 of them did not match the eligibility criteria leaving the total at 38 valid articles of which 21 were classified as ‘scientific’ and 17 were classified as ‘non-scientific’. The main problem of finding these articles was that even though there were thousands of hits, not many articles were eligible. Many scientific articles mentioned “the Challenger disaster” without elaborating, assuming the disaster was so widely known no further explanation was needed. Another problem was that there were many articles covering the Challenger of thousands of words on all the contributing factors of the disaster and these were also not eligible.

Data Analysis

To quantify the causes and complexity of the articles, a coding scheme was used. In this scheme, a few facts about the article were written down and the number of words dedicated to a cause mentioned in the text was also noted. There was also a table to note any connections or interactions between causes mentioned in the texts and an attempt was made to measure ‘story grammar’. The complete coding scheme can be found in the appendix together with a filled out example of the coding scheme. The causes mentioned in the coding scheme are based on the data provided by the original Rogers report which can be found online at the NASA website (http://history.nasa.gov/rogersrep/genindex.htm). The list of causes was obtained by studying the Rogers report and summarizing the causes. The list of causes was later adjusted and reduced to prevent overlap in the categories.

The first version of the coding scheme was made for the Tenerife disaster, but was later adapted to the Challenger disaster and applied to a single article on the Challenger disaster which was rated by two independent coders. They obtained similar results, but offered suggestions for improvement. Version 2 had the list of causes improved and updated and the inter rater reliability was calculated (Kappa = 0,50). For version 3 the list of causes has had minor updates to prevent overlap between causes and to make categories more clear. In version 3 'story grammar' was also added to be able to measure 'gist'. The inter rater reliability of the third version had a Kappa of 0,68.

The coding scheme was applied to the articles. This resulted in quantitative data which was analyzed with IBM SPSS statistics, a software solution used for statistical analysis. The causes mentioned in the articles were investigated, where more causes mentioned suggest higher complexity and less reduction. The articles were also categorized according to the year they were published (’86-’94, ’95-’03, ’04-now) and according to type (scientific or non-scientific), such that a correlation between amount of reduction and year/type could be analyzed. After the data had been gathered the causes were also split in blunt and sharp end causes to test for a difference in blunt and sharp end factors.

Sharp end causes are causes that happened close to the disaster or directly involved it. The following sharp end factors could be distinguished in the Challenger case:

- External fuel tank exploding
- O-ring malfunction
- Concerns about the low temperatures/O-rings did not have enough data/evidence to convince management not to launch.
- Thiokol (producer of solid rocket booster) management recommended launch at urging of Marshal, ignoring their own engineers (they put on their ‘management hats’).

Blunt end causes are causes that contributed to the disaster, but did not directly cause or trigger the disaster. The following blunt end factors could be distinguished in the Challenger case:

- Declaring the space shuttle operational despite known problems

- Pressure to launch (political/economical)
- Wrong management attitude.
- Management (level III) rationalizing engineering concerns (when primary seal fails, there is a secondary seal). Management did not think O-ring seal problem was critical.
- Low temperature.
- Poor O-ring design. Even though the O-rings directly caused the disaster the faulty design was a problem that had been playing for a while.
- Poor communication between different layers of the (NASA) management.
- Lack of sleep and time pressure for managers.

Ice on launch pad/joints is technically a complicating factor, but it did not cause or contribute to the disaster, so even though it is in the latest version of the coding scheme, it will not be taken into account.

To see if an article is complete and mentions all elements of the story the ‘story grammar’ or ‘gist’ is used. The gist/story grammar should consist of the parts:

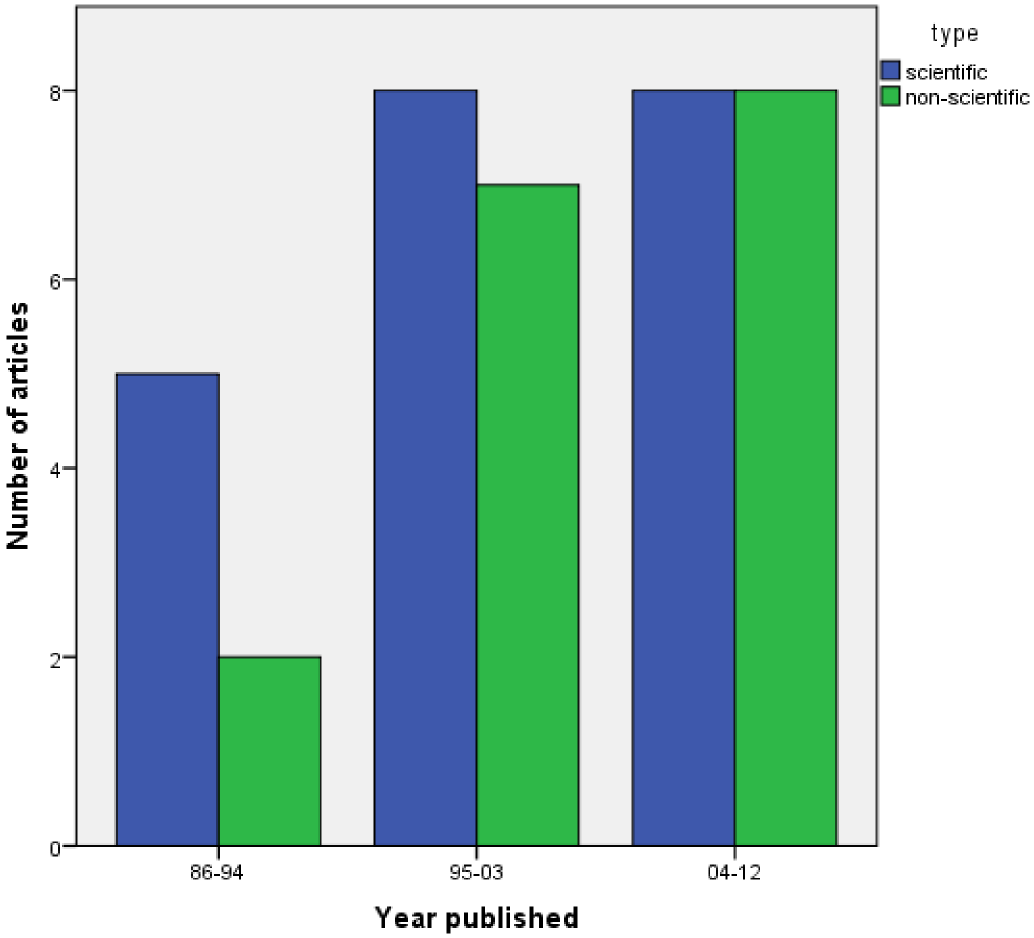
1. **Setting** consisting of *Characters* (management/engineers) and the *Location* or *Date* of disaster (January, 28, 1986). So a story containing the characters and date, but not location is correct, while a story containing date, location but no characters, or characters but no location or date are not correct.
2. **Theme** consisting of *cold weather* and *disagreement of management and engineers* or *wrong NASA mindset*. The cold weather was the trigger that caused the O-rings to malfunction and should be mentioned. What allowed the accident to happen was the poor management structure at NASA and Thiokol, so this needs to be mentioned as well. A story that mentions the cold weather and either the disagreement of managers and engineers or the wrong NASA mindset is correct. A story does not need to mention both the disagreement between management and engineers and the wrong mindset of NASA.
3. **Plot** consisting of *hard/malfunctioning O-rings leading up to explosion*. The O-rings are the physical cause of the disaster, so leaving them out of the description of a disaster would leave it incomplete. A story is considered complete if it mentions the O-rings as the physical cause of the explosion or disaster.
4. **Resolution** consisting of *explosion of fuel tank/disintegration Challenger* AND *number of victims*. Some articles mention the Challenger without actually mentioning what really happened; an explosion and loss of human life. Obviously the explosion or burning up of the external fuel tank

since it technically wasn't an explosion is a crucial part of the Challenger story and the loss of human life is what makes it a disaster. Leaving either out would leave the story incomplete, so for the story to be complete the explosion or disintegration needs to be mentioned and the loss of the crew.

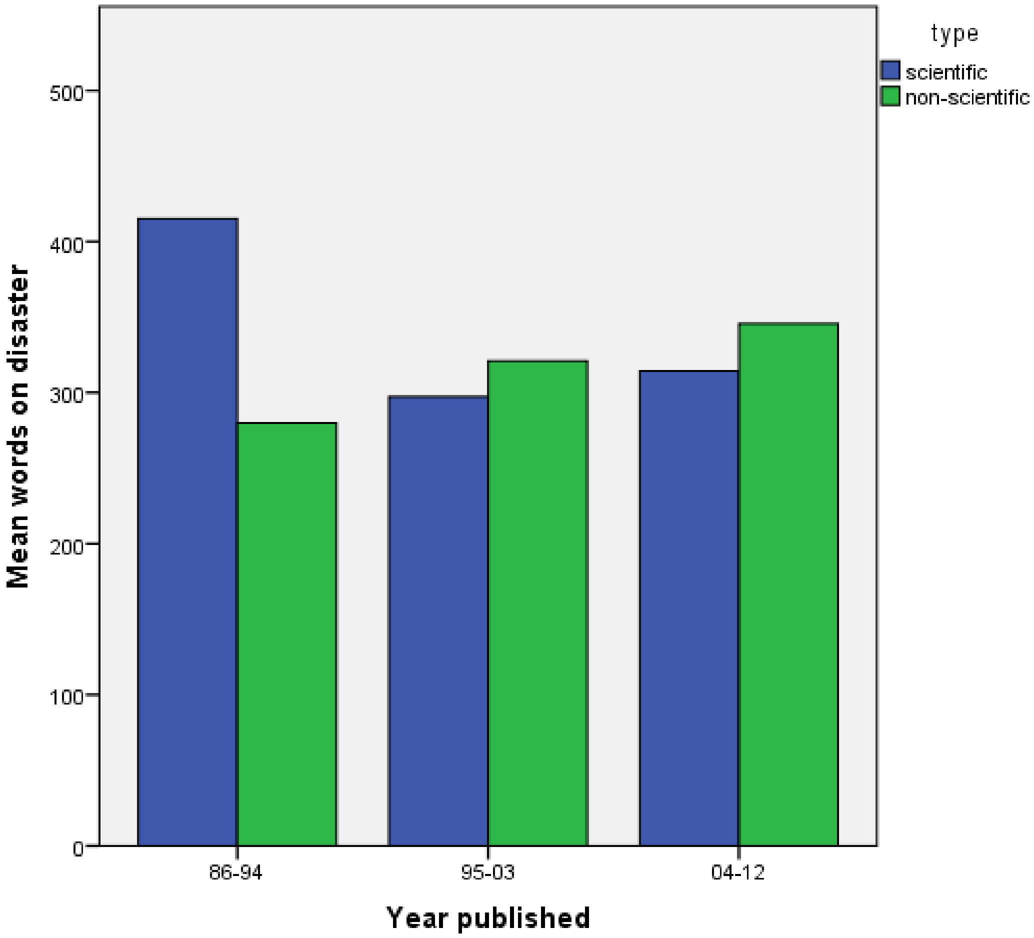
If the story contains a correct setting, theme, plot and resolution it is considered to be a complete story containing the 'gist'.

Results

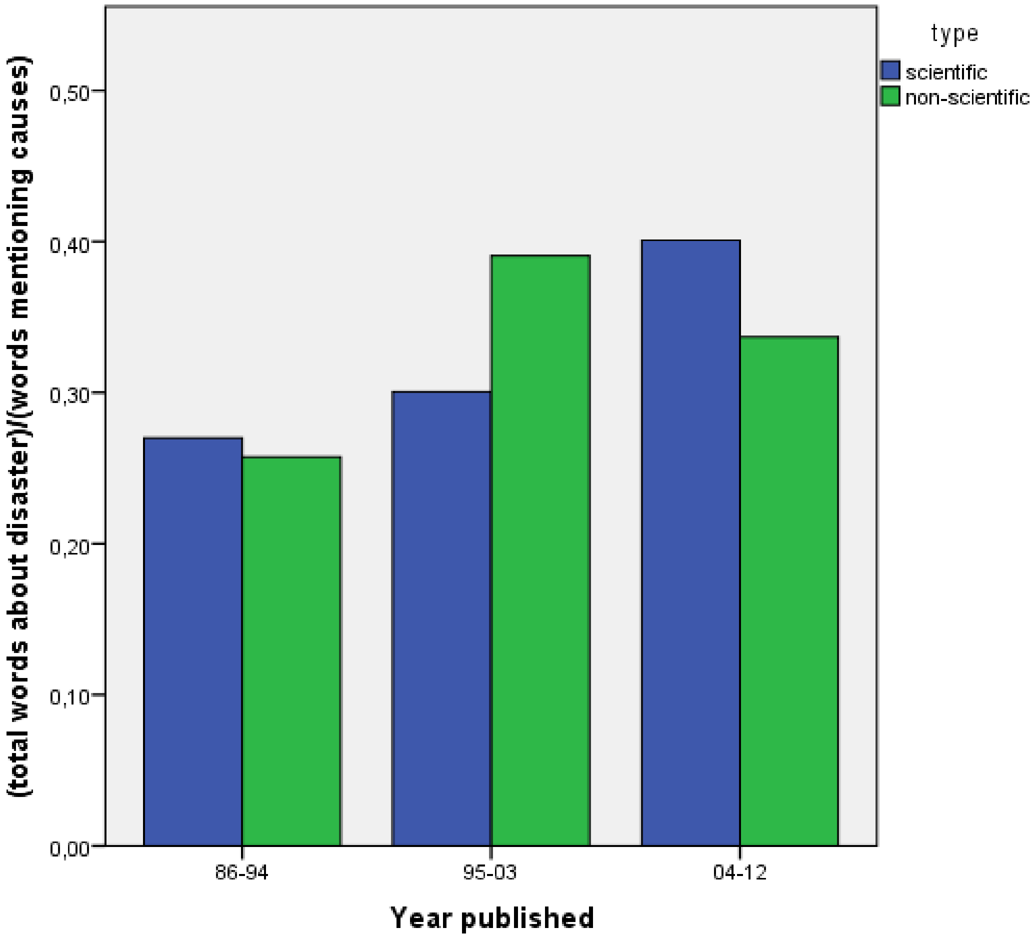
Of the 38 articles found, 21 were scientific and 17 were non-scientific. The articles were distributed across time as shown by the graph below.



Graph 1: this graph shows the number of articles published in the three periods and the number of scientific and non-scientific articles.



Graph 2: the average amount of words used to describe the Challenger disaster over time comparing scientific and non-scientific.



Graph 3: On the Y-axis is the number of words divided by the number of words mentioning causes. A high ratio means that a high percentage of the total amount of words is dedicated to the causes. Possibly indicating less reduction. This graph also shows the relationship of this word-ratio and the year the article was published and it shows the difference between scientific and non-scientific.

On average an article uses 330 words to describe the Challenger disaster. Of those 330 words 105 words are used to actually describe the contributing causes that allowed the disaster to happen (around 34% of the words are used to describe the causes).

Most of the articles found were published between 2004 and present day and least were published between 1986 and 1994. This is true for both scientific and non-scientific articles.

	C1: Launch pressure	C2: Operat ional	C3: Tank expl.	C4: O-ring fail	C5: ice	C6: Wrong att.	C7: Poor com.	C8: data	C9: sleep	C10: Rationa-lize	C11: Thiokol	C12: Low temp	C13: Poor O-ring design
Times mentioned	14	16	4	30	0	11	17	1	0	4	8	17	5
Not mentioned	24	22	34	8	38	27	21	37	38	34	30	21	33
Percent of cases mentioned	36,8%	42,1%	10,5 %	78,9%	0%	28,9%	44,7 %	2,6 %	0%	10,5%	21,0%	44,7%	13,2%

Table 1: number of times (and percentage) a specific cause is mentioned

Of all the causes C4, C7, C12 and C2 are mentioned the most often. These stand for: Failure of O-rings (78,9%), Poor communication (44,7%), Low temperatures (44,7%) and Declaring the space shuttle operational despite known problems (42,1%).

	C1: Launch pressure	**C2: Operat ional**	**C3: Tank expl.**	**C4: O-ring fail**	**C5: ice**	**C6: Wrong att.**	**C7: Poor com.**	**C8: data**	**C9: sleep**	**C10: Rationa-lize**	**C11: Thiokol**	**C12: Low temp**	**C13: Poor O-ring design**
% mentioned scientific	42,9%	42,9%	9,5 %	71,4%	0%	42,9%	38,1%	4,8%	0%	9,5%	9,5%	38,1%	19,0%
% mentioned non-scientific	29,4%	41,2%	11,8 %	88,2%	0%	11,7%	52,9%	0%	0%	11,8%	35,3%	52,9%	5,9%

Table 2: percentage of scientific and non-scientific articles mentioning particular causes

The biggest difference in causes mentioned is C6, the wrong attitude of NASA, where scientific articles mention it more often than non-scientific articles ($\chi2$ = 4,42 p=0.04) and C11, the recommending launch by Thiokol and ignoring their own engineers, where the non-scientific articles mention this cause more often than the scientific articles ($\chi2$=3,75 p=0,05). The difference between the other causes is not significant.

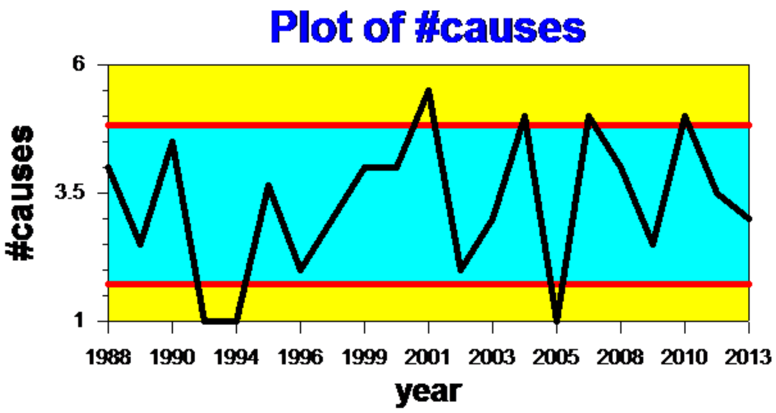
	C1: Launch pressure	**C2: Operat ional**	**C3: Tank expl.**	**C4: O-ring fail**	**C5: ice**	**C6: Wrong att.**	**C7: Poor com.**	**C8: data**	**C9: sleep**	**C10: Rationa-lize**	**C11: Thiokol**	**C12: Low temp**	**C13: Poor O-ring design**
% mentioned ‘86-‘94	14,3%	57,1%	0%	85,7%	0%	14,3%	57,1%	0%	0%	14,3%	28,6%	42,9%	28,6%
% mentioned ’95-‘03	40,0%	46,7%	0%	80,0%	0%	26,7%	40,0%	0%	0%	6,7%	13,3%	53,3%	13,3%
% mentioned ’04-‘12	43,8%	31,3%	25,0 %	75,0%	0%	37,5%	43,8%	6,3%	0%	12,5%	25,0%	37,5%	6,3%

Table 3: causes and the percentage of times mentioned when comparing the three groups over the years.

There appears to be a difference with many of the causes, but only C3 is significant ($\chi2$= 6,15 p=0,05).

On average 3,61 causes were mentioned with scientific = 3,57 and non-scientific = 3,65 causes. The number of causes mentioned between the groups scientific and non-scientific was not significant ($F < 1$ p=0,89 with n-1=37 degrees of freedom).

Of the scientific articles 69,2% mentioned a reference of their information concerning the Challenger disaster versus 25,0% of the non-scientific articles mentioning a reference. The reference often mentioned is the Rogers report (1986).



Graph 4: This graph shows the number of causes mentioned in articles over the years.

There is no significant correlation between year and number of causes mentioned. The individual differences between articles are too large to see a trend or correlation. A one-way-ANOVA confirms that the difference between groups ('86-'94, '95-'03, '04-now) based on year is not significant (F= 0,106 sig= 0,90) For the blunt end vs. sharp end the causes for both were added up (sharp end = C3 + C4 + C8 + C11)/4 and (blunt end = C2 + C1 + C6 + C10 + C12 + C13 + C7 + C9)/8. The sums of the causes were divided by the number of causes to allow for easy comparison of the mean scores.

Type	**Mean**	**Std. deviation**
Sharp: scientific	0,76	0,20
Sharp: non-scientific	0,66	0,20
Blunt: scientific	0,71	0,14
Blunt: non-scientific	0,74	0,16

Table 4: difference in mean scores on blunt and sharp end between scientific and non-scientific articles.

An independent samples T-test showed that between the scientific and non-scientific groups there was no significant difference in sharp end factors (t=1,542 p=0,132 with 2n – 2 = 74 degrees of freedom) and blunt end factors (t=-0,690 p=0,495 with 2n – 2 = 74 degrees of freedom) mentioned.

'Story grammar'

	Location	Characters: management	Characters: engineers	Date	Theme: Cold	Theme: Disagreement	Theme: Wrong	Plot: Malfunctioning	Resolution: explosion	Resolution: victims	Gist

					weather	**managers engineers**	**NASA mindset**	**O-rings**			
Mentioned in % of cases: Scientific	9,5	42,9	33,3	61,9	47,6	19,0	71,4	57,1	71,4	42,9	9,5
Mentioned in % of cases: Non-scientific	5,9	76,5	58,8	82,4	58,8	58,8	70,6	88,2	100,0	82,4	41,2
Mentioned in % of cases: total	7,9	57,9	44,7	71,1	52,6	36,8	71,1	71,1	84,2	60,5	23,7

Table 5: the different elements of Thorndyke's story grammar applied on Challenger comparing scientific and non-scientific.

Of the whole story grammar the following elements are significant: Characters: management (χ2= 4,35 p=0,04), Theme: disagreement between managers and engineers (χ2=6,39 p=0,01), Plot: broken/malfunctioning O-ring (χ2=4,42 p=0,04), Resolution: explosion (χ2=5,77 p=0,02), Resolution: victims (χ2=6,13 p=0,13), gist (χ2= 5,21 p = 0,02). All of these elements are mentioned more often in non-scientific articles. The 'gist' of an article contains a setting, theme, plot and resolution. This means the article comes close to containing the 'whole' story. Comparing scientific and non-scientific articles concerning the 'gist' resulted in the following table:

The 'gist' is mentioned more often in non-scientific articles than in scientific articles.

	Location	**Characters: management**	**Characters: engineers**	**Date**	**Theme: Cold weather**	**Theme: Disagreement managers engineers**	**Theme: Wrong NASA mindset**	**Plot: Malfunctioning O-rings**	**Resolution: explosion**	**Resolution: victims**	**Gist**
Mentioned in % of cases: '86-'94	14,3	28,6	42,9	57,1	42,9	42,9	71,4	85,7	85,7	42,9	14,3
Mentioned in % of	0,0	66,7	40,0	60,0	53,3	33,3	73,3	66,7	86,7	60,0	13,3

cases: **'95-'03**											
Mentioned '04-'12	12,5	62,5	50,0	87,5	56,3	37,5	68,8	68,8	81,3	68,8	37,5

Table 6: the different elements of Thorndyke's story grammar applied on Challenger comparing the different groups of years published.

None of these differences are significant. The gist mentioned is also not significant ($\chi 2 = 2{,}92$ $p = 0{,}23$).

Discussion

Firstly to answer the questions asked in the introduction.

-What is the level of complexity seen in written descriptions of the space shuttle Challenger disaster?

On average 3,61 causes are mentioned and around 34% of the text is used to mention or explain the causes. The 'story grammar' as described by Thorndyke (1977) is often incomplete. Important elements are often missing so that the article does not contain the complete 'gist'. Even though the data seems to imply the descriptions are generally simplified, the results are not conclusive due to the lack of a good baseline.

-How does the complexity of articles on the space shuttle Challenger disaster change over time?

There was no significant correlation in the amount of causes mentioned and the year the article was written. The difference in mentioning the 'gist' between the different time categories is not significant. The mean amount of words over time is also not significant. We have not studied large texts, but for smaller texts time does not seem to have an effect on complexity.

-Is there a significant difference in complexity between scientific and non-scientific articles referring to the Challenger disaster?

If one would define reduction by the number of causes mentioned in an article, then the difference between scientific and non-scientific articles is not significant. However there seems to be a slight difference in what causes are mentioned. Scientific articles mention the wrong attitude of NASA more often than non-scientific articles, while non-scientific articles mention the recommending launch by Thiokol and ignoring their own engineers more often.

The 'gist' is mentioned more often in non-scientific articles than scientific articles (41,2% compared to 9,5%) and this difference is statistically significant. This is most likely because many scientific studies will use the Challenger disaster as an example or case study to prove their point and therefore will not need to mention the whole story, just the parts of the disaster they need to prove their point or support their theory. Non-scientific articles on the other hand are writing about the Challenger disaster for the sake of explaining and writing about the Challenger disaster and are therefore more likely to tell the whole story. This is consistent with the research done by Harris (1979) and shows that we should be aware of the motives of the author, since the motives of the author determines for a big part the story the author tells (Harris, 1979, Cedergren & Petersen 2011).

This research also shows there is a large amount of reduction in scientific literature. If the aim is to eliminate reduction as much as possible it is key to use the original source material, rather than citing second hand sources. This will reduce the chance of further error, misconception and more reduction (Vicente & Brewer, 1993, Bartlett, 1932). However, most of the reduction and incompleteness of the disaster descriptions seems to be intentional rather than error. Authors do not tell the ‘whole story’, because they do not need the whole story to support their argument or consider some of it too obvious to mention. There might be no need to mention that the entire Challenger crew died after you just mentioned that it exploded in mid-air, since the death of the crew seems like an inevitable result of the explosion.

It is also important to realize when reading the original accident report that this is already a reduction of reality and that the contents of this report are highly dependent on the expertise of the investigator (Cedergren & Petersen, 2011, Lundberg, 2010).

So can reduction really be prevented or reduced? Reduction is a natural process and the way people learn (Feltovich, 1994), so there will always be some reduction. However by further exploring the effect of reduction on the literature of disasters it might be possible to limit reduction. If for example if official investigation reports were to submit a 500 word summary on the disaster, authors could use this summary in their text, rather than summarizing the disaster themselves. This would possibly lead to less reduction, since the 500 word official summary will contain all the factors the investigators consider ‘key factors’ and would therefore be less of a reduction than second hand literature.

An important limiting factor of this research is the fact that this research only studied the space shuttle Challenger. The space shuttle Challenger was unique in fact that it happened on live television with millions of people watching, meaning that there was much speculation and media attention. A lot of ‘blunt end’ factors contributed to an accident with a relatively simple ‘sharp end’, making the Challenger an interesting and unique disaster. It is possible that the findings of this article do not apply to other disasters. It is also possible that because of the small sample size of relatively small texts some correlations were concluded as not significant, but will become significant with a larger sample size, where individual difference between the articles will make smaller difference.

The coding scheme used was clearly not perfect, seeing as there was only moderate to substantial agreement between independent raters. Two of the causes in the list of causes were never mentioned (ice on Launchpad and the lack of sleep for NASA managers). This could mean that they are not mentioned because of reduction, but it is more likely that they are not relevant and therefore should not be in the coding scheme. The coding scheme also contained a section to compare the relationship between causes and the strings of causes. In theory this is a nice addition, but in practice no article clearly mentions (causal) relationships so this section did not add value to the coding schema.

To conclude, reduction plays a role in all studied literature. Brief descriptions of disasters especially are already a reduction of a complex reality, so it is obvious some reduction is found in this research. As it appears reduction cannot be avoided, special care should be taken to make sure that reduction does not lead to any misconceptions.

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Appendix

Appendix A: complete coding schema

Coding Schema

Analysis of publications concerning descriptions of disasters

Unit of Data Collection: Each publication which a) contains a description of the particular disaster with a minimum of 50 words and a maximum of 500 words, b) was searched by particular search terms c) has an author mentioned, d) is retrievable by a third-party.

Coder ID: Indicate the number of the person who coded that sheet.

Publication ID: Give each publication a unique 3-digit number, beginning with 001 and proceeding upward without duplication across all episodes.

Reference and brief description: Give a short description of the publication by mentioning the context in which the disaster is described and give a reference in APA style.

Internet-link/author name and/or date: Give the internet link with which you can retrieve the publication and the date of finding it.

Total number of words publication: Give the total number of words of the whole publication including heading, abstract and references. Use the copy/paste-function to be able to count the words in Microsoft Word.

Total number of words disaster: Give the total number of words concerning the description of the disaster. Count all words in the whole paragraph(s) and make no distinction on the basis of the content.

Source: Is the author mentioning a source of information concerning the disaster?

0 Yes 1 No

If yes, which source?

____

Publication: Use the copy/paste-function here to put in the whole description of the disaster.

1. Genre: Say to what genre the publication belongs.

0 scientific (peer-reviewed journal, conference paper, dissertation)

1 non-scientific (popular)

2. Number of causes and their proportions

Instruction:

-All words within a sentence in which a cause is mentioned, should be counted.
Example: 'The KLM aircraft had to take-off (with destination Amsterdam Schiphol), through a wall of dense fog'. Coding should be: cause number 11; 16 words.

-Each space between letters marks a new word.
Example: 'Las Palmas' are 2 words.
'Take-off' is 1 word

-If one sentence contains more than one cause, the words should be divided evenly over those causes.
Example: 'The Pan Am crew confusion about which taxi lane to take, was partly due to unclear communication with the Tenerife traffic tower and partly due to the low visibility'.
This sentence should be coded as cause 4; 9 2/3 words
cause 11; 9 2/3 words
cause 14 9 2/3 words

Causes	Number of words mentioning a specific cause	Percentage of words mentioning a specific cause, related to the total number of words concerning causes *(round the number behind the comma up or down to get an even number)*	Cause mentioned in article 0 = Yes 1 = No
1. Launch postponed many times. Political/economical pressure to launch in time.			
2. NASA declared space shuttle operational, which erroneously suggests airline like degree of routine operation: -Big list of 'acceptable flight risks'.			

Many problems were known for a long time, but were not top priority to be fixed.			
3. External fuel tank exploded			
4. Failure of O-rings/O-ring hardness			
5. Ice on launch pad/potential for ice in joints			
6. **Management had wrong attitude**: -demanding proof for launch to be not safe, rather than demanding proof for it to be safe -Management waiving launch constraints at the expense of safety. -Faith to overcome any obstacle			
7. **Poor communication between different layers of management:** -Concerns of level III NASA personnel were not communicated to level II and I management responsible for launch. -Different layers of management try to solve issues internally instead of communicating them forward.			
8. Concerns about the low temperatures/O-rings did not have enough data/evidence to convince management not to launch.			
9. Lack of sleep and time pressure for managers.			
10. Management (level III) rationalizes engineering concerns (when primary seal fails, there’s a secondary seal)/management did not think O-ring seal problem was critical.			
11. Thiokol management recommended launch at urging of Marshal, ignoring their own engineers (they put on their ‘management hats’).			
12. Low temperatures/launching space shuttle below operating temperatures.			
13. Poor O-ring design.			
Total	..... words	100%	

3. Setting

3 a) Is the location (KSC) mentioned?

0 Yes 1 No

3 b) Characters

Is the NASA management mentioned? 0 Yes 1 No

Are the engineers mentioned? 0 Yes 1 No

3 c) Is the date mentioned (January, 28, 1986)? 0 Yes 1 No

4. Theme

4 a) Is the cold weather mentioned? 0 Yes 1 No

4 b) Is the disagreement between management and engineers mentioned?

0 Yes 1 No

4 c) Is the wrong mindset of NASA mentioned? 0 Yes 1 No

5. Plot

Is it mentioned, that the hard O-rings caused the right solid rocket motor to malfunction leading up to the explosion?

0 Yes 1 No

6. Resolution

6 a) Is the explosion of the external fuel tank and/or disintegration of the space shuttle mentioned?

0 Yes 1 No

6 b) Is/are (the number of) deadly victims mentioned?

0 Yes 1 No

7 Gist/ story grammar

7. a) Is the gist/ story grammar mentioned by the author(s)? *The gist/story grammar consists of the parts*

1. Setting: Characters: management/engineers AND location OR date of disaster (January, 28, 1986).

2. Theme: cold weather AND disagreement of management and engineers OR wrong NASA mindset.

3. Plot: hard/malfunctioning O-rings leading up to explosion.

4. Resolution: explosion of fuel tank/disintegration challenger AND number of dead victims.

0 Yes 1 No

If the last question was answered with ‘No’ go on with item 7. b). If the last question was answered with ‘Yes’ go on with item 8.

7. b) What part(s) from the story grammar is (are) missing? (Setting, Theme, Plot, Resolution)?

____

8. Relation between causes

Strings of causes. Xa led to Xb led to Xc etc.

Instruction:

- Find mentioned relations between the different causes. Be alert for cues such as:

- *.... led to ...*
- *... leads to ....*
- *due to ....*
- *.... resulted in ....*
- *..... results in ...*
- *as a result .....*
- *..... because .....*
- *etc.*

- Strings of causes should be filled out as follows:

Example:

Cause Xa	Cause Xb	Cause Xc	Cause Xd	Cause Xe	Cause Xf	Effect	Number of X's per string	Highest number of causes per X
3	6, 8,11	1	7			14.	4	3
2, 5, 13, 14						15.	1	4

Meaning:

- *Cause 3 led to causes 6, 8 & 11. Causes 6, 8 & 11 led to cause 1. Cause 1 led to* *cause 7. Cause 7 led to cause 14. In schema:*

Xa(3)>Xb(6,8,11)>Xc(1)>Xd(7)>Effect(14)

- *Causes 2, 5, 13 & 14 together led to causes 15. In Schema:*

  Xa(2,5,13,14)>Effect(15)

- Only fill out the longest option of a particular string.

Example: *when Xa(1)>Xb(4)>Xc(5)>Effect(12), only fill out that string.*

So do not note: *Xa(1)>Xb(4)>Effect(5), or*

Xa(4)>Xb(5)>Effect(12), or

any other possible separation

Cause Xa	Cause Xb	Cause Xc	Cause Xd	Cause Xe	Cause Xf	Effect	Number of X's per string	Highest number of causes per X
						1.		
						2.		
						3.		
						4.		
						5.		
						6.		
						7.		
						8.		
						9.		
						10.		
						11.		
						12.		
						13.		
						14.		
						15.		
						16.		
						17.		
						18.		
						19.		
						20.		
						21.		

						22.		
						23.		
Total number of strings:						Total:		

Appendix B: complete coding schema filled in as an example

Coding Schema

Analysis of publications concerning descriptions of disasters

Unit of Data Collection: Each publication which a) contains a description of the particular disaster with a minimum of 50 words and a maximum of 500 words, b) was searched by particular search terms c) has an author mentioned, d) is retrievable by a third-party.

Coder ID: 001

Publication ID: 001

Reference and brief description: Spurrier, N., 2009, Hard lessons. Engineering & Technology

Internet-link/author name and/or date: found on 1-1-2013. www.theiet.org/magazine

Total number of words publication: 3270

Total number of words disaster: 246

Source: Is the author mentioning a source of information concerning the disaster?

0 Yes 1 No

If yes, which source?

____

Publication:

On 28 January 1986, space shuttle *Challenger* broke apart 73 seconds after launch, killing its seven crew members. The subsequent Rogers Commission found that the immediate cause of the accident was the failure of both primary and secondary O-rings on the right solid rocket booster, allowing hot gas and flame to escape, which then came into contact with the booster attachment and external tank, resulting in structural failure.

The problems with the O-rings had been known about for nine years but had been ignored, partly because safety was deemed ensured with the presence of the second ring. However, as was later made clear, the second ring was there for unforeseen failure, not a failure that had been considered. Engineers' warnings that low temperatures would exacerbate the problem were also ignored by Nasa managers because of pressure to keep to the launch timetable.

Now widely used as a case study for trainee engineers, this

disaster taught us many lessons: that the advice of engineers should be considered carefully by management; that the ethics of whistle-blowing and group decision-making should be introduced. Afterwards, there was a total redesign of the solid rocket boosters, in which three O-rings were incorporated, watched over by an independent oversight group as stipulated by the commission.
In summing up the disaster, Richard Feynman, a member of the Rogers Commission, made a telling point to the effect that "for a successful technology, reality must take precedence over public relations, for nature cannot be fooled".

1. Genre: Say to what genre the publication belongs.

0 scientific (peer-reviewed journal, conference paper, dissertation)

1 non-scientific (popular)

2. Number of causes and their proportions

Instruction:

-All words within a sentence in which a cause is mentioned, should be counted.
Example: 'The KLM aircraft had to take-off (with destination Amsterdam Schiphol), through a wall of dense fog'. Coding should be: cause number 11; 16 words.

-Each space between letters marks a new word.
Example: 'Las Palmas' are 2 words.
'Take-off' is 1 word

-If one sentence contains more than one cause, the words should be divided evenly over those causes.
Example: 'The Pan Am crew confusion about which taxi lane to take, was partly due to unclear communication with the Tenerife traffic tower and partly due to the low visibility'.
This sentence should be coded as cause 4; 9 2/3 words
cause 11; 9 2/3 words
cause 14 9 2/3 words

Causes	Number of words mentioning a specific cause	Percentage of words mentioning a specific cause, related to the total number of words concerning causes *(round the number behind the comma up or down to get an even number)*	Cause mentioned in article 0 = Yes 1 = No
1. Launch postponed many times. Political/economical pressure to launch in time.	12	12,6%	0
2. NASA declared space shuttle operational, which erroneously suggests airline like degree of routine operation: -Big list of 'acceptable flight risks'. Many problems were known for a long time, but were not top priority to be fixed.			1
3. Right solid rocket booster exploded	25	26,3%	0
4. Failure of O-rings/O-ring hardness	46	48,4%	0
5. Ice on launch pad/potential for ice			1

in joints			
6. **Management had wrong attitude**: -demanding proof for launch to be not safe, rather than demanding proof for it to be safe -Management waiving launch constraints at the expense of safety. -Faith to overcome any obstacle			1
7. **Bad communication between different layers of management:** -Concerns of level III NASA personnel were not communicated to level II and I management responsible for launch. -Different layers of management try to solve issues internally instead of communicating them forward.			1
8. Concerns about the low temperatures/O-rings did not have enough data/evidence to convince management not to launch.			1
9. Lack of sleep and time pressure for managers.			1
10. Management (level III) rationalizes engineering concerns (when primary seal fails, there's a secondary seal)/management did not think O-ring seal problem was critical.			1
11. Thiokol management recommended launch at urging of Marshal, ignoring their own engineers (they put on their 'management hats').	12	12,6%	0
12. Low temperatures/launching space shuttle below operating temperatures.			1
13. Poor O-ring design.			1
Total	95 words	100%	

3. Setting

3 a) Is the location (KSC) mentioned?

0 Yes 1 No

3 b) Characters

Is the NASA management mentioned? 0 Yes 1 No

Are the engineers mentioned? 0 Yes 1 No

3 c) Is the date mentioned (January, 28, 1986)? 0 Yes 1 No

4. Theme

4 a) Is the cold weather mentioned? 0 Yes 1 No

4 b) Is the disagreement between management and engineers mentioned?

0 Yes 1 No

4 c) Is the wrong mindset of NASA mentioned? 0 Yes 1 No

5. Plot

Is it mentioned, that the hard O-rings caused the right solid rocket motor to malfunction leading up to the explosion?

0 Yes 1 No

6. Resolution

6 a) Is the explosion of the right solid rocket motor/disintegration of the space shuttle mentioned?

0 Yes 1 No

6 b) Is/are (the number of) deadly victims mentioned?

0 Yes 1 No

7 Gist/ story grammar

7. a) Is the gist/ story grammar mentioned by the author(s)? *The gist/story grammar consists of the parts*

1. Setting: location KSC AND/OR characters management/engineers AND/OR date of disaster (January, 28, 1986).

2. Theme: cold weather AND disagreement of management and engineers AND/OR wrong NASA mindset.

3. Plot: hard/malfunctioning O-rings leading up to explosion.

4. Resolution: explosion of right solid rocket motor AND number of dead victims.

0 Yes 1 No

If the last question was answered with 'No' go on with item 7. b). If the last question was answered with 'Yes' go on with item 8.

7. b) What part(s) from the story grammar is (are) missing? (Setting, Theme, Plot, Resolution)?

____

8. Relation between causes

Strings of causes. Xa led to Xb led to Xc etc.

Instruction:

- Find mentioned relations between the different causes. Be alert for cues such as:

- *- .... led to ...*
- *- ... leads to ....*
- *- due to ....*
- *- .... resulted in ....*
- *- ..... results in ...*
- *- as a result .....*
- *- ..... because .....*
- *- etc.*

- Strings of causes should be filled out as follows:

Example:

Cause Xa	Cause Xb	Cause Xc	Cause Xd	Cause Xe	Cause Xf	Effect	Number of X's per string	Highest number of causes per X
3	6, 8,11	1	7			14.	4	3
2, 5, 13, 14						15.	1	4

Meaning:

- *Cause 3 led to causes 6, 8 & 11. Causes 6, 8 & 11 led to cause 1. Cause 1 led to cause 7. Cause 7 led to cause 14. In schema:*
  Xa(3)>Xb(6,8,11)>Xc(1)>Xd(7)>Effect(14)
- *Causes 2, 5, 13 & 14 together led to causes 15. In Schema:*

Xa(2,5,13,14)>Effect(15)

- Only fill out the longest option of a particular string.

Example: *when Xa(1)>Xb(4)>Xc(5)>Effect(12), only fill out that string.*

So do not note: *Xa(1)>Xb(4)>Effect(5), or*

Xa(4)>Xb(5)>Effect(12), or

any other possible separation

Cause Xa	Cause Xb	Cause Xc	Cause Xd	Cause Xe	Cause Xf	Effect	Number of X's per string	Highest number of causes per X
						1.		
						2.		
						3.		
3						4.	1	1
						5.		
						6.		
						7.		
						8.		
						9.		
						10.		
						11.		
						12.		
						13.		
						14.		
						15.		
						16.		
						17.		
						18.		
						19.		
						20.		
						21.		
						22.		
						23.		
Total number of strings:						Total:		

Appendix C: written descriptions of the disaster used.

001

Spurrier, N., 2009, Hard lessons. Engineering & Technology

On 28 January 1986, space shuttle *Challenger* broke apart 73 seconds after launch, killing its seven crew members. The subsequent Rogers Commission found that the immediate cause of the accident was the failure of both primary and secondary O-rings on the right solid rocket booster, allowing hot gas and flame to escape, which then came into contact with the booster attachment and external tank, resulting in structural failure.

The problems with the O-rings had been known about for nine years but had been ignored, partly because safety was deemed ensured with the presence of the second ring. However, as was later made clear, the second ring was there for unforeseen failure, not a failure that had been considered. Engineers' warnings that low temperatures would exacerbate the problem were also ignored by Nasa managers because of pressure to keep to the launch timetable.

Now widely used as a case study for trainee engineers, this disaster taught us many lessons: that the advice of engineers should be considered carefully by management; that the ethics of whistle-blowing and group decision-making should be introduced. Afterwards, there was a total redesign of the solid rocket boosters, in which three O-rings were incorporated, watched over by an independent oversight group as stipulated by the commission.

In summing up the disaster, Richard Feynman, a member of the Rogers Commission, made a telling point to the effect that "for a successful technology, reality must take precedence over public relations, for nature cannot be fooled".

002

Pidgeon, N.F. 1988. Risk Assessment and Accident Analysis. Acta Psychologica 68 (1988) 355-368.

A contemporary case-study example is provided by the destruction of the Space Shuttle Challenger mission 51-L on January 28, 1986. The principal technical cause of the disaster was the catastrophic failure under low temperature of a critical O-ring joint seal in one of the solid rocket motors. Significantly, O-ring failure had been identified by some NASA engineers as a potential safety concern at a very early stage in the programme, prior even to the first Shuttle flight. Much has been written since the disaster of the judgements and actions of the individuals responsible for the flawed decision to launch the flight. However, the U.S. House of Representatives Report (1986) on the accident documents in addition the complex background factors which contributed to the disaster over a period of some 13 years. The almost inevitable catastrophe occurred because the O-ring problem, which posed a serious threat to safety, had come to be viewed within NASA as an acceptable flight risk. The factors underlying this situation included the inadequate engineering attempts to resolve the problem on a short-term basis; a corporate failure over a period of years of the safety decision making at all levels in NASA; a faith within NASA in the ability of the organisation to overcome any obstacle, leading to an 'illusion of invulnerability" (cf. Janis 1972); and the background economic and production pressures on the Shuttle project. Three general characteristics which the Challenger case shares with other disasters are that the causes were *multiple* over time, qualitatively *diverse*, and compounded in *complex interactive* ways.

003

Kovoor-Misra, S. 1995. A Multidimensional Approach to Crisis Preparation for Technical Organizations: Some Critical Factors. Technological Forecasting and Social Change 48, 143-160

Crises are caused by factors from a range of organizational dimensions. Actual incidents of crises indicate that crises in technical organizations are systemic. They are caused by an interaction of failures across the organizational system [3, 8, 9, 13, 14]. For example, the Challenger explosion was attributed to poor communication, dysfunctional cultural beliefs, a weak safety and quality control department, and a poor design of the"O" ring [14]. It was caused by the interaction of technical and nontechnical factors. This interaction of factors from a range of organizational dimensions in causing crises was also evident in other crises such as the Bhopal gas leak [13] and the Exxon Valdez oil spill [151. Thus, to prevent crises in technical organizations, it is necessary to detect signals from the different organizational dimensions, and avoid dysfunctions or failures within the different dimensions. Thus, a multidimensional approach is necessary.

004

Kovoor-Misra, S., Clair, J.A., Bettenhausen, K.L., 2001. Clarifying the Attributes of Organizational Crises. Technological Forecasting and Social Change 67, 77–91

We suggest that technological disasters are likely to be sudden and have an unexpected onset. This is because a certain combination of failures needs to be present for a disaster to occur. For example, the Exxon Valdez oil spill was due to the design of the ship, an alcoholic captain that was not vigilant, inadequate crisis preparedness, and poor coordination with the Coast Guard [14]. The Challenger explosion was caused by failures that led to a poor design of the "O" ring and inappropriate weather conditions on the day of the launch [50]. Thus, failures in various parts of the organizational system combine in particular ways creating a sudden onset.

In addition, the development of disasters is often ambiguous. Disasters develop over a period of time and often there are signals of this development [8, 21]. However, we suggest that these signals frequently go unnoticed because of the complexity of the information involved. Typically failures occur in different parts of the organizational system [14, 20]. As a result, signals of impending crises are diffuse as different individuals or departments have access to different pieces of information [21]. Further, organizations may experience a problem of "variable disjunction of information," where the resources available to handle information are inadequate given the complexity of the information [21]. Thus, it is difficult for individuals to consolidate and make sense of such information. For example, in the case of the Challenger explosion, a number of factors, in hindsight, were found to be involved. A weak Quality Control department, beliefs in the organization that they were invulnerable, a poor design of the "O" ring, and pressures from Congress to launch the shuttle were some of the causes [50]. Signals indicating problems were emitted prior to the crisis. However, because of the diffuse nature of these signals it was difficult for NASA to see the relationship among these signals and predict the explosion. In technology-intensive organizations it is possible to predict that there will be technological failures over time. However, we suggest that because of the complexity of the information involved, it is difficult to trace the development of disasters and predict the onset of a particular disaster. Signals of a disaster in hindsight often seem obvious. However, prior to a disaster they are usually diffused and/or ambiguous.

005

Leveson, N., 2004. A new accident model for engineering safer systems. Safety Science 42 237–270

Treating safety as an emergent property that arises when the system components interact within a given environment leads to accident models that view accidents as a control problem: accidents occur when component failures, external disturbances, and/or dysfunctional interactions among system components are not adequately handled by the control system. Emergent properties are controlled or enforced by a set of constraints (control laws) related to the behavior of the system components. Accidents result from interactions among components that violate the safety constraints—in other words, from a lack of appropriate control actions to enforce the constraints on the interactions. In the space shuttle Challenger accident, for example, the O-rings did not adequately control propellant gas release by sealing a tiny gap in the field joint. In the Mars Polar Lander loss, the software did not adequately control the descent speed of the spacecraft—it misinterpreted noise from a Hall effect sensor as an indication the spacecraft had reached the surface of the planet. Accidents such as these, involving engineering design errors, may in turn stem from inadequate control over the development process. Control is also imposed by the management functions in an organization—the Challenger accident involved inadequate controls in the launch-decision process, for example.

(..)

As an example, the unsafe behavior (hazard) in the Challenger loss was the release of hot propellant gases from the field joint. An O-ring was used to control the hazard, i.e., its role was to seal a tiny gap in the field joint created by pressure at ignition. The design, in this case, did not effectively impose the required constraints on the propellant gas release (i.e., it did not adequately seal the gap), leading to an explosion and the loss of the Space Shuttle and its crew. Starting from here, there are then several questions that need to be answered to understand why the accident occurred. Why was this particular design unsuccessful in imposing the constraint, why was it chosen (what was the decision process), why was the flaw not found during development, and was there a different design that might have been more successful? These questions and others consider the original design process. Understanding the accident also requires examining the contribution of the operations process. One constraint that was violated during operations was the requirement to correctly handle feedback about any potential violation of the safety design constraints, in this case, feedback during operations that the control by the O-rings of the release of hot propellant gases from the field joints was not being adequately enforced by the design. There were several instances of feedback that were not adequately handled, such as data about O-ring blowby and erosion during previous shuttle launches and feedback by engineers who were concerned about the behavior of the O-rings in cold weather. In addition, there was missing feedback about changes in the design and testing procedures during operations, such as the use of a new type of putty and the introduction of new O-ring leak checks without adequate verification that they satisfied system safety constraints on the field joints. As a final example, the control processes were flawed that ensured unresolved safety concerns were adequately considered before each flight, i.e., flight readiness reviews and other feedback channels to project management making flight decisions

006

http://www.history.com/topics/challenger-disaster found on 4-01-2013

On January 28, 1986, the American shuttle orbiter Challenger broke up 73 seconds after liftoff, bringing a devastating end to the spacecraft's 10th mission. The disaster claimed the lives of all seven astronauts aboard, including Christa McAuliffe, a teacher from New Hampshire who had been selected to join the mission and teach lessons from space to schoolchildren around the country. It was later determined that two rubber O-rings, which had been designed to separate the sections of the rocket booster, had failed due to cold temperatures on the morning of the launch. The tragedy and its aftermath received extensive media coverage and prompted NASA to temporarily suspend all shuttle missions.

Challenger's Catastrophic Launch

The mission's launch from Kennedy Space Center at Cape Canaveral, Florida, was delayed for six days due to weather and technical problems. The morning of January 28 was unusually cold, and engineers warned their superiors that certain components—particularly the rubber O-rings that sealed the joints of the shuttle's solid rocket boosters—were vulnerable to failure at low temperatures. However, these warnings went unheeded, and at 11:39 a.m. Challenger lifted off.

Seventy-three seconds later, hundreds on the ground, including the families of McAuliffe and the other astronauts on board, stared in disbelief as the shuttle exploded in a forking plume of smoke and fire. Millions more watched the wrenching tragedy unfold on live television. Within instants, the spacecraft broke apart and plunged into the ocean, killing its entire crew, traumatizing the nation and throwing NASA's shuttle program into turmoil.

Investigation by the Rogers Commission

Shortly after the disaster, President Ronald Reagan appointed a special commission to determine what went wrong with Challenger and to develop future corrective measures. Headed by former secretary of state William Rogers, the commission included former astronaut Neil Armstrong and former test pilot Chuck Yeager. Their investigation revealed that the O-ring seal on Challenger's solid rocket booster, which had become brittle in the cold temperatures, failed. Flames then broke out of the booster and damaged the external fuel tank, causing the spacecraft to disintegrate.

007

Martin, R.M., Boynton, L.A., 2005. From liftoff to landing: NASA's crisis communications and resulting media coverage following the Challenger and Columbia tragedies. Public Relations Review 31 253–261

At 11:38 a.m. EST on January 28, 1986, the space shuttle *Challenger* launched skyward beginning its tenth mission into outer space. The flight had been delayed for 3 days because of poor weather, and NASA officials eagerly watched as the shuttle finally got off the ground. Then, the unthinkable occurred. Approximately 73 seconds and 10 miles after takeoff, the spacecraft suddenly exploded leaving only two white lines of smoke racing through the air. All seven passengers on board were killed (Broad, 1986). The *Challenger* explosion, although not the first NASA mission resulting in loss of life, was the most horrific event in the history of the United States space program—until it happened again.

008

Kray, L.J., Galinsky, A.D., 2003, The debiasing effect of counterfactual mind-sets: Increasing the search for disconfirmatory information in group decisions. Organizational Behavior and Human Decision Processes 91 69–81

On January 28, 1986 the eyes of the world watched as the Space Shuttle Challenger launched into the Florida sky, embarking on a much-publicized mission to deliver the world_s first civilian to outer space. The mission had recently experienced a series of delays due to bad weather, and NASA_s decision to proceed with the launch was remarkable given the fact that the air temperature was a full 15_ colder on January 28 than any other previous launch date. As many people vividly recall, the shuttle exploded after just 73 s, killing all of its crew members. Although the data compiled after the disaster by the Presidential Commission investigating the accident clearly indicated, O-ring resiliency is directly related to its temperature.'' this relationship between ambient temperature and O-ring failure was not fully grasped prior to the accident (Report of the Presidential Commission on the Space Shuttle Challenger Accident, 1986). Perhaps most disturbing of all was the Commission_s conclusion that ''there was a serious flaw in the decision making process'' leading up to the launch. If only the NASA officials had adopted a more systematic approach to examining the relationship between air temperature and O-ring failures prior to the launch, the true risks of the launch might have been realized, and disaster averted.

009

Whyte, G., 1998. Recasting Janis's Groupthink Model: The Key Role of Collective Efficacy in Decision Fiascoes. Organizational Behavior and Human Decision Processes Vol. 73, Nos. 2/3, February/March, pp. 185–209

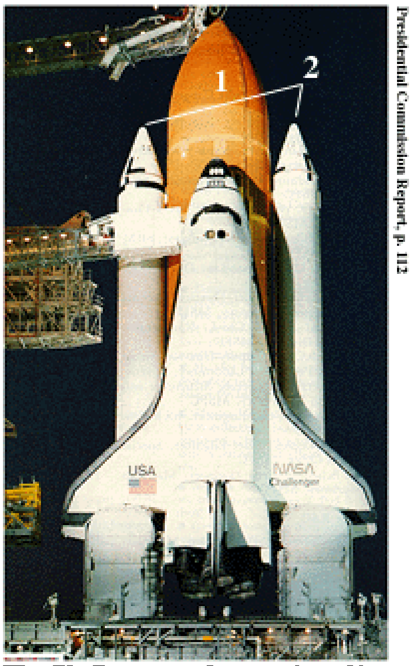
The final example in this section of a possible connection between groupthink and collective efficacy is the decision to launch the space shuttle Challenger on January 28, 1986. A little more than a minute after being launched, the Challenger exploded, killing all seven crew members in the worst tragedy in the history of space flight. The space shuttle program as a result was put on hold for 32 months as the National Aeronautics and Space Administration (NASA) was restructured and its technology revamped.

There is evidence that groupthink pervaded the decision making process leading to the Challenger disaster (Esser & Lindoerfer, 1989; Moorhead, Ference, & Neck, 1991). There is also evidence that the group that made the launch decision had very high collective efficacy. The flaw that ultimately destroyed Challenger was often discussed at flight readiness meetings prior to launch. The problem was identified in 1985 by NASA as a reason not to launch, called a launch constraint in NASA terminology. This constraint was overridden in six consecutive flights leading up to the Challenger accident. Many other launch constraints were also overridden repeatedly (Vaughan, 1995).

Richard Feynman, member of the Presidential Commission on the Space Shuttle Accident, concluded that a mentality of overconfidence existed in the group. In their own minds, they could do no wrong (Moorhead *et al.,* 1991). The source of this belief apparently was NASA's record of successful space flights. This is also known as enactive mastery, an important source of efficacy perceptions. The last time that NASA had lost an astronaut was 1967, when three perished as the result of a flash fire in the Apollo 1 space capsule. Since that time, 55 successful missions had been conducted, including 24 consecutive space shuttle flights. On the basis of this experience, in which every mission that went up came down, it is understandable that standards got lower and acceptable risk got higher (Moorhead *et al.,* 1991). NASA had repeatedly gotten away with launching other risky missions. Beating the odds with previous missions induced the belief thatNASA would beat the odds again. This evidence is also consistent with the view that the same factors which induce high collective efficacy might also contribute to the formation of structural organizational faults.

"What Went Wrong" Online Ethics Center for Engineering 8/29/2006 National Academy of Engineering. http://www.onlineethics.org/Topics/ProfPractice/Exemplars/BehavingWell/RB-intro/Wrong.aspx found on 4-12-2012.

What Went Wrong



The Challenger on the morning of its final launch. (1) The External Tank. (2) The Solid Rocket Boosters.

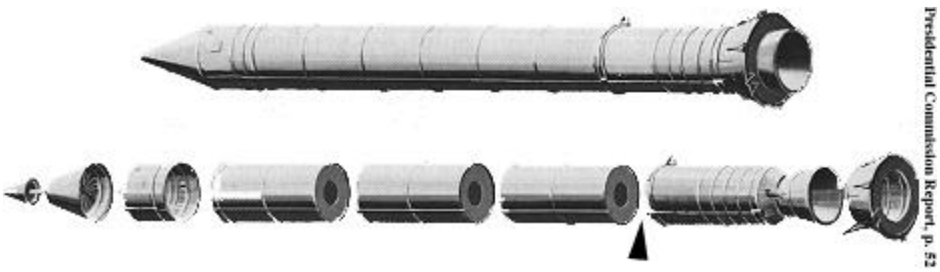
Why was Roger Boisjoly so concerned about O-Rings? These seemingly insignificant pieces of rubber played a critical role in the joints between segments of a solid rocket boster (SRB).

The two SRBs attached to a space shuttle orbiter provided eighty percent of the thrust necessary to propel the shuttle into space. About two minutes after a normal launch, the SRBs would detach and parachute back to the ground to be reused in subsequent missions. Several cylindrical segments make up the 149.1-foot- (45.4-meter-) tall SRB. Each joint between these segments contains two O-rings, positioned concentric with the SRB. The O-rings must be in perfect condition to prevent hot gasses from leaking through the joints of the SRB.

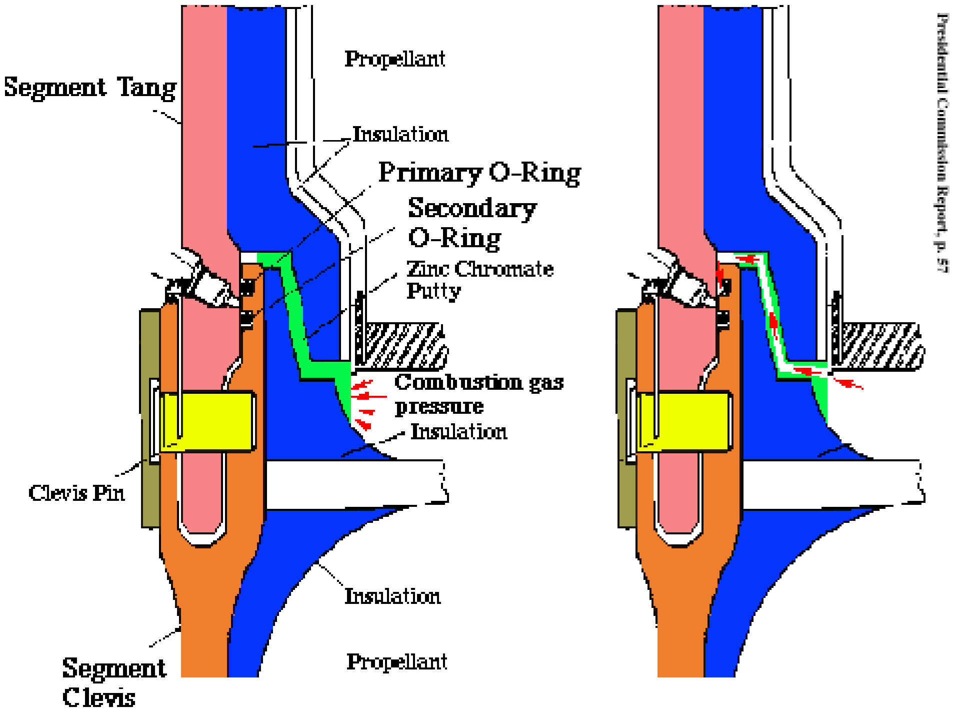
The Challenger: What Went Wrong

Within a second of the launch of Challenger on January 28, 1986, the first signs of failure of a joint in the right SRB were visible. Puffs of black smoke, whose color suggested that 5800-degree gases were eroding the O-rings, spewed out of that joint three to four times each second. At the end of the first minute, a small but steady flame was evident.

Atmospheric and aerodynamic conditions directed the flame plume onto the surface of the External Tank, used to supply liquid hydrogen and liquid oxygen fuel to the shuttle's engines during the launch. The flame eventually breached the tank, and a massive amount of hydrogen and oxygen burst into flame. At 73 seconds, a nearly explosive burn of the hydrogen and oxygen quickly resulted and claimed the Challenger with its crew.



Above: A Solid Rocket Booster and its segments. The aft field joint (arrow) failed in the Challenger's right SRB.



A Solid Rocket Motor Joint. Its parts are colorized in this diagram for clarity. In pink is the **tang**, which joins the **clevis**, colored orange. 177 huge steel pins (yellow) hold the joint in place. The O-rings shield the joint from 5800-degree gases inside the booster.

On the left scenario, hot gases (red arrows) are shielded from the joint by the zinc-chromate putty. On the right, immense pressure creates a blowhole in the putty, allowing the O-rings to move into the positions needed to seal the joint as the gap between tang and clevis expands. Through the blowhole, gases penetrate and wear away the O-rings.

Boisjoly had noticed that O-rings eroded, to an extent, in this fashion previously. NASA and Thiokol, however, decided that, since the O-rings were not completely eroded, there was minimal risk. Boisjoly's concern was that the low launch temperature would cause the O-rings to contract and further compromise their sealing value.

This diagram is a cross section. In actuality, the joint itself, tang, clevis, and O-rings have the circular shape of the SRB.

011

Rosness, R., Blakstad, H.C., Forseth, U., Dahle, I.B., Wiig, S., 2012, Environmental conditions for safety work – Theoretical foundations. Safety Science 50 1967–1976

In an ethnographic-historic study of the Challenger disaster, Vaughan (1996) proposed that a culture of deviance had developed because of the environmental conditions that faced NASA and its contractors during the space shuttle programme. Repeated signals of potential danger occurred as tests or flight experiences produced anomalies. These signals were processed in accordance with the formal rules, each time leading to the acceptance of the risk and a new shuttle launch. However, the repeated acceptance of anomalies led engineers and managers to develop and institutionalise a cultural construction of the risk as acceptable. It was considered safe to fly in spite of increasingly serious signs that the O-rings might fail to contain the burning gases inside the solid rocket boosters. Vaughan argued that the production pressures that the space shuttle project faced strongly contributed to this process, which she labelled ''normalisation of deviance''.
This perspective reflects the processes within an organisation that may gradually come to accept serious anomalies as ''normal'' and acceptable while complying with formal safety management requirements. This perspective emphasises the need to introduce outsiders who may challenge the assumptions and norms ingrained in the culture.

012

Labib, A., Read, M., 2013, Not just rearranging the deckchairs on the Titanic: Learning from failures through Risk and Reliability Analysis. Safety Science 51 397–413

8.1.1. Generic lesson 1 – Too much belief in previous successes
We argue that experience with success can be, and has been, counterproductive. For example, too much belief in the unsinkable ship made the Titanic Disaster in 1912 to come as a major surprise. The Titanic was perceived in 1912 'as the safest ship ever built' (The Sinking of the Titanic, 1912, 2000). This false perception led to the fatal error of providing insufficient life boats. The life boats capacity was for only 1178 people which is about half of her 2200 passengers and crew on board. In fact the life boats were not intended for those who were on board but rather to rescue survivors of other sinking ships because of the too much belief in the 'unsinkable' ship and that the Titanic was herself considered as a life boat and hence there was no need to install lifeboats, which took up valuable deck space. More recently, much belief in the success of previous shuttle missions caused NASA to ignore warning signals related to both the o-rings damage prior to the Challenger disaster in 1996 due to cold weather before launch, and again on the fuel tank foam losses prior to the Columbia disaster in 2005. According to the investigation report 'NASA's safety culture had become

reactive, complacent and dominated by unjustified optimism'.

013

Jasanoff, S., 1998, The political science of risk perception, *Reliability Engineering and System Safety* 59 91-99

We often recognize the force of such insights in the wake of major technological mishaps. The Rogers Commission appointed to investigate the Challenger disaster in the United States blamed a management structure that failed to convey engineers' concerns to the uppermost reaches of political decisionmaking. Interestingly, this was the Commission's major finding, even though the late physicist Richard Feynmann caught the headlines with his celebrated demonstration of the O-ring that froze at the temperature of freezing water. The Rogers Commission intuitively understood that people had to be held accountable for the Challenger disaster; the public would not have been content with the conclusion that the O-ring alone was at fault. Yet, when experts engage in prospective risk assessment -- the formal prediction of future harm -- they generally blame things by themselves. QRA glosses over the permeability of the human and material spheres and the shared agency of people and things.

014

Blose, L.E., Bornkamp, R., Brier, M., Brown, K., Frederick, J., 1996, Catastrophic Events, Contagion, and Stock Market Efficiency: The Case of The Space Shuttle Challenger. Review of Financial Economics. Vol 5. No 2 117-129

On January 28. 1986 the nation paused to witness the historic launch of the space shuttle Challenger. This 25th launch of the National Aeronautics and Space Administration (NASA) space shuttle program was the first flight to have a civilian on board, teacher Christa McAuliffe. President Ronald Reagan decided that a teacher should be first and that she would broadcast a lesson to children all over the country from space.

The Challenger flight had been delayed several times due to minor mechanical problems and weather conditions but on January 28th it received a "go" and the countdown began. School children everywhere waited in anticipation and at 1 I:38 a.m. the Solid Rocket Boosters fired starting the launch. Seventy three seconds into its flight, the space shuttle exploded.

The horror of what happened was not immediately apparent to those who watched from the ground. Many witnesses thought the rockets had ejected normally. When it became clear that something was wrong, many hoped the shuttle would separate from the disabled fuel tank and return to the launch site. However, during the period of the flight when the solid rocket boosters are thrusting, there are no survivable abort options.

Classes were canceled across the nation. Congress adjourned. President Reagan canceled his State of the Union address and instead gave a tribute to the Challenger astronauts. The rest of the world was transfixed to the video footage which was replayed over and over again. Condolences poured in from countries around the world.

The final tribute to the seven astronauts-Francis R. Scobee. Commander; Michael John Smith. Pilot; Ellison S. Onizuka. Mission Specialist One; Judith Arlene Resnik. Mission Specialist Two; Ronald Erwin McNair, Mission Specialist Three; S. Christa McAuliffe. Payload Specialist One; and Gregory Bruce Jarvis. Payload Specialist Two-was attended by Senators. Congressmen, NASA employees, the President and Nancy Reagan, and family members of the Challenger crew.

The country then turned its attention towards determining the cause of the worst NASA disaster ever and to the impact the tragedy would have on the space program. NASA refused to speculate on the cause and didn't want anyone else to either. Despite their pleas, speculation was rampant. Within days, the media had discussed many theories as to the cause of the accident.

President Reagan signed Executive Order #12546 on February 3. 1986 establishing the Presidential Commission on the Space Shuttle Challenger Accident. Its mission was to investigate the accident and determine the cause in order to prevent any recurrences in future flights.

The Commission spent four months retracing every action that related to the flight, studying the debris retrieved from the explosion, and the video tapes documenting the launch. It held hearings from February 6th through May 2nd. Upon Completion, the Commission Report indicated that a failure in one of the Solid Rocket Booster's O-rings made by Morton Thiokol Corp. caused the accident. This report was not rcleascd until June 6th.

On the day of the explosion these findings were still unanswered questions. No one knew how NASA or the Space Shuttle Program would bc affected. Investors were uncertain as to how such a catastrophe would impact the stock returns of Morton Thiokol and others who contracted with NASA.

The Challenger disaster unfolded over a matter of seconds, and there was no lag time between the actual event and the announcement of the event as it was televised.

015

Hastings, D., 2001. The Challenger Disaster. MIT

On 28 January, 1986 the Challenger took off with a teacher on board and exploded 73 seconds later. The immediate cause of the explosion was a burn through of one of the Orings on one of the solid rocket boosters causing the shuttle Challenger to be ripped apart at altitude.

The proximate cause was the leakage of two rubber O rings in a segmented solid rocket booster. The rings has lost their ability to stop hot gas blowby because on the day of launch they were cold (estimated at 20 degrees F, well below freezing). The ambient temperature at launch was in the low 30s.

Amazingly the exact cause of the accident was debated for hours the evening before the launch between Morton Thiokol engineers, managers and NASA managers. Given the predicted temperatures of 26 degrees F, the engineers were concerned that the O rings might not be resilient and that there was a history of O ring erosion on the STS during cool weather launches. This led them to recommend that the STS not launch at these low temperatures. This was the first no launch recommendation from Morton Thiokol in the history of the STS. Initially, the Thiokol managers supported the engineers. But under disbelieving questioning by the NASA managers, the Thiokol managers put on their management hats, changed their minds and changed the Thiokol recommendation to launch. The NASA managers were thus mollified and felt justified in approving a launch with the well known result that Challenger exploded.

Poor Communication and Poor Ethics

In the investigation that followed a number of contributing factors were identified. First, NASA managers under pressure to show the STS was reliable had authorized a launch even though the temperature criteria were outside of the known operational range of the STS. In a sense the operational mindset had overtaken them. They overruled the engineers who warned of possible danger. Second, NASA and Morton Thiokol engineers had known for some time that there were problems with gas blowby through the O-rings. However, the NASA system ignored these signs and did not calculate the consequences of a blowby. Third, the NASA communication system by this time was so poor that senior managers did not know of these potential issues and the NASA administrator for the first time ever did not go to the Cape for the launch. Thus the great R&D agency which had done Apollo in a few short years was reduced to an operational agency which could not even do this job well.

These factors point up issues of communication and ethics. Even though there was great danger, no one in the system felt empowered to listen and act. The managers ignored the experts and did not allow multiple ways of checking on these critical systems. There should have been a communication system whereby the engineers could have spoken to the NASA managers and caused an independent review of the relevant data (on the grounds that two independent sets of eyes are better than one). In addition, the engineers should have been willing to resign over an issue where the stakes were so high. Every engineer and decision maker needs to understand what is his or her bottom line with respect to engineering decisions. When the bottom line is crossed, then the ethical choice is to separate oneself from the decisions. This is fundamentally a question of values based on integrity, excellence and service. When a critical decision is imminent is too late to decide on what values are important.

016

Boisjoly, R.P., Curtis, E.F., Mellican, E., 1989, Roger Boisjoly and the Challenger Disaster: The Ethical Dimensions. *Journal of Business Ethics* 8: 217—230.

On January 28, 1986, the space shuttle Challenger exploded 73 seconds into its flight, killing the seven astronauts aboard. As the nation mourned the tragic loss of the crew members, the Rogers Commission was formed to investigate the causes of the disaster. The Commission concluded that the explosion occurred due to seal failure in one of the solid rocket booster joints. Testimony given by Roger Boisjoly, Senior Scientist and acknowledged rocket seal expert, indicated that top management at NASA and Morton Thiokol had been aware of problems with the O-ring seals, but agreed to launch against the recommendation of Boisjoly and other engineers. Boisjoly had alerted management to problems with the O-rings as early as January, 1985, yet several shuttle launches prior to the Challenger had been approved without correcting the hazards. This suggests that the management practice of NASA and Morton Thiokol had created an environment which altered the framework for decision making, leading to a breakdown in communication between technical experts and their supervisors, and top level management, and to the acceptance of risks that both organizations had historically viewed as unacceptable. With human lives and the national interest at stake, serious ethical concerns are embedded in this dramatic change in management practice.

In fact, one of the most important aspects of the Challenger disaster - both in terms of the causal sequence that led to it and the lessons to be learned from it - is its ethical dimension. Ethical issues are woven throughout the tangled web of decisions, events, practices, and organizational structures that resulted in the loss of the Challenger and its seven astronauts. Therefore, an ethical analysis of this tragedy is essential for a full understanding of the event itself and for the implications it has for any endeavor where public policy, corporate practice, and individual decisions intersect.

017

Edy, J.A., Daradanova, M., 2006. Reporting through the lens of the past : from Challenger to Columbia. *Journalism* 7: 131

Scholars and pundits consider the launching of the space shuttle Challenger on 28 January 1986 to be an archetypal example of bad decision-making arising from poor decision-making processes (Esser and Lidoerfer, 1989; Hirokawa et. al., 1988) and institutional culture (Vaughan, 1997). The immediate causes of its destruction were cold weather conditions that exacerbated problems with the O-rings, essentially large synthetic rubber washers, used in the solid rocket boosters that should have helped put the shuttle in orbit. Stiff with cold, the O-rings failed to seal, a booster exploded, and the orbiter was destroyed. But the 'lessons of history' from the Challenger disaster have typically focused not on mechanical failure but on the decisionmaking process and institutional culture that led to the launch decision despite concerns about the weather and the O-rings' performance.
The renowned, iconic event that illustrates processes thought to contribute to the accident was a lengthy teleconference held the night before the launch. NASA representatives and the outside contractor that made the solid rocket boosters, Morton-Thiokol, had known for more than a year that the Orings often experienced partial failure during a launch and that if they failed, the shuttle would be seriously damaged or destroyed. Yet they believed, or convinced themselves, that the shuttles were safe enough to fly while the Oring technology was redesigned. On the day before Challenger was to launch, engineers at Morton-Thiokol expressed reservations about O-ring performance during the proposed launch because it was scheduled to occur on a morning when weather forecasters said the Kennedy Space Center would experience record cold, an overnight low of 18F degrees. Previous experience suggested that the O-rings were even more vulnerable in cold weather. A teleconference was scheduled to discuss the issue. As McDowell claims:

The long Monday night teleconference has acquired mythical proportions . . . Many people have come to view the conference as a tense and acrimonious battle of wills between callous bureaucrats on one side and greedy capitalists on the other, with a virtuous group of engineers forming a Greek chorus of alarm, which the villainous managers on both sides scornfully ignored. (McDowell, 1987: 191)

Somewhere in the decision-making process, a critical line was crossed. Although the flight safety standards set out by NASA demanded that contractors and managers certify the shuttle safe to fly, in the course of the meetings, NASA administrators, managers and contractors began to demand evidence that the shuttle was *not* safe to fly as a prerequisite for delaying the launch. The Morton-Thiokol engineers (and, later, engineers at Rockwell International asked about potential problems that the buildup of ice on the fixed service structure that surrounded the shuttle might produce) could not provide hard data that the shuttle was not safe because launch conditions were outside of known parameters. Managers and corporate representatives therefore certified that it was safe.
Reasons for these failures have been variously placed. Communication chains were flawed. Morton-Thiokol was renegotiating its valuable contract to provide NASA with solid rocket boosters and may have been reluctant to acknowledge the weaknesses of its technology. NASA managers and administrators, seeking to preserve and expand their budget and assure the future of manned spaceflight, had emphasized the reliability and routine nature of shuttle flight, so repeated delays and delicate technology were more than an annoyance. Putting Challenger in space on 28 January could mean a mention in the president's state of the union address that night, an important bump up the federal agenda. And so they launched. Less than a minute later, the shuttle

experienced a catastrophic explosion.

018

Wynne, B., 1988, Unruly Technology: Practical Rules, Impractical Discourses and Public Understanding. *Social Studies of Science* 18: 147

http://sss.sagepub.com/content/18/1/147 found on 27-12-2012

Normal Abnormality

Accidents and their subsequent inquiries are perhaps the only passing moment when outsiders may glimpse the routinely less orderly, less rule-controlled world of technology and science. However, because it is seen this way only around accidents, the belief is consolidated that *normally* practices are more orderly. Thus it came as a major shock to public confidence in the NASA space shuttle programme to find, after the Challenger disaster, that the shuttle had often been fired into space with various components and subsystems malfunctioning.[9] This appeared to demonstrate reckless irresponsibility on the part of those in charge, for allowing the technology to be operated in a condition where it was not fulfilling all of its rules of performance. The Challenger Inquiry found that faulty design of rubber O-ring seals in the solid rocket boosters led to the leakage of fuel which eventually caused the catastrophic explosion. However, it was already known by practitioners that several previous shuttle flights had shown signs of these O-ring faults, especially at lower ambient launch temperatures (as was true of the Challenger launch). They had exhibited thermal stressing which led to incomplete sealing of the joints, and accompanying 'leak-paths' in the insulating putty around the

O-rings. Empirical experience was that this abnormality had happened in several previous tests and real flights, without leading to an accident. On the fatal launch, therefore, the logic of decision was not that the O-rings had shown signs of failure before, and performed at less than their official performance-rule, and therefore that all further launches must be stopped until this subsystem was redesigned. Rather, the logic was: this component shows behaviour which is abnormal according to our original design-performance rules; however in several launches it has shown less than adequate performance without incident; its failure has been apparently within acceptable bounds (which we have made up under negotiation from experience as we went along). Thus the shuttle contractor, Morton Thiokol, had stated in internal deliberations that the joint O-ring design was 'not desirable, but is acceptable'.[10] The Presidential Commission of Inquiry found that both NASA and Morton Thiokol had gradually increased the amount of abnormality considered 'acceptable' as they had unexpectedly found the O-ring seals to be touched by hot gases in previous tests and actual flights, then further found that they were partially burned and damaged, still without significant wider effect. O-ring damage and leakage was 'experienced frequently during the shuttle flight history',[11] and the experts had come to accept it as a new normality. Therefore, on this occasion, the judgement was: Will it fail within what we have evolved *ad hoc* to be 'acceptable' bounds again, or will it this time fail in such a way as to produce worse knock-on effects? Failure itself was being redefined. Recall also that this was only *one* subsystem or component; many others were offering similarly ambiguous decision-judgement problems.[12]

This whole system can be seen to have been evolving uncertainly according to innumerable *ad hoc* judgements and assumptions. These created a new set of more private informal 'rules' beneath the discourse of formal rules and check procedures. This more tidy language is a caricatured version of the technology which portrays a crucially different image of control and controllability. Although it seems to be for the consumption of outsiders, it also plays a significant role for practitioners.[13]

019

Vaughan, D., 2004. Theorizing Disaster : Analogy, historical ethnography, and the Challenger accident. *Ethnography* 5: 315

http://eth.sagepub.com/content/5/3/315 found on 26-11-2012

When NASA's Space Shuttle Challenger disintegrated in a ball of fire 73 seconds after launch on 28 January 1986, the world learned that NASA was not the pristine citadel of scientific power it had seemed. The Presidential Commission appointed to investigate the disaster quickly uncovered the cause of the technical failure: the O-rings that seal the Solid Rocket Booster joints failed to seal, allowing hot gases at ignition to erode the O-rings, penetrate the wall of the booster, and destroy *Challenger* and its crew. But the Commission also discovered a NASA organization failure of surprising proportion. In a midnight hour teleconference on the eve of the *Challenger* launch, NASA managers had proceeded with launch despite the objections of contractor engineers who were concerned about the effect of predicted cold temperatures on the rubber-like O-rings. Further, the investigation indicated that NASA managers had suppressed information about the teleconference controversy, violating rules about passing information to their superiors. Worse, NASA had been incurring O-ring damage on shuttle missions for years. Citing 'flawed decision making' as a contributing cause of the accident, the Commission's Report (Presidential Commission on the Space Shuttle *Challenger* Accident, 1986) revealed a space agency gone wrong, forced by budget cuts to operate like a cost-efficient business. Apparently, NASA managers, experiencing extraordinary schedule pressures, knowingly took a chance, moving forward with a launch they were warned was risky, wilfully violating internal rules in the process, in order to launch on time. The constellation of factors identified in the Report – production pressures, rule violations, cover-up – indicated amorally calculating managers were behind the accident. The press fueled the controversy, converting the official

explanation into historically accepted conventional wisdom.

020

Coffey, J., 2010, Challenger Disaster, http://www.universetoday.com/71612/challenger-disaster/
found on 4-12-2012

Challenger Disaster

by Jerry Coffey on August 20, 2010

The space shuttle Challenger disaster occurred on occurred on January 28, 1986. The shuttle broke apart over the Atlantic Ocean just 73 seconds after lifting off from its launch pad in Florida. All seven crew members were lost. The disaster was precipitated by the failure of an o-ring assembly in the right solid rocket booster.

The o-ring failure caused a breach in a solid rocket booster(SRB) joint that it sealed. The failure allowed pressurized hot gas from the solid rocket motor to reach the outside and interfere with the adjacent SRB attachment hardware and external fuel tank. The interference was significant enough to cause the separation of the right-hand SRB's aft attachment and then the structural failure of the external tank. Active aerodynamic forces quickly broke the orbiter apart.

The Challenger space shuttle never actually exploded. The enormous fireball that many people saw was the fuel and oxidizer that was released when the external tank disintegrated. It is impossible to know at which exact moment the crew members died, but it is known that some survived the initial break up and died when the crew compartment impacted with the ocean. There was no escape plan in place for such an emergency. The shuttle program was halted for 32 months while the Rogers Commission, which was formed by the Reagan administration, looked into the causes of the accident and possible counter measures to prevent another similar incident in the future.

The investigation of the Rogers Commission led to several conclusions. The most important being that NASA's organizational culture and decision-making processes had been key contributors to the accident. Managers had known that the SRB design contained a potentially catastrophic flaw in the o-rings since 1977. They failed to address it properly for a decade. The same managers had disregarded warnings from engineers about the dangers of launching because of the cold temperatures that morning. After ignoring the engineers, they had failed to adequately report these technical concerns to their superiors.

Several times NASA had considered building an escape system into the space shuttle design. Each time the idea was dismissed after the costs were found to be too high and the limitations it would put on crew size too limiting. Escape from the a space shuttle is only possible as the shuttle is gliding just before landing.

021

Vaughan, D., 1990, Interdependence, and Social Control: NASA and the space shuttle Challenger. *Administrative Science Quarterly* Vol. 35 No. 2, pp. 225-257

http://www.jstor.org/stable/2393390 found on 27-11-2012

The Challenger disaster was an organizational-technical system accident. The immediate cause was technical failure. The O-rings-two 0.280-inch diameter rings of synthetic rubber designed to seal a gap in the aft field joint of the- solid rocket booster-did not do their job. The Presidential Commission (1986, 1: 72) investigating the incident stated that design failure interacted with "the effects of temperature, physical dimensions, the character of the materials, the effects of re-usability, processing, and the reaction of the joint to dynamic loading." The result of these interactive factors was, indeed, a technical system accident similar to those Perrow identified. But there was more. The post-accident investigations of both the Commission (1986, 1: 82-150) and the U.S. House Committee on Science and Technology (1986a: 138-178) indicated that the NASA organization contributed to the technical failure. As Turner might have predicted, the technical failure had a long incubation period. Problems with the O-rings were first noted in 1977 (Presidential Commission, 1986, 1: 122). Thus, NASA might have acted to avert the tragedy. But the organizational response to the technical problem was characterized by poor communication, inadequate information handling, faulty technical decision making, and failure to comply with regulations instituted to as-sure safety (Presidential Commission, 1986, 1: 82-150; U.S. House Committee on Science and Technology, 1986a: 138-178). Moreover, the regulatory system designed to oversee the safety of the shuttle program failed to identify and correct program management and design problems related to the O-rings. NASA insiders referred to these omissions as "quality escapes": failures of the program to preclude an avoidable problem (Presidential Commission, 1986, 1: 156, 159). NASA's safety system failed at monitoring shuttle operations to such an extent that the Presidential Commission's report referred to it as "The Silent Safety Pro-gram" (1986, 1: 152).

022

Heimann, L., 1993, Understanding the Challenger Disaster: Organizational Structure and the Design of Reliable Systems. The American Political Science Review, Vol. 87, No. 2, pp. 421-435

http://www.jstor.org/stable/2939051 found on 22-11-2012.

On 28 January 1986, the entire nation focused on a single event. Seventy-three seconds after lift-off, the space shuttle Challenger was des0troyed in a powerful explosion fifty thousand feet above the Kennedy Space Center. The losses resulting from this catastrophe were quite high. Seven astronauts, including Teacher-in-Space Christa McAuliffe, were killed as the shuttle broke apart and fell into the sea. The shuttle itself had to be replaced at a cost of over two billion dollars. The launch of many important commercial and military satellites had to be delayed as American space policy ground to a complete halt. The accident had a profound impact on the National Aeronautics and Space Administration (NASA), as well. The agency's credibility and its reputation for flawless execution of complex techno-logical tasks were lost, along with the Challenger. To this day, the legacy of the Challenger haunts the decisions of both the agency and its political superiors in Congress and the White House. An examination of the shuttle remnants and other launch data revealed the technical cause of the accident. The shuttle was destroyed when an O-ring seal on the right solid rocket motor failed, allowing the escaping hot gases to burn through and ignite the main fuel tank of liquid hydrogen and liquid oxygen. Although identifying the technical cause of this dis-aster is important, it represents only one aspect of the problem. Perrow (1984) has argued that organizational and technological failures have become so intimately linked that to fully understand the cause of most major accidents, we must analyze both the administrative and technical aspects of the situation. While there have been some administrative critiques of NASA in the wake of this disaster, almost all have centered on issues of bureaucratic culture, such as the agency's propensity to ignore key evidence and its myopic view of its mission. Surprisingly little has been done on a systematic analysis of the NASA organization structure and how it may or may not have contributed to the loss of the Challenger.

023

McKenna, D., 2009, The Space Shuttle Challenger Disaster A Study in Organizational Ethics.

http://pirate.shu.edu/~mckenndo/pdfs/The%20Space%20Shuttle%20Challenger%20Disaster.pdf

found on 4-12-2012.

A System Breaks Down

On January 28, 1986, the space shuttle Challenger exploded in midair, sending six astronauts and schoolteacher Christa McAuliffe to their deaths. The initial public reaction was shock and disbelief. Americans had come to expect routine flights from NASA. Well
before the shock had eased, the public wanted to know why the accident took place. Some of the reasons surfaced almost immediately, and they were disturbing.

The press reported that engineers at Morton Thiokol, the contractor responsible for building the solid rocket booster, had vigorously opposed the launching of Challenger, but their warning had not been heeded by management. These engineers suspected what the Rogers Commission would later support, that the immediate cause of the explosion was a burn through of the solid rocket booster joint O-rings - the same O-rings that engineers had been concerned about for more than eight years.

Despite this concern, top NASA decision makers (at levels I and II) told the Rogers Commission that they had no knowledge on January 27 that these matters had been the subject of intense controversy within Thiokol and between Thiokol and the Marshall Space Flight Center (levels IV and II in the decision-making chain). These officials added that they would not have given the final approval to launch if they had heard the views of the Thiokol engineers.

After a careful study of the variables contributing to the Challenger explosion, the Rogers Commission concluded that although the O-ring failure was the immediate cause, a flawed decision-making process was an equal, if not more important factor. The major findings of the commission:

1. The Commission concluded that there was a serious flaw in the decision-making process leading up to the launch of flight 51-L (the Challenger flight). A well structured and managed system emphasizing safety would have flagged the rising doubts about the Solid Rocket Booster joint seal. Had these maters been clearly stated and emphasized in the flight readiness process in terms reflecting the views of most of the Thiokol engineers and at least some of the Marshall engineers, it seems likely that this launch of 51-L might not have occurred when it did.
2. The waiving of launch constraints appears to have been at the expense of flight safety. There was no system which made it imperative that launch constraints and waivers of launch constraints be considered by all levels of management.
3. The Commission is troubled by what appears to be a propensity of management at Marshall to contain potentially serious problems and to attempt to resolve them internally rather than communicate them forward. This tendency is altogether at odds with the need for Marshall to function as part of a system working towards successful flight missions, interfacing and communicating with the other parts of the system that work to the same end.

4. The Commission concluded that the Thiokol management reversed its position and recommended the launch of 51-L, at the urging of Marshall and contrary to the views of its engineers in order to accommodate a major customer.

024

Maloney, M.T., Mulhering, H., 1998, The stock price reaction to the Challenger crash

The Challenger explosion occurred at 11:39 a.m. eastern standard time on January 28, 1986. (See the appendix for a list of the news stories and pertinent dates during the Challenger episode.) The announcement of the crash came across the Dow Jones News Wire at 11:47 a.m. In additional stories crossing the Wire in the next hour, Rockwell International, the maker of the shuttle and its main engines, and Lockheed, the manager of shuttle ground support, issued “no- comment” reactions to the crash. Press coverage that day also identified Martin Marietta as the manufacturer of the shuttle’s external fuel tank and Morton Thiokol as the maker of the shuttle’s solid fuel booster rocket.

The crash caught nearly everyone by surprise. The headlines the following day in the New York Times asked “How Could It Happen” and stated that there were “No Ideas Yet to the Cause.” Because of the unprecedented nature of the event, the Financial Times on January 30th predicted that “it will be months rather than weeks before NASA has any real answers to the question What went wrong with the Challenger?”

To find answers to this question, President Reagan appointed a blue-ribbon panel headed by former Secretary of State William Rogers. After several months of testimony and deliberation, the Rogers Commission concluded that the cause of the crash was the lack of resiliency at low temperatures in the seals of the shuttle’s booster rockets supplied by Morton Thiokol.2 In its June 1986 report, the commission also found fault with the chain of command at the booster’s manufacturer, Morton Thiokol, as well as within NASA itself.3

028

Cliff, D., Northrop, L., 2012. The Global Financial Markets: An Ultra-Large-Scale Systems Perspective. R. Calinescu and D. Garlan (Eds.): Monterey Workshop 2012, LNCS 7539, pp. 29–70

In Perrow's terms, the losses of the NASA space shuttles *Challenger* in January 1986 and *Columbia* in February 2003 were also normal accidents. However, the sociologist Diane Vaughan argued for a more sophisticated analysis in her classic study *The Challenger Launch Decision* (1997), in which she presented a detailed analysis of transcripts, covering the hours immediately preceding *Challenger*'s launch, of interactions between NASA staff and the staff of Morton Thiokol, manufacturers of the shuttle's solid-fuel rocket booster (SRB) that failed leading to loss of the vehicle and her crew.

The transcripts had been released as part of the official Presidential Commission on the Space Shuttle *Challenger* Accident, led by William Rogers. A shocking finding of the Rogers investigation was that the specific failure-mode (burn-through of rubber O-ring seals in a critical joint on the SRB) had been known since 1977 and the consequent potential for catastrophic loss of the vehicle had been discussed at length by NASA and Thiokol, but the shuttle had not been grounded. Vaughan concluded that while the *proximal* cause of disaster was the SRB O-ring failure, the *ultimate* cause was a social process that Vaughan named *normalization of deviance*.

Put simply, normalization of deviance occurs when the safe-operating envelope of a complex system is not completely known in advance, and where events that were *a priori* thought to be outside the envelope, but which do not then result in failures, are taken after the fact as evidence that the safe envelope should be extended to include those events. In this way, deviant events become normalized: the absence of a catastrophe thus far is taken as evidence that in future catastrophes are less likely than had previously been thought. The flaw in this line of reasoning is starkly revealed when a catastrophe then ensues. In Vaughan's analysis, the loss of *Challenger* was not a purely technical issue but rather was an organizational failure in the *sociotechnical system* comprised of the (technical) shuttle hardware systems and the (social) human individuals, teams, and organizations that had to interact appropriately to ensure safe launch and return of the shuttle

029

Maier, M., Messerschmidt, J.W., 1998. Commonalities, Conflicts and Contradictions in Organizational Masculinities: Exploring the Gendered Genesis of the Challenger Disaster. *Canadian Review of Sociology* Volume 35, Issue 3, pages 325–344

ON JANUARY 28,1986, the space shuttle Challenger took off on its last mission, tragically exploding just **73** seconds into flight, killing all 7 crew members, including New Hampshire school teacher, Christa McAuliffe. In its final report, the Presidential Commission which investigated the tragedy found that it was caused in major part by the technical failure of a rubber O-ring in the Solid Rocket Booster (SRB) to seal properly due to freezing temperatures preceding lift-off. But the Commission (1986) also concluded that the decision-making process which led to the fatal launch was "seriously flawed." The string of warnings unheeded, of recommendations ignored-from the early developmental stages years prior all the way through to the final decision processes-culminated in the disaster which has become part of our collective consciousness. As has been noted elsewhere, those horrific twisted-Y plumes etched into our memories represent the outcome of fairly typical organizational processes (e.g., Maier, 1994; Starbuck and Milliken, 1988; Vaughan, 1996). Clearly, there are various ways one could "read" or interpret this event. And, indeed, many alternative explanations have been offered in the decade or so since the disaster occurred. In this article, we seek not to replace nor to take issue with any of these previous explanations, but to supplement them. For example, depending on one's frame of reference, strong claims can legitimately be made that the disaster was caused by technological failures (Bowser, 19871, and/or managerial hubris (Westrum, 19861, and/ or poor decision-making practices (Gouran, Hirokawa and Martz, 1986; Renz and Greg, 1988; Starbuck and Milliken, 19881, andor inappropriate or conflicting organizational cultures (Schwartz, 19871, and/or a failure to adequately assess risk (Renz and Greg, 19881, and/or an improper organizational structure or organization design (Westrum, 1987; Vaughan, 19901, and/or poor personnel selection procedures (Kovach and Render, 1987) to name but some of the representative and well-articulated explanations.

031 Howell, E., date unknown, Challenger: Shuttle Disaster That Changed NASA, SPACE.com

http://www.space.com/18084-space-shuttle-challenger.html found on 27-12-2012

Challenger disaster
It was a cold morning on Jan. 28, 1986, when Challenger was supposed to fly into space. Temperatures dipped below freezing. There were certain people at NASA and among contractors that worried about the integrity of the seals on the solid rocket boosters in cold weather.
At 78 seconds after liftoff, this image shows Challenger's left wing, main engines (still burning residual propellant) and the forward fuselage (crew cabin).
Challenger launched at 11:38 a.m. Eastern time in front of more media attention than usual, as it was carrying the first teacher to go in space. Christa McAuliffe was planning to give lessons while in orbit.
She and the rest of the crew never made it. Challenger broke up 73 seconds after launch in front of the television cameras. "Flight controllers here are looking very carefully at the situation. Obviously a major malfunction," the NASA launch commentator said as pieces of the shuttle fell from the sky into the Atlantic.
Salvage crews spent several weeks recovering pieces of the shuttle and carefully, bringing up the remains of the seven astronauts. Remains that could be identified were turned over to the families, while the rest were buried in a monument to the Challenger crew at Arlington Cemetery on May 20, 1986.

Cultural and technical problems
A presidential commission was convened to look into the incident, chaired by former attorney general and secretary of state William P. Rogers. It included participation from Neil Armstrong (the first man on the moon) and NASA astronaut Sally Ride, among others.
The commission talked about the technical causes of the accident, which was traced to cold weather degrading the seal on the boosters. Additionally, it brought to light cultural problems at NASA, such as failing to voice all problems to the launch decision team. The commission also said that the shuttle's proposed flight rate was unsustainable given the size of its workforce.
NASA made technical changes to the shuttle and also worked to change the culture of its workforce in the wake of what happened with Challenger. The shuttle program resumed flights in 1988.
After the Challenger wreckage was examined, the pieces were buried and sealed in abandoned Minuteman missile silos at Cape Canaveral Air Force Station, where they remain today.
Challenger's explosion changed the space shuttle program in several ways. Plans to fly other civilians in space (such as journalists) were shelved for 22 years, until Barbara Morgan, who was McAuliffe's backup, flew aboard Endeavour in 2007. Satellite launches were shifted from the shuttle to reusable rockets. Additionally, astronauts were pulled off of duties such as repairing satellites, and the Manned Maneuvering Unit was not flown again, to better preserve their safety.
Every January, NASA pauses to remember the last crew of Challenger, and the other crews lost in pursuing space, on a NASA Day of Remembrance. Additionally, Challenger has an educational legacy: members of the crews' families founded the Challenger Center for Space Science Education program, which brings students on simulated space missions.

031

Paté-Cornell, M.E., 1990, Organizational Aspects of Engineering System Safety: The Case of Offshore Platforms. *Safety Science*.

T HE CHALLENGER, CHERNOBYL, THREE MILE ISLAND, AND the Exxon Valdez accidents (among others) have shaken the public's confidence in the safety of technology and stimulated national and international inquiries about the very nature of such events. After each of them, the consensus was that something should be done to prevent a recurrence. Eliminating a technology that does not seem to be managed properly may be tempting, but often it is not even an option. If we decide to live with the risk, we should understand what went wrong so that we do not let the same failure happen again and we should understand what else could go wrong so that we prevent accidents. Corporations tend to blame human errors or technical mishaps for catastrophic failures of engineering systems and treat them as bad luck. Yet, in many cases, the root of the problem is in the organization, even if the eventual failure can be traced back to a specific component or operator (1-3). Accidents come basically in two forms: those that are either totally unpredictable or so rare that one can reasonably decide to live with the risk, and those that are essentially self-inflicted, often through management practices that are bound to generate errors and defects with a much higher probability than generally estimated. Even though the distinction is sometimes fizzy, the former can be attributed to bad luck and little can be done about them, whereas the latter are the result of organizational factors that often can be improved. At the root of the Challenger accident, for example, was an accumulation of organizational problems (4) that included miscommunication of technical uncertainties, failure to use information from past near misses, and an error of judgment in balancing conflicting requirements of safety and schedule. The National Aeronautics and Space Administration (NASA) and its contractors had allowed the shuttle to fly several times below full capacity; yet, no accident had happened. It took a low temperature as an initiating event to cause the technical 0-ring failure that proved fatal to flight 51-L (5). Studies of such failure stories are informative, but provide only a narrow glimpse of a large number of potential failure scenarios. A systematic analysis is required to put these results in perspective and to learn from past experiences, which often involve few total failures, if any at all, but many partial failures and near-misses. Probabilistic risk analysis (PRA) is one of such techniques that was developed primarily in the nuclear power industry (6, 7). Portions of the oil industry now use PRA models to assess the reliability of offshore platforms (8). These analyses focus mainly on the probability that a platform fails because of extreme loads, such as excessive wave heights beyond the chosen design criteria. Provided that these criteria were reasonable in the first place, this particular type of failure can be attributed to bad luck. More often, as I discuss in this article, accidents result from organizational errors that decrease the platform's capacity and are rooted in the way the companies operate. In this study, I use probabilities to link some organizational factors to the performance of the components and jacket-type offshore platforms as an illustration of the method (9). The data include probabilities of errors and error detection, and probabilities of failure of the basic components (foundation, jacket, and deck) conditional on different error states. I obtained these probabilities from one expert (10). His assessments are based on his experience in the oil industry and on different data sets providing statistics about failure types and failure causes for a large class ofstructures (11-14).

033

Ge, M., 2009. Information Quality Assessment and Effects on Inventory Decision-Making

Case studies concerning information quality problems are frequently documented. Such information quality issues may not only cause inconvenience in everyday life but also potentially generate harmful disasters. For example, on the 28th January 1986, NASA launched the space shuttle *Challenger.* Seconds after lift-off, the shuttle exploded and killed the seven astronauts on board. The Presidential Commission investigated the *Challenger* accident and found that NASA’s decision-making process was based on incomplete and misleading information. Just two years later in July 1988, U.S. Navy Cruiser USS *Vincennes* shot down an Iranian commercial aircraft and killed its 290 passengers. Officials who investigated the *Vincennes* accident admitted that poor quality information was a major factor in the flawed *Vincennes* decision-making process. Fisher and Kingma (2001) carried out an in-depth analysis of the *Challenger* accident and the *Vincennes* accident and concluded that the explosion of space shuttle Challenger and the shooting down of an Iranian airbus by the USS Vincennes were the result of information quality problems and information quality management errors. Yet not only in the space and military industries but also in our daily life, information quality problems can be found to be severe. For instance, Pirani (2004) reported that one piece of wrong biopsy information caused a patient’s death in an Australian hospital. The above case studies demonstrate that information quality is a vital issue in both industry and everyday life.

036

Kerzner, H. 2009. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*

http://books.google.nl/books?hl=en&lr=&id=4CqvpWwMLVEC&oi=fnd&pg=PR21&dq=challenger+disaster&ots=LNoLtwBsXv&sig=0VEHCSBbEcrtp1kGwBz-CTHyQ-A#v=onepage&q=challenger%20disaster&f=false

24.8 THE SPACE SHUTTLE *CHALLENGER* DISASTER[2]

On January 28, 1986, the Space Shuttle *Challenger* lifted off the launch pad at 11:38 AM. Approximately 74 seconds into the flight, the *Challenger* was engulfed in an explosive burn and all communication and telemetry ceased. Seven brave crewmembers lost their lives. Following the accident, significant energy was expended trying to ascertain whether or not the accident was predictable. Controversy arose from the desire to assign, or to avoid, blame. Some publications called it a management failure, specifically in risk management, while others called it a technical failure.

Lessons Learned

The following lessons were learned from the *Challenger* disaster:

1. The crisis was created by a poor organizational culture.
2. There were significant early warning signs, which if addressed, could have avoided the crisis. They were ignored.

2. Only summary information is provided in this chapter. For a more in-depth analysis of the case, see "The Space Shuttle *Challenger* Disaster" in Harold Kerzner, *Project Management Case Studies*, 3rd ed. (Hoboken, NJ: Wiley, 2006), pp. 425–474.

Schirato, T., Yell, S., 2000. Communication and Culture: An Introduction

http://books.google.nl/books?hl=en&lr=&id=xnq2cpB96xQC&oi=fnd&pg=PR5&dq=challenger+disaster&ots=y7Wgk8zFI0&sig=QvnRJ1Pp1dzNMBPkpfaLnWbLcaw#v=onepage&q&f=false

- there had been engineering problems with NASA launches going back eight years;
- both Thiokol and NASA were anxious to prove their capabilities and competence, which were under question; and
- this launch was important to the US space program, which had been dogged by postponements and technical failures.

There may also have been other political contexts, such as the prestige that politicians and the government wished to gain from a successful launch. The textbook mentions most of these factors, but in the end ditches them all in favour of the 'failure of communication' line.

Let's consider an alternative explanation—one which takes these contexts into account. Thiokol and NASA management knew about the potential danger, but they were under pressure to launch the shuttle anyway. When Thiokol and NASA engineers tried to convince management to postpone, they ran into a stone wall: as one engineer described it, 'Arnie actually got up from . . . the table, and . . . put a quarter pad down . . . in front of the management folks, and tried to sketch out . . . what his concern was . . . and when he realized he wasn't getting through, he just stopped' (Pattow & Wresch 1993:8).

Management obviously didn't have the same agenda as the engineers. The engineers communicated effectively in a technical sense, but what they lacked was a wider cultural literacy. For the engineers to convince management to postpone the flight, they needed to take a different tack and concentrate not on technical problems, but on the possible ramifications of those technical problems, and how these might tie in with the agendas and interests of management. The engineers could have made the point, for instance, that a postponement might be a considerable setback (for NASA, Thiokol, the President), but that decision makers should also consider the consequences of the shuttle blowing up in front of a huge television audience, with the prestige of NASA, Thiokol and the President on the line (which is exactly what happened).

Had the engineers had that wider cultural literacy, they would have known that any attempt to sway management needed to involve treating the launch not as a technical problem, but as a PR exercise. We may think we understand what's going on in a situation (we understand the relevant rules, regulations and conventions), but what happens in practice is often informed, and even determined, by agendas that aren't up front, and sometimes can never be publicly articulated. The ability to negotiate between the rules of a culture and what happens in practice is what we have called cultural literacy.

An example of the relationship between communication, context and cultural literacy can be found in the example of the way the *Challenger* disaster (the explosion of the US space shuttle *Challenger* in 1986 over Cape Canaveral, and the death of the seven astronauts, including a number of civilians, on board) has been interpreted and explained. One technical communication textbook wrote that: 'The *Challenger* was not an engineering disaster; it was a communication disaster . . . [which shows that] good communication—especially for technically trained people—is essential' (Pattow & Wresch 1993:11).

Now according to this (probably reasonably representative) account, the *Challenger* disaster occurred, not simply because there were engineering problems (the O-rings didn't set in place) but because the engineers involved couldn't adequately communicate the problem to management groups of both the company involved (Thiokol) and NASA. The account given in the textbook, however, makes clear that the engineers did make several attempts, the night before the disaster, to alert management to the potential danger. The textbook assumes, because engineers were communicating to management, that the problem was a 'failure of communication'. In a sense they were right, but not in the way they think.

The textbook account of the disaster mentions a variety of contexts that could be brought to bear on why *Challenger* blew up:

038

Schiappa, E., 1995. Warranting Assent: Case Studies in Argument Evaluation

http://books.google.nl/books?hl=en&lr=&id=s-tkBPMrwYYC&oi=fnd&pg=PA57&dq=challenger+disaster&ots=IKQ7rIaWtz&sig=UPRnfdoH9Z5HlO8WSPodgdQGPiM#v=onepage&q=challenger%20disaster&f=false

In the months following the ill-fated and widely publicized flight of *Challenger*, the Rogers Commission identified "flaws in the decision making process" as the "contributing cause" (Report of the Presidential Commission on the Space Shuttle Challenger Accident 1986, p. 82 [hereafter Report]). Most notable among the factors involved was the "propensity at Marshall [the Marshall Space Flight Center in Huntsville, Alabama] to contain potentially serious problems and to resolve them internally rather than communicate them forward" (Report 1986, p. 104). At least one of these "potentially serious problems"—O-ring failure in the solid rocket booster field joints—had been an object of continuing concern, however, since at least 1977 (Cook 1986) and subsequently proved to be the actual physical cause of the explosion that destroyed the shuttle and sent the crew members to their unfortunate deaths. For nine flights prior to 51-L, moreover, evidence of the problem was consistently available to NASA officials and part of virtually every engineering assessment from 1984 forward (Cooper 1986). These facts prompted the Rogers Commission also to conclude that the destruction of *Challenger* was "an accident rooted in history" (Report 1986, p. 120).

040

Bennis, W., 1989, On Becoming a Leader: The Leadership Classic

http://books.google.nl/books?hl=en&lr=&id=6uU6BalibOgC&oi=fnd&pg=PR11&dq=challenger+explosion&ots=WcNlJx5MZM&sig=4owmMoCn4WV1NHXOEyZJdFLBYlg#v=onepage&q=challenger%20explosion&f=false

> One tragic example involves the Challenger explosion. On January 28, 1989, the Space Shuttle Challenger exploded shortly after launch, killing all on board—six astronauts and the first teacher in space, Christa McAuliffe. It was the worst space disaster in American history, made even more heartbreaking by the presence of the crew's families, and it need not have happened. Only the day before, Roger Boisjoly, an engineer with NASA supplier Morton Thiokol, had warned his superiors that there was a serious flaw in the spaceship's O-rings. Boisjoly's fate was that of so many modern-day Cassandras whose well-informed alarms are ignored. Boisjoly's reward for his courageous efforts to prevent the disaster was the end of his career. Since then, he has made his living lecturing on whistle blowing and other ethical issues, in large part, because he was unable to get another job in aerospace. One hard-won bit of advice he gives would-be whistle blowers—make sure you have another job lined up first.

041

Myers, R.H., Montgomery, D.C., Vining, G.G., Timothy J. Robinson, T.J., 2002, Generalized Linear Models: with Applications in Engineering and the Sciences

http://books.google.nl/books?hl=en&lr=&id=LBiT207QLZgC&oi=fnd&pg=PR5&dq=challenger+accident&ots=lDxE-ndpu1&sig=ugj8qWXKKAga55CMQla2MRXC1OE#v=onepage&q=challenger%20accident&f=false

As an example, consider the space shuttle *Challenger* accident, which occurred on January 28, 1986. The space shuttle was made up of the *Challenger* orbiter, an external liquid fuel tank containing liquid hydrogen fuel and liquid oxygen oxidizer, and two solid rocket boosters. At 11:39 EST about 73 seconds after launch, the space shuttle exploded and crashed into the Atlantic Ocean off the coast of Florida, killing all seven astronauts aboard. The cause of the accident was eventually traced to the failure of O-rings on the solid rocket booster. The O-rings failed because they lost flexibility at low temperatures, and the temperature that morning was 31°F, far below the lowest temperature recorded for previous launches.

042

Main, J., 1994, Quality Wars: The Triumphs and Defeats of American Business

http://books.google.nl/books?hl=nl&lr=&id=MpQR01fTv7YC&oi=fnd&pg=PR5&dq=challenger+accident&ots=B24V7vezrI&sig=4ty7VzMAv07uQ4GEaeLBqb1fqoo#v=onepage&q&f=false

The spectacular explosion of the space shuttle *Challenger* with the loss of

all of its crew on January 28, 1986, might have seemed like a freak, random accident. In fact, it had the classic pattern of a specific failure arising out of a flawed system that could have produced failure in many ways. The presidential commission that investigated the *Challenger* tragedy focused, as most such bodies do, on the immediate cause: the O-rings on one of the booster engines that allowed gases to escape through a joint in the booster. The launch occurred after a night of frost, on a day colder than that for any other shuttle launch, and the rubber O-rings lost their resilience and failed to set a tight seal at the joint.

But unlike the National Transportation Safety Board, which looked only at the immediate causes of the Southern Pacific wreck, the presidential commission looked into the root causes of the failure—perhaps not deeply enough, but more than most investigations. The commission found that the original design of the seal was flawed, that engineers at Morton Thiokol, which built the booster, and at the Marshall Space Flight Center, which was responsible for the booster and main engines, had for years warned of flaws in the performance of the seals. On previous launches, especially in cold weather, the O-rings were eroded by burns and marked with soot. But top management never listened to the warnings. NASA acted like a manufacturer such as an auto plant, with management demanding that it "push metal" out the door—and fix whatever problems might show up later. NASA was under pressure from Washington and the media to send more shuttle missions into space, but NASA had no way of fixing the shuttle's problems "later." The engineers well knew that *Challenger* should not fly right after a freeze, but NASA management did not get the message. So little frank communication existed among the NASA units and their contractors that potential problems did not get aired. Four months before the accident, Robert Ebeling, the head of a task force at Morton Thiokol appointed to study the O-ring problem, sent what he called a "red flag" message to his boss. He reported that the work of the task force was being delayed by "every possible means" available to seasoned bureaucrats and that the people in manufacturing, quality, and procurement whose help the task force needed "are generating plenty of resistance."[6]

043

Schiappa, E., 1995, Warranting Assent: Case Studies in Argument Evaluation

http://books.google.nl/books?hl=nl&lr=&id=s-tkBPMrwYYC&oi=fnd&pg=PA57&dq=challenger+accident&ots=IKQ9xMdPxx&sig=cN1hgLiMfgpz_nesyQjSuqheu0U#v=onepage&q&f=false

Dennis S. Gouran

In the months following the ill-fated and widely publicized flight of *Challenger*, the Rogers Commission identified "flaws in the decision making process" as the "contributing cause" (Report of the Presidential Commission on the Space Shuttle Challenger Accident 1986, p. 82 [hereafter Report]). Most notable among the factors involved was the "propensity at Marshall [the Marshall Space Flight Center in Huntsville, Alabama] to contain potentially serious problems and to resolve them internally rather than communicate them forward" (Report 1986, p. 104). At least one of these "potentially serious problems"—O-ring failure in the solid rocket booster field joints—had been an object of continuing concern, however, since at least 1977 (Cook 1986) and subsequently proved to be the actual physical cause of the explosion that destroyed the shuttle and sent the crew members to their unfortunate deaths. For nine flights prior to 51-L, moreover, evidence of the problem was consistently available to NASA officials and part of virtually every engineering assessment from 1984 forward (Cooper 1986). These facts prompted the Rogers Commission also to conclude that the destruction of *Challenger* was "an accident rooted in history" (Report 1986, p. 120).

As one sifts through the volume of facts and testimony that have surfaced in investigations of the Rogers Commission, the House Committee on Science and Technology, and scores of independent journalists, the conclusion that the decision-making process was flawed seems hardly subject to dispute. Why the process in arriving at launch decisions failed, however, is a matter worthy of further inquiry. The Rogers Commission locates the problem in the procedures NASA established, but I would contend that the system failed not so much as a result of the procedures involved, but because of weaknesses in argument. The failure in the particular case of *Challenger*, further, was the culmination of a set of historical circumstances in which argument, conceived both as reasoned judgment and persuasive influence, played an important role.

044

Miller, A., 1999, Environmental Problem Solving: Psychosocial Barriers to Adaptive Change

http://books.google.nl/books?hl=nl&lr=&id=6FVjFJ6snIsC&oi=fnd&pg=PR5&dq=challenger+accident&ots=rL1FtLWYtD&sig=5EcLO7XQEJYvgCYZOW17nr1QUX0#v=onepage&q&f=false

tigating the accident to include, among other things, flawed decision-making procedures.[12] The *Challenger* accident, therefore, is a prototypical example of a complex sociotechnical problem.

The destruction of the *Challenger* space shuttle is a good example of a complex but relatively tame problem. On January 28, 1986, shortly after takeoff, *Challenger* exploded, killing the seven-member crew. Subsequent investigation determined that the immediate cause of the accident was a failure of the O-ring seals in a booster rocket. The potential problems with these seals in cold weather had been recognized before the launch by engineers working for the manufacturer of the booster rockets. On that fateful day, they had argued against launching the shuttle because of the dangerously low temperatures at the launch site, only to have their position overridden by a management decision.[11] It later became apparent that the technical problem with the O-ring seals was embedded in a much broader set of human shortcomings that were found by the Presidential Commission inves-

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http://books.google.nl/books?hl=nl&lr=&id=v_28AeB1VZYC&oi=fnd&pg=PA1&dq=challenger+disaster&ots=MFN1ohkWnW&sig=iVGkF_gdcx9CS4poOscvu-3A2vY#v=onepage&q&f=false

The *Challenger* Disaster

On the morning of January 28, 1986, schoolchildren around the country watched as, after repeated delays, the space shuttle *Challenger* finally lifted off. Seventy-three seconds later, *Challenger* disappeared in a raging fireball. The Rogers Commission, appointed to investigate the disaster, determined that the immediate cause of the explosion was physical: two O-rings designed to seal joints on *Challenger*'s right booster rocket had failed.

The more fundamental cause of the accident, however, was *organizational and political* (Hult & Walcott, 1990). The Rogers Commission called the decision-making system for the shuttle program "clearly flawed." The decisions by NASA management and the contractor were influenced by myriad (political) factors that combined to produce the fateful *Challenger* incident: "turf" consciousness among the three space centers, inadequate communication of the technical uncertainty associated with O-ring risk, and congressional/public pressure to produce results, to name just a few.