for a more thorough analysis of this report and the trends following it. (Marples himself is currently engaged in a second book on the post-Chernobyl developments).

Finally, has the Chernobyl accident acted as a stumbling block in the path of the Soviet nuclear energy expansion porgramme? Marples maintains that in spite of the growth of the anti-nuclear lobby in the USSR and Eastern Europe, the nuclear energy programmes there are scheduled to go ahead at full steam. Marples hastens to add that the Chernobyl catastrophe does not prove that the nuclear industry in the world is inherently unsafe, but rather, in the Soviet case, safeguards had not been adhered to sufficiently; in disregarding safety regulations when 'playing with fire' you can expect to get burnt.

Although our knowledge of the particulars of the Chernobyl accident has been enhanced since the appearance of Marples' book, *Chernobyl and Nuclear Power in the USSR* contains a wealth of information on the nuclear industry in the USSR and Eastern Europe unparalleled in any other study to date. It is likely to endure as a major treatment of this subject for some time yet.

REFERENCE

1. See, for instance, the articles on Chernobyl (including one by David Marples) in the *Journal of Ukrainian Studies* II, 1, Summer, 1986, pp. 3-35, and the recent book by Viktor Haynes and Marko Bojcun, *The Chernobyl Disaster: The True Story of a Catastrophe — an Unanswerable Indictment of Nuclear Power*, The Hogarth Press, London, 1988.

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Challenger: A Major Malfunction *by Malcolm McConnell*
(Simon and Schuster, London, 1987) pp. xv + 269, ISBN 0-671-65439-X.

This book is written in journalistic style, i.e. it is devoid of academic references or footnotes, thus reading is pleasurable and the book will reach a wide audience. The author has done a marvellous job of reconstructing the event of the Space Shuttle Challenger flight which ended in disaster on 28 January, 1986. The author takes the reader on a day-by-day description of what took place. Indeed, it is fascinating reading for anyone who has not been as intimately involved in the mishap as the author. Prior to this assignment, Malcolm McConnell brings credentials as an author of three novels and eight books of non-fiction. He not only was at Cape Canaveral on the day that the Space Shuttle exploded after blastoff, but he has investigated the sequence of events at NASA, has obtained documents through the *Freedom of Information Act* and has questioned a great number of witnesses and important officials, in his quest to make his reporting credible and alive. He succeeds admirably.

McConnell shows how NASA operates. He shows that the agency and its officials were always pressed to ensure that schedules were met, in order to persuade Congress that NASA was efficient so as to obtain funding. This pressure justified cutting corners, changing specifications in spite of technical reasons

not to do so, and, in general, overlooking the human and safety aspects of space travel.

On the one hand, NASA's management has always stated that it would never sacrifice safety for political gain. On the other, McConnell shows, time and time again in his reporting, that the name of the game is to do everything possible to obtain funds and to increase the budget for the agency, even if it meant 'to exercise deceit' (p. 18). Managers balance the tradeoff between what constitutes optimal flight safety and optimal schedules. After a particular space flight is scrubbed four times, project managers were unprepared for the exhausting effort to keep the pressure on crews and on maintenance personnel, in order to follow the exhausting sequence of the following flight attempt. The author shows that, at NASA, 'the order of the day' is to stay on schedule.

An outsider may have difficulty understanding why this is so important. It seems that NASA 'was under the gun' not to disappoint Congress which controlled the purse strings (p. 24). When Challenger was being prepared for flight, spare parts were 'cannibalised' from Columbia because of an inventory shortage. In 1984 and in 1985, NASA was trying not only to meet self-imposed goals, but had to do it under budget constraints and funding cuts. From now on, NASA must make ends meet by having the shuttle program pay its own way. It must show that it is a reliable agency that can send missions up in space on a regular basis. The Shuttle must be designed to be reusable and the program must be cost-effective. NASA promises Congress to keep development costs low and to enter a phase of routine operations. Obviously, it made unrealistic promises that it could not keep. The myth that pervaded the agency is that it could become a 'profitable space transportation agency' (p. 36). NASA has competitors in the European Space Consortium which has successfully launched its own space program and is reaping commercial successes by placing communications satellites in orbit under private contract.

Therefore, it seems that, due to political pressure imposed by Congress, the bureaucrats at NASA compromised the design of the shuttle. It was shaped by economic and political considerations (p. 30). They had to abide by 'cost-effectiveness considerations'. In order to obtain credibility and funds they became involved with the Air Force which had goals of its own (p. 38). They changed the design to accommodate to Air Force requirements. They abandoned prudence because they were forced by weight restrictions to remove the launch-abort rocket escape system. Safety was to be engineered in the space shuttle system to obviate the need for escape rockets (p. 40).

The author dwells on interesting questions of vehicle design. The Shuttle design presented vexing technical challenges. Two main problems resisted easy solution: first, tiles would not stay glued on the orbiter and, second, the main propulsion system was not fail-safe (p. 41). Engineering problems are liable to be solved by technical people. However, they became enmeshed in political wrangling. In 1972, the wrangling apparently ended and the space shuttle design was frozen and received the go-ahead for the building stage. In the end, "Instead of a horse . . . NASA got a camel . . . : a hybrid machine created by a series of compromises and the politics of procurement" (p. 43).

McConnell describes how the contractors secured positions of influence to become the suppliers of choice. Supposedly, a confidential process to pick bidders was used. The author tried to obtain information through the *Freedom of Information Act* but his application was rebuffed and never really honoured (p. 47). He accounts appeals and disputes between rival bidders.

A McDonnell-Douglas proposal, related to the design and construction of the space shuttle orbiter, 'actually anticipated the cause of the Challenger accident' (p. 49). They proposed a "burn through wire" system that would have sensed the 'O-ring leakage'. However, the system was deemed to be too heavy and was never accepted (p. 49).

Utah was the home state of Dr K.J. Fletcher, NASA Head Administrator. He had an interest to see Utah prosper. The author concentrates on the secret work of the Source Evaluation Board, the membership of which NASA apparently keeps secret, to decide on successful bidders of multibillion dollar contracts. McConnell brings up the connection between Dr Fletcher and the Mormon Church whose home base is Utah. He questions whether the choice of Thiokol as the prime contractor was solely carried on technical merit. The author even raises the ugly issue of religious bigotry whereby '. . . organised religions have long lobbied the political leadership to obtain specific secular goals' (p. 55). In the end, with an under-funded spare parts system which undermined the vehicle's operational efficiency, the author labels the question of 'turnaround time' to maintain established schedules 'a semi-public scandal' (p. 61). As we well know it, it took its human toll.

As I stated above, about this time, NASA found itself with serious competition for the lucrative international satellite program. The European Consortium could offer very competitive launch fees to its growing international clientele (p. 63). Thus, NASA had to prove it could meet the 1985 flight schedule in a dependable manner. However, the very nature of tight schedules created pressures and engendered conditions that threatened launch schedule reliability (p. 65).

The problem of re-uniting all the parts of the shuttle became a real headache: the orbiter, external tank, solid rocket boosters and the various payloads were to be brought together in exact sequence. Inspection, refurbishment, repair and certification were added responsibilities. Almost every inspection revealed unforeseen problems. Failures of the engines and the chronic tile problem delayed the first shuttle flight several years.

Thousands of systems and sub-systems had to achieve a perfect level of reliability to obtain overall fail-safe status. There were over 700 items with Criticality 1, which meant that they had no backup systems: they had to operate correctly in every flight. Operator fatigue, caused by the pressure of the working conditions, became a major reason for the mishap (p. 73).

The author refers to the 'Spellbound Press' (p. 79). Through the barrage of a highly skilled publicity campaign, the excitement of high technology and an elaborate security system, the press, somehow, came to believe that NASA was pretty-high infallible and took the shuttle program too much for granted (p. 81). The author himself pleads guilty to have fallen for that myth (p. 82): reporters 'had been seduced by the myth of the operational space shuttle' (p. 87).

Then, the author refers to the politics of space flight which involves the choice of astronauts to fly the Shuttle missions. McConnell recounts important anecdotes and 'juicy tidbits' about the people at NASA and about how they make decisions. He describes the personnel running the Marshall Space Flight Center and, in particular, Dr W.R. Lucas who 'ran the place'. Marshall managers were under strict orders to raise no issue that might result in a launch delay (p. 112).

In 25 Flight Readiness Reviews not a single 'no' on launch readiness had ever come from the Marshall delegation (p. 115). However, in all their might, they could not control the weather which proved to be a major consideration in creating havoc with schedules.

The question of the O-Rings technology. On the second space shuttle mission, when the Solid Rocket Booster (SRB) field joints were recovered, disassembled and inspected, it was discovered that the primary O-Rings in the aft field joint of the right-hand SRB had been badly eroded by hot combustion gases. Officials kept the problem within the confines of the Marshall-Thiokol reporting channels. That they did not report the problem to the Flight Readiness Review Committee reveals the existence of a cover-up. At this time, no one called a halt to the flights until the problem could be corrected. Management waived five more launch constraints (p. 121).

McConnell also reveals the existence of what was referred to as the 'Apocalypse Letter' (p. 108) which basically condemned Lucas and his 'feudalistic' style of management which did not admit criticism. The Capture Feature (or 'Big Fix') refers to a design feature which would have prevented joint rotation and failure. However, it was not incorporated in time (p. 122).

As mentioned, the weather and the pressure of time played important roles in the unfolding drama. First, there was a problem with hatch micro-switches which did not operate properly. Then, ambient degree restrictions led to a flagrant example of rule bending when NASA management 'simply wrote a waiver to the temperature rules which controlled certain parts of the nose cone: '[NASA was] taking yet one more "acceptable risk" with disastrous potential' (p. 163).

Then came the question of the infamous O-Rings joints. The author recounts with 'horrible' detail the problems concerning the booster field joints. He provides a graphic exhibit of the evolution of the shuttle booster joint at the beginning of the book which vividly illustrates the various design proposals, the original design and the adopted design under unstressed and launch stress conditions.

And then came 27 January, 1986, the day prior to the launch. McConnell takes the reader through the recommendation to launch under unfavourable weather conditions. On the one hand, the solid propellant rocket propulsion motors had performed flawlessly for 19 space shuttle space flights. On the other, the field joints of the solid rocket booster had been a source of mounting anxiety. They had been the subject of a continuous redesign effort (p. 179).

NASA did not want to expose the original field joint design to hostile Congress scrutiny (p. 181). Engineers at Thiokol were aware of the dangerous situation. They were concerned with the effect of predicted cold weather on the operation of the field joint under extreme conditions. The situation prompted the convening of a teleconference which involved two NASA organisational levels (p. 186). However it never involved Levels I or II (p. 186).[1] Additionally, the reader is referred to other works which show the fundamental dilemmas which the management of highly complex technological systems are facing nowadays.[2]

The author of *Challenger. A Major Malfunction* emphasises the fundamental difference between judgemental decisions taken by managers and politicians, and technical decisions taken by engineers. The former are based, for the most part on qualitative evidence weighed by a smattering of quantitative data, whereas the latter are usually based on what engineers believe to be complete and fully documented information (p. 187). This difference was to play a crucial role in the history of the Space Shuttle. One of the Thiokol Engineers had earlier been requested to prepare a detailed engineering presentation on quantifiable test data that would convince NASA management about the sensitivity of the booster O-Rings to cold temperatures. The Thiokol engineers always claimed that deciding on the decreased resiliency of the joint under very low temperatures

should be 'an engineering decision, not a program management decision' (p. 193). A discussion between engineers and management ensued (p. 197). Finally, it led to the removal of the discussion from the realm of engineering and the calling for a management decision.

The author recounts in detail the fateful teleconference where the decision to launch was taken. The vice-presidents of Thiokol overruled their own engineers and recommended for launch. However, the author tells of the 'mutual deception' that 'lay at the heart of the exchange between NASA and Morton Thiokol' (p. 203).

The Decision to Launch. The computer tapes which were studied after the accident revealed other mistakes that occurred during the launch. There was evidence of bureaucratic wrangling such as discussions on who reports to whom and who will tell what about conversations concerning the hazard due to the weather. The evidence, as revealed during the Rogers Commission[3] is far from clear. Arbitrary decisions were taken (p. 218). The eternal question of the extent to which 'unquantifiable risk' can be quantified was raised (p. 229). The Rogers Commission cited the 'breakdown of communications as the prime example of NASA's flawed decision-making process' (p. 235). The author provides detail into the anatomy of conflagration and destruction which led to the disintegration of Challenger.

McConnell is an excellent writer and, therefore, paints a very moving picture of the events which surround the launch and the final episode of a 'Major Malfunction'. He closes the book with a plea to NASA and to the public 'to return to reality', shatter for ever the myth of infallibility, and above all, try to fit the space program within a more realistic view of technological, economic and political constraints.

NOTES AND REFERENCES

1. See also US Presidential Commission, *Report on the Space Shuttle Challenger Accident*, Washington, DC, June 1986, and J.P. van Gigch, *Decision Making about Decision Making: Metamodels and Metasystems*, Abacus Press, Tunbridge Wells, 1987.
2. See C. Perrow, *Normal Accidents, Living with High Risk Technologies*, Basic Books, New York, 1984 and J.P. van Gigch, J.A. Borghino, J.F. Le Moigne, A.R. Logan and V. Vervilos, 'A Metasystematic View of a Disaster: Example of the Space Shuttle Challenger Failure', *Human Systems Management*, 7, 259-64, 1988.
3. US Presidential Commission, *op. cit.*

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