symptoms and mitigative aspects of such games to provide a rationale for effective management that transcends such behavior.

As technology becomes increasingly more complex, the distortion of information carries the potential for ever more catastrophic results. For the culture of safety to prosper in an organization, it needs to weed out any problems in the flow of information by analyzing its style or styles of management and, if necessary, adjust its attitude on the flow of facts in order to assure that management has the best possible information to work with. Safety, as indeed performance in general, can therefore be seen as a combination of: (1) Structure; (2) systems; (3) culture; and (4) behavior in an organization. By actively pursuing a policy of unbiased information utilization, management will assure not only proper performance of organizational function, but will also insure the financial health of the organization.

Appendix. References

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Discussion by Carlos Santamarina,[8] Member, ASCE

The author has presented the important issue of self-serving distortion of information within organizations, which certainly affects the civil engineering field. In the process of proving his thesis, different sources of biases have been mentioned. The following discussion briefly presents some of these sources related to the author's paper. Potential solutions different from those suggested by the author are envisioned following this analysis.

Limited Perception

All perception is an abstraction of reality, therefore: (1) The perceived world is uncertain and allows for different interpretations; and (2) in all but the simplest cases, one *needs* to have an idea of what to perceive it ("you see what you look for" type of effect). Hence, perception is inherently dependent upon subjective preconceptions. Obviously, only the information that is perceived can be considered in decision making.

Biased Decision Making

There is a large number of biases in individual decision making, e.g., poor intuitive comprehension of probabilities, misuse of heuristics, biased

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processing of feedback. Commitment, to one self or to others, is a particularly important one: it makes individuals vulnerable to external manipulation (in fact, it is the essence of brainwashing). From the point of view of cognitive psychology, both catastrophes discussed by the author can be blamed on commitment: the *Challenger* reflects NASA's commitment to a program, and to the world; Chernobyl shows the commitment of a team determined to run an experiment even if it meant disabling redundant safety devices, one after the other.

Group Decision Making

Collective intelligence may help improve the quality of decisions made by a group relative to an individual's decisions. However, other factors may limit this effect, e.g., influence of seniority and polarization, group pressure and conformity, and different individuals' understanding of a problem.

Communication Difficulties

Communication is much more than transferring information; it is sharing meaning. It requires common interest, background, and understanding; it also needs feedback and a no-noise environment. It is not possible to fulfill all these requirements in practice, so communication distorts information.

Communication in Organizations

As the author indicates (Fig. 1), information is also affected as it flows within an organization. To reduce distortions and omissions, redundancies (i.e., additional channels) and verifications (i.e., checks) are implemented. These measures produce information overload and slow handling of messages. To improve this situation, organizations react by filtering information, queuing messages, and adding assistants. The result is new distortions and omissions; Fig. 2 depicts this cycle.

In conclusion, characteristics inherent to the human nature are found at the heart of the organizational problem. It is doubtful that increased level of responsibility or even changes in education and training would have a major

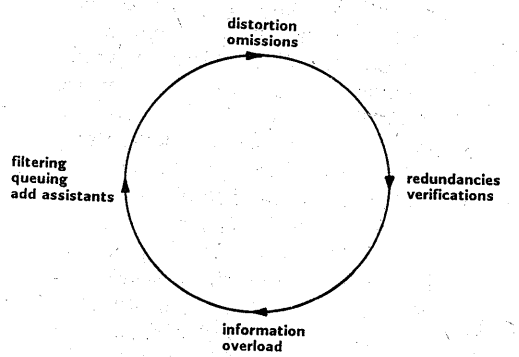

FIG. 2. Effect of Redundancies and Verifications (Ferguson and Ferguson 1980)

effect on preserving information (assuming that an adequate level of motivation already exists). In addition, redundancy in communication may not have an important effect either. Radically different forms of organization or maybe the use of intelligent communication systems will be needed to have a real impact on this reality.

APPENDIX. REFERENCE

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Closure by David A. Bella[9]

From the discussions, it is clear that engineers with varied backgrounds have reached similar conclusions. Organizations can and do produce systemic distortions, the consequences of which can be serious, even catastrophic, and these problems have not been adequately addressed. The discussions provide important additions to the original paper.

Stephen Johnson is correct in his assessment that systematic distortions should be expected in all organizational systems, and he is correct that the Vietnam War provides tragic examples (Gibson 1986). I agree completely with his assessment that "many of the problems faced by modern society cannot be solved by either more complex organizations or by technology." Two hundred years ago the authors of the U.S. Constitution were deeply concerned for checks and balances on power. In our world, unprecedented power arises through the organizational management of technology. Unfortunately, our society has failed to address adequately the need for checks and balances on this form of power. Instead, we are led to believe that any problem should be solved by increasing this power itself. Johnson presents an alternative view. I agree!

The last sentence of Johnson's discussion states clearly that "we should recognize the current limit of our ability." More than 17 years ago, the author published a paper that claimed that our ability to foresee the environmental consequences of technological change would increasingly fall behind our ability to produce technological change (Bella and Overton 1972). The paper reasoned that we would lack the ability to predict the consequences of our actions and thus a strategy was outlined that recognized such a "limit of our ability." Events since this publication support this assessment and thus, the strategy proposed 17 years ago is relevant today.

David Colony states that history provides tragic lessons where organizational systems led to senseless and destructive wars and the risk continues (Bella 1987). The outbreak of World War I is a case in point (Tuchman 1962). However, Colony also points out that despite the dangers, we depend upon such organizations "to achieve much of what we regard as benefits of civilization." This paradox of danger and dependency was the central theme of President Eisenhower's famous farewell address in which he warned us about the "military-industrial complex (Eisenhower 1961)."

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Colony correctly states that a serious deficiency in ethics, including engineering ethics, is the tendency "to deal largely with relations between individuals or between an individual and society; there is little consideration of organizational systems as potent forces in that society." This deficiency is reflected in professional education which, too often, is limited to preparing students merely to serve functional roles within organizations. We do not adequately prepare "citizen engineers" who can improve the independent assessments of organizational actions. Colony's concluding paragraph, and the last sentence in particular, should be required reading. I agree!

Carlos Santamarina points to different sources of biases. His statement, "communication is much more than transferring information, it is sharing meaning," is extremely important and contains philosophical implications that are seldom addressed in this "information age." I agree that radically different forms of organization may be needed, though I am skeptical that "intelligent communication systems" will help resolve the important problems.

The discussion by Rao, Kavianian, and Sanchez also points to the importance of ethical behaviors. I particularly agree with their assessment that "as technology becomes increasingly more complex, the distortion of information carries the potential for evermore catastrophic results." However, I question their assessment that the primary responsibility for avoiding such responsibilities rests with top management. Frequently, top managers are most dependent upon the information networks of the systems that they manage. Consequently, their perceptions are most influenced by systemic distortions. In addition, they have been selected by the organizational system itself, and we can't count on top managers to act upon unfavorable information that might "rock the boat." Thus, if they are to produce the needed changes, they will need to be pushed by others who are not at the top. In other words, top managers must be held more accountable to independent assessments.

I agree with Ananda Moonasingha's assessment that the "momentum to implement the project" can pose serious problems. This is why it is important to raise difficult questions as early as possible. Difficult questions often lead to unfavorable information. Once the momentum of a project is established, such unfavorable information tends to be filtered out.

On the Chernobyl accident mentioned by Moonasingha, it is important to point out that, while the detailed events that produced the accident could not be predicted, the tendency of these types of nuclear reactors to go unstable at low power levels was known. Consequently, this type reactor design was rejected in the West. The Soviets did construct such reactors, perhaps because, unlike in the West, there were insufficient independent assessments to expose "unfavorable" information concerning the dangers. Perhaps "glasnost" (openess) and "perestroika" (restructuring) will serve to reduce such systemic distortions.

Finally, it appears that all agree that the tendency of organizational systems to distort information is a serious problem that has not been adequately addressed. It follows that ASCE should devote serious efforts to address this problem. I hope that the ASCE organization itself does not filter out such "unfavorable" information and dismiss both the author and the discussions as "troublemakers." (See Fig. 1.)