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Writing Assignment – Professional Development (reading 10 minutes, writing ~20 minutes)

Please read *The Design of Aerospace Mechanisms, A Customer's Opinion*, by Major James C. McSherry (1969) and then answers to the following questions.

Two attitudes appear in mechanism design as well as many other fields and component sub-classes:

Apathetic indifference Complete distrust

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1) Describe two subject/fields/components types in your organization in which the attitude is apathetic indifference. Why do you think this is the prevalent organizational view?

2) Describe two subject/fields/components types in your organization in which the attitude is complete distrust. Why do you think this is the prevalent organizational view?

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Please answer two of the following three questions.

3) Describe an example in your organization in which individual prejudices or biases had an outsized influence on the design of a system.

4) What prejudices do you hold? About design, about designers, analysts, analysis, and/or management?

5) Identify one or two "Management created constraints" on your project. What is the likely impact of these constraints?

6) Where are funds being limited in your organization or project which risk system success?

The mechanisms designer, therefore, is faced with a seemingly impossible job. He must convince Case II thinkers that "mechanical" is not a dirty word, while, on the other hand, he must convince Case I thinkers that mechanisms are not so simple and trivial that development testing is unnecessary.

1) From the conclusion paragraph reprinted above, please describe how you would convince Case I and Case II thinkers to change their views to a more moderate stance.

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Assignment Feedback

Your feedback is used to refine and hone these assignments as part of a continuous improvement process.

Question	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
I would recommend this assignment to colleagues	O	O	O	O	O
This assignment was relevant to my work and professional experiences	O	O	O	O	O
I enjoyed this assignment	O	O	O	O	O
The length of this assignment was just right	O	O	O	O	O

Other Comments

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The Design of Aerospace Mechanisms—A Customer's Opinion*

Major James C. McSherry

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The overall design of an aerospace system is—and ought to be—highly influenced by the customer. But far too often the design of details is equally influenced by personal bias of the program manager. The biases seem to take the form of two attitudes: (1) anybody can build a mechanism, or (2) nobody can build a mechanism. It is the responsibility of mechanism designers, through efforts such as this symposium, to combat such biases.

I. Introduction

On one of the first flights of the X-7A-3 ramjet test vehicles over the White Sands Missiles Range in New Mexico, an actuator rod failed in the elevator control system. The failure caused the vehicle to nose over, go unstable, and eventually crash.

A few days after the flight, a group of engineers came into our office to show us the proposed solution. The hydraulic actuator and rod were to be replaced with an electric motor, worm gear, and rack and pinion system. This would be much stronger and give better response, etc., but would cost several dollars and delay testing about a month on a crash basis.

*The opinions expressed in this paper are those of Major McSherry himself, and do not in any way reflect the opinion of the Department of Defense, the United States Air Force, or the Office of Aerospace Research.

Since I was still quite naive in 1958, I asked them why they did not just put in a stronger actuator rod at comparably no cost, and no delay, especially since the current design had worked on two other flights, and this failure had nothing to do with the hydraulics at all, just the rod. After some uneasy squirming and a few nervous coughs the spokesman for the group said, "Well, that *was* our original proposal, but frankly, we didn't think the Air Force would buy it."

This was the first time I realized just how much the individual prejudices of the customer, be he the Project Officer, SPO, Program Manager, or whatever his title, influence the detail design of an aerospace vehicle. Some managers are often prone to arbitrary decisions based on their own bitter experiences. As a general rule, in satellites, bitter experiences with oddly behaving mechanisms are more bitter than bitter experiences with electronics.

A mechanism failure usually means mission failure: antennas that don't deploy, satellites that don't separate from their booster, etc. An electronic failure can be disastrous, but more often (and they are more often) they result in degradation, not negation, of the mission objectives. For example, two of the OV1[1] failures to achieve orbit were mechanical.

II. The Two Cases

Those managers whose programs have escaped disastrous failures of mechanisms, however, seem to feel that mechanisms are no problem since they always work. Therefore, there appear to be two basic attitudes towards mechanisms: apathetic indifference or complete distrust.

While pyrotechnics, propulsion, and electronics have often enjoyed (or suffered) top-level management attention, the lowly mechanisms have been brushed aside with the premise that since *anyone* can design a mechanism that works perfectly, there is no need to expend wasteful manhours in testing or improving these mechanisms. Following the catastrophic failure that nearly always results from such philosophy, the same high-level managers then assume that *no one* can design a working mechanism, and proceed to see how it can be replaced by a solid-state subminiaturized electronic component costing ten times as much, with many hours of testing, redesign, and qualification.

The foregoing hypothetical situation illustrates what I will call Case I and Case II thinking; that is,

Case I: Anybody can build a mechanism.

Case II: Nobody can build a mechanism.

Case I thinking is most evident in low-budget programs, where, because of the proverbial champagne tastes and beer pocketbooks, the first thing to be scratched is extensive testing of the mechanisms. This can be seen in such actions as modification of existing designs, such as stretched heat shields or adaptation of mechanisms.

Case II thinking is usually seen in high-budget programs, and as a result I don't have too much experience in this area. The examples with which I am familiar lie in the area of electronic vs electromechanical components. The trend is obviously away from anything mechanical. The solid-state commutator in telemetry systems has replaced mechanical commutators. Mechanical timers for programmers are a thing of the past. Solid-state memory circuits with literally thousands of electronic parts are replacing tape recorders for satellite data systems, and relays will someday be replaced by solid-state electronic devices. The dream of every electronic engineer is to point with pride to his satellite and proclaim "It has no moving parts." Those people who suffer from Case II thinking generally believe that "mechanical and simple" is crude, while "electronic and complex" is sophisticated. The result of this philosophy is higher cost to the customer and not necessarily higher reliability. The tape recorder in OV1-13 has now been operating for 11 months with no anomalies, and the tape recorder on OV1-15 operated until reentry.

Following are some examples of mechanism failures that may have resulted from Case I thinking.

III. SESP 68-1

In order to lower the high cost of putting satellites into orbit, one recent trend has been the increased complexities of launch vehicles as more and more satellites are launched from a single booster. This trend gives rise to complex truss, separation mechanisms, and heat shield designs.

One example of this concept was the SESP[2] 68-1 launch of an *Atlas* (SLV-3) with a *Burner II* upper stage using a *Thor/Burner* heat shield that had been stretched some 266 in. longer than its original length of 134 in. A total of 10 satellites were launched on this booster, all of which were lost because the heat shield did not separate.

IV. OV1-7

The OV1 satellite was mounted on the nose of an *Atlas* inside a "double coffin" style of heat shield. One experiment was too big to fit inside the satellite and so a small bulge was added to the heat shield. The bulge changed the aerothermal loading enough to cause the

[1]*Orbiting Vehicle*, Type 1, one of a series of basic research satellites managed by the Air Force Office of Aerospace Research. Each satellite carries a different complement of scientific experiments. OV1-17 is the seventeenth satellite in the OV1 series; OV5-4 is the fourth satellite in the OV5 series, etc.

[2]Space Experiments Support Program, managed by the Air Force Space and Missile Systems Organization.

door to temporarily hang up before opening. The delay was just enough to allow the satellite to collide with the door during the ejection sequence. Needless to say, this impact caused a rapid misorientation of the vehicle and, even though the propulsion module guidance tried to correct, the initial offset was too much. Rather than going into orbit, the satellite impacted in the Indian Ocean.

V. OV1-86

This OV1 was a basic research satellite which should have been gravity-gradient-stabilized. However, volumetric constraints dictated that the gravity-gradient system had to be mounted inside the satellite and then "unfolded" in orbit. The resulting mechanism was quite complex and failed to erect properly in space. This caused the loss of a great deal of data.

The major cause for these failures was the management decision that created the constraint. Since then, the OV1s have been mounted within an 84-in.-diameter heat shield that allows such protuberances to be mounted in the erect position. This eliminates the problem at its source.

VI. OV2-5

This satellite had many mechanisms on board to erect or deploy solar panels and experiments. The deployment sequence was very unsuccessful. Of the 12 antenna paddles and/or experiments to be unfolded or extended, only five performed without some sort of an anomaly.

The foregoing examples of what can go wrong with mechanisms are primarily examples of lack of sufficient testing in the final flight configuration, usually caused by limited funds. The program manager must decide where to limit funds, and often the mechanisms testing is the first area to be limited. Although this is a compliment to mechanism designers, the trend of more failures can cause your customers to adopt Case II philosophy and turn to the belief that anything mechanical is unreliable.

To combat this belief, it is imperative that the design engineer demand, and fight for, his share of the testing time and the development dollars. One good way to do this is to emphasize the consequences of a mechanism failure such as the examples presented here.

VII. Electrical Connectors

And while I have your attention, I would like to voice a complaint about my own pet peeve: electrical connectors that can be reversed. Mechanism designers can be of great service in preventing such failures as the following examples of Murphy's law.

During the final prelaunch test of an X-7A test vehicle the 400-cycle inverter was found to be defective. The test was halted and the faulty inverter was repaired and reinstalled. When the test was resumed, a technician noticed that the pens on his strip recorder moved the wrong way, so he quickly reversed the polarity switch. The test was finished successfully even though every gyro in the missile was running backwards.

The malfunction went undetected through launch, and *everyone* who saw the reversed polarity automatically assumed the mistake was in the test gear.

The vehicle was launched from the bomb bay of B-50 airplane, and the first disturbance came in roll a few milliseconds after release. The backward-running roll gyro sensed the error and caused the control system to move the aileron in the wrong direction, first a little bit, and then to full deflection in the wrong direction. The booster rockets ignited and the vehicle, spinning at a very high rate, proceeded directly earthward and screwed itself into the New Mexico desert, traveling about Mach 2.5 on impact. The tail of the 28-ft-long vehicle was found after digging down a little more than 10 ft.

The point here is simple. Proper design of the power connector to the inverter would have made it impossible to reverse the leads. It was a small, simple part, on which just a little bit more thought would have prevented a catastrophic failure of a million-dollar vehicle. Perhaps even more important is the fact that at least 15 people had the opportunity to catch the mistake, but no one did. The obvious fix was incorporated. The same design problem, i.e., reversing two wires at a connector, has caused catastrophic failures on other programs, such as

(1) A converted *Matador* missile, which was used at Holloman Air Force Base as a target drone for such missiles as *Nike*, *Falcon*, *Hawk*, and *Sidewinder*. The left and right controls were reversed and the drone was launched in that configuration. The flight lasted about 2 seconds and the missile

crashed a few hundred yards in front of the launch pad.

(2) The famous incident at Cape Kennedy where the Range Safety Officer's plotting board was miswired between East and West. This caused the Range Safety Officer to think that a ballistic missile heading downrange was going inland towards Orlando; whereupon, he destructed a perfectly good missile.

(3) A Q-4B target drone on which the pitch gyro was miswired, not once, but on *three* separate flights! You would think they would have learned after one.

VIII. Conclusions

The mechanisms designer, therefore, is faced with a seemingly impossible job. He must convince Case II thinkers that "mechanical" is not a dirty word, while, on the other hand, he must convince Case I thinkers that mechanisms are not so simple and trivial that development testing is unnecessary.