Instar

Doing Things Right in Space Programs

This article is part of a series started in January, 2000. My intent is to share a philosophy and ideas for how to increase the chances of success in space missions while also reducing total cost. Once these articles are completed, I plan to assemble them into a book. Please send comments to me at Tom.Sarafin@instarengineering.com.

Ten Principles for Doing Things Right in Space Programs

1. **Adopt the right attitude**
2. **Invest in knowledge and understanding**
3. **Instill ownership and responsibility**
4. **Constantly seek ways to improve teamwork**
5. **Follow a sound engineering approach**
6. **Reduce total cost through good engineering**
7. **Keep everything as simple as possible**
8. **Establish an effective quality system that involves everyone**
9. **Be willing to accept risks, but only those you truly understand**
10. **Make sure everyone has enough time, resources, and freedom to do things right**

Article #10

Constantly Seek Ways to Improve Teamwork

November, 2000

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In the ideal space program, everyone works together with trust and cooperation. Everyone has the same objectives; there are no hidden agendas. Roles and responsibilities are clearly defined and well understood, with no overlaps and nothing missed. Requirements and designs aren't released until all inputs are incorporated; designs flow seamlessly into manufacturing because processes and tooling are already in place, and the products move equally without problems into test and integration.

Everyone diligently meets his or her responsibilities and is fully informed about the work of others. Issues and risks are shared openly between contractors and customers.

Nothing I've described here is unique to the space industry. Such an ideal—such teamwork—is the goal when developing any product, regardless of industry. It's not an easy goal to achieve.

We will never achieve perfection, but we should always strive for it. Let's look at some of the things that support this goal. Before we do, let's recognize that much of the difficulty in achieving effective teamwork stems from conflicting objectives:

- Everyone must feel part of the team: customers, contractors, technicians, secretaries—everyone. Anybody excluded will feel resentment and will have different objectives. We all know (or should know) how an uninformed or misled customer can make our lives miserable and impose nonsensical requirements. If a technician can cause the entire mission to fail by installing a countersunk washer upside down, we can't risk alienating him by treating him with mistrust or derision. And a single disgruntled secretary can sabotage relationships and nearly cause a program to grind to a halt.
- But teams work best when small. The ideal team is a single person who keeps everything in his or her head. The more people on the team, the more time spent communicating, and the greater the chance of misunderstanding. Large teams spend much of their time in ineffective meetings and struggle to get things done.

When developing a complex system , we solve this apparent dilemma by creating teams at multiple levels. Everyone is on the top-level team, with the objective of a successful program, even though not everyone attends every meeting. Small product teams are represented by their team leaders in subsystem teams, and subsystem leads represent their teams at system-level meetings.

As discussed in previous articles, we also try to reduce team size by broadening the roles of team members rather than staffing programs with dozens of specialists. This is especially important for teams at higher levels. Leads representing teams at system-level meetings must have a broad and deep understanding of all the technical and non-technical issues related to the product team, as well as those related to interfaces with other products.

The role of a systems engineer is to coordinate efforts of the product teams towards the goal of an efficient and dependable system. As such, the systems engineer should have the broadest knowledge of all, along with a sound appreciation of the contributions of each supporting discipline. An effective systems engineer is also a good communicator and is the obvious choice for team leader, especially for a high-level team.

Any form of competition between team members is a barrier to effective teamwork. Several of W. Edwards Deming's fourteen points addressed this issue, including #8 ("Drive out fear") and #9 ("Break down barriers between departments"). An example of competition is annual raises based on ranking one employee against another. Can you see how this might discourage cooperation? Individual awards rather than team awards can do the same thing. There is nothing wrong with recognizing stellar performance on the part of an individual, but nomination for an award should come from within the team rather than an outside entity.

Creation of functional departments within an organization, although justified to ensure technical competence, invites barriers. Departments often fight for the same pot of money and evolve their own functions and responsibilities that sometimes don't mesh.

People within departments tend to sit together rather than with team members. As a result, interdisciplinary team members tend not to trust one another and thus work toward separate goals.

Many programs have succeeded in breaking down departmental barriers and creating closely knit product teams. But, even here, competition between teams can become a problem. It does little good to award a team for getting their product out on time if that product doesn't interface properly with others in the system, or if that team delayed another by withholding information.

We can't forget we're all part of the overall team. We all must treat each other, regardless of position, with respect and common courtesy. I once worked for a manager who, when in a foul mood (which was often), would not acknowledge my presence when I said hello as we passed in the hall. If he treated me this way, as one of his lead engineers, how must he have treated the people building his hardware when he visited the assembly room?

In hindsight, it's easy to recognize our own failures in treating others with respect. I recall, as lead test engineer, making it clear to the instrumentation technicians that I didn't trust them by insisting on personally inspecting all their setups of displacement gages. There's nothing wrong with conducting such a review; what was wrong was the way I handled it.

One of the most important ingredients for effective teaming is honesty. We openly share what we know only when we fully trust the people we are working with. Your customers load you up with requirements pertaining to <u>how</u> to do the job when they don't trust you. Quite often, such lack of trust stems from a belief that you aren't telling them the whole story. Customer representatives attending design reviews usually know when you are hiding something. Above all else, treating your customers right means being honest with them. The same is true for our relationships with contractors, coworkers, supervisors, and subordinates.

Most people don't give out their trust freely. Some amount of suspicion is normal between strangers. As I mentioned above, departmental barriers breed additional suspicion. To develop the needed trust, team members must spend time together (co-location helps greatly) and be permitted to socialize. Standing around the coffee machine talking about last night's football game may appear to be a waste of time, but, in moderation, such small talk is essential. Only then do people see each other as people and realize they have the same overall objective. We must break down the inevitable interpersonal barriers before we can function as a team. The most effective people do NOT keep their noses to the grindstone all day!

As an example, I once was hired to represent a space-mission customer to review the work of the prime contractor and assist where I could to ensure a successful mission. Yes, I was to be a dreaded "customer consultant." My client introduced me to my counterpart on the contractor side, who shook my hand but otherwise made it known I was not welcome. As I had never served in this role before, I was faced with a new problem. I had no hammer; the contractor could skirt around any suggestion I made. How could I influence things for the better?

For the first month or so, my counterpart and his people dismissed my suggestions and questions without thought, and I was starting to get dejected. But I persisted. I worded my comments with respect, and I thought through things before I said them. I listened to the responses carefully. As time passed, these people realized I was a reasonable person sharing honestly my desire for program success and raising questions that they should be able to answer. Along the way, we got to know some about each

other's personal lives. Before long, my counterpart was calling me: "Tom, we've got a problem, and I was wondering if you could come out here and help us with it."

Adopting the Right Attitude with Contractors and Employees

Having the right attitude (Principle #1) obviously includes treating your customers right, but what about your contractors? You are their customer; how do you treat them?

A couple years back, I was at a relatively small company to teach a course and was introduced to the company president. The philosophy he had bred at his company was that the customer is king. They weren't going to treat their customers arrogantly like so many other companies; they would bend over backwards to make their customers happy. Sure enough, he walked his talk in my presence. While greeting me, he suddenly turned his head to look down the hall, where two men in suits were approaching. Interrupting himself in mid sentence, no longer making eye contact with me, he said "I have to go. My customer's here." His face lit up in a big smile, he left me, and he profusely greeted his customer.

This man was my customer, and I had wanted to teach the best course I could to his people. But, for a moment there, as I stood left in the lurch, having been told clearly that I was unimportant … I wasn't quite so sure I wanted him to succeed.

Remember this: **the quality of your product is only as good as the quality of your suppliers and contractors.** You want them to do the best they can for you. You want them to want you to succeed. They won't if you don't treat them right!

Treat your contractors as you treat your customers!

The same is true for your employees. Times have changed. Managing by intimidation, although never desirable, does work when times are tough. My grandfather was a farmer and a bricklayer in Northern Ohio. In the great depression, he would head out each day looking for work and sometimes finding it. One day, he came across a line of men building a long brick wall. He went to the foreman and asked if he could use another hand. The foreman answered, "Not right now. But you see all these fellows bent over that wall? Sooner or later, one of them's going to straighten his back. You can have his job." And his voice was loud enough to be heard by the last man.

Nowadays, how well do you think such a tactic would work? Jobs are easy to come by, and people aren't so much motivated by the need to put food on the table. Managing with a club works only if you have a big club. Without it, people will either go elsewhere or stick around merely to collect a paycheck, knowing full well they can ignore the club holder.

As economic times and lifestyles have improved, management philosophies have gone through necessary change. We've discovered different things that motivate people to do good work, such as challenging assignments, influence, and respect from others. Along the way, we have learned that treating our people right and keeping them happy (W. Edwards Deming used to say that everyone had the right to joy in the workplace) leads to greater cooperation, productivity, and quality than we ever got through intimidation.

Treat your employees and coworkers as you treat your customers!

Communicating Effectively

Regardless of your position, time spent improving your communication skills will pay off many times over in terms of cooperation by team members and your own influence and contributions. Communicating effectively wins business, lets us understand issues and the things that are important to others, enables us to persuade people to do things we believe are important, and gets us the resources we need to do our jobs. Engineers typically spend more than half their careers in some form of communication; for those becoming managers, the percentage is far greater. Yet probably less than 5% of the typical engineering curriculum is spent developing communication skills.

It shows. Engineers are notorious for poor writing, lack of tact, and indecipherable jargon. We've even been called social morons. (Can you imagine that?)

We may have become engineers because we enjoyed crunching numbers and solving problems far more than writing and speaking, but it's high time we recognize the importance of communication in our jobs and start doing something to improve it. Our influence as engineers depends on our ability to communicate as much as our competence. Our ability to build trust in team members—and thus receive cooperation—depends on our ability to communicate nearly as much as our integrity. And, yes, our assignments and salaries depend on our communication skills perhaps more than anything else. Such dependency may not be fair, but it's undeniable.

Probably more than anything else, poor communication is to blame for high cost in the space industry and mission failures. Consider the following examples of inadequate communication; I'm sure you've experienced some of them:

- Contractor not fully understanding what the customer wants before bidding the job or signing the contract (a lose-lose situation)
- Customer not understanding cost-savings associated with acceptable alternatives
- Customer assuming the contractor will do something regarding verification and quality assurance that the contractor is not planning to do
- Product-team members not understanding what the others need from them and when they need it
- Engineer not fully understanding the purpose of an assigned activity or a legislated standard (not understanding the problem)
- Supervisor, manager, or customer not understanding how thoroughly an engineer or organization has ensured that nothing will go wrong

When two people communicate, one provides information (speaks or writes) and the other receives information (listens or reads). Either part of the process can break down, but the person providing information has the most control.

In technical writing, your goal usually is to help someone understand something or persuade someone to do something. People don't read technical documents to be entertained or to admire your vocabulary or artistic presentation. Keeping a few guidelines in mind will help make your writing more understandable:

- **Keep it simple: words, sentences, paragraphs, and even the document itself.** George Orwell had two rules for writing: (1) If it's possible to eliminate a word, always eliminate it. (2) Never use a long word when a short word will

do. Here's an example of a complex sentence I took from a page-long paragraph in a technical handbook: “The importance of thermal effects for structural components requiring ceramic materials also justifies at least an attempt to rationalize such conditions both with respect to defining the important design considerations and with respect to the question of safety factors.” Can you imagine anyone staying awake through several pages of this?

- **Avoid long strings of noun modifiers**, such as "The communications antenna acceptance vibration test report is due on Friday."
- **Don't use too many acronyms, and frequently define the ones you use**: “The PSLV/FTS CLA LTM results for the PSU exceed the loads achieved in the SMS ATP centrifuge test.”
- **Use punctuation to clarify.** Even the experts don't always agree on how to use commas and other forms of punctuation, so don't worry if you don't use them the way others do. The key is, if use of punctuation clarifies your sentence, then use it. For example, consider "The bid which came in Friday was too high." Is there more than one bid? Do you mean "The bid, which came in Friday, was too high" (there was only one bid) or "The bid that came in Friday was too high" (more than one; we're talking about the one we got on Friday). Use of the word "which" without a comma is ambiguous.
- **Use active voice; don't be afraid to use first person.** Passive voice and never using "I" or "we" are illogical rules that inhibit understanding. “It is assumed (by whom?) that the predicted temperature distribution will be test confirmed (by whom? by which test?).” How about this instead: “I assume you will confirm the predicted temperature distribution with your system-level thermal balance test.”
- **Don't sacrifice clarity for archaic rules for formal writing.** It's okay to occasionally split an infinitive, and sometimes a preposition is the best word to end with.[1]

Although mastering the English language is a never ending and often frustrating pursuit, much difficulty in communication comes simply from not following a sound process. The process of effectively communicating is rational and logical. As such, it's puzzling that so many engineers—supposed masters of the rational and logical—are poor communicators.

When writing something or developing a presentation,

1. **Define the objectives**
   - Why are you writing or presenting this?
   - What do you want to say?
   - How will this document be used?

(continued)

[1] Winston Churchill once responded to a reporter who had criticized him for ending his sentences with prepositions: "Young man, that is exactly the kind of nonsense up with which I will not put!"

2. Identify the target audience
- Who will read, listen to, or use it? How will they use it?
- What do they want to know?
- What do they know already?

3. Identify your constraints
- Available time for development
- Page limit, or time limit for presentation

4. Plan your writing or presentation accordingly
- Develop an outline
- Draft and organize key thoughts and generate figures and tables
- Emphasize the important information and make it easy to find

5. Fill in supporting text
- Anticipate questions and answer them

6. Iterate: Assess, check, and revise your work

As you can see, this process is not much different from how we develop any other product or perform an analysis or test: start by understanding the objectives and constraints, find an effective solution (design), build the product, and then confirm the product's quality before implementing it. If you undertake the task of writing with this idea in mind, your effectiveness as a communicator—and as an engineer or manager—will improve immensely. A similar thought process applies when you prepare to attend a meeting.

Documents and presentations that add little or no value are usually the products of people who are not following such a process. Ask them why they wrote that report, and the answer, more than likely, is something like, "It's required." Or "My boss told me to do it." If you are generating a document or presentation only because your customer or boss told you to do it, I can almost guarantee that document or presentation will be a waste of time—not only your time, but also the time of your audience.

Whether a document is useful or useless depends on whether the person writing it understands and believes in its purpose and users.

I found out long ago, from being on a long-term project, that the main customer or user of the reports I generate is myself. Information changes throughout a space program, and we often have to revisit an issue we thought we had closed. My own memory, as is true with most people, is simply not reliable enough. Without good documentation, we usually have to start from scratch.

As an example of communication within a team, consider a critical design review (CDR). Ask most contractor personnel supporting such a review what the purpose of a CDR is, and the answer will be something like, "To obtain customer concurrence that we are ready to commit to the design and proceed with manufacturing." Before charging off and developing your charts, though, put yourself in your customers' shoes: why are they coming to the review? Most likely, it's because they want to see if you missed anything. Is the design indeed ready for manufacturing?

At first glance, this may seem like the same objective, but look more closely. As a contractor wanting concurrence from our customer, we're tempted to tell our customer only the good stuff. Our customer, on the other hand, is well aware of that temptation and is thus not always willing to believe us. The more underlying concerns we hide from

our customer in order to paint a rosy picture, the less our customer trusts us. People usually know when you're lying to them.

For a truly successful design review, in which one of your objectives is to build customer trust, try to think of the review as your customer sees it. Anticipate your customer's questions and address them beforehand. Not only will this approach lead to a more effective review, it will lead to better engineering.

If you're caught with your pants down in the review, with a legitimate question you can't answer, don't shrug it off or attempt to answer it superficially. This may be the most critical point in developing customer trust; your customer will be watching closely to see how you react. Take an action item and promise to close it soon.

Unfortunately, many programs are under such cost and schedule pressure that the purpose of a design review becomes lost, and the review becomes merely a necessary formality. In such cases, perhaps we should cancel the review altogether (or maybe even cancel the program!). If we can't give the review its due and diligently address the issues and concerns, going forward with the review wastes a great deal of time and detracts from other work. I, myself, believe one or more design reviews, in which we all step back for a minute and try to look at the forest, are requisites to a responsible process.

Like many in the space industry, I've participated in design reviews from both sides of the fence, contractor and customer. When in a customer role, I go to the design review with a single question in mind: "Will it work?" I've attended many CDR presentations in which I'm inundated with numbers, acronyms, and jargon that I don't understand. Afterwards, I'm still asking myself, "Will it work?"

About the Author

Tom Sarafin has been involved in the space industry full time since 1979, at which time he graduated from The Ohio State University with a BS in civil engineering and took a job as a stress analyst at Martin Marietta Astronautics in Denver, Colorado. While at Martin, he was involved with design, analysis, verification planning, and testing on several spacecraft and launch vehicle programs. After contributing to the book *Space Mission Analysis and Design* [Larson and Wertz, editors, first edition published in 1991], he obtained management's support and funding at Martin Marietta for the development of a book on the interdisciplinary development of structures for space missions, and served as principal author and editor for 23 other authors. He left Martin Marietta in 1993 to complete this book, under the guidance of Dr. Wiley Larson at the U.S. Air Force Academy. The result of nearly four years work—*Spacecraft Structures and Mechanisms: From Concept to Launch*—was published in 1995 jointly by Microcosm, Inc., and Kluwer Academic Publishers.

In 1993, Mr. Sarafin formed his own company, Instar Engineering and Consulting, Inc. Once he finished his book, he began providing review and advice as a consultant to space programs. He also developed a short course based on his book and began teaching it throughout the industry. The course has been quite popular, and the business has grown. Now Instar offers a curriculum of courses taught by experienced engineers and continues to add to that curriculum.

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