"Principles for Space Experimentation Success"

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Abstract

Knowledge on how to successfully plan and carry out space experiments is important to have, whether you are flying a mid-deck on board the Space Shuttle or are the only payload on a Pegasus. This paper will discuss principles for the experimentation team to use in the process. Some will be appropriate, some will not, but using the ones that are will aid the team in getting to a successful conclusion.

Managerial techniques and individual lessons learned can be applied to the space experimentation process. From pre-launch planning to post-launch data evaluation, there are things a project manager, yes even an entire team, need to remember. Principles to guide decisions and discussions, affecting every aspect of a successful operation. The effort and expense of doing a space experiment daunts every person who attempts it. The principles exposed below may provide the experimenter with relevant insights and guidance so that many pitfalls may be avoided.

Introduction

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For the people involved in the management of the space experimentation process there exists minimal training programs to teach them how to be successful. The expertise in how to successfully complete the process needs to be provided to new managers. The Principles are an attempt to begin that training, passing along the things that have made decisions easier, sayings that capture the essence of an idea. Thoughts on how to build a team and make it work together better. Encouragement to persevere even when no hope seems to exist. These are things that space experimenters need and the Principles are a first attempt at meeting that need.

The Principles are organized loosely

into categories of my own choosing, "Technical Matters, Project Success, Prioritization and Planning, and People Are Important." These are somewhat arbitrary, but I hope that they flow and will help you.

Technical Matters

Design to "End-of-Life" when looking at your margins

I know this seems like common sense to a more experienced engineer. However, you must remember that your satellite needs to operate just as well at the end of its mission as it did at the beginning. This means that you must include the amount of time it needs to operate in your design. Let me use battery power as notional example. If you need two-ampere hours of capacity to do the task, then a conservative engineer says we need some margin, let's say twenty percent. So, your original power designs would be for a two point four ampere hour battery. This is a straightforward process, but does not take into account any degradation in the capability of you batteries and recharging system because of being in space. A quick search of the literature would tell you that batteries are not as robust in space, suffering from increased aging effects and reduced capability over time. Plus, each recharging cycle will not bring the system up to one hundred percent. What does this mean to our notional system? Let's put some numbers to the process and see if our twenty percent margin is enough.

Take the Original Capacity (2.4 AH) times the Recharge Degradation (0.8) times the Derating for Space Aging (0.75) and you get a battery power at end of life of one point four four ampere hours (1.44 AH). That's not enough to get the final piece of information you wanted from you satellite.

Or, looking at it another way, a satellite that had an expected life of two years now only operates for just over seventeen months.

Again, this is just an example of the process you need to go through. The numbers are unrealistic and only there to make a point. The point is, the last thing the satellite is going to do is just as important to you as the first bit of data you get. So make sure you can get that data. Apply this concept to every part, subsystem, and function - it will make you sleep better at night.

It Is The Little Things That Will Kill You, Know Them

As you go about the process of preparing and launching a space experiment you will find that the most crucial things for your success are the ones that seemingly are minor. The classic example of this is old poem..."For want of a nail a shoe was lost, for want of a shoe a horse was lost, for want of a horse a rider was lost, for want of a rider the battle was lost..." This is very true in all of life, but especially in working on space projects. It is a given that once you get it into orbit, you can no longer fix any problems. So, no matter what anybody tells you about the relative importance of any component or process, they are all important. Take the time to identify them and ensure that they are taken care of. How much all this attention to detail saves you may never be know. How important one of these details can be is something you don't want to find out.

I am reminded of something an astronaut said he thought of while sitting in the Space Shuttle middeck area just prior to a launch. He exact words escape me but the gist of it was, "I'm sitting there looking up at the middeck lockers. Just about to get shaken by the vibration of launch. And I

realize that all of those lockers, all that weight hanging above me, is held into place with just four bolts. And those four bolts were made by the lowest bidder!"

I know you are thinking "But I can't know everything!" Now you know what gives project managers gray hair and ulcers. Take heart though, most things work and work well, just keep and eye out for those things that everyone else seems to avoid. After all, potential problems don't wave signs at you; you have to "uncover" them. My rule of thumb is that if it can't be explained simply in five minutes, it deserves looking into.

If it won't affect the operational characteristics of your satellite - it's not important

Now here's an ugly little question that will help you make tough choices during your design. Keep in mind that if you ask it, you have to deal with the consequences. There are a great many "terrific" ideas that won't pass this test. But in order to use the question, you really have to know what you want, as well as where you are going to be operating. Think about it...if a satellite is going to be operating under the radiation belts, then radiation affects on the computer aren't really a problem. But if it will be exposed to high levels of radiation (or go through the South Atlantic Anomaly), then you better take that into account in your design. This is a pragmatic approach to resolving issues. For instance, two people will have different approaches to solving a design problem - each is valid and would work. How do you choose? Does it really make a difference which one you chose? Not really, unless one is cheaper than the other or more reliable. I would personally go with the cheaper solution, but then I know that

money will always be short later.

You will not make any friends in the choices that have to be made in project management - that's not part of the job. The job is to get the project done successfully. It will entail making tough decisions and enforcing them. But if you want success, that's the price you pay.

Project Success

Plan what you are to do, don't let Panic Set In

Planning is not the most pleasant thing in the world for scientists. I don't know why, but the laying out of a development plan is really hard. People just want to jump in and do stuff. That can be a fatal mistake. The more time you spend doing up front planning, the smoother your project will go. I mean real planning - focusing on the nuts and bolts, not just envisioning what you will have when you are done. Look for the details in the plan and how each task is related to another. Then do "what if's" with your team, come up with variations on the plan and discuss them. What if your solar cells are delivered late? How could you make up the time? Is there anything that could keep the team busy while you wait? What are the weak points in the design? Which parts will likely fail during environmental testing? What will you do about it?

There is an old saying, "The plan won't work, but we can work the plan." It is much easier to make a course correction than to re-invent the plan every time. Keep your changes to a few, and those should be carefully considered. Remember all the thought you put into the original plan… changing it on the fly may have unintended consequences you can't live with. I like to tell people to keep a baseball bat next to

their desk, anyone proposing a change should be hit with it - if they really believe the change is needed, they'll propose it. Also, be wary of anyone who says they want to remain flexible, and uses that to get out of planning. Those people are planning to have problems they aren't prepared to deal with later. In effect, they are planning to fail. Remember, "The person who aims at nothing will usually hit it."

Finally, a quote from General George Patton, "A good plan violently executed now is better than a perfect plan next week".

Everything Works If You Let It

This sounds a little trite, and is meant to be. The processes and systems that are set up work, they wouldn't have lasted so long if they didn't. So give them a chance to succeed, and with them, your project. For instance, if your thermal analysis is going to take 3 weeks and a one-week update gives you bad news, don't panic! You know that it isn't done yet, so let them finish and evaluate the results. Most "back of the envelope" calculations are conservative; so don't let them scare you. There are people and processes out there that will help you get through almost every problem. The real challenge is finding them and using them. The hardest part of the manager's job is to not "fiddle with the controls", knowing when to let something alone is the hardest challenge. Especially if you were an engineer before - watching is agony. But, that is the key to success - letting the process flow with as little disruption as possible. On a previous space launch mission we had weeks of dire news about how our satellite would not survive the launch environment. As the overall project leader, I held my tongue on the issue, letting the structural and launch vehicle engineers work it through. In the end we were "ok", launching and operating a satellite successfully. But we had to let the process work it self-out, we could have called the whole thing off when we got the initial bad news. That would have resulted in failure, failure to launch a satellite, and failure of management in achieving mission success.

A caution, letting something work out is not delaying a decision - it is getting the timing of a decision right. If a decision needs to be made, make it - they don't get any easier with time.

Don't Tell Me How Hard You Worked, Tell Me What You Got Done!

This is a direct quote from an exasperated manager. Basically, most people just care about results - so don't bother talking about anything else unless you are asked. Fight the urge to focus on hours worked or # of people involved - they are great things, but it is the results that count. As in raking the back yard, the amount of time you spent is irrelevant; the question was "Did all the leaves get raked?" Results count; they are after all what you are doing the project to get. Don't forget this point, it has gotten many a project manager fired.

I don't mean to denigrate all of the effort a lot of great people have put into any project. We all know that without literally hundreds of hands nothing could get launched into space. What I am specifically talking about is status reporting and communicating to upper management and the public. Those audiences may appreciate the scale of the task at hand; they may even enjoy discussing statistics privately. But, the majority of people really care about the bottom line, the results.

A final point, there is a great Italian proverb; "It is a good answer that knows

when to stop". That is really appropriate here. Understand your audience and pay attention to them - when you have communicated, stop talking. I have been in a store and have had a salesman talk me out of buying something because he wouldn't shut up and take my money. Don't let this happen to you.

Data Are Wonderful, But Not Necessarily Worth Anything

You have to know what information you need, how you are going to get it, and who is going to get it in order to make a decision. I have spent many hours doing testing in order to find out how something will work once it gets on orbit. But none of that time will make a difference if it was done wrong. Spend some time understanding what is going on. If you don't have a good background in the area under consideration, get someone to explain it to you. Just the act of going over what you are trying to do will clarify things.

Keep in mind that during the course of any technical project you will be inundated with data. Some of it will be critical, some of it will be trivial - you must figure which is which. After all, "Not all data are information, Not all information comes from data, Not all data or information are important". Learning to tell the difference is what will make your job in project management hard or easy. The key data you need are what you should focus on getting, even if someone doesn't what to give it to you. Successful space projects have lots of communication, between all of the people who are putting forth effort.

A final thought on data, consider the source of the data you are getting. As Sir Josiah Stamp says, just because the charts are pretty it doesn't mean they tell the correct story.

"The government are very keen on amassing statistics. They collect them, add them, raise them to the Nth power, take the cube root, and prepare wonderful diagrams. But you should never forget that every one of these figures comes in the first instance from the Village Watchman, who just puts down what he damn pleases." -Sir Josiah Stamp (17th Century)

Prioritization

Remember what you intended to do, daily remind yourself

There are times when you get so involved in a task that everything else becomes a blur. At those times, as well as when things are going well, keep your goals in mind. This is especially important if you are dealing with strong personalities. Don't be distracted by anything that will try and take resources (time, people, money) and use them for something else. The key question is "what does this do to get to the goal?" If it means you have to put up posters on the wall, do it. Keeping not only yourself, but also your team focused is really important. Have priorities and a plan….and work to them. If it takes a "daily" meeting before starting to keep everyone on plan, then that is what you have to do. I have spent entire summers going to 0630 meetings (prior to start of work at 0730) so that everyone knew what was going on. Now your projects probably won't need that kind of meeting, but do what is necessary. Post the schedule and the overall plan - keep them updated. Ensure your team knows what needs to be done, when and why. Like a marching band, everyone needs to be playing the same tune, as well as moving together. And like a marching band, everyone needs to practice to get it right.

All of your evaluations, for progress or correction, need to be done against your plan to reach the goal. No other evaluation is really valid - because if it isn't helping you

reach your goal you shouldn't be doing it anyway. You have a plan, work to it and use it as the tool it is supposed to be. There will come a time when you must stop talking and start building - your plan will tell you when that point comes. Then you must remember, "There comes a time in every project to shoot the engineers and begin production."

The Urgent Shall Not Interfere With The Necessary

Earlier I talked about having to make decisions about what to include and what to exclude. This point is the corollary…your time and your team's time should be spent on the necessary activities. Everyday a "crisis" will occur, eating away at the finite amount of time and other resources you have to get the project finished. Be ruthless in protecting your project. Don't be afraid of offending someone who needs to be told that their meeting will not be supported or that their instrument will not be included. They need to know that as soon as possible so they can work another option. You are doing them a favor by getting them an answer fast and in enough time for them to pursue something else. Your team needs to understand what their priorities are also. Be clear about priorities, communicate them often, and enforce them. Without someone at the helm as ship will wander with the wind until all onboard starve to death. Don't let that happen to your project.

Another time waster is meetings, keep them on the point and short if you can. I know sometimes there will be discussion, but you can tell when it has lost productivity. During general meetings, when everyone is attending (the usual suspects, idiots, etc.,) your main role is

traffic cop. Keeping the meeting on track and defer topics to later if need be. Don't hesitate to defer a topic or question-if it takes more than 5 minutes to discuss, then it probably needs more prep time than you have in the meeting. So do everyone a favor and give them time to prepare a real good discussion, not a lame, spur of the moment one. If you have troublemakers in your meeting, treat them like the 2-year olds they are acting like. Cut them off and during a break, take them aside and explain your reasons for deferring their topics, but do not let them run wild. They will only hinder progress. Ask them to give a 10-minute presentation on the relevant aspects of their point at the next meeting. Don't give them any longer than 10 minutes-if they can't succinctly say what is important, then they can't be trusted to have a valid opinion.

My recommendation for a productive project meeting follows the agenda below, with backup information provided. You will notice that there is a private management meeting first, in my experience it helps to get together with the team leaders. It doesn't waste the time of the entire team, and it focuses the "leadership" on what needs to be included.

Part I - Private Management Meeting (.5 - .75 hr)

(Focal point and team leaders, not all the people who will be attending the general meeting. This meeting is to give you time with the senior managers to go over stuff that shouldn't be brought out in a general meeting. Order on this list is important; it shows them what your priorities are! Also, don't skip any item, they are all important.)

1) Financial Status (how much have they spent, how much is left, are they on plan?)

2) Technical Status (how is the work going, % complete, on plan?)

3) Management Issues (anything the team needs you to know; are team members working well, any problems?; is anyone trying to influence the team?)

4) Open/Other Information (agenda of general meeting; action item status/problems; likely issues for general meeting)

Part II - General Meeting

This is the real "meeting" to talk about your program and its stuff. Generally run by the contractor, with an intro by government. Most meetings will generate "side discussions," make sure there is a room available for them or time set-aside after the main meeting.

You will notice that I didn't spend a lot of time planning the "general meeting", but went over the agenda in the private one. That is because your team leaders should have made inputs and should control the content of their individual sections of the general meeting. They will follow the overall project lead's tone, so if you are the boss, you will set the example.

A final thought, have an "action item" list that is numbered, suspensed, and status'd at every meeting. This will keep people on their toes and things will get done. Remember, if it is worth mentioning, then it is worth tracking/actioning. Things will unravel if you don't track them. After all, if you are not measuring it, you aren't managing it.

Time to Do Data Review is Sacred

Every program has a pace that seems to get faster and faster as you get further along. As the project director you must control the pace and keep people on track.

In the test phase of subsystems there will be a tendency to "get it out the door". Fight this as much as you can. After all, if you did the test you should make sure the results are acceptable before proceeding on. This goes for any analysis needed, also. If the structural analysis isn't done, it won't do you much good to decide on the stiffness of the structure. Faulty data leads to faulty satellites. It's your job as the boss to ensure that the project doesn't get caught in the rush to finish.

How will you know if your experiment is successful if you don't evaluate it? If you spent all this time and effort to gather data from space, but don't look at it - you have wasted your time. Develop your own "lessons learned" archive, after all how can you learn from the past if you never evaluate it?

Finally, if the data was so important you had to do the experiment to get it, how come you can't analyze it?

Never Do Anything For The First Time

At this point in the paper you probably need a break… go ahead and take one because this point is vital. Never, ever skimp on dry runs, practices, pathfinders, and trailblazing, I cannot recall a single payloader who didn't complain about having to do them, but was also swearing at the end of it that they learned something critical. What am I talking about? Simple, practice what you are going to do before you do it. When you build an engineering mockup, you are doing this. For launch operations, nothing substitutes for going and seeing the facilities and walking through the places you are going to do your operations.

A couple of examples, first during the preparations for a shuttle mission we had an RF experiment (they needed to receive only) take a walk through the ground

processing facility they were going to use. That led to discussions about what they were going to do, the specifics of the ground processing. It turned out that they needed to set up a big antenna outside and find the same RF signals on the ground in preparation for flight. After some discussion about how to do it, we came to the conclusion that a hundred foot antenna cable was needed to reach from the clean room to the parking lot where the antenna was. Since the experimenter didn't do cables, we had to have one built pretty quickly. It got done, but only by doing a walk through did we have enough time to get a cable built so that the ground processing was successful.

On another launch we were preparing for on-orbit operations and had several incidents. Mostly it was people not knowing their procedures or the procedures being wrong. That led to four formal mission practice sessions, a policy that carries on still. We corrected the procedures and trained the people, what we got in the end was flawless on-orbit performance.

To make my point, practices are valuable because this is when making a mistake won't cost you the mission or delay the launch. How can you do this? Well mostly it's insisting that it be done. Remember I mentioned the complaints earlier? That is where the courage to force it comes through. It won't make you popular to have the entire team fly to Kodiak Alaska (as I once did), just to walk around some facilities, but if it avoids loss of mission - it's worth it. Making people "play act" out the work they are going to do can make a real difference. I had a team find out that their technician needed six-foot long arms, leading to a re-design by the way, during just such a practice.

An Ounce of Preparation Is Worth a Pound of Panic

As the old saying goes, "The plan won't work, but we can work the plan", know what your plan is and try to stick to it. You have already thought ahead (see above) and understand what could go wrong. Now you just have to have the presence of mind to do what you were planning to do. I am always surprised that people expect you to redo your planning when something happens. That's why you practice anomalies during rehearsals (kind of like looking for the exit on an airplane) - so you know what to do. As I told one top manager just prior to the start of a launch countdown "I will not ask you about this situation, we have already decided on a plan, I will just implement it."

It helps if your plans are specific (i.e. usable), so when you are coming up with them. Avoid generalities and keep asking questions until the answers are <u>very</u> specific. This is all part of knowing your goals and the path to get there…find out what the goal is, the problems that may come up and then concentrate your efforts on that.

I am talking about how to handle a problem when it comes up… first, you as the leader should remain calm (you can panic later - right now you have work to do). The leader sets the tone, so you don't have time to fall apart. If there is a contingency plan that this situation fits, then get your team working on it (if it's an on-orbit problem, you may only have a few minutes to get corrective actions uplinked). Then get the team started on the "what caused this to happen" part, don't let them get sidetracked on other things, that comes later.

You as the leader will set the tone - if you are professional then the team will act that way too. Remember that.

<u>People are Important</u>

Relevance Increases Motivation and Concentration

When the people helping you understand <u>what</u> you are doing and <u>why</u> you are doing it they perform much better. This has always been the case in the space program, but it is true of every activity you will engage in.

Also, remember that the people you are working with, on a personal level, want you to succeed. They take pride in what they do and in their individual contribution to mission success, let them help you succeed! So don't defeat yourself, let the process and the people do what is supposed to be done. Something's you can affect and some you can't, you <u>must</u> rely on other peoples judgment. Just don't give up! Always be ready to support the people supporting your payload! It can pay off in ways you can't even imagine. Dr. Penny Haskins, the scientist behind the Shuttle Activation Monitor (SAM) experiment can attest to that. During our preparations prior to a mission, we were locked out of the Orbiter Processing Facility (OPF) for hazardous operations. Now for Penny to really get the best data, she needed to take measurements inside the orbiter, something that NASA wouldn't let her do. While we were waiting to get into the OPF, some of the workers asked us about our equipment and why we were waiting. I encouraged Penny to explain to them who, what, why, etc... It turned out that this group was the "forward shop", i.e. the guys who worked in the crew cabin. Once we finally got into the OPF, these guys took Penny (and her equipment) into the crew cabin for a personal tour. Not only did she get her data, but made friends who did their best to see that she succeeded, not only on that mission, but future ones too. So always be ready to explain to those who ask…it may be the first step in getting you to where you want to be.

Nothing will perk up the ears of a group of students better than the following phrase: "THE FOLLOWING MATERIAL IS TESTABLE". Relevance and giving people an internal motivation to ensure your success is important. So, never begrudge someone an explanation, remember they are interested in your success, too

Everyone has a job, let them do it

Specifically for you engineers who are now project leads - just because it isn't your design does not mean it won't work - don't mess with it! People are generally going to come up with solutions to problems; it's in our nature. So let the people on your team do their jobs. Nothing will hurt your team's morale faster than your nit picking them over stuff that they know is irrelevant to the real function of the spacecraft (like the color of the wire they are using). So only force a change if you have to. And be careful how you ask questions (I see big question marks in the air here)! How you ask a question may be more important to your team than what you actually said. I know this sounds nuts to a technical type, but it is true. This is a key management principle - your language must be positive and re-enforcing, even when you are asking a question. I use the "I don't understand because I'm dumb, please educate me" tactic a lot (I've just given myself away). That is letting the person you are talking to educate you about what they are doing, asking questions positively, "I am unsure of the function of this circuit, how does it relate to this other one?" to find out what you need to know. I have used this to successfully lead an engineer to realize that he had a design problem. Thus it became his discovery of a problem, not me dumping

on his design (if you don't know why this is important, think about how you feel when you get a test back).

Every project needs people to fulfill specific roles, assign those roles early and enforce the rules. If you have a business person who must sign off on all expenditures - ensure that they do. Don't let the team shortcut the processes that make you successful. Also, don't put non-compatible roles on the same person - you can't be the budget enforcer and the chief designer for instance. To have a successful project you will need many people in different roles, let them do them well and your project will be a success.

Some people, like data, are more significant than others

Some of your team are going to be more of a contribution to project success than others. Who the "keystone" people are may not be obvious to you, but you should find out who they are and protect them. Your project needs them, I can't think of a better illustration than this story; "Five Cannibals get appointed as engineers in a Defense Company. During the welcoming ceremony the boss says: "You're all part of our team now. You can earn good money here, and you can go to the cafeteria for something to eat. So don't trouble the other employees". The cannibals promise not to trouble the other employees. Four weeks later the boss returns and says: "You're all working very hard, and I'm very satisfied with all of you. One of our cleaners has disappeared, however. Do any of you know what happened to her?" The cannibals disavow all knowledge of the missing cleaner. After the boss has left, the leader of the cannibals says to the others: "Which of you idiots ate the cleaning lady?" A hand raises hesitantly, to which the leader of the

cannibals says: "You fool! For four weeks we've been eating Team Leaders, Task Leaders and Project Managers so no-one would notice anything, and you have to go and eat the cleaning lady!"

All of your team members are precious, value them, but remember that some are more significant than others.

Summary

I hope I have contributed to your project manager's toolkit with this article, as you gain experience, keep track of what works for you and be willing to pass that information along. If we all contribute then we will all be more successful.