Managing Creativity:
A Practical Guide to Inventing, Developing and Producing Innovative Products

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Introduction

During 30 years of working at the Jet Propulsion Laboratory (JPL) in Pasadena, California, I've had many different engineering and management jobs. I've been involved in creative teams developing everything from concepts for automatically identifying drugs, to national energy plans, to robotic missions flying to Venus, Mercury, Jupiter, Saturn and Mars. In spite of detours to other endeavors, I've always come back to the magnificent creative ventures that are space projects. In 1994 I became manager of JPL's Mars Exploration Program, which means leading a creative team of several hundred people sending missions to Mars every 26 months. The first launches were in late 1996. Through all this activity I've collected a lot of experience and information on how to manage teams developing creative products. This book is a compilation of that experience - about the management of what one acquaintance calls "collective creativity" - the leadership and focusing of creative teams.

What do I mean by a creative team? Here's a recent example.

Looking for Life on Mars

"Meteorite Find Incites Speculation on Mars Life" read the headline inside the Monday, August 5, 1996 *Space News*. "The prospect that life once existed on Mars is being raised following analysis of a meteorite recovered on Earth," the article began. Within two days the story had swept around the world. "Life on Mars? A Stunning Discovery," read the cover of *US News and World Report*. The cover of *Time* was even more certain: "Life on Mars" (with no question mark). The human imagination was sparked by the idea that an alien life form, long speculated about but never proven to exist, might finally have been discovered. Space scientists and engineers at the National Aeronautics and Space Administration (NASA) sprang into action. A barrage of phone calls, requests for interviews and television appearances descended on the Mars Exploration Program office at JPL.

Three days after the news broke nationally, I was called into the my boss's office (the Director of JPL) for a teleconference with Wes Huntress, head of the space science program at NASA Headquarters in Washington, DC "I need a plan," said Wes, "for finding out whether life ever existed on Mars. What do we have to do to find out, how soon can we find out, and how much will it cost?"

Wes wanted the answer in less than a week. As manager of the Mars program, my job was to provide it. "Piece of cake," I told Wes, and left to assemble a creative team for this job.

The JPL Mars exploration team had already spent two years developing a program to systematically explore Mars on a shoestring budget using robotic spacecraft. One objective of this program, escalated in importance by the recent discovery, was to find evidence of past or present life on Mars. The first two spacecraft in our series of robotic Mars missions were ready to be shipped to Cape Canaveral in Florida for launch in November and December 1996. Two more were on the drawing boards for flight in late 1998. Two additional spacecraft were scheduled to be launched to Mars every 26 months for at least the next ten years. Each mission would cost about as much as a major motion picture, a fraction of the huge sums spent on earlier planetary exploration missions.

In the previous two years of working on the latest round of Mars exploration, the JPL Mars exploration team had already laid the foundation of a Mars Life plan, and now we needed to rapidly develop it further. We had computer programs to quickly identify possible trajectories to Mars, plus a design center and team capable of developing and costing space mission designs in a single day. We had electronic tools for data exchange, and a videoconferencing system to consult with our bosses at NASA Headquarters without the time and cost of travel. Our main asset, however, was creative people representing nearly every profession at JPL: scientists and engineers, secretaries and managers, videoconference room operators and computer support technicians.

NASA quickly organized a press conference in Washington, DC on Friday, August 9, 1996, to showcase the scientists who had analyzed the ancient Martian meteorite. Television newscasters jostled each other to interview the scientists in Washington, and anyone they could find at JPL who might know something about the discovery. My secretary was buried under an avalanche of phone calls from newspapers, magazines, television and radio stations, all wanting to interview somebody, and it was usually me. Between interviews and radio talk shows, I organized a team of "Martians" to work on the "life search" plan, developed a work plan and schedule, figured out how to pay people to work on the study, negotiated with other projects to schedule the rooms and computer facilities to enable the planning effort, and—at the request of NASA Headquarters—contacted people at the Johnson Space Center in Houston, Texas, to support them with another rapid-fire study of an early *human* mission

to Mars. Within hours, I was fully in the business of managing creativity—again.

About 30 of us Martians started on Friday morning and worked through the weekend. I provided suggestions, encouragement and pizza, and worked on the team that would coordinate the results of the overall study. Other teams scattered around JPL were developing various aspects of the program. We met a few times each day to review our progress and integrate the results. Late Saturday afternoon, when the "first cut" program was beginning to emerge, a major power outage shut down the Western United States—lights, air conditioning, and most importantly, computers. To Plan B! We assembled on the patio of the JPL cafeteria in 100-degree heat and continued the meeting with verbal reports and pencil sketches.

At a videoconference at 6:30 a.m. on Monday, we showed Wes Huntress our first cut at five options for seeking life on Mars. The options were based on a science strategy for, first, identifying the most likely places to look for ancient life, and then bringing samples back from those places. We had developed engineering solutions that ranged from expensive programs that could probably answer the question by the year 2008, to a program that could be done within the current budget but wouldn't return all the needed samples until 2020. Wes gulped, and asked us to develop an intermediate solution that would increase the budget only by 50%, but still get the first sample back to Earth by 2006. And we had to have the answer in two days.

By 11:30 a.m. on Wednesday, at the "final report" videoconference, we were able to provide fancy color charts of the option—suitable for Wes to show the White House if necessary—plus charts describing a cheaper alternative. We'd graphically illustrated a science strategy. We had innovative engineering solutions for accomplishing the missions within cost constraints. We'd defined the technology "tall poles" that needed to be developed rapidly to support the program. We had estimated the cost year by year for implementing the program—plus we'd made comparisons to our current budget. "Thanks," said Wes, "Just what I need."

This story is an example of what occurs when creativity is sought, cultivated and *managed*. We formed and used a creative, diverse team to produce an innovative product (the options) within tight money and time constraints. We planned the process. We used models and modern computer tools to develop the product. We communicated with each other and the outside world through

a variety of techniques. The creativity of the individuals in the group was amplified and channeled by technology and efficient processes to get the product out rapidly.

Throughout my career as an engineer at NASA, I've used the principles of teamwork and the force of creativity to produce high-quality results, quickly I've been involved with groups who have created and used products— primarily for the robotic exploration of space—for more than 30 years. I also paint, write music, sing, play guitar, act, ski, sail, backpack, and I've done one woodcarving and made ceramic musical instruments. Along with becoming a pilot, I've raised animals, worked backstage in theaters, done personal growth work, taught science to nursery school children, and I'm a mother. While I'm an amateur at many of these, they've taught me about the creative process and also contributed to the ideas in this book.

My experience convinces me that our ability to manage creativity is the key to success within our organizations, companies and governments. This book is a compilation of that experience, including the strategies, techniques, perspectives, points of view and tricks for harnessing the creative forces within groups. There are plenty of examples of mistakes and things that didn't work, because all creative enterprises co-exist with the possibility of sudden failure. If you know how to do something without risk, it isn't creative. Ways are included to carry out and test your creative enterprises so you have room to make mistakes that won't cost too much.

How to Use the Book

Chapter 1 presents the concepts of collective creativity and some outstanding historical examples. Chapter 2 discusses the concept of models as "templates" on which to build your creative structures, introduces some concepts and terms borrowed from systems engineering, and shows you how to use them, along with your models, for creative problem solving.

In Chapter 3 the models are put to work: producing products, building teams, recognizing relationships between things, propagating creative concepts into new situations.

Communication is the key to group creativity. Chapter 4 discusses various ways of communicating information and ideas, and of arriving at agreements and closure to actually create a final result. Communicating with "customers"

and "suppliers," within and without the group, with peers and with "superiors" and "subordinates" are addressed—although some of the terms are used in new ways.

Communication is also a tool for building and using teams for creating things. Chapter 5 deals with team-building and choosing team members with the right kind of diversity of background, ideas, skills and styles to result in team products that are more creative than the mere sum of the creative capabilities of the individuals in the team.

Once your team is built it needs creative planning to be effective. The creative planning techniques presented in Chapter 6 can help you distinguish between real and unreal constraints, and structure ways of dealing with them—because there are always constraints. Purposeful activity is never undertaken without some boundaries or limitations. Even high creativity can be stifled by a "dysfunctional infrastructure". Strategies are discussed in Chapter 7 for dealing with constraints, understanding which constraints are real and which are not, and for deciding whether or not to accept your own personal constraints.

And then, Chapter 8 gives some ideas on unleashing your personal creativity. How do you know what you really want? How do you remove your personal barriers to creativity? This chapter is based on several years of personal growth and therapy, lots of reading in human behavior and psychology, plus a lot of on-the-job training in working with, managing and leading people. You may want to start with this chapter if you're feeling frustrated by your own personal level of creativity, and then read the rest of the book.

Throughout this book are examples of managing creativity taken from my personal experience. I wrote the book for people who are engaged in producing something new - or producing something old with new techniques - in groups of people. Many of the examples concern JPL, NASA and Caltech - and there is more information about these institutions in the Appendix - but the book isn't just for aerospace managers. It isn't just for "high tech" professionals, although many of the ideas derive from my experience in a very high technology organization. It isn't aimed solely at large organizations; plenty of examples are included that apply to small teams. I contend that the inherent creativity of groups—from those forming national policy to those sponsoring change in their local communities—can be realized by structuring, organizing and nurturing the creative activity. Managing creativity is a balancing act, a

creative, dynamic, difficult and sometimes dangerous pursuit—and the most exciting and fun thing a manager can ever do.

<center>— 1 —</center>
Collective Creativity

Upon this age that never speaks its mind,
This furtive age, this age endowed with power
To wake the moon with footsteps, fit an oar
Into the rowlocks of the wind, and find
What swims before his prow, what swirls behind-
Upon this gifted age, in its dark hour,
Rains from the sky a meteoric shower
Of facts...they lie unquestioned, uncombined.
Wisdom enough to leach us of our ill
Is daily spun; but there exists no loom
To weave it into fabric; undefiled
Proceeds pure Science, and has her say; but still
Upon this world from the collective womb
Is spewed all day the red triumphant child.

<center>*Edna St. Vincent Millay*</center>

Donna's First Law: All creative enterprises are examples of collective creativity.

Creativity is generally viewed as an individual pursuit, and of course, it can be, but groups can produce things which one person can hardly imagine. Spacecraft, cathedrals, good schools, parks, medicines and computers all result from group or "collective" creativity. Plays, exhibitions and concerts are enabled by individual creativity, but they are made manifest by the creativity of a group. A well-conducted orchestra produces music more thrilling than the sum of the individual skills of its musicians.

Collective creativity is needed at all levels of society. As Representative George Brown says: "We need to build bridges between science and the rest of society and help direct change in government. A new form of cooperation between industry, government and universities is needed. We need cooperative processes for problem solving."

Several of my friends have said, "Managing *creativity*? Isn't that an oxymoron?" My answer is - obviously - "No!" In fact, I believe that the ability to manage creativity is the key to future prosperity for organizations, companies and governments. Only through group creativity can we combine "the wisdom to leach us of our ill," per Millay. "Creativity goes well beyond craft and cleverness, with which it is often confused.... creativity is the ability to join unrelated elements together to form something new" (Coates and Jarratt, *Creativity* 5).

Creativity is easily recognized in the worlds of art and science. But creativity is needed everywhere. Today's world is moving at an ever faster pace. Business is increasingly competitive.

> Wall Street needs new products every three or four years. New products give a pricing advantage. Once they become common, or even well known, they become mere commodities and don't have the high payoffs and high compensation to executives. Wall Street lives by inventions. 'Today a peacock, tomorrow a feather duster' is a Wall Street saying (Demisch).

According to David Fagiano in "Preparing for Creativity," quoted by Joseph Coates and Jennifer Jarratt in *Creativity in the Workforce: Future Directions,* corporations are using at least four approaches to embrace creativity:

1. Teaching and training creativity
2. Using creativity tools,
3. Setting up creative units that are isolated from the mainstream, and
4. Establishing a creative environment in the entire organization.

Individuals and organizations are being prepared by changes in society to accept and support creativity, but organizations are going to have to change their practices in order to take full advantage of the creativity of their people.

Group creativity begins with an idea—the vision of a single person. Usually a creation is built around a mental template, structured from experience or training; pure creation occurs rarely, if it exists at all. The best individual creations aren't spontaneous eruptions of an idea. They result from often frustrating trials that ingeniously combine known concepts and things into original forms. In other words, creativity is hard work.

In groups, visions are shaped and structured into reality through a series of processes that consciously or unconsciously use tools, resources and people in complementary or competing ways. Toynbee, and then Bronowski and Eisler, extended this concept to all of human history.

> The growth of a civilization lies in the hands of a creative minority. This elite must have the power not only to cope successfully with the challenges to which their society is exposed, but also to carry along with them the majority of uncreative people.... In societies in the process of civilization...creative personalities... command a following because they are pioneers on the road towards the common goal of human endeavors.... A society ..thus directed forward towards the future...is in dynamic motion along a course of change and growth (Toynbee, 161).

> Among the multitude of animals which scamper, fly, burrow and swim around us, man is the only one who is not locked into his environment. His imagination, his reason, his emotional subtlety and toughness, make it possible for him not to accept the environment but to change it. And that series of inventions, by which man from age to age has remade his environment, is a different kind of evolution—not biological, but cultural evolution (Bronowski, 19).
>
> ...the people of Crete—who built viaducts, paved roads, designed architecturally complex palaces, and had indoor plumbing, a flourishing trade, and a great deal of knowledge about navigation—must...have made extensive use of left-brain as well as right-brain thinking. In these prehistoric partnership societies technological advances were used primarily to make life more pleasurable rather than to dominate and destroy...(Eisler, 74-75).

Margaret Wheatley takes this theme a step further. She sees group interconnectedness through the medium of information as key to group creativity. In fact, she defines information as the creative energy of the universe. She likens the free flow of information in organizations to the field concept (like gravity fields and electromagnetic fields in space) in physics (56, 105).

Wheatley tries to extend a physics model—that of allowing information to organize itself through chaotic processes—to organizations. There are some valuable concepts here. But I think the model that best supports the chaotic process is Life, which by definition, organizes information. The stuff of the basic molecules of life is chemically organized information. The information that makes a bacterium or a human a faithful copy of its progenitors is organized by processes that can be applied to organizations. And the high efficiency of these processes allows the organization or organism to compete successfully. An organization that can structure its processes to enhance and amplify individual creativity, and then manage the chaos this creativity produces, will succeed.

Historical Examples

Creative geniuses, both the well-known and virtually unknown, have used the creative power of groups to extend their own creativity.

In the 12th century Hildegard von Bingen, abbess of a convent, became the most celebrated woman of her age as a visionary, naturalist, playwright, poetess and composer. She also had tremendously wide influence on the policies of the day, swaying the actions of rulers and popes (Page). By herself, in a world dominated by powerful men, Hildegard couldn't have accomplished what she did. The voices of her nuns were

the instruments that made the vision of her music soar. She channeled her leadership and personal creative drive into the group of nuns, into the church itself, and by managing their creativity, extended her ideas into the world.

From the 15th century, the creative genius of Michelangelo Buonarrati still speaks to us today: in St. Peter's Cathedral, in the paintings on the ceiling of the Sistine Chapel, and in many other statues, tombs, and buildings throughout Italy (*Complete Works*). Leonardo da Vinci, another ideal Renaissance Man, expressed his creative genius in painting, sculpture, engineering, geology, anatomy and botany, but he left very few complete works by the time of his death in 1519.

> What shall we say about an architect, city planner, and engineer who cannot be credited with a single monument, civic improvement, fortification or canal? A theoretician who never finished a treatise, yet who is justly famous the world over? (Boussel 127).

Both Michelangelo and da Vinci had groups of students and colleagues who worked with them. Both depended upon a team of stone quarrymen, patrons, and models. Neither could have produced his creations without a team, but Michelangelo produced far more sculptures, paintings, buildings and tombs than da Vinci did. Was Michelangelo more creative or was he a better leader of creative teams?

In more modern times, many major breakthroughs in science have occurred through the collaboration of teams. For example, Marie Curie discovered radium in conjunction with her husband, Pierre. Marie was the publicly acknowledged leader of the team, but Pierre was a vital contributor. Later, Robert Oppenheimer, a well-known scientist in his own right, created and led the Manhattan Project, a team of renowned scientists who produced the first atomic bombs in 1945. He bolstered the science team, some of whom would later win Nobel prizes, with engineers and technicians. Oppenheimer marshaled money, transportation and security for their work. In a remarkably short period of time, his team created new weapons from work that had been basic research.

A Matter of Balance

Group creativity is both necessary and inevitable; the challenge is to make it more productive, more congenial, and more fun. The key to managing creativity is to maintain balance between competing ideas, disciplines and forces that erupt from collaboration. The management fad-of-the-month isn't the answer to every challenge. The customer is *not* always right; the customer may want something that is impossible

to produce. Fast cycle time is *not* always better; you may produce a product that won't sell or can't be maintained, even if you're first to market. The freedom of workers to be creative has to be supported by enough structure so that their productivity is channeled into desired outcomes, which can change as the creative process unfolds.

*Donna's Second Law: "Management is a balancing act."*

A fascinating model for looking at creativity in organizations is based on chaos theory as described by Stacey in *Complexity and Creativity in Organizations.* In this model any organization will have both a stable, legitimate, structure—designed and honed to efficiently produce what the organization has produced before—and an underlying "shadow" structure that is dynamic, creative and probably rebellious. The shadow structure is the source of creativity and the source of instability which, if unbalanced, can tip the organization into total chaos. To survive, the organization must operate at the "edge of chaos." If the legitimate organization succeeds in stamping out troublesome, creative rebels, it will stagnate and die. If the rebels succeed in totally overcoming the legitimate organization, the supporting infrastructure may be destroyed and the organization will collapse into warring factions that will endlessly fight for domination—like Yugoslavia.

Operating at the edge of chaos produces discomfort and anxiety in any organization. The risks seem very high, personalities and schedules and costs seem to inhibit rather than support progress, and desired results seem nearly impossible to achieve. *Successfully* operating at the edge of chaos is a matter of balance. In a balanced state, discomfort gives way to excitement and determination. Anxiety is transformed into energy, as the creativity of the group is focused on getting a job done. In this state, desired results are not only possible, they call forth the best efforts that often attain greatness.

A manager of a creative team has to achieve balance in many dimensions. The following figure illustrates the concept of balancing time. "Fast Cycle Time" idealizes the concept of rapid production, but there's a catch. Yes, it's good to produce quickly; if you don't, you'll be overtaken by the agile competition. But you'll also get eaten alive if you move so fast that you produce junk that will turn your customers away, or drive you bankrupt trying to meet your warranties. If your staff experiences burnout or is tempted by the greener pastures of more balanced organizations, your performance will soon diminish.

Michael Hammer and Jeffrey Pfeffer emphasize that you can't just produce things faster without changing your processes. You need to revise your processes, team with

your suppliers and outsource things you aren't good at, but you must pay attention to production while you're "re-engineering," or you'll spend all your resources on process change and not get the product out.   This balancing of time to product between too little and too much is shown below.

Balancing Time and Performance
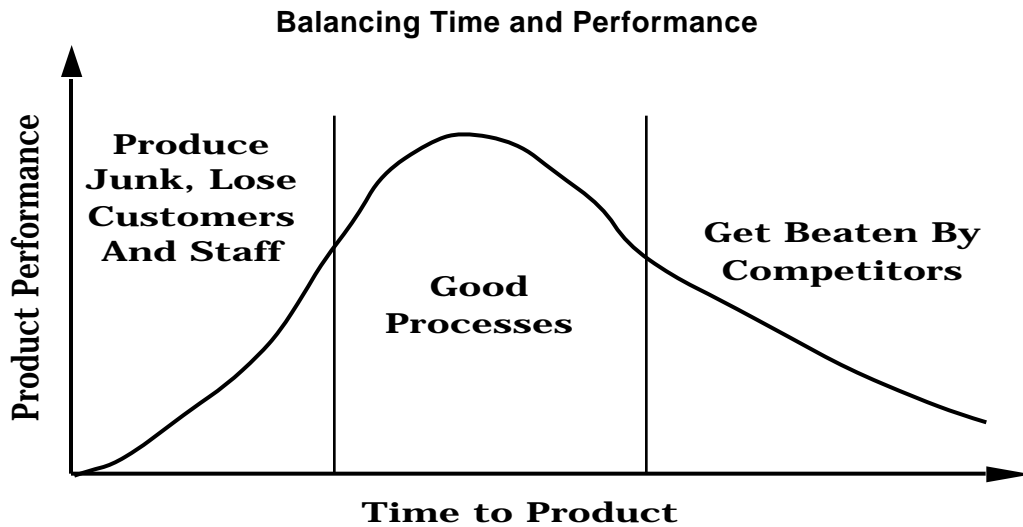
Management control is another balancing act, as the next figure shows. Creative endeavors should be fun, exciting, stimulating and allow for personal expression, but they must also produce something that will work and sell.

Balancing Management Control and Performance
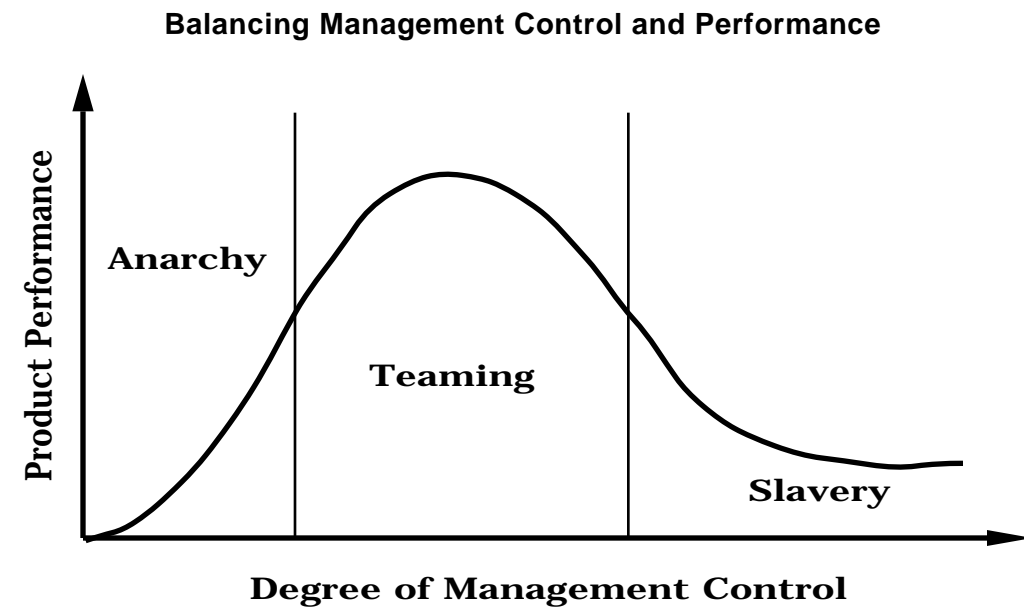
Anarchy doesn't work. Your team has to be motivated, but their energies must be directed toward a desired outcome. At the other end of the scale, slaves are not particularly productive and eventually will revolt. And as a manager, achieving balance through teamwork—that area of productive, focused effort—is the secret to managing creativity.

The following chapters will show you how to implement ideas like these in your own organization.   We'll start with the creativity which can be unleashed and focused by the use of models and metaphors.