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Dominick Barry
Veridian, Space Systems and Operations

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The Future of Space Endeavors: Our Search for a Revolution

By Dominick Barry

Director, Business Development
Veridian, Space Systems and Operations

In his landmark book, The Structure of Scientific Revolutions, published in 1962, Thomas Kuhn articulated a view of the scientific method and the processes that lead to revolutionary change in science “fact”. This paper will discuss the Kuhn’s treatment of the scientific method, and his views on how adherence to sound scientific practices simultaneously leads to improved understanding of nature, while impeding true revolutions in the fields under investigation. Through a comparison of the current state of today’s space launch industry the model suggested by Kuhn can identify some of the challenges our industry must address within the coming century.

As we move forward toward the creation of next generation space launch vehicles, work toward the improvement of existing expendable concepts, or expand the life of current systems, we should also take the time to evaluate the very processes we use to bring about improvements and change to our systems. Kuhn suggests that historically, revolutionary change in every scientific endeavor can trace its roots more frequently back to a divergence from the experimental norm, an “accident” which produced a new or unexpected result, or the insight from a “new set of eyes”, someone with vastly different experience and training.

Processes closely allied with the scientific method are central to the success of the space launch industry. We rely on the adherence to strict disciplines, which bring about repeatability. Without repeatability our industry could not survive. But, for our industry to make the leaps in technology necessary to achieve our future goals, revolution will be necessary as we develop and test new systems. Kuhn provides a rational starting place for structuring our approach to achieving those technological leaps.

To accomplish the visions of our future, as defined by our views on space travel, exploration, and ultimately colonization, we must achieve substantial changes in the systems we use. The processes in-place today were designed to maximize and protect technology largely stemming from the 1960’s. These systems have been stretched and seem to hold little promise for movement to the new levels of tomorrow. To achieve those far-reaching visions of space travel, we must prepare for and expect a revolution in technology and capability. We must address the question: Are we truly working toward the revolutions of tomorrow or are the forces of our industry actually prohibiting the very changes we need?

Key Tenants Described by Thomas Kuhn

In his writings, Kuhn focused on the history leading up to and following the discoveries by famous scientists and theoreticians. Through his study of scientific discovery, he identifies several patterns present in the behavior of those associated with the endeavor, prior to and
flowing from the ultimate discovery. Some of these patterns are listed below and will be related to our industry later within this paper.

Discovery and the Ignorant Man

The man who is ignorant of the current field of study but who knows what it is to be scientific may legitimately reach any one of a number of conclusions incompatible with the accepted science. Among those legitimate possibilities, a particular conclusion arrived may be determined by prior experience in other fields, by accidents during investigation, and by personal makeup. “What belief about the stars, for example, does he bring to the study of chemistry and electricity?” … “Which of the many conceivable experiments relevant to the new field does he elect to perform first? And what aspects of the complex phenomenon that then results strike him as particularly relevant to an elucidation of the nature of chemical change or of electrical affinity?” Kuhn sees answers to questions such as these as pivotal to an understanding of scientific change.

Equipment Failure

On occasion a piece of equipment designed and constructed for the purpose of normal research fails to perform in the anticipated manner, revealing an anomaly that cannot, despite repeated effort, be aligned with professional expectation. In these and other ways, normal science repeatedly goes astray. And when it does – when the profession can no longer evade anomalies that subvert the existing tradition of scientific practice, then begin the extraordinary investigations that lead the profession at last to a new set of commitments, a new basis for the practice of science. The extraordinary episodes in which that shift of professional commitments occurs are the ones described by Kuhn as scientific revolutions. They are the tradition-shattering complements to the tradition-bound activity of normal science.

Support From the Community

Much of the success of the enterprise derives from the community’s willingness to defend the new assumption, if necessary at considerable cost. Normal science often suppresses fundamental novelties because they are necessarily subversive of its basic commitments. Stated in another way, change is often resisted simply because it is different and it is easier (and safer) to adhere to traditional beliefs than to attempt adjust to new ways of viewing the world.

Kuhn speaks very clearly regarding the processes which inhibit our ability to accept change “….further development (of new paradigms) calls for the construction of elaborate equipment, the development of an esoteric vocabulary and skills, and a refinement of concepts that increasingly lessens their resemblance to their usual common-sense prototypes. That professionalization leads to an immense restriction of the scientist’s vision and to considerable resistance to paradigm change”.

It’s a Human Endeavor

What lies below Thomas Kuhn’s treatment of normal science and the history of revolutionary change within the sciences, is that no matter how structured, how unemotional, how process oriented, science is a human endeavor. It therefore is simultaneously reflective and limited by the very involvement of those associated with that endeavor. It is this reality which
links Kuhn’s study of change within science with the Space Launch Industry and provides a springboard for addressing the issues confronting our industry in the coming century.

The Current State of Our Industry

Setting the discussion on Kuhn aside momentarily, let’s take a look at some factors governing the reality of today’s space launch industry. We can use this backdrop as away to address the challenges confronting our industry and put into perspective what will be necessary to achieve our visions of the future as it relates to space travel.

With record numbers of satellites being manufactured and delivered, the short and long-term health of the satellite-manufacturing sector appears assured. The production flexibility exhibited by manufacturers striving to meet the demand for high quantity, smaller mobile communications satellites while also improving the capabilities of large geo-stationary satellites is remarkable. This flexibility will benefit the industry in the future, as increased efficiencies will continue to reduce costs and expand margins. Combined with the development of spacecraft for military, commercial remote sensing, earth observation, and scientific missions, the industry’s revenues from satellite manufacturing will remain significant, even in years when demand is cyclical.

While government payloads have been reducing in size over the past few years, commercial communications satellites continue to grow. The larger satellites offer commercial service providers more power, longer life, and multiple beam applications, effectively reducing the cost of each transponder. A higher concentration of the satellite signals in each beam makes smaller ground equipment feasible and also permits frequency reutilization, a very useful feature in today’s saturated frequency spectrum. As these more versatile satellites replace and supplement the older, less capable ones already on orbit, capacity is anticipated to grow substantially. Smaller satellites offer a less expensive means to enable moderate capacity or short duration missions for messaging, intelligence gathering, or placing scientific payloads. With small satellite capabilities increasing rapidly, their utility in commercial telecommunications is expected to expand.

Satellite manufacturers have risen to the challenge of producing spacecraft in record numbers. To accomplish this, the industry has embraced the use of standard bus designs, manufacturing process improvements, serial production techniques, integrated product development, and automated test procedures. Manufacturers have also resorted to pre-ordering long lead parts and services.

One effect of the increase in business for satellite manufacturers and the resultant efficiencies has been the reduction of satellite prices and the improvement of systems that they offer. Since the first half of the 1990s, commercial GEO satellite prices have dropped by 10 percent per year. This deflation has been accompanied by a substantial increase in electrical power availability and ever increasing availability of intelligence. Far from being the bent pipes that they were regarded as in the past, modern satellites are becoming an integral part of the communications switching capability of the networks they support.
There are signs that primary and secondary subcontractors to the satellite primes are approaching full capacity. As major companies reduce cycle time and shift less profitable parts manufacturing to subcontractors, some companies have often attempted to increase capacity without adding resources. This has limited their ability to meet overall demand. This trend underscores for manufacturers the critical importance of standardization, pre-ordering, and dual-sourcing whenever possible.

Market Pressures

The space-based communications boom expected as early as 1996 has yet to appear. The slow emergence of the satellite based mobile communications constellations has allowed terrestrial alternatives to assume control of domestic markets in the US, Europe, and Asia. In fact as we enter this new century, the market potential for these services is largely unproven. The early bankruptcy of Iridium, combined with the disappointing performance of the next contender, Globalstar, has left this and other related markets strapped for cash and investors. Meanwhile telecommunications giants such as ATT, MCI-WorldComm, and Sprint have rushed to fill the gaps in the most lucrative portions of the market.

This same scenario is repeating itself in the internet services and high data rate applications. The still pending introduction of “Internet in the Sky” constellations has allowed terrestrial/cable/fiber alternatives to move into the market. Perhaps the most visible competitors are ATT with its recent acquisition of TCI, MCI-WorldComm with UUNet, and Microsoft with the introduction of its’ WebTV platform. These cable-based applications will quickly dominate the US domestic market well in advance of the introduction of the Internet in the Sky.

Space: The Next Economic Frontier

Despite these short-range setbacks, space is becoming the next economic frontier, the next territory to be charted and claimed. Historically there is a very distinct pattern to mankind’s process of exploration. This pattern can be seen to follow periods of exploration, exploitation and then colonization. If we follow this model we are currently in the process of expanding our exploitation of space, having completed the exploration phase in the 1950’s, 60, 70’s. Today our use of space for the improvement of our lives has become second nature as the examples discussed clearly illustrate.

It would be tempting to declare the continuous operations of the Mir and the International Space Station as the early phases of colonization of space. But, this is more accurately representative of an aggressive form of exploitation, because physical access to space is limited to a select few, primarily government (and NASA/Civil) astronauts. True colonization will not occur until space is accessible to a much broader (civilian/scientific) population.

Today the exploitation of space centers on military, science, and commercial applications. Each of these critical applications has very specific requirements that must be achieved to meet mission objectives, produce the desired science, or generate the expected revenue. These very tight/restrictive parameters for each and every operation are simultaneously necessary and ultimately preventing the leap in technology necessary to achieve true colonization of space.
The processes in-place today, ensure that today’s technology provides maximum effect and repeatability. The goal is consistency and predictability. Change and/or variation are closely scrutinized and every effort is made to ensure they are eliminated. These processes are necessary in order to ensure risk is reduced and that there are no surprises on the path to achieving mission objectives, acquiring the desired science, or generating the expected return on investment.

Achieving The Revolution

The question must then be posed… how do we achieve the revolution necessary to leap toward true colonization of space as our vision of the future suggests? This question is what brought me to the study of Thomas Kuhn’s writings in the first place. The collective vision of our future in space suggests a leap will occur in many areas of science that will collectively lead to an expansion of human presence in space. These revolutionary changes will likely include the discovery of new, lighter weight, stronger materials, as well as the creation of new and previously elusive propulsion systems. Easy to say, but as of yet unobtainable, as experiences on programs such as Venture Star highlight.

If the revolutions are to occur, Kuhn’s analyses may provide some insight as to where. As discussed earlier, space launch, space exploration, and the sciences are all human endeavors. And as human endeavors, Kuhn suggests that significant advances are just as likely to occur through errors in application, experimentation, or process. Those who are ignorant of our industry and its requirements may provide the revolutionary insight. And most significant, Kuhn suggests the revolutionary event may be aggressively suppressed because of its tendency to diverge from the conventional. The very culture put in-place to enhance performance may prevent truly revolutionary changes from emerging.

Recent Example: Resistance By Culture

NASA’s pursuit of the Faster Better Cheaper (FBC) initiative met with widespread industry skepticism upon it’s initial introduction, and during the mission failures experienced on programs developed under the FBC initiative, many industry representatives seem to say “see I told you so.” But studies performed following the failures indicated, among other things, that project members did not properly implement FBC and that major elements of the Faster Better Cheaper initiative were virtually ignored. Tony Spear, leader of one of the FBC study teams stated that program managers seem to focus on only two of the three elements. It didn’t matter which two they chose, but when they didn’t include all three elements, Faster, Better, and Cheaper, they were establishing the pattern that led to eventual failure.

How does a discussion on Faster Better Cheaper fit within a paper on revolutionary change? Two ways. First the experience of FBC within NASA and its implementation highlight very clearly the cultural restrictions our industry can place on the very initiatives we must pursue to achieve revolutionary change. Second, for those who have looked closely at the FBC initiative, they will recognize Kuhn’s observations in form of FBC principles.

Faster Better Cheaper Principles

If we looking to the principles of Faster Better Cheaper, we can see a real effort to initiate revolutionary change consistent with Kuhn’s historical analysis of how revolution occurs.
Set Goals That Make You Stretch: Stretch goals force us to go beyond gradual improvements. Pushed to operate on a completely different level, we have to come up with strategies and techniques that greatly extend or reach. This triggers our competitive spirit, and turns on our creativity.

Let Limitations Guide You To Breakthroughs: Constraints and limitations can be more of a blessing than a curse. They force you out of standard operating procedure. They call forth cleverness, push you toward simplicity, and give rise to elegant solutions. Demanding conditions also influence you to focus your efforts on what’s most important.

Deliberately Choose To Do Things Differently: Be willing to abandon your existing approaches. You must actively search for new solutions. And in making these new moves, it’s not enough to improve on your established practices, such as trying to do more of the same, faster better cheaper. The idea is not just to intensify your same old efforts. It’s to do something entirely different.

Discipline Creativity: Everyone must align with project goals. Participants must have clearly defined, measurable, tangible deliverables. Creativity is encouraged, but new ideas must pass rigorous tests. Teams and individuals must operate with a strong sense of discipline, with strong adherence to disciplined practices. Risk must be calculated and understood. Risk must be respected and managed – random creativity can not be accepted.

Invite Different Perspectives: Innovation feeds on multiple points of view. Get input from diverse sources. People with more experience, less experience, those who bring different expertise, older/younger. The point is to break your established pattern for development and thinking. Pay attention to how things are done in entirely different fields.

Plan and Improvise: Maintain careful preparation, be willing improvise. Begin your preparation by deep planning your project. Anticipate in advance all the possible outcomes, develop scenarios, run calculations. Then prepare for an environment of constant change. Continue to actively pursue your objectives. In the end, skillful improvisation may account for your success more than the efforts you put into crafting your approach. But in-depth planning at the outset helps you figure out what you don’t know. It points to those unmapped areas where you’ll have to play it by ear.

Embrace Eccentricity: Don’t allow your thinking to land on the predictable solution. Move beyond the boundaries of the ordinary.

Proceed With Optimism and a Can-Do Spirit: The Can-Do spirit is a mind set that sustains. This kind of thinking produces a mental toughness that enables us to press on through failure, and to harness mistakes as part of the learning experience, not as a final result.

Develop Robust Solutions: Take risks, but don’t fail. Expect innovation, but maintain a keen focus on risk management. Build within the margin, craft solutions which are tolerant to uncertainty. Unusual solutions can be successful as long as you maintain an appropriate safety margin.
Maintain Momentum and Forward Motion: Press forward and steadily cover ground. Movement accelerates the discovery process. Momentum stands as a high priority, because loss of schedule control comes with such high program cost impacts. Slowing down also causes the team to learn more slowly, miss opportunities, and burn up more energy getting started again. Innovation should take place in real time, on the fly. Do as we go, rather than trying to plan it in advance. Stay on the offensive, keep moving and push ahead. This forces innovation and helps hold momentum.

Be Fully Trustworthy: Everyone must adhere to a code of conduct, engendered by creativity and maintained by a climate of trust. This calls for mutual respect, with each individual fully competent in their domain – they must be worthy of trust.

Take Personal Responsibility For Communication: Information hoarding is counter productive and openness is critical to success.

Conclusion

In conclusion it is important to point out that I have never been involved in any program that has implemented Faster Better Cheaper. I came to appreciate FBC as I approached the question of Revolutionary Change. It has been my observation over the past twenty years, that the very processes we use to achieve standardization and repeatability, stifle creativity and imagination, the elements critical to leaps in technology.

Therefore, I conclude this paper with a question. If we are going to achieve the revolutionary changes necessary to extend our reach into space, are the organizations and cultures tasked to accomplish these goals assuming the appropriate structures? Are they approaching the problem with a new set of eyes, with new perspective? Are they encouraging change? Or is the culture of standardization, repeatability, and profitability inhibiting the revolution?

The opinions expressed in this paper are those of the author Dominick Barry and do not reflect the policies or views of Veridian Information Solutions