Escaping the Space Acquisition Death Spiral
Part Three of a Three Part Series

Col James D. Rendleman, USAF, retired
Space Law, Policy, and Strategy Contributor
Colorado Springs, Colorado

Mr. J. Walter Faulconer
President, Strategic Space Solutions, LLC
Ellicott City, Maryland

Escaping the Death Spiral

Warning signs of systems engineering and process failure have a tendency to aggregate and compound to create the space program acquisition "death spiral," driving the overall program to failure, as graphically described in figure 1. Program managers, corporate brass, agency heads, and legislative sponsors must work their hardest to prevent their space programs from falling into a "death spiral," refusing to let the factors that manifest the spiral auger in by confronting them head-on.

Performing Triage on Failing Programs

What should a space system manager do if confronted by a program that is failing? There are precious few examples of what needs to be done to right a failing space acquisition program. Only rarely has a floundering program been rescued without harming the taxpayer or the customers who needed the proposed system's capabilities. Employing massive infusions of dollars, manpower, and other resources, together with schedule relief, has been the typical way managers respond to problems.

Figure 1. The Space Acquisition Death Spiral.

Upon detecting a programmatic warning sign, immediate triage is a must if the manager wants to escape the death spiral. According to Thomas Taverney, "There aren't many people who can actually manage turn-arounds. And there isn't an easy common rescue formula, because failing space programs all seem to have very different reasons for their problems. The approaches needed range from just containing the risk to public hangings (what General George Washington did to keep his Army together at Valley Forge). Getting to the issues and establishing leadership are the key first step. And if there program is in free-fall, there isn't much time, so you can't just spend all your time trying to observe and figure out what's going wrong and what needs to be fixed. That would be like replacing your fan belts in the middle of the Indy 500."[1]

Once emplaced, a manager who has been tipped off to a problem in his or her program must act fast. The manager must move quickly to set up lines of communication within the team, and must develop trust relationships with the program's key technical people. During the triage phase, and depending on the size of the program, Taverney suggests a new manager schedule two-a-day, morning and early evening, meetings of the program's leadership team to learn what members of the team know, get familiar with the team members, and figure out who should be talked to. Then he suggests getting in the trenches with the team. "Do a dinner run (get food for the staff) during an evening test cycle, or a midnight coffee and doughnut run. Help bring in equipment from other locations to the test or assembling facility. Personally record data from tests. Set the example that everyone on the team should be ready to do any task to get things done."

In applying triage, a manager must know to execute four basic problem-solving steps:

- Observe—Assess and observe the realities of the organizational, technology, and schedule problems.
- Orient—Orient the program to confront the problems
- Decide—Develop, analyze, and select options.
- Act—Ensure the manager is empowered to bring resources to bear on the problems and implement the selected solutions to get the program back on-track.

Seasoned Air Force space professionals no doubt recognize that the observe-orient-decide-act, or *OODA loop*, is a concept originally applied to combat operations processes, and often at the strategic level. This decision-making construct, developed by

the late Air Force Col John Boyd, has become important in both business and military strategic thinking. Boyd contended that decision making occurs in a repetitive observe-orient-decide-act cycle. If one can process this cycle quickly, observing and reacting to unfolding events more rapidly than an opponent, he or she can "get inside" the opponent's decision cycle and gain an advantage, or respond effectively to management issues.[2]

First, the manager must first assess and observe the realities of the organizational, technology, and schedule problems. Whether it takes a week or a month, he or she must get fully immersed into the technical aspects of whatever is going on, and into technical aspects of what is being built. The manager must identify the causes of program failures—people, technology readiness, systems and software, engineering, manufacturing, resources, optimistic planning and schedules, industrial base, and the like. He or she should direct an end-to-end systems and software assessment of the program, to better understand its programmatic risk and status of available technologies. The current status of system and subsystem technology readiness levels should be ascertained, and the manager must develop realistic funding profiles for the program, as inherited or confronted.

Second, the program must be oriented to confront the problems. The manager must clean up the program organization and orient the team for success. He or she must form or re-form the solid foundations to the program, and find and fix the resources available to respond to the problems. The program must be oriented to address the causes of the warning signs of failure that the manager observes.

Third, options must be developed, analyzed, and selected. The program manager should orchestrate and set for delivery the necessary resources to fully complete the program. The program manager must be prepared to cancel the program if there is no way to succeed, or to select an alternative program that is good enough to satisfy mission requirements if the primary program is unwinnable. The program manager should also ensure early selection of a launch system.

Options for saving a program are best developed after ascertaining "honest" mission requirements and preparing a realistic analysis of options for a way ahead. Adding more money and schedule is usually not the best solution to a program's problems. Managers should attempt to develop options that can deliver the hardware, software and mission within the time and budget remaining, but, satisfying a smaller set of the requirements that achieve the desired mission objectives. If no path can be found to meet schedule constraints, even with reduced requirements, then the manager should look at options to rebaseline the schedule. Options that increase costs should only be considered as a last resort.

Finally, fourth, once options have been selected, the program manager must be empowered to act, bring resources to bear on the program's problems, and get it back on-track. The manager must take immediate triage steps to stop the bleeding and loss of resources, for each failed element of the programmatic death spiral. If the program cannot be salvaged, the manage must immediately cut his or her losses and move to restart.

Regardless of the option selected, the program manager must be given an authority to act matching his or her accountability when performing these triage steps. If the manager is required, however, to endure multiple reviews for each and every decision, the program will likely fail, despite the managers best efforts. Any course of action selected to correct the program's problems no doubt will need some midcourse corrections; accordingly the manager must be empowered to exercise the agility necessary to direct these steps.

The objective of these four triage steps is to return the program to a point where it can be effectively managed using time-tested practices for program management. These practices were described by Taverney and Rendleman in their 2009 *High Frontier* article on "Ten Rules for Common Sense Space Acquisition," a companion piece to this series.[3] Of course, a program manager must be wary of the warning signs of a pending programmatic death spiral before he or she initiates triage, and, accordingly restructures the program for success.

Confronting Technical Problems and Cost Growth to Achieve Success

As previously noted, systems engineering and process failures have a tendency to aggregate and compound to create the space program acquisition "death spiral," driving the overall program to failure. Program managers, corporate brass, agency heads, and legislative sponsors must work their hardest, therefore, to resist letting their space programs falling into a "death spiral" by confronting head-on the factors that manifest the spiral. They must directly address the distinct *warning signs* of impending program doom, and apply the observe-orient-decide-act triage steps to eliminate them.

Failed systems engineering. Of course, failed systems engineering must be confronted. In doing so, Space and Missile Systems Center (SMC) executive director Doug Loverro argues a program manager should never get so close to a program that he or she cannot make objective trade-offs, even those that might call the program into question.[4] He observes that many program managers "learn" to avoid casting doubt against the system's ability to meet the validated key performance parameters (KPPs). Missing a KPP means having to re-justify a program and risk cancellation. Loverro relates a sad story when this issue confronted the program manager on a major space effort soon after it began:

> He had been the person who "sold" the program, and had shepherded it through the byzantine approval process that accompanies multi-billion dollar developments. Approaching [the preliminary design review], it became apparent that the system design was going to fall short of one of his many (too many it turned out) KPPs. He had a choice: (A) go back to the combined Department of Defense (DoD) and intelligence requirements boards and ask for relief, or, (B) direct the contractor to change their design and find another way. He chose (B) because choosing (A) would have reopened the debate of whether this system was the right one to build.
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> The contractor complied. They redesigned the spacecraft to meet the requirement. But the weight of the satellite increased

by 50 percent in the process as did the cost. By the time they were done (nearly a year later) the program was hopelessly behind schedule, over cost, and on a nearly unrecoverable downward spiral. As it turned out though, the requirements community had been prepared to provide relief. The calculation was that the system would have missed the KPP by less than five percent. In fact, the calculated value was still better than any prior system had ever delivered. But, because the [program manager] was unwilling to risk possible cancellation by asking for relief, he had doomed the program by forcing a compliant design. The program was cancelled four years later after billions more had been spent.[5]

Hard decisions can be made, and they sometimes result in big wins for the taxpayer. In the early 1980s, one of the authors worked on a tiger team to address crushing cost-overruns facing the standup of Falcon Air Force Station (now Schriever AFB, Colorado). The project's program overruns were projected as $1 billion by the time the tiger team was formed. Much of the stand-up cost issues were driven by a requirement that the old Air Force Satellite Control Facility, the venerable "Blue Cube" in Sunnyvale, California, provide a mirror-image backup mission control station to each being set up at Falcon. The author and several of his colleagues posed the question: Is that a real requirement? By questioning subject matter experts, the team learned that mirror-image backups were not expected to work, and it would be extremely expensive to maintain an effective configuration control to achieve them. Indeed, the mirror-image configuration control requirement was driving a lion's share of the projected overrun. Armed with this data, the tiger team recommended junking the proposed construct. In its place, the new, nascent Air Force Space Command was designated to exercise administrative control of operational space systems, such as the Defense Meteorological Satellite Program weather, defense system communications satellite communication, and new GPS positioning, navigation, and timing satellites. SMC, then part of Air Force Systems Command, would exercise administrative control of the science and technology (S&T) and research and development systems and unique one-of-a-kind systems through the Blue Cube. The recommendations were accepted, and the tiger team celebrated helping the taxpayers escape a serious problem.

Unrealistic funding realities, including incomplete budgets or volatile program funding. Managers must be attuned to system engineering failures and be willing to strike fast to resolve the problems, and to stop the associated funding losses. The Secretary of Defense Robert Gates cancelled the Transformational Satellite Network (TSAT) system because SMC had not set its Advanced Extremely High Frequency Satellite System (AEHF) program on a winning track. While cancellation was necessary, the move has had the regrettable consequence of delaying deployment of new laser cross-link communication capabilities inherent in the proposed TSAT system.

Similarly, a DoD agency wisely cancelled funding for a complex space technology experiment and demonstration during the 1980s. When one of the authors was newly placed in charge of the mission's experiment design, he was appalled when told by program scientists that the technology proposed for the demonstration could never be scaled up to any type of operational system. Consequently, the demonstration would be a tragic waste of hundreds of millions of taxpayer dollars (to wit: Why demonstrate a technology if it would be something you could never use?). The author then helped set in motion a process that circumvented a program manager who only wanted to press ahead and conveyed the message to the agency through alternate Air Force and retired general officer channels. The contracted systems engineering and technical assistance team that assisted in de-scoping the program knew they would lose continuing work but were true patriots in not wanting to waste taxpayer dollars. The agency agreed, de-scoped the program, and moved the technology efforts in more appropriate directions.

Unreasonably pushing the technology envelope, with unstable requirements. Managers must spot when pushing the envelope will overwhelm the value their program will bring to the customer. For example, US government and Boeing engineers smartly addressed the issues that arose during inaugural Boeing Delta 4-Heavy rocket launch in December 2004. Its RS-68 engine suffered premature engine shutdowns due to cavitation, or bubbling, in the liquid oxygen feed system.[6] After considerable analysis, program managers came to realize no extensive or expensive system changes were needed in the propellant systems hardware. There were objections to this conclusion, primarily from engineers who wanted to deliver a perfect system, rather than one with a minor flaw. But analysis showed that there was adequate margin for the engine system under the worst case conditions, as matched against planned missions. "Cavitation margin adjustments, if required, can be made by changing the flight profile to throttle the RS-68 earlier, and can also be made by pressurizing the oxygen tank to a higher ullage pressure later in flight."[7]

Of course, when designing a rocket, it is not possible to account for every possible case, so good and reasonably designed rockets are designed with flexibility and margin in mind. The number of possible trajectories, payload weight, and atmospheric conditions create a huge number of possibilities. Fortunately, when the unpredicted RS-68 propellant system's cavitation problems occurred, the overall Delta launch system had enough margin to operate around the situation and satisfy the real and proven requirements for the system. Thus, pushing the envelope with further technical improvements was unnecessary.

Overly optimistic planning estimates, with weak program cost and schedule reserves. A program manager must spot overly optimistic planning. Fortunately, there is a relatively easy way to confront the problem—compromise. Achieve success by accepting less. Some of the wonderful successes achieved by NASA's Faster-Better-Cheaper programs can be directly attributed to applying this engineering philosophy. A space program capability is placed on-orbit and provides 90 percent of what the mission desires is far better than one that promises more, but remains on the drawing board.[8] SBIRS program managers should have learned that lesson.

The General Accounting Office also had it right when it recounted some of NASA's failings:

NASA asserts that contractor deficiencies, launch manifest issues, partner performance, and funding instability are to blame for the significant cost and schedule growth on many of its projects that we reviewed. Such unforeseen events, however, should be addressed in project-level, budgeting and resource planning through the development of adequate levels of contingency funds. NASA cannot be expected to predict unforeseen challenges, but being disciplined while managing resources, conducting active oversight of contractors, and working closely with partners can put projects in a better position to mitigate these risks should they occur. Realistically planning for and retiring technical or engineering risks early in product development allows the project to target reserves to issues NASA believes are outside of its control.[9]

Launch vehicle selection driving program complexity. A program manager must monitor closely launch costs and options available to access space. While little can be done directly to confront the high cost of launch, a program manager can apply out-of-the-box thinking to consider packaging missions (including national security missions) as hosted payloads on civil or commercial systems. Resources can be leveraged, as NASA did with Strategic Defense Initiative Organization's (SDIO) organization and resources to fund the Clementine Lunar-mapping mission; and SDIO used the opportunity to demonstrate the performance of lightweight sensors. The spacecraft was "widely hailed" as a successful demonstration of the faster, better, cheaper approach.[10] "The mission cost only $80 million, including launch and operations, and had made its way from design work to lift-off in just 22 months."[11]

Unreasonable "sunk-cost" arguments. A program manager must be on guard when he or she hears sunk-cost arguments for contamination of a failing program or portions of one. Unfortunately, sunk-cost arguments are difficult to defeat in bureaucracies, especially with their attendant Machiavellian machinations. This is the case, even though managers have preached the mantra "don't send good money in after bad" for several millennia. Sunk-cost questions were posed about SBIRS, but the sunk-cost arguments won out. The US government only half-heartedly explored alternate SBIRS program ideas, with very modest funding directed, first, to study of the Alternate Infrared Satellite System (AIRSS) and, then, to the Third Generation IR Satellite (3GIRS) program.

Even with a very high level of success in the AIRSS and 3GIRS programs, which have culminated in an Air Force flight demonstration program called Commercially Hosted Infrared Payload (CHIRP), the US government is still having a hard time moving away from their significant sunk costs and emotional investments in SBIRS.

According to the Department of Commerce:

> Hosted payloads can allow the government to plan and implement space missions on shorter cycles compared to the time it takes to procure an entire satellite—typically 24 months versus seven to 15 years. This is especially important for agencies facing impending gaps in operational capability. The commercial partnership gives the government an opportunity to leverage an already planned or existing satellite bus, launch vehicle, and satellite operations.

> Placing a hosted payload on a commercial satellite costs a fraction of the amount of building, launching, and operating an entire satellite. The commercial partner only charges for the integration of the payload with the spacecraft and the marginal use of power, launch services, and other resources. The total price is far below that of deploying an independent, government-owned satellite.[12]

CHIRP will employ a telescope that can view a quarter of the Earth from geosynchronous orbit, and is capable of high frame rate imaging in four specific spectral bands. Its large format focal plane arrays accommodate a wide-field-of-view infrared staring system, and, at the same time, reduce cost and complexity. The sensor for CHIRP was developed and delivered in less than two years. Its wide-field-of-view overhead persistent infrared system is the result of collaboration between the Air Force and industry, and, when deployed, marks the first time an Air Force payload will fly as a secondary payload on a commercial mission. The innovative acquisition approach reduces total system costs through the use of a previously-developed commercial satellite.

Smart managers turn away or reject sunk-cost arguments. After the National Polar-orbiting Operational Environmental Satellite System failures eventually became too much to ignore, the secretary of defense pulled out of the program's three-agency management circus despite the embarrassment and decade or more of joint program affiliation. He directed his department to start a new program.

Government/customer is not acting and thinking strategically. Program managers can act strategically and must be wary when strategic decision making is not being attempted. They should look for strategic opportunities. The decision to cancel the TSAT effort in favor of completing the AEHF system, for example, was smart and strategic. The secretary of defense properly concluded it was better to finish one new advanced military communication satellite successfully, than fund two failures. Fortunately, space laser technology efforts associated with the TSAT program continue, and can be brought forward, when the DoD is ready to pursue its next advanced communications satellite capability.

Faltering industrial base. The space community's leadership needs to better separate technology development from acquisition; to adopt evolutionary approaches that pursue incremental increases in capability; and to guide program start decisions with investment strategies that identify (1) overall capabilities and how to achieve them, highlighting the role space will play versus terrestrial-based assets and (2) priorities for funding.[14] The DoD laboratories were once significant incubators of space technology innovation and imagination. A return to basics might reclaim that excellence for these laboratories. Closing the gaps between available technologies and customer needs before beginning an acquisition puts programs in a better position to succeed—they can better focus on design, system integration, and manufacturing tasks. Of course, this may not always be possible, but the DoD recently revised parts of its space acquisition policy to emphasize this principle, in part to respond to the criticisms and poor TRLs and ensure its engi-

neers and acquirers have a better grounding in required technologies before starting an acquisition.

Stunts being used as a substitute for mission value. Program managers must evaluate their programs continually to ensure they are not just creating expensive stunts to keep interest in the program and retain funding.

The Kepler Mission Recovery Success

The *observe-orient-decide-act* triage steps were applied successfully to recover the NASA's Science Mission Directorate's planet-hunting Kepler spacecraft mission and get the spacecraft launched without a new infusion of cash. As a result of the triage, the mission has been a terrific success, trumpeting a treasure-trove of planetary observations.

The Kepler spacecraft employs a 0.95-meter Schmidt telescope optimized to scan star fields for signs of potentially habitable Earth-size planets. Unfortunately, due to a combination of factors, including management problems, technical challenges, and budget fluctuations beyond the project's control, the price tag for the mission rose several times since its 2001 selection. In mid-2006, NASA accepted a 21-percent cost increase for construction of the telescope, pushing the total cost of the mission above $550 million. The launch date also was slipped. Then, in the spring of 2007, the Kepler mission team, which included Ball Aerospace and Technology, Ames Research Center, and the venerable Jet Propulsion Laboratory (JPL), told NASA science chief Alan Stern it needed an additional $42 million and an extra four months to finish the spacecraft.[15]

Observing a festering problem, Stern's response was: "No, [the Science Mission Directorate] no longer manages by open checkbook. You need to find a way to get it back in the box because I don't have $42 million in the astrophysics program anyway."[16] As related by Stern, he told the team to come back with a plan for getting the job done within the revised budget NASA had approved for Kepler the previous year.[17]

According to Stern, the team came back with a request for $54 million instead of $42 million, at which point he said, "Apparently you don't think I'm serious.… If you don't think I'm serious just come back to me with numbers like these again and that will be the end of the project." Stern already had made clear the program was all but canceled, and that was before the Kepler team responded to his call to cut costs by asking for even more money. After rejecting their request for the $54 million, Stern gave the team a month to reorient itself and take another stab at putting their program "back in the box."[19]

When the Kepler team returned to NASA headquarters, it had taken Stern's threats very seriously and had decided on necessary changes. Stern said, "They came back with no cost increase."[20] The team proposed staying within the budget by cutting six months off the end of the four-year mission, scaling back spacecraft testing, reducing schedule reserve, and making management changes. In addition, Ball, the firm building the spacecraft and instrument, gave up millions of dollars in earned fees. Under the change, the mission missed its launch target only by a few months, which satisfied Stern.[21] "The only thing more important than keeping Kepler marching towards launch

is to have responsible management in the Science Mission Directorate," he said. "I won't write checks any more. There's a new team in town and we don't work that way."[22]

While reducing testing and cutting schedule reserves could generate problems, Stern believed the reductions were responsible and would not increase the mission's risk. According to Stern, "They [also] had very lavish schedule reserves by normal industry standards. They elected to cut themselves back to JPL standards."[23]

The new plan also streamlined Kepler's "convoluted" management structure, which had been a significant contributor to its systems acquisition woes. Initially, when NASA selected Kepler for funding, the agency required Ames Research Center to pick either JPL or Goddard Space Flight Center, in Greenbelt, Maryland, to help run the project. With JPL added to the mix, Kepler essentially had "three bosses": the JPL project manager, the Ames project manager, and a rookie Ames principal investigator.

Streamlining the management structure simplified the program. NASA *acted* to put entire Kepler team under the direction of a seasoned JPL project manager and engineer who had worked on Mars Pathfinder, was the flight system manager for Deep Space 1, and ran Starlight before that ambitious three-telescope project was reduced to a ground-based technology demonstration. According to Stern, the program "had to make some tough choices and it takes a professional program manager and not a rookie program instructor to do this." The principle investigator was retained to take charge of the entire science investigation.[24]

Summarizing Thoughts

Ultimately, failure to call out and confront programmatic technical problems and cost growth challenges will limit the success of the whole space community in the 21st century. Fortunately, technical problems can be solved and obstacles avoided, but this demands smart systems engineering, scientific and technical insight, crafty resource administration, and wise program management. The US space program needs its own Alexanders, to cut through the Gordian knots of space acquisition and decisively help redefine significant programmatic challenges on their own terms, to cut through the challenges to new solutions. To do this, acquisition leaders must push back against policy makers who improperly match resources to requirements before beginning a space program. They must balance the cross-cutting factors which make it difficult to achieve a match between resources and requirements for space acquisitions. These factors include: diverse arrays of competing interests; a desire to satisfy all requirements in a single step, regardless of the design or technology challenges; the tendency for acquisition programs to take on technology development that should occur within the S&T environment; cascading effects as older programs are extended or overrun, thereby reducing S&T investments and putting additional pressure on the investment portfolio for ambitious future projects; and the government starting more programs than it can afford in the long run, forcing programs to underestimate costs and over promise

capability. Each of these factors must be confronted and re-solved to achieve future success.

Notes:
[1] Major General Taverney (USAF, retired) is former vice commander, Air Force Space Command. A member of the Space Operations Hall of Fame, he is recognized for helping rescue several classified and unclassified programs during his career.

[2] Colonel Boyd is said to have never written a book on military strategy. His theories on warfare can be found in a lengthy slide presentation entitled "Discourse on Winning and Losing" and several essays. See also Robert Coram, *Boyd: The Fighter Pilot Who Changed the Art of War* (Little, Brown and Company, 2002).

[3] This article serves as a prequel to Thomas D. Taverney and James D. Rendleman, "Ten Rules for Common Sense Space Acquisition," *High Frontier* 6, no. 1 (November 2009). A short-form description of its rules is summarized in endnote 40, Part I.

[4] Douglas Loverro, "Getting it Right: Lessons from Failed Space Acquisitions," *High Frontier* 6, no. 1 (November 2009) 14.

[5] Ibid.

[6] The cavitation issue was not with the engine itself. It occurred in the plumbing between the system's oxygen propellant tank and the engine. The bubbling was caused by the speed of the propellant flow, and a bubble formed at a shut off sensor location. The oxygen propellant's flow valve was designed to close when the shut off sensor no longer detected oxygen flowing. Upon sensing the unexpected bubbling anomaly, the system concluded that propellant flow had stopped, and shut the flow valve, shutting down the Delta's engine prematurely.

[7] Justin Ray, "Delta 4-Heavy investigation identifies rocket's problem," *Spaceflight Now*, 16 March 2005, http://spaceflightnow.com/delta/d310/050316rootcause.html.

[8] Many times program desires exceed the essential mission needs.

[9] *NASA: Projects Need More Discipline Oversight and Management to Address Key Challenges*, GAO-09-436T, 5 March 2009, 6-7.

[10] Howard E. McCurdy, *Faster, Better, Cheaper: Low-Cost Innovation in the US Space Program* (The John Hopkins University Press, Maryland: 2001), 46-47.

[11] Ibid, 47.

[12] "Hosted Payloads," Department of Commerce: Office of Space Commercialization, 13 April 2011, http://www.space.commerce.gov/general/commercialpurchase/hostedpayloads.shtml.

[13] "SAIC Completes Integrated Testing of Commercially-Hosted," SAIC News & Media, 3 November 2011, http://investors.saic.com/phoenix.zhtml?c=193857&p=irol-newsArticle&ID=1490991.

[14] "GAO Report: Satellite Programs Show Overruns Across the Board," *Defense Industry Daily*, 4 August 2005, http://www.defenseindustrydaily.com/gao-report-satellite-programs-show-overruns-across-the-board-0969/; Sam Churchill, "Advanced EHF – Wait for It," *dailywireless.org*, 3 January 2007, http://www.dailywireless.org/2007/01/03/advanced-ehf-wait-for-it/.

[15] Brian Berger, "Kepler Team Cuts Cost, Avoids Cancellation," *Space News*, 16 July 2007, http://www.space.com/4069-kepler-team-cuts-costs-avoids-cancellation.html.

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] Ibid.

Col James D. Rendleman, USAF, retired (BS, Chemistry, University of North Carolina - Chapel Hill; MBA and MPA, Golden Gate University; JD, Whittier College School of Law; LLM, University of San Diego School of Law). Mr. Rendleman was commissioned a second lieutenant through the Air Force ROTC at the University of North Carolina - Chapel Hill. He served in a wide variety of science and technology, engineering, management. and policy positions within the Air Force laboratories and space acquisition community, Headquarters, Air Force Space Command, the Air Staff, and the National Reconnaissance Office. He is a level-3 space professional and trained director, space forces. He served as study director for The National Academies study of the US Aerospace Infrastructure and Aerospace Engineering Disciplines. An attorney and member of the State Bar of California, Mr. Rendleman engaged in law practice as a partner, solo practitioner, and associate with firms in Los Angeles, San Francisco, and Napa, California. He is a member of the American Institute of Aeronautics and Astronautics' Legal Aspects Aero and Astro Technical Committee and International Activities Committee, and is an elected member of the International Institute of Space Law. He taught management theory for Cerro Coso Community College and Golden Gate University. He also taught space law, policy, command and control, international cooperation, and missile defense for the National Security Space Institute.

Mr. J. Walter Faulconer (BS, Space Sciences, Florida Institute of Technology; MS, Systems Management, University of Southern California). Mr. Faulconer is president, Strategic Space Solutions, LLC. He has spent over three decades in the aerospace industry providing executive leadership, creative program management, systems engineering, and business development to civilian, commercial, and national security space customers. Before assuming his present duties, Mr. Faulconer was business area executive for civilian space at John Hopkins University's Applied Physics Laboratory (APL), leading 500 scientists and engineers on cutting edge space programs such as: the MESSENGER Mercury orbiter mission; the TIMED study of Earth's upper atmosphere, ionosphere, and thermosphere; the twin spacecraft STEREO study of the sun and its coronal mass ejections; and NEW HORIZONS, the first mission to Pluto. Before APL, he worked at Lockheed Martin Space Company and Martin Marietta Astronautics Company as a director, program manager, flight test manager, systems engineer, and mission operations lead on a wide variety of classified and unclassified programs dealing with space launch, space control, missile defense, Space Shuttle, and other missions. Mr. Faulconer is an Associate Fellow of the American Institute of Aeronautics and Astronautics, a member of the board of directors for the American Astronautical Society, and a member of the International Astronautical Federation and National Space Society. He has taught graduate level business marketing and strategy at John Hopkins University, Whiting School of Engineering.