MITIGATING RISK for INVESTMENT in AEROSPACE COMPANIES

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Abstract

Aerospace companies, especially young space companies, need investment capital to grow and prosper, yet they are often viewed as ***high risk*** by the investment community. This paper examines the specific factors that contribute to this dilemma. Successful angel and venture investors and professionals that work with them are interviewed to address the obstacles from an investor's perspective and to consider solutions for achieving investment objectives.

Lastly, Systems Engineering methods and processes will be analyzed to address mitigating investment risks addressed by the interviewees to assist aerospace companies in achieving and sustaining prosperity. Ultimately, we ask,

Can Systems Engineering offer solutions to investment risks posed by aerospace ventures?

Background

The Rise of NewSpace

Understanding our world, our universe and beyond is integral to the survival of humankind. This understanding can only be achieved through exploration and challenging the unknown.

Until recently, only a handful of countries had the technological and financial means to undertake space exploration. Large aerospace companies competed for government contracts to build launch vehicles, satellites, a space station, and other items sent to space. Each item sent to space was technically complex, expensive to develop, build and launch, and could only be used one time.

Recent advancements in technology, changes in government funding priorities and changes in the public philosophy toward access to space and space travel have shifted our collective expectations and perspectives. The first International Space Station privately financed visitor, Dennis Tito, inspired wealthy individuals such as Elon Musk to establish SpaceX and develop low cost launch vehicles that are disrupting markets worldwide. The 2004 $10M Ansari X Prize contest, won by Burt Rutan and Scaled Composites, led to Sir Richard Branson developing a

spaceship to take tourists to space. Twenty-six teams are currently competing for the $30M Google Lunar X Prize, all privately funded. The Commercial Spaceflight Federation, a private spaceflight industry group, has over 40 member companies and organizations.

The term NewSpace varies in meaning but generally describes companies that are developing space systems principally with private capital, in contrast to the approach taken by NASA and the mainstream aerospace industry. They take low cost, innovative approaches to developing space capabilities. A company may combine existing technologies in an innovative way as well as develop new technologies. Their programs often feature incremental development that produces revenue, enabling company viability and increased capability. Their objective is to enable low-cost space access for everyone, and to prosper as they do so.

As NewSpace companies expand, so do the investment opportunities associated with them, as well as business opportunities for suppliers and service providers. This paper addresses investment risk for all of these types of companies, as well as both start-up and established traditional aerospace companies, seeking private capital. Thus they are referred to collectively as "aerospace companies" in this paper.

Method of Approach

Investors, and professionals that work with them, were interviewed to provide the perspectives of the investment community towards aerospace ventures, as given in Table 1. They were asked a set of questions (Table 2) with slight adjustments made depending on the interviewee's role. For example, those that advise investors would have question 3, "What types of companies do you invest in?" posed as "What types of companies do your clients invest in?" In addition to investors, other investment professionals besides investors were included in the survey to provide a broader perspective. Investment risks addressed in this paper are applicable to ***new*** or ***established*** aerospace companies seeking outside investment. *All interviewees agreed to be recorded and to be quoted for this paper.*

Table 1. Investors and Other Professionals Interviewed for This Paper

Interviewee	Position	Background
Brian Barnett	Entrepreneur	Founder and CEO SatWest LLC, a mobile satellite services, management and space services consultancy. Former aerospace investment advisor at KPMG.
Hoyt Davidson	Investment Advisor	Founder and Managing Partner, Near Earth LLC. Before founding Near Earth in 2002, Hoy was a Managing Director as Credit Suisse First Boston and at Donaldson, Lufkin & Jenrette.

Amaresh Kollipara	Entrepreneur, Strategic Advisor	Founder and Managing Partner, Earth2Orbit, LLC, as provider of satellite launch services, as well as a Principal at the Space Angels Network Network. He was formerly a Strategy Manager at Accenture advising Global 500 clients.
Joe Landon	Manager and Engineer	Managing Director at Space Angels Network Network, Director of Program Development at Space Adventures, Formerly Sales Manager at McMaster-Carr, Engineer and Project Manager at Boeing Satellite Systems
Rick Citron	Investor, Lawyer, Investment Advisor	Owner at Citron & Deutsch, An Entrepreneurial Law Firm, CEO of ADAM Inc., a mobile applications developer
Andrew Sherman	Lawyer, Investment Advisor	Partner, M&A and Corporate Department at Jones Day. Formerly Corporate/M&A Partner at Dickstein Shapiro and McDermott Will and Emery
Dick Reeves	Investor, Entrepreneur	Director, Huntsville Angels Network, CEO at Biztech, a high-tech incubator, Board member, Time Domain Corporation, a wide band radio technology manufacturer. Founder or principal of several high-technology companies
Rosanna Sattler	Lawyer, Investment Advisor	Partner at Posternak Blankstein & Lund LLP, chair of the firm's Space Law and Telecommunications Group
Per Wimmer	Investor, Entrepreneur, Adventurer	Founder, Wimmer Financial Investment Bank, former equity advisor at MF Global/Man Securities and Collins Stewart, Director for Institutional Sales of European Equity products for Goldman Sachs & Co.

Table 2. Questions Used During Each Interview
1. Why did you become a business investor?
2. How long have you been an investor?
3. What types of companies do you invest in?
4. What is your maximum level of investment? (optional)
5. What would you consider to be your greatest successes?
6. Why do you invest in aerospace companies?
7. What factors do you consider before investing in a space company?
a. How important are these factors in relationship to each other?
b. How do you measure/weigh/evaluate these factors?
8. How do you measure/weigh/evaluate the technical acumen and capabilities of an aerospace company vs. the program/managerial vs. sales/marketing aspects?

9. What do you view as the greatest risks in investing in aerospace companies in terms of cost, schedule and technical risks?
10. Is there a return for investors other than equity? If so, what does that look like?
11. With respect to these risk factors, what can a company do to decrease their risk profile and become a more attractive investment?
12. What role, if any, would risk evaluation tools play in evaluating levels of risk, and/or alleviating them?
13. Have you used risk evaluation tools? If so, do you have any recommendations?
14. What unique risks do space companies pose vs. investments in other aerospace or technology companies?
15. What additional advice would you give to a new aerospace company in terms of achieving venture capital funding?
16. Are there any recent articles, interviews or studies that they would like to highlight as a part of this interview or that I should mention as part of this interview?

Results

Investors

The term investor refers to private investors or companies that invest in other companies. For the purposes of this paper the term investor covers the following: private, venture capital and strategic investors.

Private investors refer to those individuals, either singly or in groups, that are known as '"angels' or "bands of angels," and they are a rapidly growing sector of the private equity market.'[1] Angels are often on the front line of company investment as companies tend to attract small investment initially. A typical angel investment ranges from the tens of thousands to a few million dollars. Angels may or may not be professional investors but often have business experience in a particular industry the company is focused in. In addition to achieving their Return on Investment (ROI) objectives, angel investors often have a personal interest in the industry and seek to assist the company. A good example of this is the Space Angels Network Network, a group of California angel investors that invest in space companies.

Venture capitalists are professional investors who invest other people's money. They typically invest to achieve 25 percent or more return within a one to five year time period, and can demand a controlling stake in a company to offset their risk. They provide management and industry expertise that the company would not otherwise be able to access. Their investment range starts in the millions and increases from there.

Strategic investors are usually companies that invest in a smaller company for strategic reasons. A small company may have a technology or product needed by the larger company, or have customers in markets that the larger company wants to access.

Why do people invest in companies? "'Finance, strategy, and emotion' are the core reasons that motivate investors."[2]

We now discuss the feedback from the investors and investment professionals selected as interviewees for this paper with a discussion of the conclusions drawn from their responses.

The interviewees found their way into the investment area in a variety of ways. Brian Barnett guided aerospace investors when he worked for KPMG, and now invests in his own company. Amaresh Kollipara has a background of advising investors and entrepreneurship: he currently works with both investors and entrepreneurs understanding both investor needs and assisting entrepreneurs to be solid investment candidates as a principal of the Space Angels Network Network. Early in his career, Rick Citron, a lawyer, was involved in many business deals and decided to become an investor. Dick Reeves backed into investing after struggling to find financing for his own companies and later organized Huntsville Angel Network to help others. Andrew Sherman was an entrepreneur early in his career and, fascinated with the interaction between investors and entrepreneurs, became a lawyer and has been involved in deals since that time. Joe Landon, Managing Director of the Space Angels Network Network, leverages his interest and familiarity with aerospace, aviation, and defense to work with entrepreneurs and investors. For Rosanna Sattler, her law firm clients include investors that invest in aerospace companies as well as her personal interest in this area. Per Wimmer combines his desire to fly to space and his entrepreneurial and investment acumen.

The interviewees run the gamut from very experienced, with 40+ years, to less than 5 years of investment experience. Some have experience in numerous industries, and some have remained focused in the aerospace and space areas. Investment values ranged from $250,000 to $5.5 M in one company over several rounds of investments.

Conclusion: Market opportunity and a strong management team are the most important factors in the decision to invest, as well as the business model.

This finding is nearly unanimous among those interviewed. "Number one is the market opportunity, what market does this company address, what is the investment horizon period, how predictable is it?"[3] "Those in space industry need to understand that [space] investments are treated just like other investments… investors look at the same factors – market, management team, and their history and experience. Technologists, in general, are so enamored with their technology that it should be invested in [on technical merits alone], and that's not the case… there needs to be compelling business reasons [to invest].'[4] "For every business the management team is the most important – if the idea is good it will attract a good team: smart, dedicated, experienced people is the key."[5] The "quality of the management team – experience not just in

the technical/service area, but experienced in developing new companies and new ideas and learning from their mistakes. Also, having a diverse set of folks on the management team."[6] "Management is key. Cool ideas are not enough."[7]

Critical questions investors ask include: "How are you going to make money? How am I going to make money as the investor?'[8]

Technical risk also is also examined but more often than not the technologists involved are good at what they do. For challenging or complex undertakings, external consultants are sometimes hired to evaluate technical risk. Other issues that could be a factor such as government and regulatory risk also factor into the decision to invest.

Conclusion: Although technical acumen and skills are important, management, marketing, and sales skills and experience are critical.

"Having a wonderful technology but no business skills equals failure. If the product is acceptable, but the management team has great business skills, success is much more likely. Windows is much more successful because they were first to market. Facebook not as good as MySpace but got users much more quickly and they have more users." [6] "The investors assume the technology is going to work (you're the expert) but has the technologist run a company?"[4] "People assume technical expertise into the equation, they assume you know your stuff…and that is confirmed as a matter of due diligence" says Sherman, adding "if the only thing the company has is technical competence, it is not compelling to the investor. The ability to execute, the ability to manage projects when they come in, to develop a branding strategy, the ability to manage relationships, all these things are important."

Conclusion: A shorter investment horizon, ideally with interim revenue milestones, is a key investment factor.

Most investors need to meet their return on investment objectives in 3-5 years. Angel investors are often more patient with a 5-7 year horizon. This means that the company has to have gotten a product to market and is achieving revenue in this time period. "In aerospace business what is the time period for success for the company? Those that could be put into place or part of it can be in place in a year, then much better, 1-3 years time frame. "[5] "Many space companies have impressive goals but they are long term goals (for example, launch vehicles, space stations); there needs to be short term goals of getting revenue - 3-5 years - the company has gotten to market and achieved a financial goal within this time. Caveat: these are rules of thumbs for investors"[6] Per Landon "space companies need a business model that can make money within a few years – for Space Angels Network Network it is 5-7 years." "More sophisticated investors understand that it takes time, and are more patient, with respect to aerospace," says Sattler.

Conclusion: Cost uncertainty is the greatest investment risk factor.

There are numerous reasons for cost uncertainty. In certain cases companies require a great deal of upfront capital to get the business underway. The size and complexity of space vehicles and

satellites engenders more upfront money, a longer timeline to market, and lower salvage value in the case of business failure. Technical risk leads to cost risk: technical uncertainty that accompanies that which has not been done before creates uncertainty around how much and how long it will take to make the technology, the end item, work. "Whenever doing a technology, what exists, what is close, and what is hard? Hard is weak link in chain and gotta ask can we do this with the resources, time, people we have? Kistler's George Miller brought in Apollo engineers to help solve the tough problems – like return of the vehicle."[5]

Another critical risk factor is the ability to "adapt and pivot, in changing market conditions."[2] Sattler maintains a primary risk for certain aerospace companies is obtaining "insurance for those carrying humans into space, and export control for dual use (civilian, military) technologies on the United States Munitions List (USML)." For certain businesses, their greatest risk is the loss of their intellectual property. "There is a need to safeguard IP throughout the business cycle, not just at the beginning when patents or other protections are obtained."[7]

Conclusion: Investor ROI can take several forms.

"Financial investors want a financial return, not a technology achievement: they want unlimited upside through equity participation, or convertible debt securities, and manageable downside risk protected by preferences in the capital structure and some floor on company value through marketable assets or valuable intellectual property, a variety of ways to get there, but the focus is always a cash return on investment."[3] "Investors buy equity in the company: equity percentages vary a lot and are the subject of negotiation. The company is valued based on assets and future sales and investment is compared to value and that's how much of the company that is taken as equity as a general rule."[6]

In contrast, a strategic investor will invest because of a key technology or product that helps them elsewhere. For example, "Boeing invests in a small company that has a technology they need for a new market they wish to enter, or a new government agency they aren't currently doing business with. It is the same situation with American companies investing in Canadian companies to gain access to Canadian markets. …' Hoyt indicates. [Strategic investors are the] best investor if you can find them… Federal government can be strategic investor but they want the rights to the technology.'[5]

Conclusion: Entrepreneurs need to see their companies as investors see them.

Investors evaluate the business team and therefore, so must the entrepreneur. They "need a team that covers the bases and ideally includes start-up experience' and 'get advisors that plug holes in the team in these areas."[6] "Business risks are also related to business track record. Suppose someone has a great idea who has no business experience – teaming is key. Put technical ego aside – PhDs that were CEOs that burned through monies with no result. Need CEO and CFO that have the business building experience."[4] "The key element that is often missing is the money man: translating the engineer's dreams and ambitions and inventions into a real business

plan that can be understood by sources of capital," says Citron, adding "they will help you build a business plan and a management team that can be financed."

Companies "need a plan to get to revenue that is laid out and makes sense."[3] They need to "accomplish as much as possible before seeking outside funding…. The further along you are, the closer you are to revenue."[5] Further, "understand that there is fierce competition for investment funding, including companies in hot sectors like social media, internet, and biotech and at all stages of investment, and for all types of investors."[3]

The entrepreneur needs to "show that the product or service is an extension of earth based activities to increase investor comfort level. Market the company as part of the larger terrestrial products and services industry – make that connection – avoid NASA [as the] only connection. It is an extension of what we do on earth," says Sattler, who cited the example of "Celestis tying their services to burial services worldwide."

Ensure "shareholder agreements that are specific enough to avoid problems later when the company becomes more viable."[7]

Entrepreneurs need to "take the time and effort to present your ideas well, and be open to coaching. Aerospace [companies]usually do a very poor job of presenting ideas and so Space Angels Network coaches them before they present in front of the group. We want to provide good opportunities to our investors and not waste their time, and we want to increase the company's chances of attracting some attention from investors."[8]

Conclusion: Investor due diligence includes analysis of personnel, markets, technology, finances, relationships and previous experience.

For angels and smaller venture capitalists, due diligence consists of gathering information from company personnel. This also includes examining the management team, those that have had previous dealings with the management team including other investors and colleagues, and a financial and competitive analysis. "When angel investors evaluate deals, they don't use tools, they use their experience and use financial analysis to evaluate deals."[6] Investors "will talk to customers, and others familiar with market, product."[8] Previous startup experience is also examined.

Large venture capital firms (that make bigger investments) do use risk evaluation tools as part of their due diligence process – it was not clear from the interviews conducted what tools are used, what they do, and whether they are off the shelf or custom-developed tools. The interviewees indicated that internal analysis is performed. "Institutional investors often hire marketing or tech consulting firms to help them with due diligence."[3]

Conclusion: Investors view space endeavors as higher risk than other aerospace ventures.

Investors gave varying reasons for why they view space ventures as being riskier than other aerospace ventures including increased market, financial, technical, legal, and strategic risks.

"Generally, it can be more challenging to establish the market need."[4] "It is a very capital intensive industry, [which] typically requires a lot of proof of capital before you get to first revenue dollars... technology risk is also typically a concern because it tends to be big assets and if they blow up the assets go out the door, the investment goes out the door. Thirdly even if you do succeed in creating something that has validity in some sort of technology, it still doesn't guarantee that you have validity in terms of revenue generation. You could have something that technically works fantastic, but nobody wants to buy it….I think that there is a lot of risk when it comes to the business model actually working even if the technology is working. Those are probably the three biggest risks."[9]

Doing things that have not been done before involves higher technical risk, causing more cost and schedule uncertainty, which increases investment risk. "When doing something with lots of new pieces, can be hard to understand investment risks. With other types of business (clothing) you know costs for manufacturing, logistics, storage, shipping etc. When in the space tech business it's all brand new so [it's] higher risk. Will this work or not? [It] costs more to find out if it will work or not, and to prove along the way to investors, clients that you are doing the best possible. Another risk is more cost and time involved than initially thought."[5]

"There are fewer space companies and less of a track record, so [that] makes deal evaluation harder. Also less later stage capital to ensure long term success."[8]

"For items going to space including launch vehicles and satellites, there are legal challenges due to less developed legal liability regime in this area, and due to ITAR. Due to less of a track record, there is less insurance industry experience here, and so getting insurance is more challenging."[7]

'Manage the opportunities with larger companies. [There is a danger of] competition of much larger companies to copy you instead of buy you," says Reeves.

For convenience the conclusions drawn above are re-iterated here:

- Market opportunity and a strong management team are the most important factors in the decision to invest, as well as the business model.
- Although technical acumen and skills are important, management, marketing, and sales are critical.
- A shorter investment horizon, ideally with interim revenue milestones, is a key investment factor.
- Cost uncertainty is the greatest investment risk factor.
- Investor ROI can take several forms.
- Entrepreneurs need to see their companies as investors see them.

- Investor due diligence includes analysis of personnel, markets, technology, finances, relationships and previous experience.
- Investors view space endeavors as higher risk than other aerospace ventures.

Now that we have examined the comments from the interviewees, we revisit the original question:

Can Systems Engineering offer solutions to investment risks posed by aerospace ventures?

Systems engineering is a multi-disciplinary effort that involves both the technical effort and technical project management aspects of a project. The International Council on Systems Engineering (INCOSE) provides this definition of Systems Engineering:

"Systems Engineering (SE) is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs."

Although technical acumen and skills are important, management, marketing, and sales are critical.

While SE can't help companies select a management, marketing or sales team, SE processes can help them be more effective. SE processes can provide the means for the management team to *optimize* company products to achieve market, investor, regulatory, and other stakeholder needs. Optimization means bringing a product to market that meets or exceeds market needs, as quickly as possible, within the allocated budget, thus helping to ensure positive cash flow. Systems Engineering personnel often work directly with the program management in their dual management/technical role.

SE processes provide a structured approach to accounting for all requirements up front at a time when they are the cheapest to implement. Requirements have numerous sources including those generated by the end customer, applicable laws and regulations, industry standards, legal agreements, company policies and directives, in addition to program cost, schedule and solution constraints. In the case of launch vehicles for example, the FAA Office of Commercial Space Transportation imposes safety regulations that add technical complexity and cost to the program, and must be met before permission to fly is granted. Systems engineers can perform operational analyses to understand what the product must do in each lifecycle stage. For example, the lifecycle of a satellite includes ground transport, storage and flight preparation stages, as well as

flight to space, operation in space, and disposal stages, with time allocations for each stage. At each stage there are functional and physical environment requirements (e.g. vibration, thermal) that the satellite must endure to subsequently operate nominally in space. Most products operate with or as a part of other systems, and the interfaces to those systems must be identified and specified so the design accommodates them. Rocket stages must be able to mate with each other, and be compatible with the launch pad services for oxidizer and fuel, for example. In addition to performance requirements, other market requirements such as how the final product looks and feels need to be accounted for. Program constraints also must be adhered to, such as not to exceed weight and size of the item. All requirements need to be identified, expressed as achievable requirements and documented so that all program personnel will have this critical information.

'Best is the enemy of good enough'. One responsibility of systems engineers is to look across the program to ensure that the end product is being optimized, not just certain parts of it. SE enables getting to 'good enough' for the market versus the tendency for groups within the program to make their subsystem or piece of the work the best ever, often driving costs higher to provide more performance that cannot be utilized by the rest of the system, thus wasting money and time. (Envision the old MAD magazine pictures of cars with enormous, outsized carburetors or wheels and this illustrates the point).

System engineers are often involved with every phase of the program to help keep the program moving forward towards completion. Systems engineers work with the design engineers and other specialists to ensure that all requirements are specified appropriately (clear, achievable) and assist design efforts to implement requirements properly and completely. System engineers can also plan verification activities including testing and analyses, write test procedures and assist in testing. They can be involved in the transition of the product to operation, and in operations and maintenance activities.

With their 'system' view and deep knowledge of the product overall, systems engineers are alert to problems in one program area affecting other areas and assessing these affects, as well as ensuring that problem fixes in one area don't break something elsewhere.

SE processes and personnel can help ensure investment objectives are achieved because of early, thorough systems definition in collaboration with stakeholders and the design team. Their overall deep knowledge of the program can ensure product optimization.

A shorter investment horizon, ideally with interim revenue milestones, is a key investment factor.

The chances that a company will raise the capital it needs and bring its product or service to market on time are greatly enhanced by a well laid out program plan and schedule, with revenue milestones, and rigorous Systems Engineering definition early in the program.

A solid program plan and schedule, with interim revenue milestones, makes aerospace companies more attractive investments. "Predictability is important. …So you know all the steps that have to be taken from A to B and you have quantified all the milestones to be achieved. There are cases where investors will tie the release of funds to the achievement of milestones like Preliminary Design Review, Critical Design Review, flight qualification of hardware or other major performance tests …you know all the steps that have to be taken, no showstoppers, no leaps of faith."[3]

"[Companies] need interim products that make money – the stepping stone approach."[6] Systems Engineering processes enable the definition of the distinct milestones: the requirements, the design, development, testing and all the work that must be accomplished for each milestone, and whether the achievement of that milestone produces revenue directly or not. Long-term programs require interim revenue producing milestones to raise capital. For example, while developing a new launch vehicle that takes 10 years to complete, a company can generate cash flow along the way by providing subsystem products such as communications or navigation systems or fabricate structures for customers as demonstrated by XCOR and other space companies. Specific milestones in the program as it is planned are specified through Systems Engineering processes to achieve the revenue milestones. Systems definition, requirements, development, test and other program activities are lined up to achieve these milestones resulting in paying customers thereby generating interim revenue.

Systems Engineering can benefit programs by achieving faster time to market. Three airplane manufacturing tools at The Boeing Company were developed to hold large airplane parts during the manufacturing process. Each complex tool weighed over 20,000 pounds, had approximately 100 axes of motion, required a rack of electronics to operate, and cost several million dollars to develop. The tools were developed with varying levels of Systems Engineering support - specifically varying degrees of requirements definition and systems management. All three tools met cost objectives. However, the tools that employed medium and high amounts of requirements definition and systems management had a project duration less than 50% of the third tool, and were ready for production 1.7 and 2.6 times faster than the third tool.[12]

Cost uncertainty is the greatest investment risk factor.

Systems Engineering processes initiated early in a program can greatly reduce program technical, cost and schedule risks, thus reducing investment risks. Specifically, Systems Engineering can reduce the chance that unknown problems will occur later in the program, costing substantially more money and time to address. Systems Definition, a Systems Engineering process, enables the identification of all system needs early in the program when they are the least costly and most simple to include in the system design. Successful product development and realization of profitability and ROI objectives depend on actual program costs not exceeding projected costs. The system definition process significantly increases the likelihood that this will occur.

Significant cost penalties are incurred when design changes are made later in the program due to rework, due to test failure, and due to late incorporation of requirements. The Boeing Company performed a study on airplane problems discovered during the test and certification phase. The cost of fixing the problem during test and certification was compared to the cost of changing drawings and documentation before the hardware was procured. The cost ratio is 30 to 1.[13] That is, if $30,000 is spent changing design data only, $900,000 in hardware costs can be saved. A study of NASA programs shows a direct correlation between the amount of up front engineering investment in requirements understanding with project cost growth.[14] A software rule of thumb gives the following multiplier: if the cost of software is X during the requirements phase, and the cost to change it during testing is 4X, the cost to change it during maintenance (operational phase) is 100X.[15]

Cost uncertainty, and therefore investment uncertainty, can be significantly reduced by Systems Engineering processes implemented early in aerospace development programs.

Investors view space endeavors as higher risk than other aerospace ventures.

Cost and technical risk reduction measures previously discussed include early and complete requirements development, technical program oversight, and optimizing for 'good enough' performance to meet market, cost and schedule objectives. To this list we add program risk management.

Managing cost uncertainty, and thus managing investment risk, can be greatly assisted through a disciplined approach to managing program risk. Risk is always present in the life cycle of systems and can be introduced at any point in the program. "The system may be intended for technical accomplishments near the limits of the state-of-the-art, thus creating technical risk. Risk can also be introduced during architectural design caused by the internal interfaces that exist between the system elements. System development may be rushed to deploy the system as soon as possible to exploit a marketing opportunity or to meet an imminent threat, thus leading to schedule risk. All systems are funding-limited so that cost risk is always present. Risk can also develop within a project…" [16] Risks can also be generated via legal, regulatory and other non-technical sources.

"Even if the risks are somewhat large, if you can really quantify them pretty accurately, and identify them step by step, I think that helps a lot… "[3] Systems Engineering provides a disciplined approach to identifying, tracking and mitigating risks throughout the program, significantly increasing the likelihood that they are addressed in the most cost effective way – the earlier the better. Actions to mange risks are known as mitigation. Once a risk is identified, its likelihood of occurring is assessed, along with how serious an impact the risk occurrence would have on the program. Risk mitigation, typically in the form of mitigation steps, can be determined. Risk particulars and their mitigation can be tracked, usually in a database, and the risk likelihood and severity can be reduced as the mitigation steps are implemented. The risk management process needs to be established as early as possible and continued throughout the

program, with risks being reviewed on a regular basis. For example, the program risks are often reviewed monthly along with other financial, technical, and schedule information to ensure mitigation progress and to address new risks or other issues.

Conclusion

Investors seek to maximize their ROI wherever they invest their resources. Aerospace companies can position themselves as an excellent investment target by showing a strong market opportunity for their products and choosing an experienced management team in terms of start up, marketing, management, and sales experience, as well as technical acumen. Prospective companies must have a clear, achievable plan with interim revenue milestones necessary to achieve near-term revenue. Aerospace entrepreneurs need to address cost uncertainty, as well as the reality that they compete for investor dollars with many other potential investments, and so must position themselves as favorably as possible. Unlike other entrepreneurs, space entrepreneurs must also address the additional risk inherent in space systems in order to achieve the revenue needed to bring products to market.

Systems engineering provides critical processes and tools that can help mitigate risks while achieving the race to revenue. SE provides a rigorous structured approach to systems definition, requirements development, and risk management that continue throughout the program. In addition, systems engineers provide crucial technical oversight functions throughout the program to ensure product optimization. Systems engineering provides the means to greatly assist investors and entrepreneurs achieve their ROI by ensuring products make it to market on time, on budget while meeting market needs and expectations

Acknowledgements

The author would like to thank all those that that were interviewed, and provided their valuable insights and the lessons learned through their experiences. Further, the author extends appreciation for the assistance of Robert Jacobson, Eva-Jane Lark, and Scott Taylor, as well as the INCOSE SEDS team.

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Biography

Laurie Wiggins is a systems engineer and an entrepreneur. She has 24 years of systems engineering experience, including 19 years at The Boeing Company in Aerospace systems development. She has significant expertise working with NASA, FAA, other government and commercial programs and proposal development, with a special focus in commercial space systems. She is the Founder and CEO of LJW Enterprises, www.ljwenterprises.com, providing ***systems engineering, risk management and business development services***.