

Analysis of a "Meta – Trade Study" Interpretation of Decision-making with a Value Proposition for Space Programs

Edward B. Rockower*
Lockheed Martin Space Systems Company, Sunnyvale, CA 94089

Tightening budgets and greater competition for funding are increasing the need to more completely, persuasively, and transparently value and market complex, and often exotic, Space Programs. This is driving an expanding view of what's required in an engineering, economic, and political language of discourse. Words and phrases like *holistic, future generations, new frontiers, vision, inspiring, and sustainable* are increasingly important to encompass the full range of stakeholders, the full spectrum of societal needs and values, and the vastly differing awareness, sophistication, and priorities among stakeholders. There's a well-known saying in Sales, that "you sell the sizzle, not the steak". This is increasingly necessary to achieve widespread understanding, public buy-in, and sustainability. We consider how the components of a "value proposition" may be mapped to corresponding parts of the final report for a kind of "Meta – Trade Study" with respect to allocation of Society's resources among alternative objectives and programs. We investigate how that viewpoint helps us to understand, quantify and communicate a "Value Proposition for Space". We also point out limitations of this perspective, hence areas that must be extended, and suggest how this may be done.

I. Introduction

"The greatest challenge to any thinker is stating the problem in a way that will allow a solution"
-- Bertrand Russell

In dealing with a large, highly complex situation it is sometimes helpful to begin by defining terms, establishing ground-rules for investigation, and agreeing upon principles to guide our thinking. If we do that consistently, coherently, and transparently it may help us avoid losing the thread of our thoughts, and missing consideration of some of the important aspects of our problem. It may also help us better perceive the structure and interrelations of the complex reality with which we're dealing. Being thus firmly grounded helps us explore the issues, wherever the path leads. When we have a very important, *highly* multidisciplinary, often confusing, and extremely visible job to do, we want all the help we can get. A single individual, almost certainly, will be forced out of their comfort zone. By beginning with basic principles, analyzing "from the ground up", we can identify the full spectrum of talents and experience we need on our team.

In this investigation we consider an *ostensibly provable proposal for a suggested course of action* called a "Value Proposition" and a *Process for Decision Analysis* we call a "Trade Study Process". We suggest that the familiar engineering-based Trade Study Process may help in formulating and communicating a Value Proposition for a complex, multi-generational endeavor such as a Space Program. It may, in fact, serve as an organizing principle for thinking through the costs and benefits of the Space Program from the many perspectives of the large number of stakeholders and Decision Makers (DM's).

A. "Value Proposition"

We begin our analysis by looking at the two words in "Value Proposition" (VP):

* Systems Engineer, Sr. Staff, Advanced Technology Center, Modeling, Simulation & Information Science

“Value”: In discussions of modern marketing of goods and services using a “Value Proposition” it’s often emphasized that the modern business must focus on selling benefits and value for the customer, not merely products. The marketing and sales efforts must be customer-focused; hence the value is always in terms of their wants and needs. The Value Proposition promises, if you buy “A” you’ll receive “B” in value. We will use the term “Measure of Effectiveness” (MOE) to represent any measures of value. Questions that arise include a) “value” (and costs) to whom, b) how values are measured and aggregated, and c) over what time frames (present value of future costs, and of future benefits)?.

“Proposition”: Value *Proposition* implies there’s a proposal, a marketing statement in aid of convincing the customer to decide in favor of your products, i.e. to purchase your goods and services.

One suggested template for creating a "value proposition"¹ begins with a sentence that identifies a) the target customer, b) their wants and needs, c) a description of the product or service, and d) a statement of the benefit. The second sentence (a "positioning statement") describes e) the primary alternative product(s) or service(s) and shows f) how our product is differentiated from, and presumably better than, the competing alternatives.

We will return later to how one defines, measures, and compares the, possibly incommensurable, wants, needs, and benefits mentioned in the template.

B. “Trade Study Process”

In dealing with complicated systems and situations, we’ve observed that it’s useful to have an “organizing principle” on which to hang your facts, details, and theories. It’s true that “a poor plan is better than no plan at all”, as long as one is flexible in responding to the feedback from reality that forces us to modify and evolve our plans and methods. There are three “levels” to focus on here: 1st is the organization of this discussion concerning how to think through a “Value Proposition” for Space Programs, 2nd is the organization of the Trade Study planning and team-building (another “meta-process”) which must take into account the 3rd viewpoint, which is the organization of the actual Trade Study as it is conducted and presented with a Value Proposition as a possible deliverable from the Study. A “Trade Study” is so-called because it’s based on the notion of “trading off” two or more desirable things, thus obtaining more of one desired thing, at the expense of accepting less of something else, with the result that we obtain higher overall value. There are a number of dimensions in which we seek to balance some conflicting demands. We may be willing to take on more “risk”, if it yields an increase in “reward”, but there will be a limit on how much “risk” is acceptable under any circumstances. We may need to trade-off some measure of near-term benefits in order to obtain greater long-term benefits (or, conversely lesser life cycle cost vs. initial i.e. fly-away cost). The typical dimensions of quantities considered in Trade Studies can usually be categorized into cost, performance, risk, or schedule.

By having a coherent Trade Study process we’re more likely to 1) solve the correct problem, 2) solve that problem correctly, i.e. determine the best solution from our customers’ points of view, 3) be understood, believed and trusted when we present the results of the Trade Study, and 4) create a more useful and flexible Trade Study report that the customer (and Decision Maker) can make the best use of (not just acting on the recommendation, but possibly changing the conclusion based on their own, or later, information and judgments). The process helps us to clarify, visualize, and stick to our goals for the Trade Study in the face of all the complexities and obstacles that arise.

Our Trade Study Organization Goals include:

- Force Coherence to the Process
- Add insight into Data and Assumptions
- Quantify Subjective Judgments so they can be aggregated
- Allow the Decision Maker (DM) to tweak Model Assumptions & Adjustable Parameters
- Fully Characterize the Trade Space
- Choose the Best Risk Reduction Plan

Central to the goal of delivering a successful Trade Study is the concept that the customer (including the ultimate Decision Maker) makes the decision, based on the Trade Study materials delivered in the final

report. “Computers don’t make decisions, people make decisions”, is meant to remind us that the numerical (and judgmental) results of our analysis do not provide the decision as to which engineering alternative will be chosen. In fact, they provide a quantitative ranking of alternatives, sensitivity studies, and *some of* the materials from which the Decision Maker will make the decision. The DM will usually add their own judgments and intuitions, taking account of their assessment of our analytic materials. As we’ve all heard, one of the prime dictums of writing is to know your audience, and to write with the audience in mind. When you present the results of the Trade Study, the audience may consist of any or all of the stakeholders including the Decision Maker(s), their advisors and analysts, the users, maintainers, and beneficiaries of the system, etc. (including, possibly, The President, Cabinet Members, Admiral/General/Congressman + technicians/advisors/soldiers, and The Public). You must lay out a clear audit trail for the Trade Study so the audience knows what crucial assumptions you’ve made, what data you used, your methods of analysis, and that you’ve actively consulted with the stakeholders.

The Trade Study Report informs the intuition and sheds light on the alternatives; it alerts the DM to consequences and risks (as well as benefits). To the extent possible, the Trade Study report and documentation must empower the DM to make the best decisions possible, allowing for their wider relevant experience, scientific, business, military and budgetary expertise, and other imponderables to be factored in to the decision.

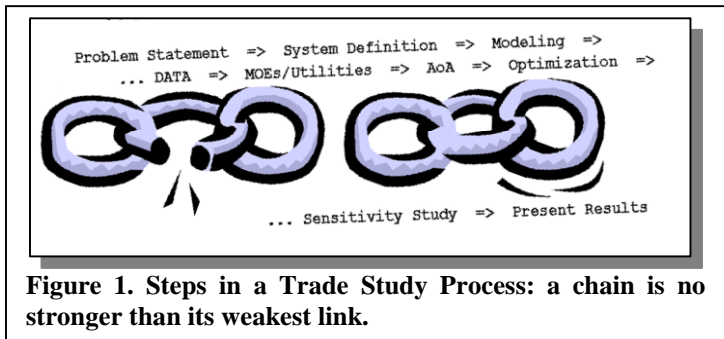


Figure 1. Steps in a Trade Study Process: a chain is no stronger than its weakest link.

We suggest a simple, coherent Trade Study Process that is easy to visualize and easy to remember, without initially concerning ourselves with the inevitable embellishments of convoluted

logic that may arise in the actual execution of the Trade Study. Figure 1 shows the steps in the process.

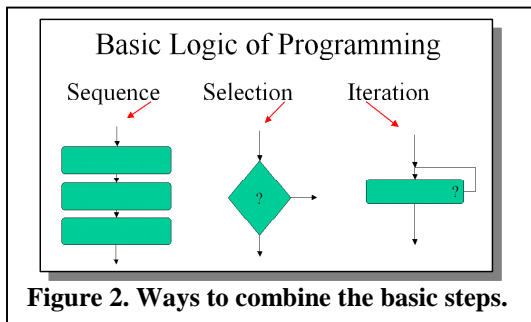


Figure 2. Ways to combine the basic steps.

These steps may be executed in an actual Trade Study according to the basic logic of “sequence”, “selection”, and “iteration” (displayed in Figure 2), familiar from computer programming, to make an arbitrarily complex wiring diagram.

II. Mapping a Value Proposition to a Trade Study Report

“It is the theory that decides what can be observed.”

-- Albert Einstein

We suggest that the Trade Study Report is related to the written and verbal communication of a Value Proposition. The above Value Proposition template maps to elements in a “Meta – Trade Study” as follows:

- a) => Identifies the entire spectrum of stakeholders and customers, including the Decision Makers.
- b) => The complex hierarchy of Measures of Effectiveness for all stakeholders that quantify the relative desirability (or utility) of outcomes from developing and using the System, product, or service. This includes the weightings of benefits and stakeholders’ interests, and their priorities.
- c) => Models, Data, Drawings, pictures, and operation of the System, product or service.
- d) => The quantitative values of the MOE’s along with the sensitivity studies from optimization or Analysis of Alternatives (AoA), showing that our System, product, or service meets the stated requirements, and is better than the alternatives.

- e) => A complete list of alternative products, the extent of the Trade Space, including constraints on design parameters and resources.
- f) => Analysis of the near-optimal MOE's, tables and carpet plots, results of the AoA, sensitivity studies, and a robustness calculation for the optimal design solution (i.e. Risks that it will prove NOT feasible or NOT superior to the alternatives).

This suggested mapping is set out in tabular and graphical form in the Appendix.

We discuss in more detail the consequences of this mapping only for those elements that are significantly different when evaluating a Space Program. Many of the, perhaps nonstandard, considerations that follow are actually well known, yet usually considered only implicitly in most Trade Studies.

Leveraging this perspective, "Trade Studies" can be extended to aid our thinking, help in the full identification of value, and better communicate the benefits of Space Programs. Figure 3 shows some notional relationships assuming the Trade Study supports the creation and marketing of the Value Proposition in a dynamic multi-generational world in which DM's, themselves supported by their various constituencies and a dynamic Vision, change, evolve, and are replaced over time.

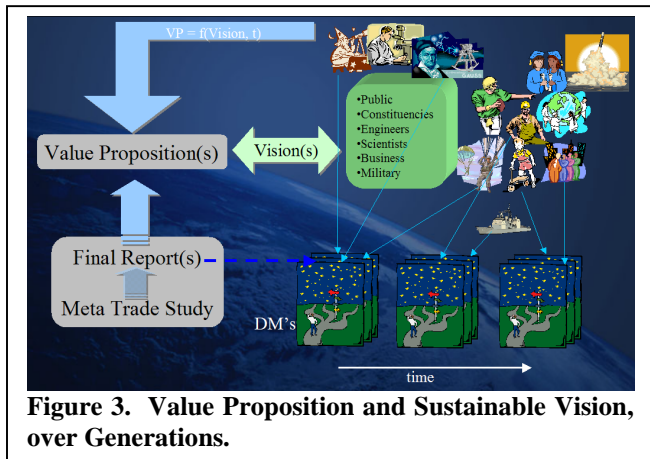


Figure 3. Value Proposition and Sustainable Vision, over Generations.

III. Trade Study Process Step: “System Identification”

When we try to pick out anything by itself, we find it hitched to everything else in the Universe.
-- John Muir

Problems of limited scope are best solved by focusing our attention on the tightest System definition often allowing application of the sharpest tools in our toolbox. Problems of large, historic scope generally require us to expand our view to include all the less precise, fuzzy, uncertainties of real human life.

System Identification is a process of conscious decisions to choose:

- what is included inside the System being studied (the “endogenous variables”),
- what is outside the system (the “exogenous variables”) and
- what variables are at our disposal to “dial-in” the optimal System performance (the “decision variables”)

What is particularly challenging here is that we’re dealing with such a large and heterogeneous System over decades or longer. Hence, to do it justice, we’re denied the luxury of analyzing well-defined subsystems in (relative) isolation from other parts of the System. “Loose coupling” of subsystems would allow us to simplify our problems, whereas “tight coupling” often makes our job harder. We need to specifically address the flows and interactions that bind our subsystems together into the larger System in order to know when we’re justified in focusing on one subsystem at a time, and when we must keep the entire System in our view. It’s tempting to think we already know what constitutes our System, so for this task, especially, we must resist the tendency to “premature closure”².

The Vision is about the Space Program, but it is also a part of the System to be identified; in fact it’s part of what binds the System together. The Stakeholders, especially the Public, are heavily influenced by the Vision. Hence *previously predetermined* factors such as desirability/utility curves, goals, and group identifications may change, preferences and priorities may evolve. As a result, Stakeholders are more dynamically *inside* the System, not just outside and using the system, or merely reaping the benefits of the system.

The MOE's, desirability or utility curves, and weights are now not set independently of the Vision and details of the Space Program, but are themselves shifted and modified by the values of other System parameters and variables. In a sense the parameters used in evaluation of the MOE's and utility curves are now dynamical variables of the System.

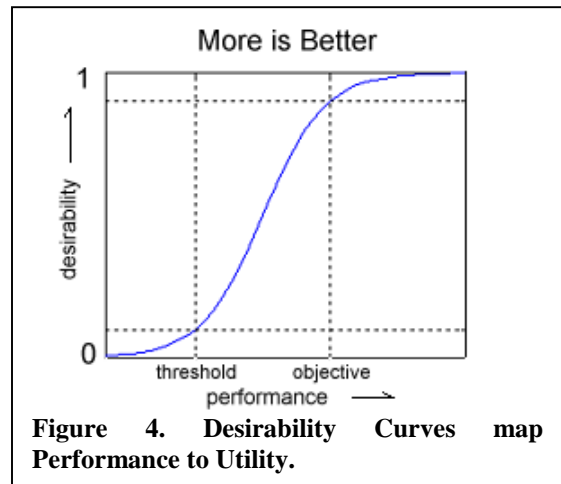
IV. Trade Study Process Step: "MOEs/Utilities"

"Happiness does not depend on outward things, but on the way we see them".

-- Leo Tolstoy

Measures of Performance often relate to actual engineering parameters of a System that can be physically measured. They measure how the subsystem performs its functions in a given environment. Measures of Effectiveness relate to how well the System delivers what the user needs to have done. In general, as Daniel Bernoulli discovered hundreds of years ago, the degree of "Utility" of a quantity of something (in his case money) does not necessarily scale linearly with the quantity. Figure 4 shows a notional curve relating an arbitrary performance variable to a dimensionless "Desirability" normalized to lie between zero and one. These curves can have many different shapes, and for some variables, such as cost or weight, the desirability curve will be non-increasing, hence will reflect "Less is Better". The questions we need to ask regarding MOE's include:

- Who cares -- how much do they care
- What metrics/costs/performance-parameters are of interest
- What are the units of measure of performance/cost
- What is the "Threshold" and "Objective" specified
- Is there a reward for exceeding "Objective"
- What is the "desirability" at "Threshold" (the minimum acceptable value)
- Affordability as customer defines it
- Different stakeholders may have different utilities, weightings, goals



As suggested above, if some of the definitions of MOE's and Utility curves are to be considered *inside* the System, we must look more closely at how they are influenced by the State of the System, the Vision, and other System variables.

Because so many constituencies, including the Public, are involved over so long a time span, we must consider the deep, lasting motivations and needs of all the stakeholders, and consider how to obtain and maintain long term interest, and deep public engagement in the Space Program³. Figure 5 shows one version of Abraham Maslow's Hierarchy of Needs. The bottom four layers are deficiency needs or D-needs. If not filled, one feels anxiety and attempts to fill them. If filled, one feels nothing; you feel only the lack. Each layer also takes precedence over the layer above it; you do not feel the lack of safety and



security until physiological needs are taken care of, i.e. a need does not become salient until the needs below it are met. We suggest that these deep needs must be included in our considerations, analytically for evaluations of value, and intuitively and artistically in communicating the Vision⁴.

It is tempting to map Business and the Military to the Physiological and Safety levels of the Hierarchy, and perhaps Education and Science to the Esteem and Actualization levels. That is certainly too much of a simplification, so we'll simply point out that all levels apply to all people.

We must anticipate that unexpected benefits will accrue from such a large scale Program based on an enhanced network flow of influence, benefits, synergy, creativity, and opportunity among all the participants. We merely suggest a few areas that need to be considered.

There may be significant benefits arising from the "network effect" (Metcalfe's Law or Reed's Law), enhanced cultural and economic connectivity, industries and technological capabilities reaching "critical mass", bringing an industry "to scale", Horizontal Integration, etc.. We should ask, and answer the question, how do we quantify these benefits? Analogous to the ubiquitous Internet connectivity, will the Space Program result in a "Friction Free Economy"⁵, and "Increasing Returns" (rather than "diminishing returns"). Should we look for a 'tipping point' into a more productive, collaborative Global identity? Perhaps there are many synergistic, nonlinear, positive feedback effects (e.g. stimulating National and Global Economies). Because the payoff from these effects is likely to be so great, we must address these very complex questions in spite of the fact that they are very difficult to answer definitively.

In calculating the net Benefits and costs, it should be remembered that all of the money will be spent on Earth, all of the New Discoveries in Science and Technology, and the new Business will be on the Earth, and (for the foreseeable future) 99.99% of the jobs will be on the Earth

V. Sustainability

*"Dear friend, all theory is gray, And green the golden tree of life."
-- Johann Wolfgang von Goethe*

Sustainability has been addressed from a number of viewpoints. It has been said that "policy robustness... Together with affordability, value delivery, and moderated risk exposure, ... comprise the four pillars of sustainability."⁶ However, President Bush's space vision tells us "the success of future U.S. space exploration will unfold over generations." It is certainly challenging to contemplate operations over such a long time frame, involving generations unborn, far removed from Earth. Adding the need for international cooperation and involvement of many layers of society requires us to re-examine principles and methods of valuation and risk estimation. The enlarged scope, numbers and types of stakeholders, and newness of the enterprise, forces us to dig our foundations deeper into the bedrock of scientific, engineering, sociological, and economic understanding. To assess the value of the "vision" we've suggested above that it's helpful to consult Maslow's Hierarchy of Needs in which the lower "deficiency needs" are complemented by the higher "growth needs". Maslow's later Hierarchy⁷ included the need to know, understand, and transcend one's individual needs through connecting to something beyond oneself. A truly sustainable Value Proposition might quantify the degree to which each of these levels in the hierarchy is satisfied, and account for the changing priorities (e.g. of Defense vs. Exploration) as the deficiency needs are met for different classes of stakeholders. Hence, as

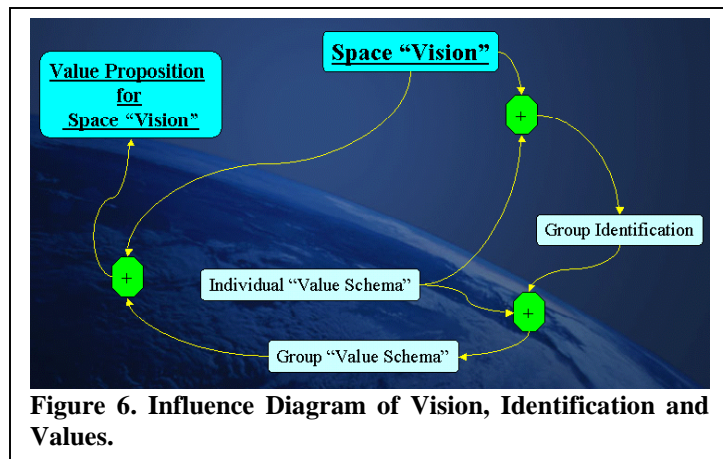


Figure 6. Influence Diagram of Vision, Identification and Values.

part of extending the standard hierarchy of Trade Studies to include a "Meta – Trade Study", we also consider extending the hierarchy of MOE's⁸. While these are admittedly speculative and difficult suggestions, they may open up avenues for fruitful investigation.

At the top of our extended hierarchy of MOE's is the much-touted "vision", a hallmark of leadership, and a necessity for sustainability. Leaders know that vision promotes group identification and belonging, empowers the individual, and fosters commitment to group goals. Hence, the "value schema" of the individual is changed, often to a great extent. Individuals who are by themselves "risk averse", with a given utility or desirability function, may become "risk seeking" when identifying with a group. It's well known that the position on the utility curve, along with its local shape, determines one's risk preference. The power of "vision" includes changing both the shape of, and the group's position, on that utility curve. Figure 6 presents an influence diagram that indicates both the ability of a Vision to drive group identification, and its ability to modify the "Value Schema" used to quantify the Value Proposition. This and other factors important for quantifying the buy-in and sustainable commitment from the full spectrum of stakeholders may thus be analyzed more fully in the context of a decision-making process, a "Meta – Trade Study", as it were.

VI. Trade Study Process Step: “Present Results” (Proposing the Value Proposition)

*Just because you do not take an interest in politics doesn't mean politics won't take an interest in you.
-- Pericles (430 B.C.)*

The goal of the Trade Study Final Report includes presenting coverage of:

- Visibility and auditability of your trail
- Credibility of the analysts, the process, and the data
- Clearly stated assumptions and limitations
- Sensitivity to audience backgrounds
- Political and marketing considerations
- How results will be used
- Who will see the report

These same factors must also be borne in mind when crafting and presenting the Value Proposition. Just as the DM's analysts will be required to vet the analytic underpinnings of the Trade Study Report, the act of proposing a Value Proposition to politicians, leaders, constituencies and the general public will raise questions of the detailed justifications for that Value.

No matter how well designed, well thought out, and wisely planned the Space Program, if it is not “Proposed” (i.e. stated, communicated, marketed, sold) effectively to the varied audiences of DM's and stakeholders, it will, quite literally, not fly.

The politicians must be addressed in language they feel comfortable with, and that they can in turn communicate to their constituencies. The scientists and engineering analysts must be addressed in scientific and engineering terms. Business must be addressed in their own terms, and the Military must be addressed in their terms. Finally, the Public must be engaged with images, symbols, and language that involve them in a powerful story with which they can relate. The entertainment industry has probably known since the beginning of time the importance of using the basic human archetypes⁹ in capturing and holding the interest of an audience. More recently Joseph Campbell popularized the meaning and significance of Myth in his PBS series of interviews with Bill Moyers¹⁰. Campbell's book “The Hero with a Thousand Faces” was explained and interpreted for writers by Christopher Vogler in a widely read summary¹¹. George Lucas credited Campbell's book on the Hero with strongly influencing his writing of the Star Wars movies. In fact, it's already been widely recognized that the private sector, the media, and other professional communicators must be involved in communicating the Vision for Space. It is clear that these media experts and storytellers are crucial to fully engage the public over many decades, as they've successfully done for other messages and stories. Finally, we emphasize that in some sense, the Vision must be shared by all the stakeholders, no matter the level of technical, political, or business savvy.

VII. Conclusion

A prudent question is one half of wisdom.
-- Francis Bacon

We've presented one perspective on how to think about a Value Proposition for Space Programs using a Trade Study Process as the basis for guiding our efforts. Following the logic of the suggested, generic, Trade Study Process we've identified some areas in which Space Programs need to be evaluated with an expanded set of concepts and tools compared with those ordinarily involved, at least explicitly, in the usual Trade Study. The Trade Study elements that we suggested are especially deserving of further investigation are:

- System Identification
- MOE's/Utilities
- Present Results

A powerful Vision can become a self-fulfilling prophecy. What was not true or merely potentially true can sometimes become true through the organizing principle embodied and transmitted by effective (possibly charismatic) leaders and communicators¹². By explicitly considering basic human archetypes, myth, and storytelling, we create a more widely accessible Vision, and more fully engage all the stakeholders. We may thereby achieve the critical sustainability over the decades needed for success. However, as indicated in Figure 7, we may need to become comfortable with less *precise* methods in order to benefit from higher *accuracy* when dealing with human values and motivations.

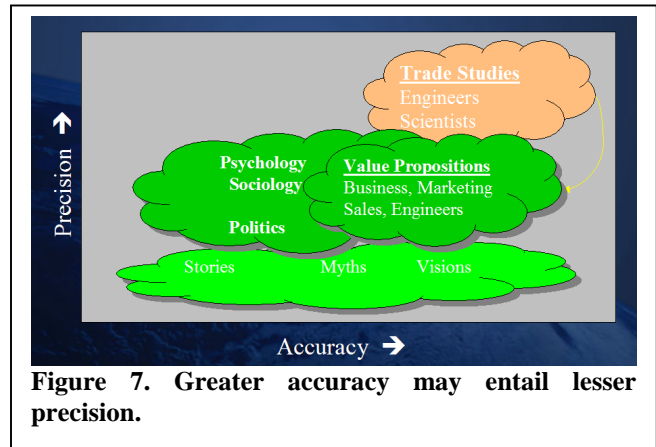
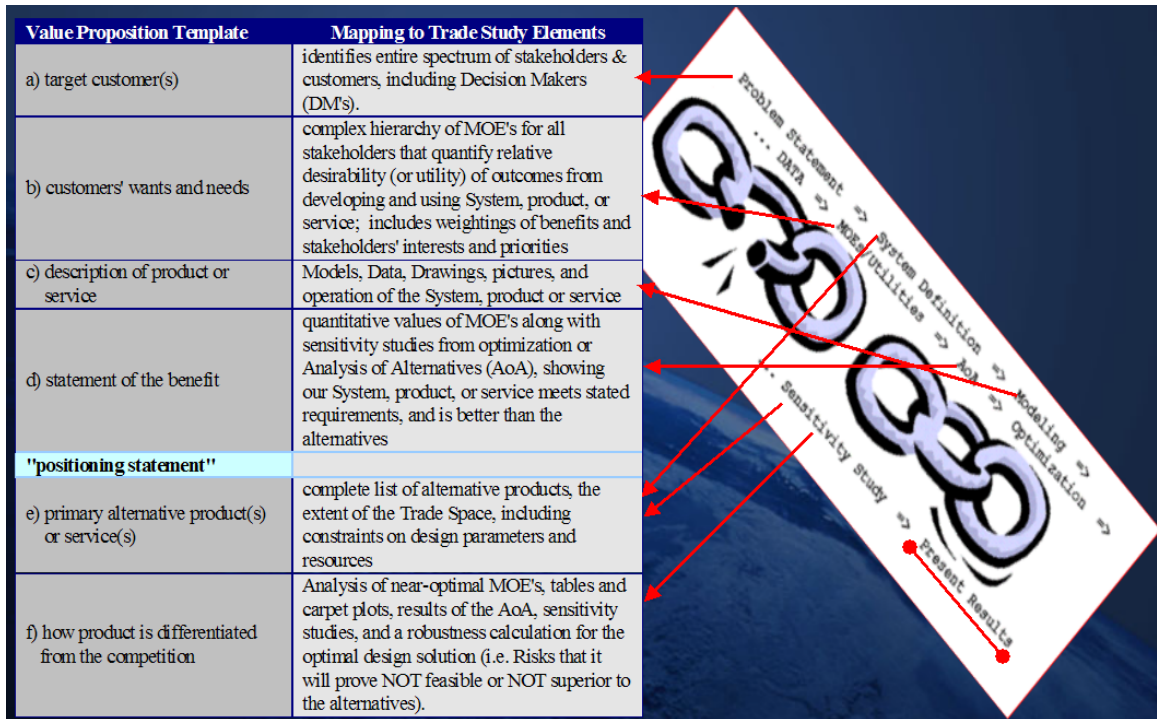


Figure 7. Greater accuracy may entail lesser precision.

Appendix: Mapping a Value Proposition to Trade Study Elements



¹ Presentations on “Value Propositions” are widely available on the web, including Business School websites such as MIT Sloan School of Management (<http://www.execseminars.com/brochures/RBS.pdf>):

- “The conventional wisdom is to put the focus on your product, when the real source of profitability in a networked economy is to develop better value propositions for your customers.”,
- “To survive and prosper today, you must shift your attention from products to customers”
- “... delivering a value proposition that places the customer at the center of your strategy”

the two sentence formulation we cite is at http://en.wikipedia.org/wiki/Value_proposition

² Nobel Prize winner in Physics, I. I. Rabi, said in response to a question, “If I’ve been able to accomplish more than others, it’s because I’ve been able to maintain fuzzy thinking longer” *Rabi, scientist and citizen* by John S. Rigden, Sloan Foundation Series; Basic Books, 1987

³ "Using Stakeholder Value Analysis to Build Exploration Sustainability" E. Rebenitsch, E. Crawley, G. Loureiro, J. Dickmann, and S. Catanzaro, AIAA-2005-2553;

"Achieving Profound Public Engagement - The Ultimate Source of Exploration Vision Sustainability" M. Craig, AIAA-2005-2568 1st Space Exploration Conference: Continuing the Voyage of Discovery, Orlando, Florida, Jan. 30-1, 2005

1st Space Exploration Conference: Continuing the Voyage of Discovery, Orlando, Florida, Jan. 30-1, 2005

⁴ “Report of the President’s Commission on Implementation of United States Space Exploration Policy”, 2004

⁵ Lewis, Ted, *The Friction-Free Economy: Marketing Strategies for a Wired World*, HarperBusiness, New York, 1997

⁶ "Policy Robustness Analysis of Space Exploration Architectures" G. Singleton and A. Weigel, AIAA-2005-6661 Space 2005, Long Beach, California, Aug. 30-1, 2005;

Also see "From Value to Architecture: The Exploration System of Systems" Ed Crawley MIT Draper Lab Dec 1, 2004;

"Political Sustainability in Space Exploration: A Game Theoretic Approach" D. Broniatowski and A. Weigel, AIAA-2005-6799 Space 2005, Long Beach, California, Aug. 30-1, 2005; "International Industrial Cooperation: Key to an Affordable and Sustainable Space Exploration Program"

P. McKenzie, C. Gilbert, AIAA-2005-2530 1st Space Exploration Conference: Continuing the Voyage of Discovery, Orlando, Florida, Jan. 30-1, 2005

⁷ Information about Maslow's work is widely available in books and on the web (e.g.

<http://chiron.valdosta.edu/whuitt/col/regsys/maslow.html>)

⁸ Rockower, E., "Notes on Measures of Effectiveness", Naval Postgraduate School, 1985

(http://www.rockower.com/articles/MOEs_Rockower.pdf)

⁹ Jung, Carl *Memories, Dreams, Reflections*, Pantheon Books, New York, 1963

¹⁰ "Joseph Campbell and the Power of Myth (1988)", PBS Series Mystic Fire Video 2001

¹¹ Vogler, Christopher *The Writer's Journey: Mythic Structure for Writers*, Michael Wiese Productions; Studio City, CA, 1998, (his highly influential: "A Practical Guide to THE HERO WITH A THOUSAND FACES by Joseph Campbell" is at <http://www.skepticfiles.org/atheist2/hero.htm>)

¹² "Man is eminently a storyteller. His search for a purpose, a cause, an ideal, a mission and the like is largely a search for a plot and pattern in the development of his life story ..." Hoffer, Eric *The Passionate State of Mind* Perennial Library edition, Harper and Row, New York 1968 p. 59