

Have We Really Lost The Space Acquisition Recipe Or Are We Simply Trying To Go Where No [One] Has Gone Before?

2009 Flight Software Workshop

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“[Space and Missile Systems Center (SMC) and The Aerospace Corporation] also conducted detailed analysis on testing in launch vehicle and satellite programs, growing quality problems in components and subsystems, and increasing system complexity, especially in the area of software development.”

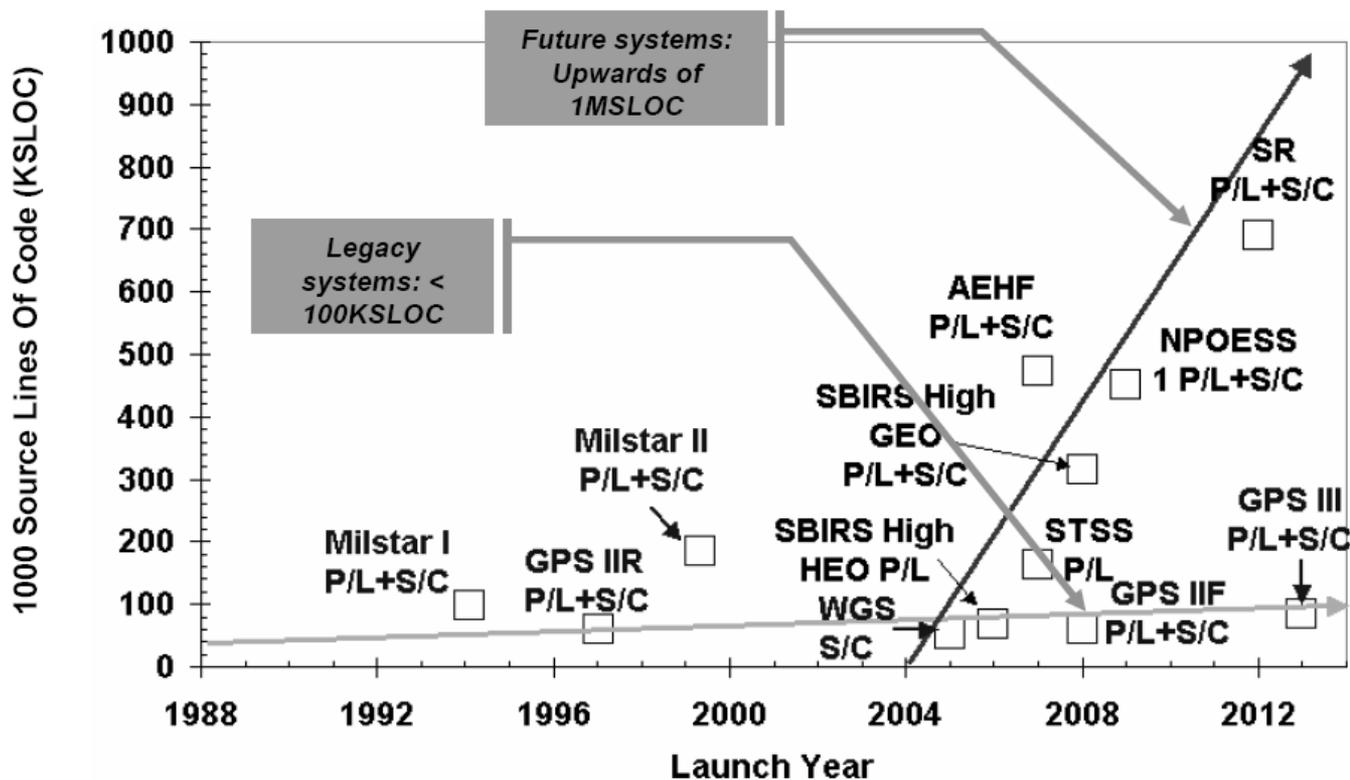
Michael A. Hamel, “Military Space Acquisition: Back to the Future,” *High Frontier*, 2006, no. 2: 6.





SMC Software Growth – Summer 2002

In October 2006 Lt Gen Michael Hamel, briefed the SMC system software growth trend to the National Defense Industry Association (NDIA) Defense Software Strategy Summit.



http://www.ndia.org/Divisions/Divisions/SystemsEngineering/Documents/Content/ContentGroups/Divisions1/Systems_Engineering/Hamel_10_18.pdf



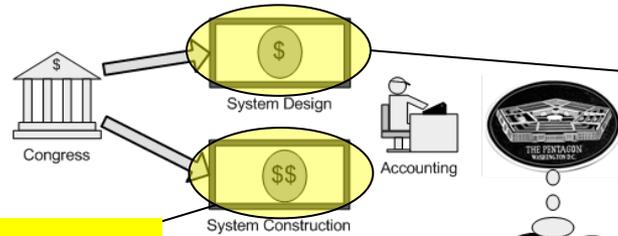


From that NDIA Software Summit ...

- Among the number of recommendations that were made
 - *Define and publish the Department's long-term objectives and course of action with **associated priorities and resources in a software life cycle strategy**.*
- Confirmation that
 - *... software demand is increasing; managing software projects is difficult; availability of trained and experienced personnel is limited; standards and processes vary; and budgets are declining. The summit also confirmed that the Department software management staff has the will and desire to improve the software environment. Department action is needed. The Department needs to continue to aggressively focus on software engineering, acquisition, management, and human resource life cycle challenges through the application of resources and focused action.*



Competition for SMC's Space Business



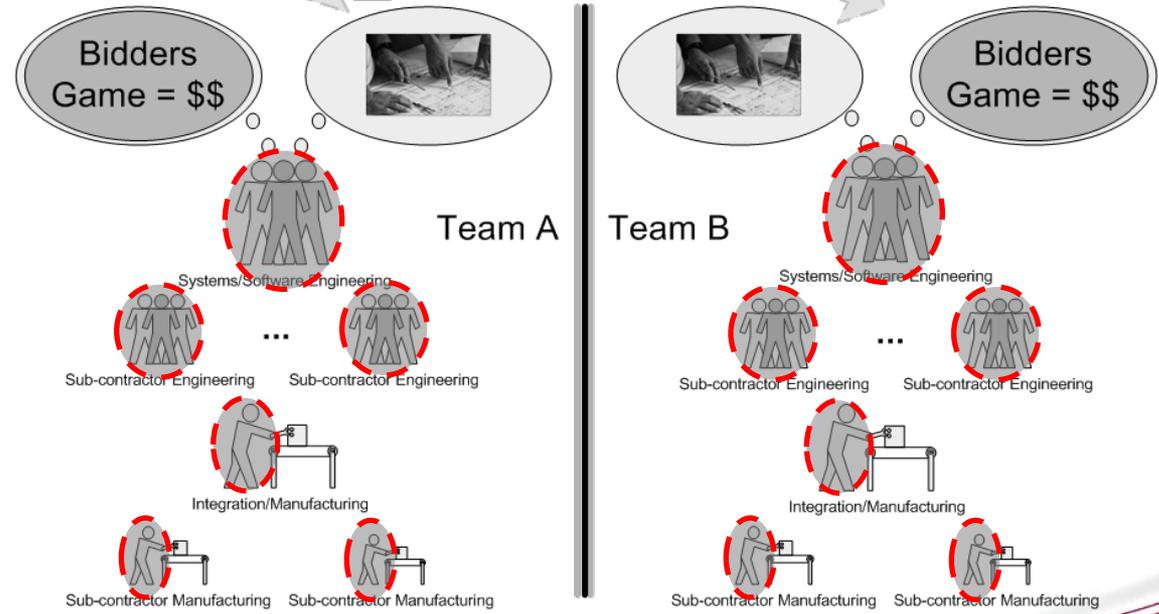
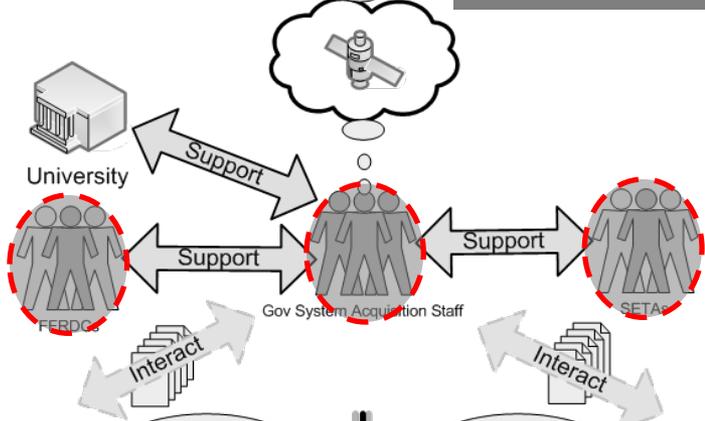
Software is generally not designed during system design phase

Its just "reused" from prior programs!

Risk mitigation funded as management reserve during construction

... *mediocre* personnel.

Mixtures of truly outstanding personnel *and...*



Major Millette: Defense Acquisition University Course



- Students assume roles of contractors preparing a bid to respond to a Request For Proposal (RFP) for a software-intensive system:
 - *Three options for software costs: low, medium, and high.*
 - *Evaluation criteria specifically indicated that cost was not a criterion*
 - But it is always considered.
- With SBIRS' development life cycle issues in our background we...
 - *Selected the high software cost as a way to mitigate the development risk.*
 - *Thought, budgeting for the higher amount and still stay under the life cycle and unit procurement cost thresholds, we would reduce the overall cost and schedule risk.*
 - Thus, be able to tolerate inevitable requirements creep, rework, and other typical software cost and schedule related risks.
 - *Vigorously discussed whether to go with the medium or low cost figures, but decided that since we could still meet the other thresholds, the high software cost presented a better risk mitigation position.*



Major Millette: DAU Course Results & Lessons Learned

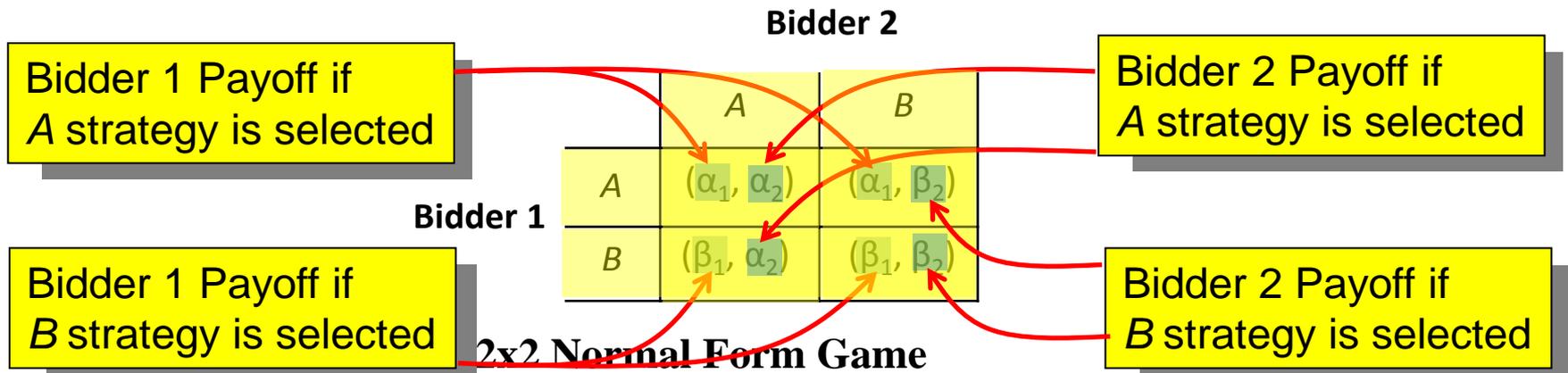


- Result:
 - *When the other groups briefed their analysis of our proposal each one of them cited our high software cost as a negative aspect of our proposal and why it was not selected.*
- Lessons:
 - *It is not in the contractor's best interest to bid the actual, expected, or risk sensitive software cost, as the evaluators may not recognize this as a positive aspect of their bid...*
 - They will only focus on the bottom line!
 - *The contractors are not devious or intentionally trying to underbid these efforts maliciously, they are simply doing what they believe they have to do in order to secure the work.*
 - *If one bidder of the group uses the realistic or conservative cost estimate, they run the risk of being identified as not providing the 'best value' bid.*



Game Theory: Applied to TSPR Era Programs

- Game Theory:
 - Is used to analyze optimal strategies for action in competitive situations with two or more players of the game.¹
 - Use a strategy matrix to analyze each player's strategies when they attempt to take into account the action of their opponent in their decision making process in order to maximize their payoff.^{2, 3}
- Consider the following non-zero sum game with only 2 bidders:



1. James O. Berger, *Statistical Decision Theory and Bayesian Analysis* 2nd Edition, Springer-Verlag New York Inc., (New York, NY, 1980): 310.
2. Harold W. Kuhn, *Lectures on the Theory of Games*, Princeton University Press: (Princeton, New Jersey, 2003): 5-6.
3. Philip D. Straffin, *GAME THEORY and STRATEGY*, The Mathematical Association of America, (Washington D.C.: 1993): 3-6.





Game Theory: The Prisoner's Dilemma

- In 1950 Melvin Dresher and Merrill Flood at RAND¹:
 - *Devised a non-zero sum game with a unique equilibrium that was not Pareto optimal.*
- Also in 1950 a Princeton Mathematician (Albert W. Tucker)^{1,2}:
 - *Added a story to the game about two prisoners arrested for a joint crime at a Stanford University seminar to psychology majors*
 - If one of them confesses, and the other does not the confessor will get a reward and his partner will get a stiff penalty.
 - If both confesses then they will both get a light sentence.
 - If neither confesses they will both go free.
 - *Following 1950 this game has become the most widely studied and used game in social science.*

1. Philip D. Straffin, *GAME THEORY and STRATEGY*, The Mathematical Association of America, (Washington D.C.: 1993): 73-79.
2. Obituary by Sylvia Nasar in the *New York Times*,
<http://www.economics.utoronto.ca/osborne/MathTutorial/TUCKER.HTM>



Game Theory: The Bidder's Dilemma in TSPR Programs



- Multi-Billion Dollar System Acquisition:
 - Winner gets cost plus a significant fee contract
 - Loser gets reimbursed for bid effort plus a small fee, hence is non-zero sum
 - Assume for this game example that mixed strategies are not possible
 - Software requirements removed from program RFPs
 - No unambiguous contractual “shall” statements understood by lawyers
- The Pure A Strategy:
 - Provide a bid for non-recurring research and development to build a system that “shall” incorporate more costly software risk mitigation.
- The Pure B Strategy:
 - Provide a bid that does not incorporate the more costly software risk mitigations.
 - Software risk mitigations are not required by the RFP.
- Mathematically we write:
 - $(\alpha_1 = C + f_1) \gg (c + f_1 = \beta_1)$ likewise
 - $(\alpha_2 = C + f_2) \gg (c + f_2 = \beta_2)$.
 - **As big C gets significantly larger than little c, the bidder's desire to identify innovative cost saving strategies that provide a competitive bid grows!**





Game Theory: This Result is a Bidder's Dilemma

- The Pure A Strategy:
 - *Is considered a losing strategy as the politically unacceptable high cost in a tight budget situation leads to either a loss for one or both bidders.*
- The Pure B Strategy:
 - *Is considered a winning strategy as the politically tolerable cost leads to a system that gets on contract.*
 - *In this case is a Nash equilibrium, however it is non-Pareto-optimal.¹*

We call this the *Bidder's Dilemma* due to its similarity with a game that is central to Game Theory called, *the Prisoner's Dilemma*.

1. Philip D. Straffin, *GAME THEORY and STRATEGY*, The Mathematical Association of America, (Washington D.C.: 1993): 65-68.





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 - *In this case is a **Nash equilibrium**, however it is non-Pareto-optimal.¹*

Strategy equilibria in non-zero sum games are called *Nash equilibria* in honor of John Nash.

1. Philip D. Straffin, *GAME THEORY and STRATEGY*, The Mathematical Association of America, (Washington D.C.: 1993): 65-68.





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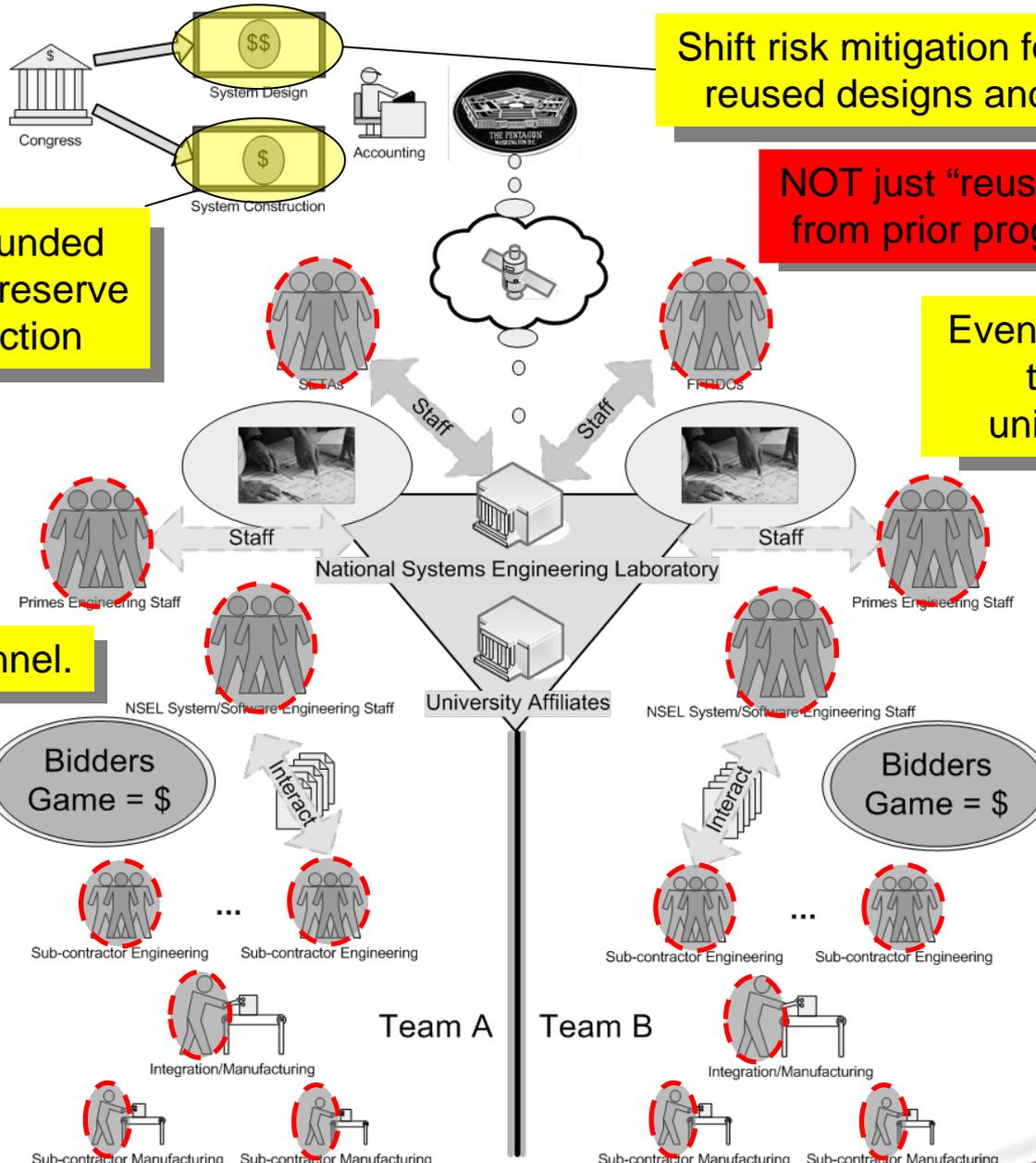
A game solution is *non-Pareto-optimal* or *Pareto inferior* if there is another solution that would give both players a higher payoff. Pareto principle states that for a strategy set to be accepted as the solution to a game it must be Pareto optimal.

Vilfredo Pareto (early 20th century Italian economist) suggested that we should not accept an economic system if there is another system that makes everyone better off.

1. Philip D. Straffin, *GAME THEORY and STRATEGY*, The Mathematical Association of America, (Washington D.C.: 1993): 65-68.



The National Systems Engineering Laboratory Paradigm



Shift risk mitigation for software to reused designs and prototypes

NOT just "reused" code from prior programs...

Risk mitigation funded as management reserve during construction

Eventually use prestige to get the best university students

... *mediocre* personnel.

Better mixtures of truly outstanding personnel *and*...





Summary and Conclusions...

- Using Game Theory we've shown
 - *How our DAU class result should be expected.*
 - *How the TSPR (Total System Performance Responsibility) era acquisition approach led to a Bidder's Dilemma that did not properly account for risk.*
 - *That we can set up acquisition games that provide winning solutions that are better for more players.*
 - Current approach is to put contractual standards back on contracts.
 - We can identify alternative acquisition approaches.
- Our NSEL approach is meant to change the game, and start discussions of alternative space system acquisition approaches that can lead us into the 21st century for software intensive systems.
 - *Under tight acquisition budgets*
 - *Under tight schedules*
 - *The demand for high quality*
- We believe that Game Theory provides an understanding of why some system acquisitions fail, or are significantly over budget.





Freeman Dyson...

In the long run, the only limits to the technological growth of a society are internal. A society has always the option of limiting its growth, either by conscious decision or by stagnation or by disinterest. A society in which these internal limits are absent may continue to grow forever.

Freeman Dyson, *Disturbing the Universe*, 212.

