Section 8. Cost and Schedule Overruns

- Background and Introduction
- Traditional View of Causes and Solutions
- Solutions that Are More Likely to Make it Worse
- Radical View (i.e., mine) of Causes and Solutions

MY BIAS

- This section was a major challenge for me to write
  - An obvious solution to avoiding cost and schedule overruns is to never undertake anything challenging, to never push on reducing cost, reducing schedule, or trying to achieve more with less
    - I call this approach ***"Objectives Erosion, OE"*** — it is basically the bureaucratic response to perceived ***"Requirements Creep"***
  - **In the OE approach, if there are consistent cost and schedule overruns, then the obvious solution is to ask for less performance, for a higher price, in a longer time**
  - **While this might, or might not, be the right solution for the space community, it is not one that I'm willing to recommend**
  - It is my strong belief that we need to dramatically reduce cost and schedule on space programs and to try to do much more with, most likely, less resources
- **I will provide both a "traditional approach" provided by two consultant organizations (RAND and Deloitte Consulting) and a "radical approach" (i.e., mine)**
  - You can decide for yourself which approach makes the most sense or, better, find a new approach that fits the culture of your organization

Cost and Schedule Overruns are an important issue and worth haggling over.

WHAT'S THE PROBLEM?

- Cost and Schedule Overruns in DoD programs
  - In 2007, the 10 largest DoD space programs were collectively overrun by $32 billion
  - Also in 2007, major weapon systems programs were over budget by $295 billion (26%), up from $42 billion in 2000
  - The schedule delays are not as well documented, but certainly average many years
  - NASA programs suffer similar problems and often cause delays in follow-on programs
    - The Chandra X-Ray Observatory was most likely delayed 10 to 15 years by cost and schedule overruns on Hubble
    - The James Webb Space Telescope started in 1996 at $2 billion and is now at $13 billion, if it can meet its delayed launch date of 2021, which seems uncertain
- **This is dramatically damaging to follow-on programs and to the credibility of both government and contractor personnel**
  - Particularly hard if you're trying to reduce cost
- **On the other hand, we want to contain cost and schedule overruns, not eliminate them entirely**
  - **If we don't have at least some cost and schedule overruns, then we're not trying hard enough to reduce cost and contain the schedule**

We need to find a reasonable balance — with some cost and schedule overruns (and some underruns) on R&D programs and operational programs that are built on time and on budget.

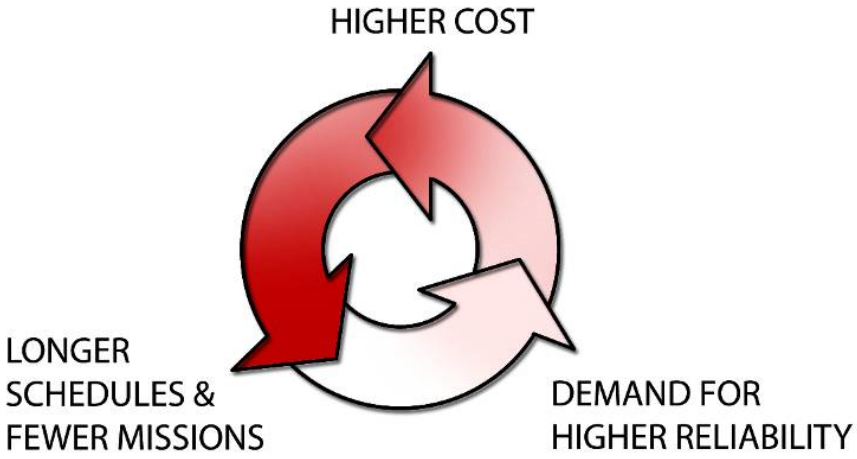
WHAT CAN WE ALL AGREE ON?

- **Cost and schedule overruns are much too widespread to be a result of bad program management, contractors that lie, or poor individual decisions**
  - In general, program managers are very experienced and very good at what they do
  - Everybody is working hard to meet cost and schedule, yet somehow we have trouble actually doing it
  - It may be that our estimates are too low or our expectations too high, but overruns are a fact of life on most programs
- **The overrun problem is something much more fundamental than bad estimating or bad management and, most likely, has multiple causes that may well feed off each other**
  - For example, in space systems there is a culture of "all is forgiven" if things work right in the end
  - Therefore, if there are cost and schedule overruns, there is more pressure to be sure you get it done "right," which, of course, leads to even more cost and schedule overruns
  - **The problem is—What about the science you didn't get or the soldiers who died because the system wasn't in place when it was needed**

Cost and schedule overruns are a systematic problem that are somehow "built in" to the process or the culture. This is what needs to change.

COST AND SCHEDULE OVERRUNS ARE DRIVEN IN PART BY THE SPACE SPIRAL

- In the Apollo program we put a man on the Moon in 8 years, including building the largest (and most reliable and lowest cost/lb) rocket ever built
  - Gemini launched every 6 weeks, irrespective of problems
- Today it takes 8 yrs to get a program underway and 10–20 yrs to get a satellite on orbit
- Why?
  - The ***Space Spiral*** at right drives both cost and schedule



- **Reversing the Space Spiral to reduce both cost and schedule and overruns in both requires simultaneously changing both the technology and process**
  - The Space Shuttle is a remarkably complex machine — the cost of building it cannot be significantly reduced by simply changing the rules
  - Changing only the technology results in the "$100 screwdriver" because of the processes put in place for much more complex technology
  - We need to change the technology to something that can be built with more-or-less ordinary tools and change the process to allow those tools to be bought at a Home Depot

Reversing this process is not easy, but it can be done.

TRADITIONAL CAUSES AND SOLUTIONS

- Back to Basics
- Avoid New Technology
- Alternative — Develop Technology First
- Studies of Cost and Schedule Overruns

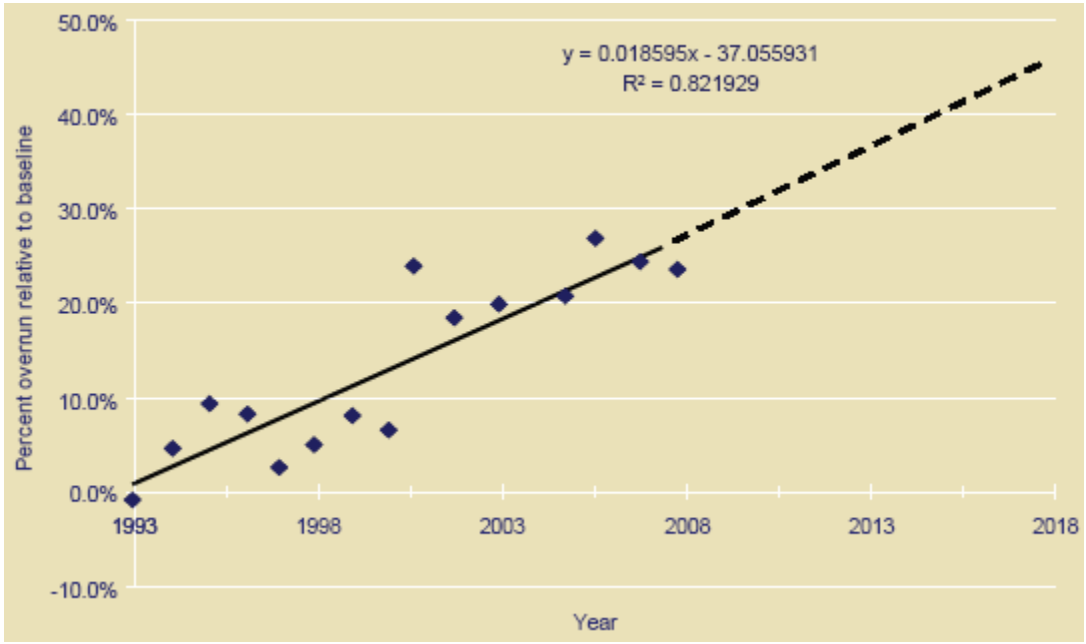
Based on

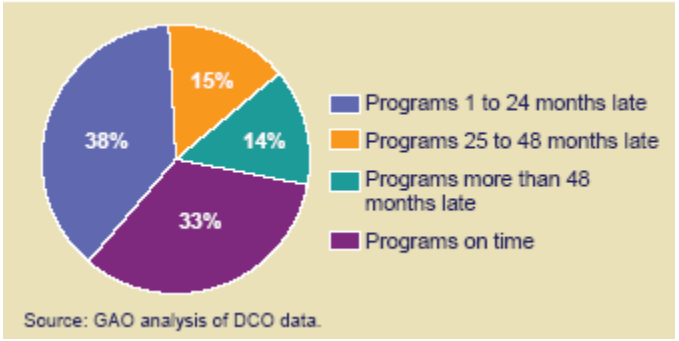
"Can we Afford Our Future? Why A&D Programs are Late and Over-Budget and What Can be Done to Fix the Problem" report of Deloitte Consulting LLP and available at http://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-ad-canweaffordourownfuture-0127.pdf

"The Lost Art of Program Management in the Intelligence Community" by E. H. Nowinski and R. J. Kohler and available at: https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol50no2/html_files/Program_Management_4.htm

CAUSES FOR COST AND SCHEDULE OVERRUNS IN TRADITIONAL DOD SYSTEM DEVELOPMENT*

- GAO reported acquisition costs for major DoD weapons systems over budget by avg. of 26% in 2007
  - Total cost overrun across programs $295 B in 2007 as compared with $42 B in 2000
- Cost overruns for major DoD programs increasing by avg. 1.86% per year
  - In 10 years, avg. overrun will exceed 46% (see chart at lower left)
- Avg. schedule delay on programs in 2007 was 21 months, with only 1/3 of programs on schedule (see chart at lower right)





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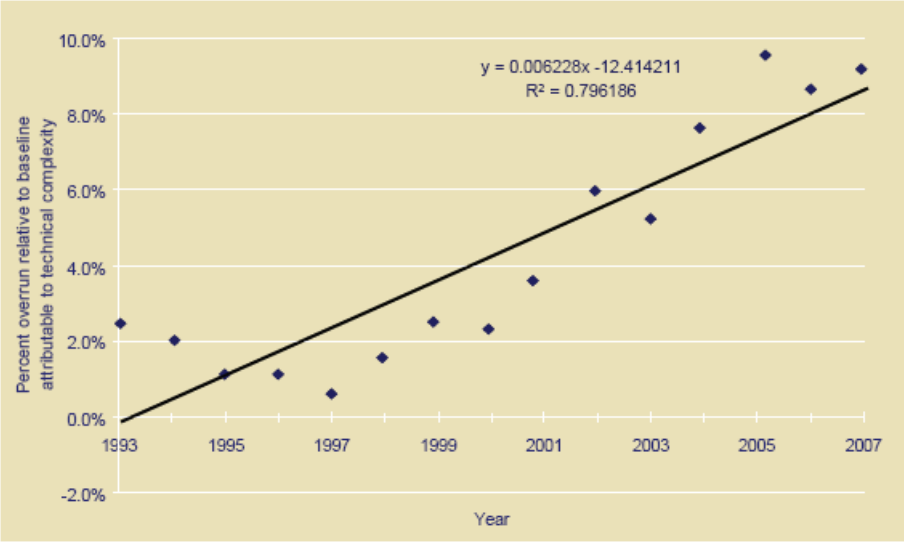
TECHNICAL COMPLEXITY AS A DRIVER OF COST AND SCHEDULE OVERRUNS*

- Strong correlation between system technical complexity and cost/schedule overrun
  - In 2007, technical complexity produced an average 8.7% overrun relative to the baseline budget
- Many programs rely on leading edge technologies that are still maturing
  - Sophisticated software and other advanced technologies that deliver greater functionality, but require a much higher level of integration/interoperability
- When large weapons systems were less complex, development cycle was shorter
  - Manhattan project to create first nuclear bomb completed in less than 3 years
  - Modern jet fighter programs take in excess of 13 years
  - Satellite Systems routinely require 10+ years

A great statistic, but what does "Technical Complexity" mean?



Program and year of first use	Years to 1st use from contractor start
Historical Programs	
Manhattan Project (1945)	2.5
F-104 (1958)	5
Intercontinental Ballistic Missile (1958)	3.5
SR-71 (1962)	3
Apollo (1967)	8
Recent Programs	
Bomber Program (1993)	11
Satellite Program (2009 expected)	10
Satellite System (to be determined)	>20
Jet Fighter A (2005)	14
Jet Fighter B (2009 expected)	13

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TECHNICAL COMPLEXITY (2)*

- Recommended Solutions
  - Divide programs into less complex work packages with shorter durations. Time is a clear predictor of budget and schedule risk. The longer the program, the greater the risk.
  - Not approving contracts for system development and demonstration (SDD) until the underlying technology is proven. Technology maturity is critical to program success, and should therefore be required prior to committing billions of dollars to development contracts.

Not consistent with Apollo — we'd still be thinking about how to get to the Moon and would have spent a lot more money!

Also note that the bureaucratic response to cost risk is to delay decision making and insert program breaks while we think.

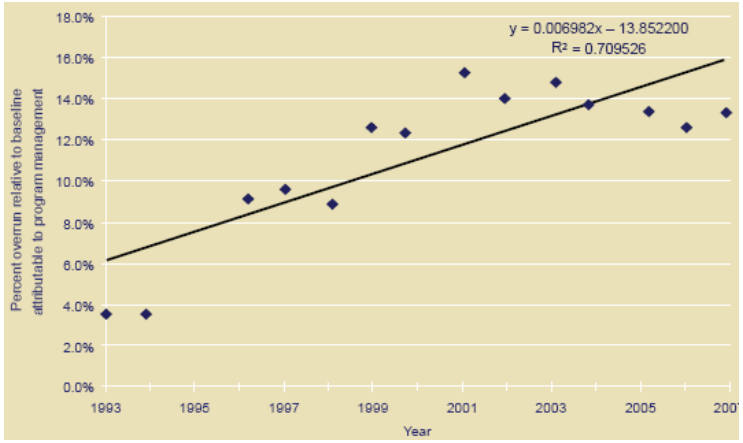
  - Require the DoD and armed services to set a program's critical design requirements and priorities. Defense contractors cannot be expected to make the appropriate affordability trade-offs and "stand-in" for the customer.
  - Improve defense contractor capabilities in systems engineering, integration, and testing. Providing more slack time in the schedule to react to unanticipated technical challenges.
  - Create budgets that reflect technical complexity risk and realistic assumptions

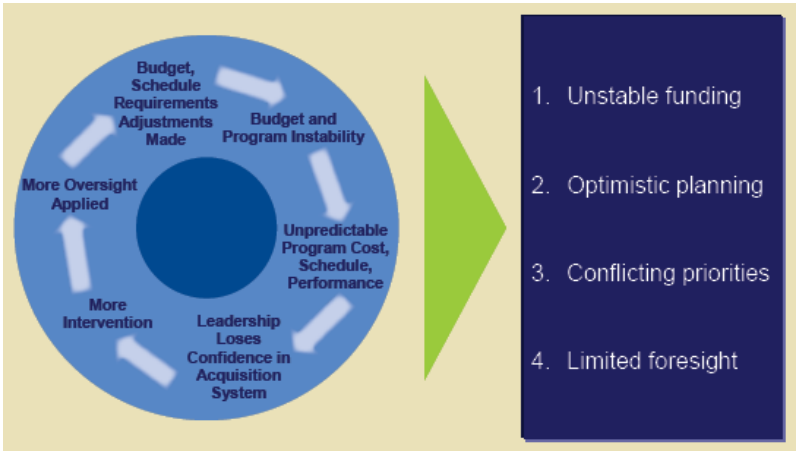
Industry and Government have a Shared Role in Tackling the Issue of Technical Complexity.

* Deloitte Consulting LLP, 2008. **"Can We Afford Our Own Future? Why A&D programs are over-budget and what can be done to fix the problem."** Corporate report available at http://www.deloitte.com/dtt/article/0,1002,sid%253D2223%2526cid%253D233750,00.html

CAUSES FOR COST AND SCHEDULE OVERRUNS IN TRADITIONAL DOD SYSTEM DEVELOPMENT— PROGRAM MANAGEMENT*

- Program management activities such as planning, sourcing, assurance, staffing, finance and integration have played a major role in program cost overruns in the past 20 years
- Overoptimistic scenarios adopted as baseline to win approval
- Technical, functional and financial risks not properly identified, quantified, and integrated into schedules and managed effectively
- DoD program management challenges
  - DoD relies heavily on outside contractors to perform traditionally government roles
  - Frequent PM turnover occurs during system development (since March, 2001, avg. PM tenure on 39 major acquisitions was 17 months)
  - Unsettled program requirements create turbulence
  - DoD PMs not empowered (little funding control, can't veto requirements, minimal staffing authority)
  - Funding constraints contribute to cost overruns





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CAUSES FOR COST AND SCHEDULE OVERRUNS IN TRADITIONAL DOD SYSTEM DEVELOPMENT— PROGRAM MANAGEMENT (2)*

- Recommended Solutions
  - Defense acquisition authorities need to understand and guard against “low bid” scenarios, where due to immature requirements specifications or lack of skill and talent, source selection awards turn out to be “change order” problems

Means that any attempts to dramatically reduce cost will be systematically and forcefully eliminated.

  - Establishing clear performance goals prior to program startup. Applying appropriate monitoring processes to report effectiveness and efficiency.
  - Establishing an enterprise-wide definition of risk. Designing ,implementing and maintaining an effective risk management program. Top executives set the tone, design, direction, and metrics; however, risk management should permeate all layers of the organization.
  - Defining clear roles and responsibilities, accountability, and authority for managing program costs and schedules. Inside the organization, establishing close coordination between multiple supporting functions, executive management, and the board.
  - Providing management and governing bodies with improved transparency into the organization’s risk management practices. Executives and the Board should keep risk on the agenda and require timely information from operations and other supporting functions for critical decisions.
  - Ensuring the overall risk program has adequate support. Certain functions (e.g., legal, IT, HR, Finance) should not just own risk, but also help other parts of the business manage risk effectively.
  - Budgets and schedules need to contain and be certified as “risk tolerant”; i.e., enough slack and contingency time is included to mitigate financial, operational, funding and human resource risks

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Solutions That are More Likely to Make It Worse

- Back to Basics
- Requirements Creep and Objectives Erosion
- “Beatings Will Continue Until Morale Improves”
- Cultural Inertia—Reasons for Not Doing Anything New

BACK TO BASICS (BTB)

- This is primarily a bureaucratic approach to slowing down and stretching out procurement programs
  - **Very unlikely to have the intended effect of reducing cost or schedule overruns, and much more likely to increase them**
- What's the problem with a logical progression of (a) develop technology and then (b) build a system?
- Problem 1 — BtB stretches the schedule
  - Unfortunately, the government works on a 1-year budget cycle and a 4-year (or shorter) major review cycle
  - **Typically, the government stops a program while it thinks and it thinks very slowly**
    - No manager likes to be told that stopping a program almost guarantees significant increases in cost and schedule, which nobody wants to take "credit" for
- Problem 2 — Good mission engineering requires working the technology and the mission simultaneously
  - **To do good mission engineering we need to trade among the requirements (and, hopefully, between requirements and cost) and the only way to do that is if they are all evolving together**

Would Apollo have been faster, better, or cheaper if we had first developed the Saturn V and then thought about how to use it to go to the Moon?

CULTURAL INERTIA —
CATCH PHRASES TO AVOID LIKE THE PLAGUE

- **"It costs what it costs"**
  - But it costs a lot less if you care about what it costs
  - Reducing cost is hard, but not impossible — it requires that we think about the problem and be creative, neither of which is looked favorably on in Aerospace
- **"Are you saying that those who built [the Shuttle, EELV, ISS, or whatever] are bad engineers?"**
  - Of course not. They were (and are) some of the best aerospace engineers in the country.
  - Different solutions arise under different circumstances, different experience base, different needs, and different times
    - ICBMs, from which many current launch vehicles evolved, were never intended to be low cost and had no need to be
  - Progress is real in virtually all other human endeavors
- **"Has it been proven in Space?"**
  - At some point, somebody had to be the first person to walk on the Moon and it doesn't have to be high risk
  - We understand the space environment remarkably well — far better than the environment that a new car or truck will see

Catch phrases are a way of avoiding responsibility for doing better.
We can do better, we have to do better, and we have done so in the past.

STUFF TO AVOID LIKE THE PLAGUE — PART II

- **"Faster, Better, Cheaper – Pick any two" — My personal favorite for avoiding any responsibility for doing things better**
  - This implies that in current programs we have created a monument to perfection — that we couldn't possibly do any better
  - That's Bull !
    - **The Aerospace community has done amazing feats in the past and can do even more amazing ones in the future — including finding ways to do our job faster, better, and cheaper**
- **The SETA Effect**
  - Obviously many SETA (Science and Engineering Technical Assistance) contractors are excellent and dedicated to helping programs move forward
  - But if your job is to find weaknesses, it's easy to fall into the trap of being negative just for the sake of being negative:
    - "It's not convincing"
    - "The conservative approach is not to believe it"
  - **For engineers being paid to either create or review projects — we should ask for the same standards of proof from both**
    - I have to show explicitly why a neat new approach will work and answer critics
    - If you don't believe me, you have to show **WHY** you believe it won't work

A RADICAL VIEW (I.E., MINE) OF COST AND SCHEDULE OVERRUN CAUSES AND SOLUTIONS

- An Alternative View of What Causes Cost Overruns
- "Radical" Solutions to Avoiding Cost Overruns
- Fixing the Schedule
- The Bottom Line — Just Do It

WHAT CAUSES COST AND SCHEDULE OVERRUNS

- Cost and schedule overruns are ubiquitous throughout the DoD and NASA space enterprise
  - Not every program is overrun or behind schedule, but enough are that the problem is clearly not just bad management, poor systems engineering or cost modeling, or some other single factor that can be easily corrected
  - **Most likely multiple factors interact to cause the problems (any single issue would be picked up and solved)**
- **Decision-Making Issues**
  - There is no incentive for the Government to make decisions promptly, particularly if there is a possible risk
  - Natural funding and decision cycles are 1-year and 4-year and many programs now extend over multiple cycles
  - **This means they will be reviewed, re-evaluated, re-assessed, and most likely re-engineered many times from concept to implementation**
    - This adds delay and delay adds cost
    - Everybody can come up with a new thing to test, but nobody has the power to say "No, we don't need that test"

The US simply could not do a $1M, 6-month CanX-2 program. Our decision-making process wouldn't support that time frame or that cost, and the follow-on would be at least 5 yrs later.

CAUSES OF COST AND SCHEDULE OVERRUNS — 2

- **Other Contracting Issues**
  - Contracting delays at every phase cause multiple breaks in execution that, in turn, create both cost and schedule overruns
  - Cost Margin isn't allowed in the contracting process and will nearly always be removed
    - Builds in the probability of cost overruns
- **Mission Design Issues**
  - Mission and System Design is essentially never done
    - Don't do trades between major elements (orbit control example)
    - Figures of Merit are almost never computed or used
  - System design teams won't trade on cost as a parameter ("It costs what it costs")
  - Orbits have a cost — but not to the mission design community
    - "Mission and Constellation Design and Management" book creates and evaluates an "Orbit Cost Function," but orbit cost is almost never considered
    - Examples of poor choices — Highly Elliptical Orbits (HEO) for CommSats or Sun Synchronous orbits to avoid eclipses
- **Programmatic Issues**
  - Forcing risk onto the contractor — forces out the small, low-cost contractors
  - No advantage to under-running a contract
  - External reviewers with "no skin in the game" — no motivation to reduce cost or schedule, but might be blamed if something goes wrong; no recognition of "reasonable risk"

CAUSES OF COST AND SCHEDULE OVERRUNS — 3
CULTURAL ISSUES

- **Cultural Issues**
  - **People don't like to talk about cost or reducing cost and it's often discouraged**
    - "It costs what it costs"
  - The tyranny of TRLs
    - Spend lots of time deciding whether something can be used in space based on heritage, rather than either engineering or common sense
  - The issue isn't cost, but cost overruns, so bid high
  - The Government is afraid of people who say they can do things more economically
    - Afraid they will simply introduce cost overruns
  - Today we fix the requirements and then look for bids
    - To win, you have to bid low and this leads to cost overruns
  - **"If it works, all is forgiven"**
    - **Few people think about the program that was canceled to cover the cost overrun, the global warming data that was obtained too late, or the soldier that died because the system wasn't yet in place**

Today's space program is driven primarily by fear, rather than by a desire to get the job done quickly, and at low cost. We have lost both the sense of urgency and the professional engineering judgment that goes with it.

RADICAL SOLUTIONS TO AVOIDING COST OVERRUNS

- **Tiered expectations**
  - FFP contracts for GEO CommSats or other well-established technologies (this is in place today)
  - CPFF contracts for programs that include R&D or first unit development
  - **Large margins for small programs, new technology, or programs aimed at dramatically reducing cost—the key is how much are we trying to save**
  - Similar approach for schedule
- **Create a Risk Mitigation Plan**
  - Identify and attack key risk areas
    - Monitor progress in this area closely
    - Have back-ups
  - Evaluate it with a goal-oriented team, not one that is process-oriented
- **Cultural Approaches**
  - Create a true team activity where we work together for the common good
  - Create a Plan of Attack—design how to attack the problem of excessive cost & schedule
  - **Make cost known and make cost matter**

Think about the soldiers that are killed, the science that is missed, the opportunities that are lost —not because the system isn't perfect, but because we didn't get it there when we needed it or couldn't afford it because of cost overruns.

RADICAL SOLUTIONS TO AVOIDING COST OVERRUNS — 2

- **Programmatic Approaches**
  - **Avoid schedule breaks — they create cost and schedule overruns**
  - **Avoid the tyranny of TRLs**
    - develop processes and equipment in parallel with the system — it allows for trades on what the process or equipment needs to do
    - Have back-ups and alternative approaches
  - **Reward cost and schedule underruns — reward is much better than punishment**
    - Split the cost savings
    - Give preference points toward future programs and contracts
    - Use 40% of savings to cut cost, 25% to new cost reduction studies or technology, 25% to the contractor, and 10% to the individuals who made it happen
  - Better systems and mission engineering throughout the program
  - Create large margins
- **Contracting Approaches**
  - **Use a "should cost" approach based on traditional cost models**
    - **Set budget based on splitting "should cost" and "bid cost" and provide a tiered reward based on how much cost can be reduced**

Faster, Better, Cheaper can work — it's just hard.

RADICAL SOLUTIONS TO AVOIDING COST OVERRUNS — 3

- **Contracting approaches (continued)**
  - Design to cost approach
  - Allow and reward creativity by specifying what and not how
    - Award a contract for attitude determination to 0.01 deg, 3 sigma — not for a blue star sensor with an 8 deg square FOV and sensitivity to magnitude 4.5 in visible light
- **Creativity in Contracting — The Cassini Resource Exchange**
  - Approach created by Randii Wessen, David Porter, and others at JPL
    - Planetary missions are particularly susceptible to cost overruns
    - No motivation for PIs to not go back and ask for more $$, more mass, more power
  - Basic idea is to create a “stock market” in cost, mass, and power
  - At experiment selection, divide all the cost, mass, and power among the PIs (no margin)
  - **If you need more mass, get it by trading cost or power to one of the other PIs; similarly for cost and power**
  - The program office tracked (and posted on their website), the value of mass and power
  - The decision-making process was now in the hands of the PIs to determine the best way to use the limited resources available to them
  - **Bottom line — the program came in on budget in cost, mass, and power**
    - As the end result became apparent, the value of mass and power went down — i.e., you got more for your excess power (or mass) if you traded early

RADICAL SOLUTIONS TO AVOIDING COST OVERRUNS — 4

- **Sets of Small Satellites do many of the things we want**
  - **Inherently much shorter schedules — implies far fewer schedule breaks**
  - Reduces the cost of individual failures
  - Cost and schedule overruns likely to be much smaller dollar values (of course, this may not matter to the rule-oriented bureaucracy)
  - Teamwork is easier in small programs
  - Individual responsibility is greater

Summary— there are lots of answers; what they all have in common is that cost and schedule have to matter from the outset.

FIXING THE SCHEDULE

- **Determine what has value and reward it**
- **Make it worthwhile to come in ahead of schedule**
  - Example: the Northridge earthquake in LA on Jan. 17, 1994, caused freeway overpasses to collapse on I10
    - Single most heavily used highway in the US — doesn't work as well when the bridges have collapsed
    - State offered a bonus of $250,000/day for every day ahead of schedule that the bridge reopened
    - I10 reopened 88 days after the earthquake, 66 days ahead of schedule
      - $16 million bonus to the contractor
- Natural funding and decision cycles are 1-year and 4-year and many programs now extend over multiple cycles
  - **This means they will be reviewed, re-evaluated, re-assessed, and most likely re-engineered many times from concept to implementation**
    - This adds delay and delay adds cost
    - Everybody can come up with a new thing to test, but nobody has the power to say "No, we don't need that test"

If we can fix the schedule — for both decision-making and contracting — we will have gone a long way toward fixing the cost.

A CRITICAL ISSUE — SOME COST AND SCHEDULE OVERRUNS ARE GOOD

- **Our real goal is to dramatically drive down cost and schedule**
- **If we don't have at least some cost or schedule overruns, we aren't pushing hard enough**
  - If a "normal" program would require 4 years and $100 million and we attempt to do it in 1 year and $20 million, then how do we assess a result of 2 years and $40 million
    - It's overrun in both cost and and schedule by a factor of 2
      - The contracting officer will regard it as a miserable failure
    - It did better than the traditional program by a factor of 2.5 in cost and 2 in schedule — and that's great
- **It's hard to find the right balance in a rule-based system**
  - Do we reward the above program or penalize it?
    - What about the second contractor who claimed they could do the program in 1.5 years for $30 million?
- The above example is clearly different than a program that "should take" 4 years and $100 million and ends up taking 8 years and $200 million — **but how do we know the difference? Judgment is key!**

As with all aspects of space mission engineering, it's a matter of finding the right balance. Some cost and schedule overruns are acceptable on programs that are pushing dramatic improvements. Continuing overruns on operational programs are dramatically bad.

THE BOTTOM LINE — JUST DO IT

- **The right answer is to move rapidly, be aggressive in what we attempt, and fix errors and mistakes as we go**
- **Do good upfront mission engineering for a program that will be needed over and over again**
  - Communications
  - Surveillance
  - Wind Lidar
- **Force rapid, parallel decision-making**
- **In the infamous words of the MISTI program manager — "Shoot the engineers and get on with the program."**
- **In the much less famous words of the USC professor — "Shoot the contracting officer and get on with the program."**
  - We shouldn't omit the up-front systems engineering — it's critical
  - Nonetheless, we have to find a way to move forward rapidly and aggressively

We need dramatic reductions in both space mission cost and schedule.
The most certain way to fail is not to make the attempt by concentrating only on overruns.

