Integrating Efficiency of Industry Processes and Practices alongside Technology Effectiveness in Space Transportation Cost Modeling and Analysis

2012 NASA Cost Symposium
August 21-23, 2012

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Contents

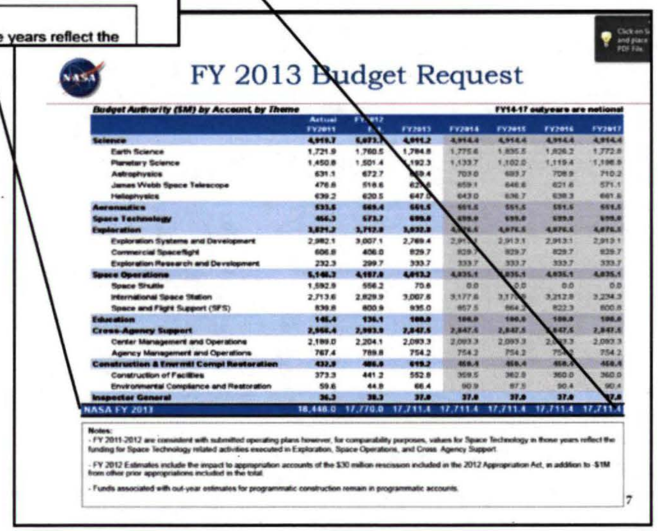
Situational Awareness

- "Budgetary pressure will increase in coming decades as more members of the baby-boom generation retire and become eligible for federal health programs." (GAO[1])

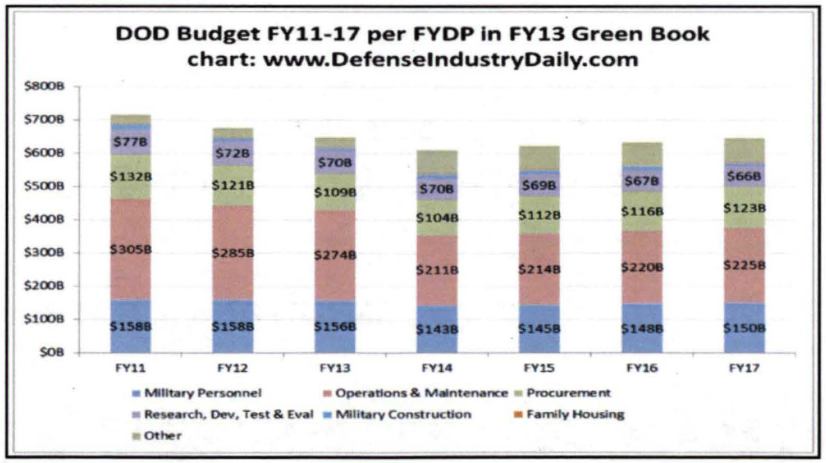
- NASA budget outlook always uncertain; currently projected as flat[2].

Construction of Facilities	373.3	441.2	552.8	359.5	362.9	360.0	360.0
Environmental Compliance and Restoration	59.6	44.8	66.4	90.9	87.5	90.4	90.4
Inspector General	**36.3**	**38.3**	**37.0**	**37.0**	**37.0**	**37.0**	**37.0**
NASA FY 2013	**18,448.0**	**17,770.0**	**17,711.4**	**17,711.4**	**17,711.4**	**17,711.4**	**17,711.4**

Notes:
- FY 2011-2012 are consistent with submitted operating plans however, for comparability purposes, values for Space Technology in those years reflect the

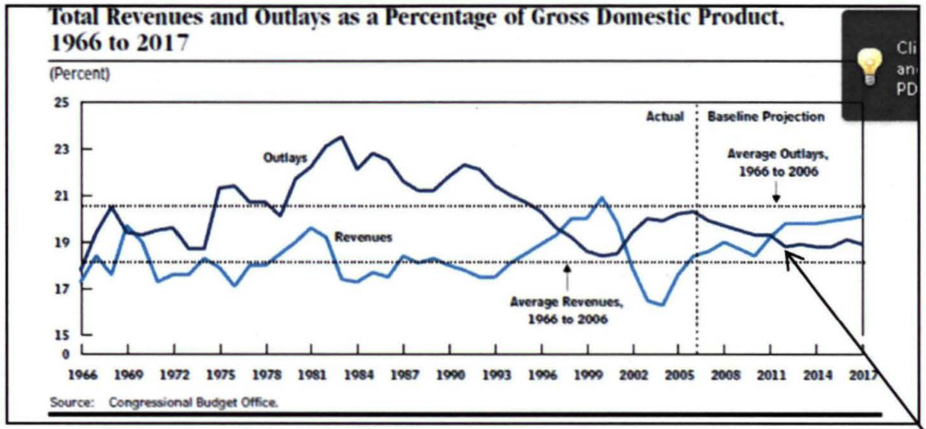


- DoD overseas ops, war costs wind down[3].



Situational Awareness

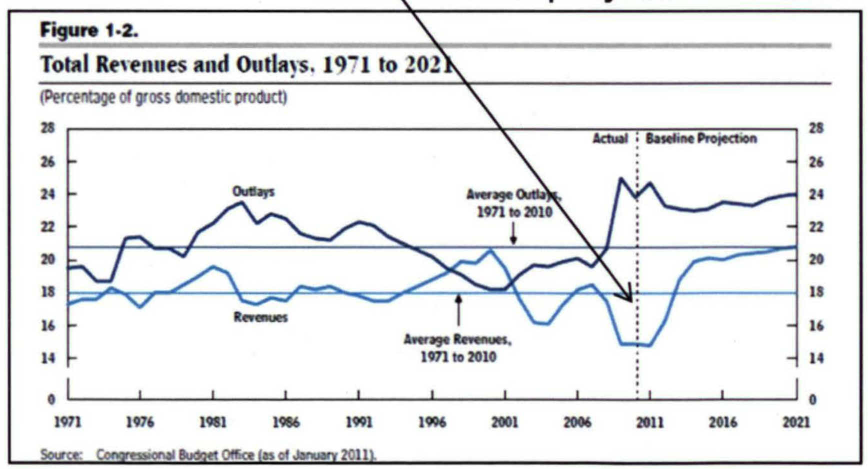
- Uncertainty and the Black Swan.



CBO projection in **2007**[1]

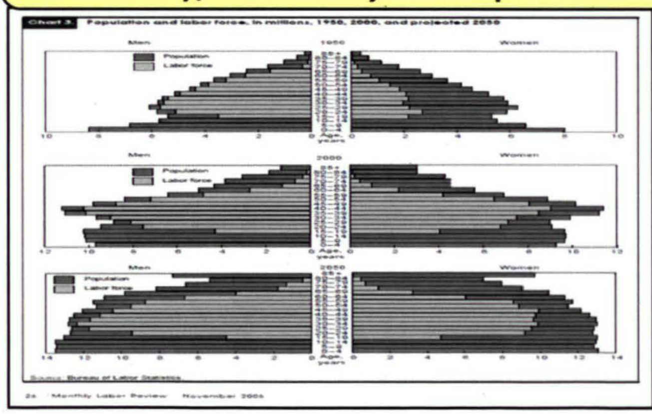
Revenue projections were a little off...

CBO projection in **2010**[2]



- *"Demography is destiny"*

City-scale 6, 7, 8-genarians (10's of millions); A wholly new phenomenon.



Year

1950

2000

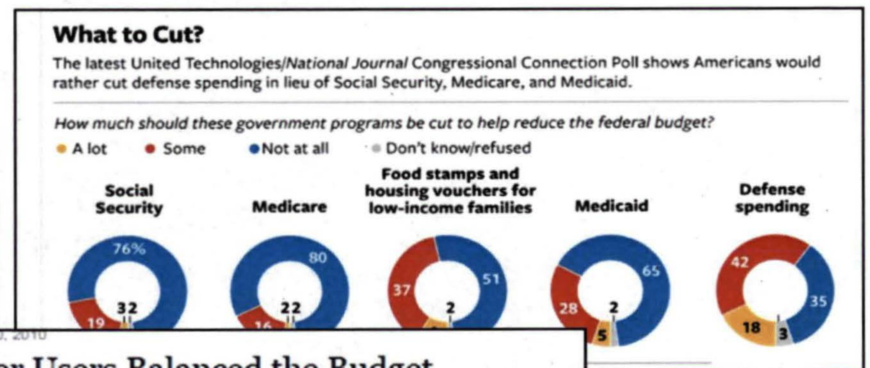
2050

2006 US Monthly Labor Review[3]

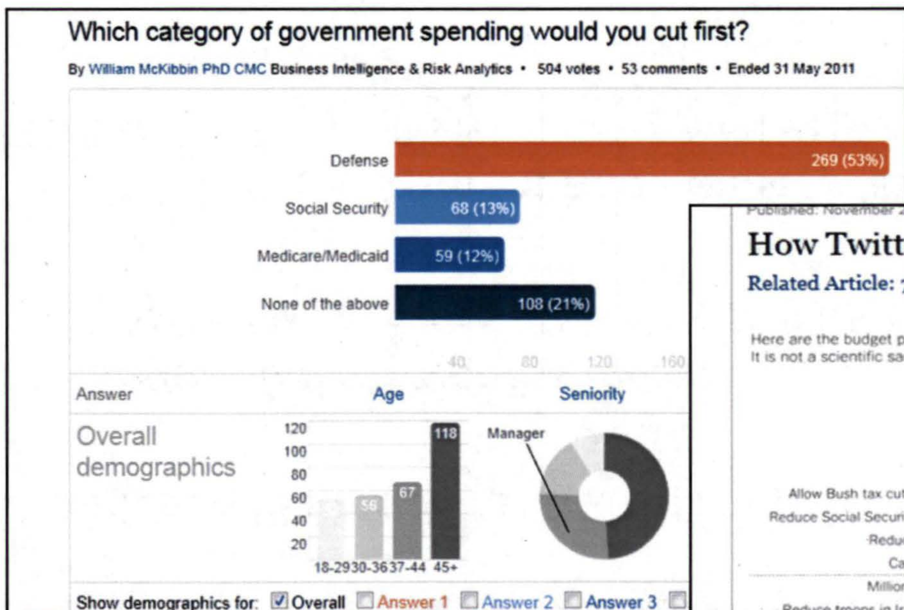
Situational Awareness

- Sequestration: Not in the prior baselines.
  - Complex. Additional DoD cuts ~ 9% per year. Additional non-defense “discretionary” budget cuts ~ 3% per year.
  - (Cuts “baselines”; unknown specifics agency by agency)

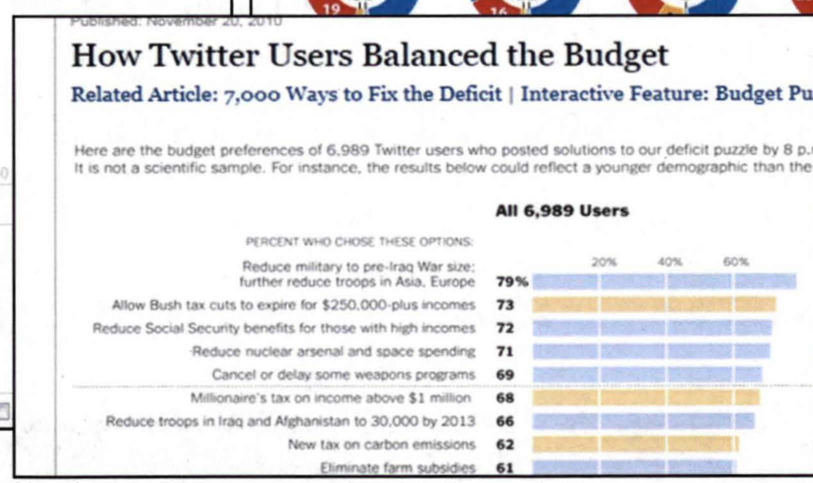
- Public opinion.



National Journal[3]



LinkedIn[1]



NYT[2]

The Need (So much for the attention getters…everyone awake now?)

- *Situational awareness tells us?*
  Effectiveness and Efficiency in NASA programs/projects is not optional.

- Yet both government and industry "efficiency", being "how", not "what", has traditionally been ignored in cost modeling.
  - Traditionally – cost models, and a "WBS" view, focus on effectiveness (the product, it's performance, mission, technology, systems, etc.)[1]

- Efficiency – *even as non-product costs dominate our industry* – relegated to cursory "wraps", or ill-defined notions about overhead, "paperwork".

- So -how can the environment at hand be addressed via costing - for example as guidance informing acquisition strategy, evaluation and procurement? While still reflecting the real world system?

How can we move to cost models that don't ignore most costs?

(Let me explain…)

Data…but first…

- ***"There was a man on his hands and knees searching and scouring the ground beneath a light post……..*** a stranger walked by and said what are you doing? The fellow on the ground said with mild panic in his voice…I lost my key's. The kindly stranger bent down and lowered himself to join in the search. After a few minutes the stranger said to the man, are you sure you lost them here? The man looked up and said no, pointing to the far off parking lot he said I lost them over there but the light is better here."[1]

Data

Where might the keys really be?

- Well known that **indirect** costs comprise more and more of the costs in aerospace over time.
  - 1990: "For example, in the aerospace industry, **indirect costs** accounted for 58% of total contract costs…"[1]
  - 1991: "Experience at these firms indicates that **overhead** had grown from about 38 percent of total business in 1973 to about 49 percent by 1987. Extrapolation of this trend indicates that **overhead** will reach about 54 percent by the year 2000."[2]
  - 2011: "About three-quarters of the 84 recommendations in the EELV should-cost review are associated with **overhead** and **indirect costs**"[3].

Data

- Space Shuttle ***detailed*** cost data was lacking till the early 1990's (The Zero Base Cost Study[1]) but matured quickly by the mid-90's (The Access to Space Study, RAND[2] study, and numerous others).

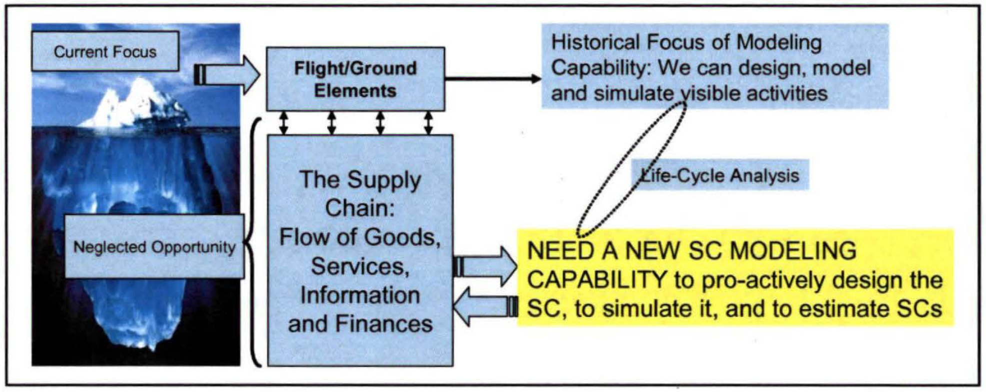
- Data confirmed *program wide* what was already observed in segments of the program (such as KSC operations) – that the cost of the effort "close-in", nearest to the product (the vehicle turnaround, the production, the materials) was the SMALLEST part of total expenses.

- The rest of these costs, making up most of the total costs in our industry, have come to be called assorted names - *"indirect"*, overhead, non-touch, systems engineering[3] (in DoD), project, program management, etc.

- Will use the term "indirect" here – though the detailed definition or substance of the term lacks consensus.

Methodologies and Indirect Costs

- 2004: Kennedy cost modeling efforts re-addressed the basic structure of inputs and outputs, causes and effects.



2004 Earth-to-Orbit Supply Chain Simulation[1]

2004 Launch and Landing Effects Ground Operations (LLEGO) Model[2]

- "Operations Practices": The term in early ground operations models. These practices drove "indirect" NASA and (mostly) Industry costs.
  - NASA-in so far as how an acquisition was structured.
    - About the efficiency of sourcing the required item, <u>not it's value</u>.
  - Industry-the largest component of cost-in so far as how the product was provided.
    - All about the efficiency of fulfilling the requirement.

Methodologies and Indirect Costs

(1)

NASA Effort to Acquire X

Industry / Project X

Direct Cost | Indirect Cost

Possibility: **NASA** efficiency

NASA Effort to Acquire X

Industry / Project X

Direct Cost | Indirect Cost

Possibility: **Industry** efficiency

NASA Effort to Acquire X

Industry / Project X

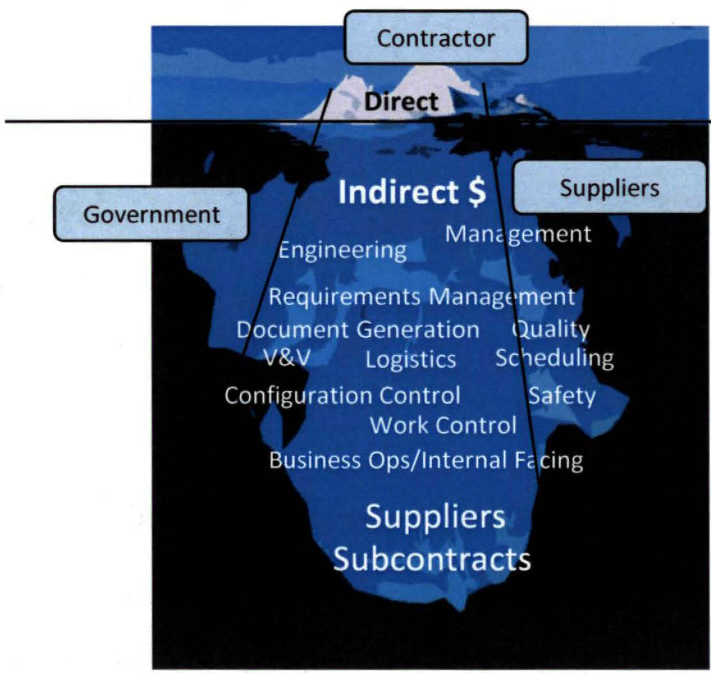
Direct Cost | Indirect Cost | Freed Up for ?

(No change in the product/service/quantity acquired)

Methodologies and Indirect Costs

- 2012: Current work with the Air Force Research Lab (AFRL) on Reusable Booster Systems Life Cycle Cost Modeling.
  - The concepts and tools have evolved significantly (if not the figures.)
  - Now all inclusive, from R&D > Development > Production > Ops.

Life According to Aerospace



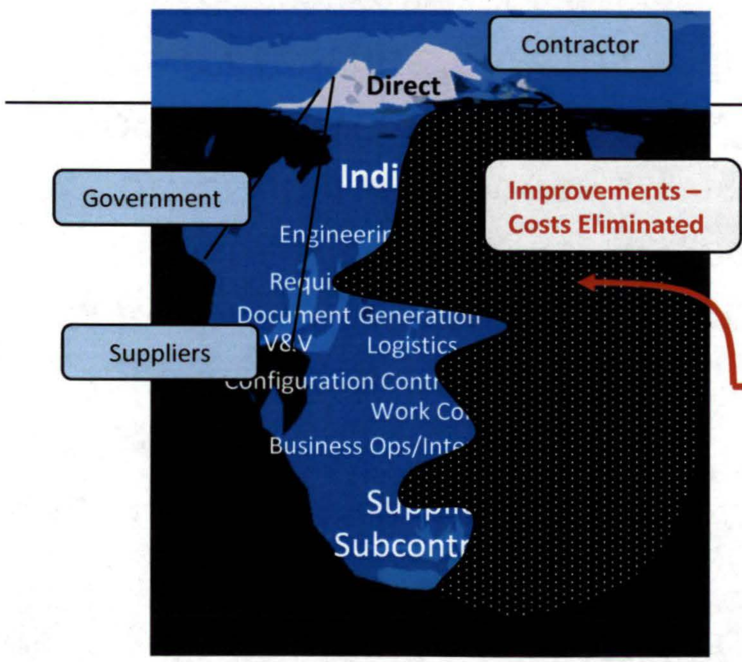
↑ Visible, closer to hardware/software

↓ Less visible, farther away from the flight/ground/production/development of flight hardware/software/infrastructure

These indirect costs and their behavior dampen demand, which favors a supply, a flight rate, at current levels.

Methodologies - Technology is not just Technical

- Worthwhile cost estimates include methodologies that explore the attributes of *efficiency* of the performing organization (indirect), process and practices, fixed costs, and their supply chain management (SCM), moving materials *and information.*
- What is different in process/practices (P/p) and SCM technologies? What is their connection to lower costs vs. historical data?



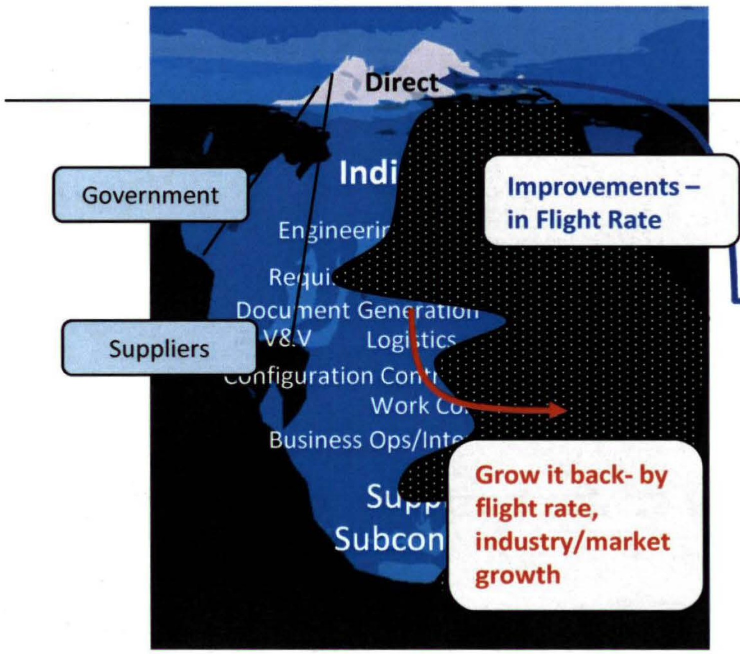
Improvements in COST *at same productivity*

Technology is the making, usage, and knowledge of tools, machines, **techniques, crafts, systems or methods of organization** in order to solve a problem or perform a specific function. It can also refer to the collection of such tools, machinery, **and procedures**.

Ref. "Making the Case for Reusable Booster Systems: The Operations Perspective" presented to the Aeronautics & Space Engineering Board, National Research Council, Committee for the Reusable Booster System: Review and Assessment, May 7, 2012, Washington DC.

Methodologies - Productivity → Costs → Technology

- Once affordability is achieved, efficient organizations can take advantage of enabling "technology" for improving their "direct" effort/effectiveness, producing MORE flights, responsiveness, a HIGHER tempo of operations or other unique product/services.
- Now the system can scale. Flight rate, sustainability, responsiveness, and industry revenue/growth can follow *causally.*



Then TECHNOLOGY *for greater productivity*

-more electric vehicle, EHA's, EMA's
-non-toxic, higher Isp, more maintainable propulsion
-health management
-automated umbilical's and handling
-simpler propulsion, ceramic NFS engine parts
-materials advances , composites, aluminum lithium...more.

Ref. "Making the Case for Reusable Booster Systems: The Operations Perspective" presented to the Aeronautics & Space Engineering Board, National Research Council, Committee for the Reusable Booster System: Review and Assessment, May 7, 2012, Washington DC.

Methodologies - and reality…

"There's this farmer, and he has these chickens, but they won't lay any eggs. So, he calls a physicist to help. The physicist then does some calculations, and he says, um, I have a solution, but it only works with spherical chickens in a vacuum."

-Big Bang Theory, Episode 9, Season 1

(There are many models of this joke)

Back to Data – An "Existence Proof" – Falcon 9 and NAFCOM

- Numerous versions to this evolving "existence proof".
- Cost of Falcon 9 development, initial production and test flight (not recurring operations) has been[1,2] confirmed by government analyst to have been between 10% to 32% of what government models would otherwise have required.
- Same "what" (medium lift rocket), far different "how".

Falcon 9 NAFCOM Updated Cost Estimate Comparison Updated

(Cost Plus Fee Vs. Firm Fixed Price)

		Firm Fixed Price Acquisition			Cost Plus Fee Acquisition		
Elements	Weight (lbs)	DDT&E (FY2010 $M)	2 Test Flt Units (FY2010 $M)	Total (FY2010 $M)	DDT&E (FY2010 $M)	2 Test Flt Units (FY2010 $M)	Total (FY2010 $M)
Stage One (Including Engines)	39,080	$188.7	$109.3	$298.0	$370.6	$218.3	$588.9
Stage Two (Including Engine)	6,506	$89.0	$23.6	$112.6	$184.7	$59.6	$244.4
Fee (12.5%)		$0.0	$0.0	$0.0	$69.4	$34.7	$104.2
Program Support (10%)		$0.0	$0.0	$0.0	$62.5	$31.3	$93.7
Contingency (30% Vehicle, 10% Engine))		$0.0	$0.0	$0.0	$193.2	$91.7	$284.9
Vehicle Level Integration (8%)		$22.2	$10.6	$32.8	$44.4	$22.2	$66.7
Total	**45,586**	**$299.9**	**$143.6**	**$443.4**	**$924.9**	**$457.9**	**$1,382.7**

- Based on technical corrections and the additional insight in to the mass summary information as well as hardware heritage gained from a recent trip to the SpaceX facility.
- Represents DDT&E and two test flight unit
- Cost plus fee acquisition approach include fee, program support, and contingency where firm fixed price acquisition reflects a space act agreement approach

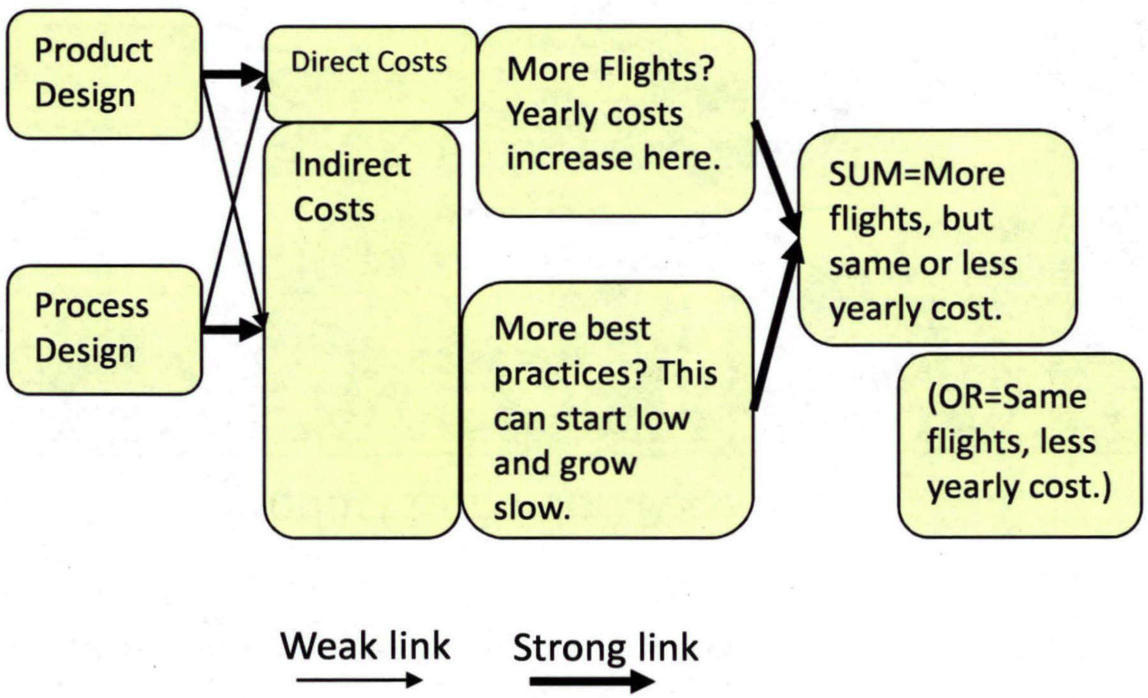
9

(1) PUBLIC: Commercial Market Assessment for Crew and Cargo Systems, Pursuant to Section 403 of the NASA Authorization Act of 2010 (P.L. 111-267), Appendix B, April 27, 2011. Available at http://www.nasa.gov/pdf/543572main_Section%20403%28b%29%20Commercial%20Market%20Assessment%20Report%20Final.pdf

(2) PUBLIC: Falcon 9 Launch Vehicle NAFCOM Cost Estimates, NASA Associate Deputy Administrator for Policy, August 2011. Available at: http://www.nasa.gov/pdf/586023main_8-3-11_NAFCOM.pdf

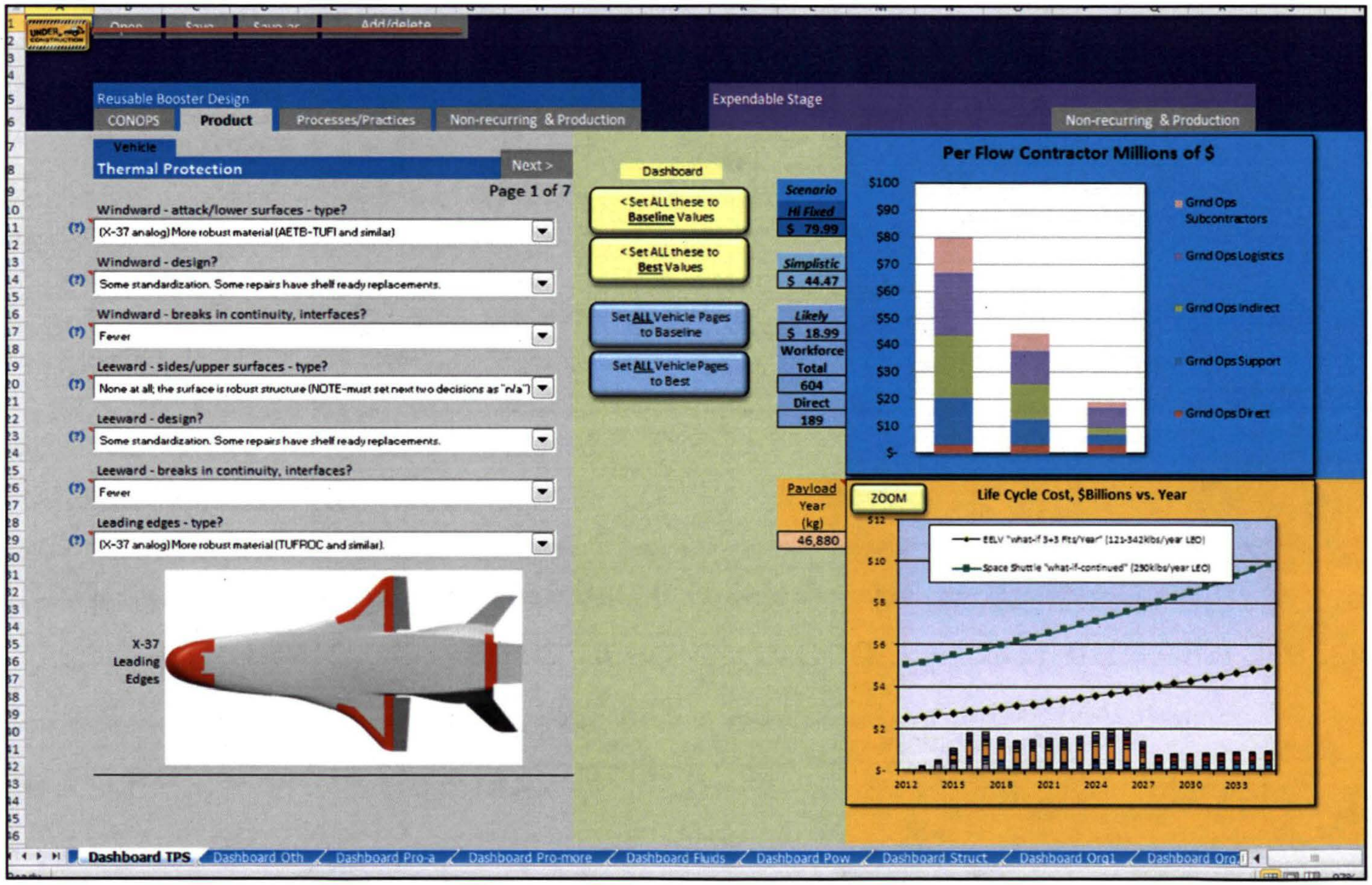
A Model – The Evolving RBS LCC Model

- The current terminology being used is "product" and "process/practices" – with decisions for these that are causes of the estimated costs.
- The Model Framework-



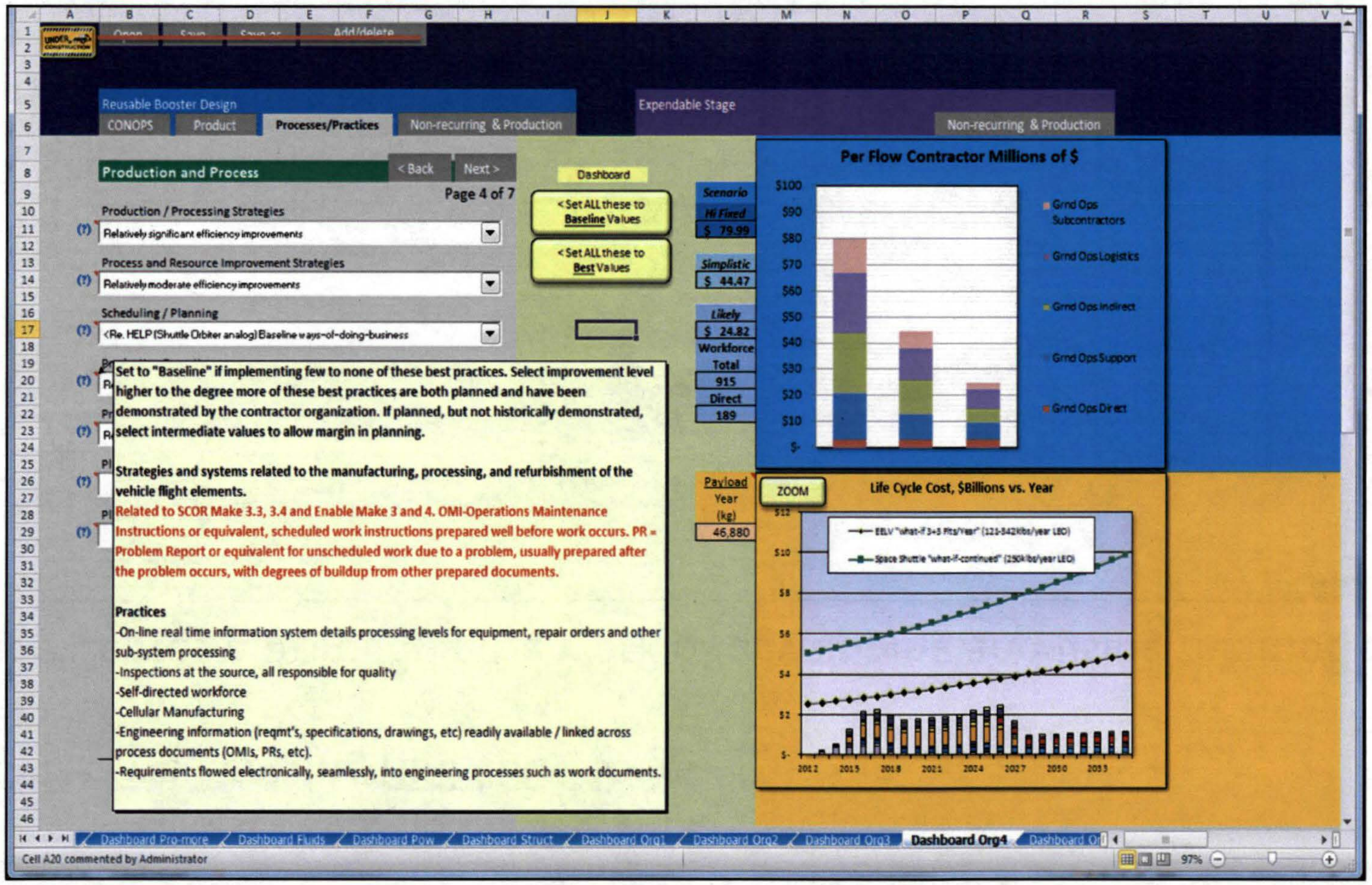
A Model – The Evolving RBS LCC Model

- Model Screen Shots-Product Definition Page



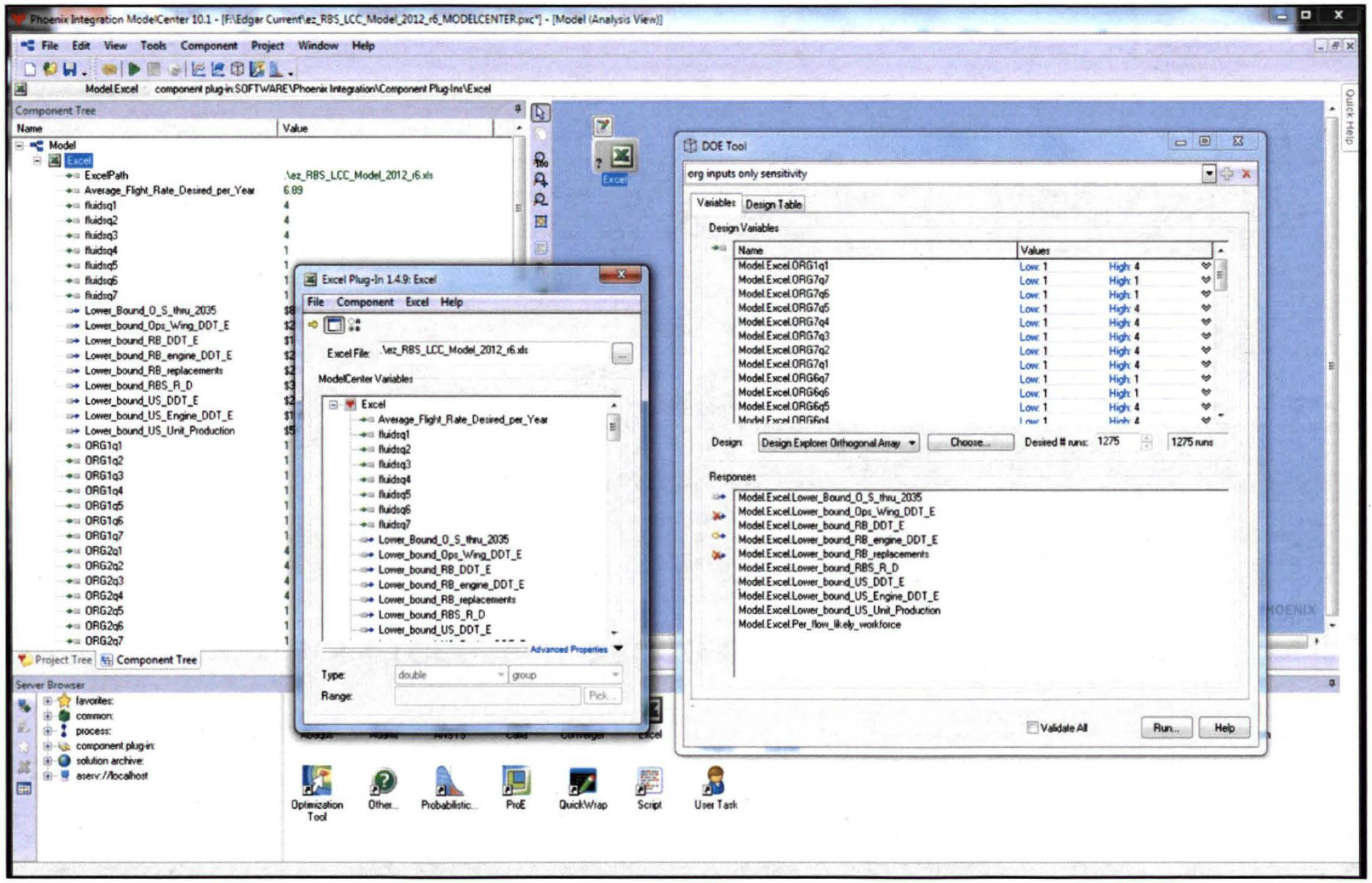
A Model – The Evolving RBS LCC Model

- Model Screen Shots-Process/Practice Definition Page showing "Help"



A Model – The Evolving RBS LCC Model

- ModelCenter-automating the work of developing and using the model



Implementation

- Stepping far from established "data points" (EELV, Shuttle, etc.) can be accomplished with relative confidence if listening closely to the data, which tells us very much about *where the keys were probably lost.*

- Cost modeling must step outside of comfort zones – else, no useful insights will be provided into the process, costs will continue to go out of control, while productivity declines.

- NASA/Industry relevance in Spaceflight is now all about enabling productivity (has been a while…).

- None of this is really new (…except applying it to us…)
  - Effectiveness and efficiency have just changed their names over many decades according to what's in business vogue.
  - 1980's "middle-management[1]" craze already saw this disruption.
  - 1990's I/T revolution was about efficiency, reducing indirect costs.
  - "Adapt or Die"[2] still true…

Going Forward

- Our cost models must increasingly address the possibility of transformative, dramatic, productivity and cost improvements – providing insights on the characteristics of our acquisition and our industry process/practices that best co-relate to these advances.

- *Then costing can move into the more challenging issues and economics to change:*

    - Industry may parrot these variables in bids, but lack the experience or desire to actually implement the new ways of doing business.
    - Where industry is ready, the number of these players may be insufficient to shift the paradigm for the industry as a whole, or quickly enough.
    - Within the NASA sourcing process, the desire to see these industry improvements *–highly disruptive to existing players-* has to come along before new NASA processes can enable a new normal.

BACKUP

Abstract

- *This paper presents past and current work in dealing with indirect industry and NASA costs when providing cost estimation or analysis for NASA projects and programs. Indirect costs, when defined as those costs in a project removed from the actual hardware or software hands-on labor, makes up most of the costs of today's complex, large scale NASA space/industry projects. This appears to be the case across phases, from research, into development, into production, and into the operation of the system. Space transportation is the case of interest here. Modeling and cost estimation as a process, rather than a product, will be emphasized. Analysis as a series of belief systems in play among decision makers and decision factors will also be emphasized to provide context.*