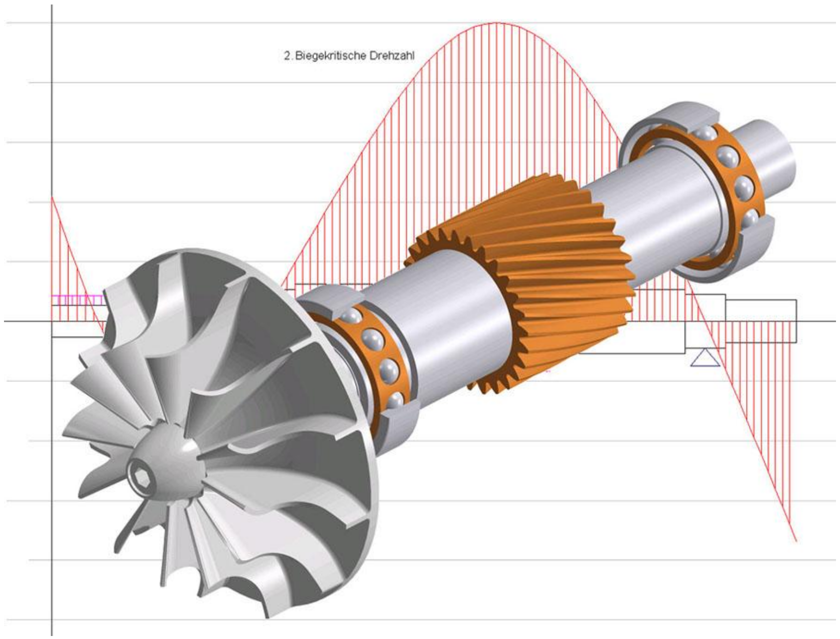
Weapon Design Tradeoff: Using Life Cycle Costs

Quentin Redman
Director – Solutions Architect
PRICE Systems, L.L.C.

Weapon Design Tradeoff . . .
Using Life Cycle Costs



LCC: What is it?

Definition:

MIL-HDBK-259 (Navy) gives a comprehensive (if long winded) expanded definition:

"LCC is the sum total of the direct, indirect, recurring, non-recurring, and other related costs incurred, or estimated to be incurred in the design, research and development (R&D), investment, operation, maintenance, and support of a product over its life cycle, i.e. its anticipated useful life span. It is the total cost of the R&D, investment, O&S and, where applicable, disposal phases of the life cycle."

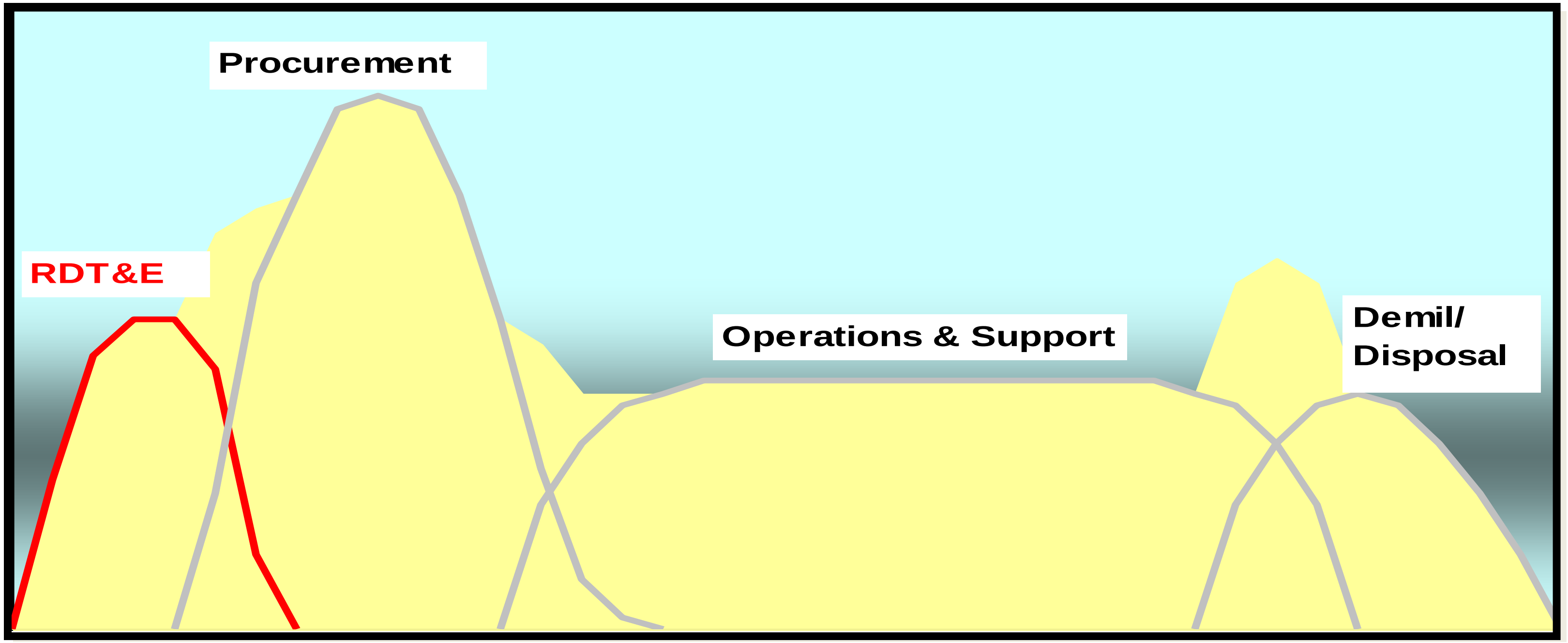
- **More simply: LCC is the total cost to the customer for a program over its full life.**
  - Includes all costs directly and indirectly attributable to the program.

"Cradle to Grave"

The Phases of the Life Cycle

LCC = RDT&E $ + Procurement $ + O&S $ (+ Disposal $)

- Phase 1: Research, Development, Test, Evaluation (RDT&E)
- Phase 2: Procurement (or Acquisition)
- Phase 3: Operations and Support (O&S)
- Phase 4: Disposal (Sometimes a subset of O&S)



LCC: **Why** do we us it?

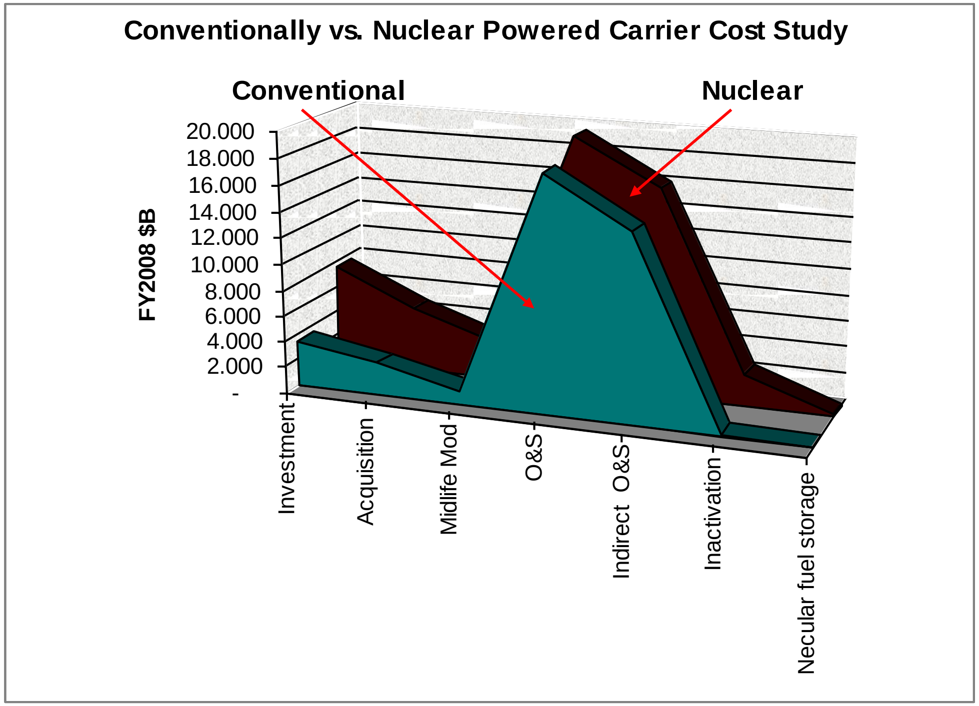
By ignoring O&S and disposal costs
what are you missing?

System	**% of LCC**
Missile ("Wooden Round")	
• RDTE	11%
• Production/Acquisition	77%
• **O&S**	**12%**
Ship (Average)	
• RDTE	3%
• Production/Acquisition	37%
• **O&S**	**60%**
Aircraft (F-16)	
• RDTE	2%
• Production/Acquisition	20%
• **O&S**	**78%**
Ground Vehicle (M-2 Bradley)	
• RDTE	2%
• Production/Acquisition	14%
• **O&S**	**84%**

- **Early design efforts determine LCC.**
- **By the time requirements are set over 80% of LCC is committed by design decisions.**
- **By the time the design is final approximately 90% of LCC is committed!!!!**
- **Clearly the time to evaluate LCC is EARLY!!**

LCC: **How** do we use it?

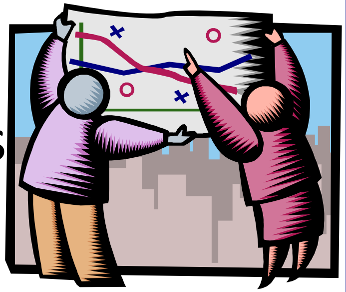
- **Option evaluation**
  - LCC allows the evaluation of competing system proposals on the basis of total ownership cost.
- **Improved Awareness:**
  - LCC allows management and stakeholders a broader and more accurate assessment of cost drivers.
  - May be a first glimpse of the total cost of ownership.
  - Facilitates the appropriate focus of resources to where they are needed.



Source: Analyses by the Naval Sea Systems Command and the Center for Naval Analysis GAO/NSIAD-98-1

LCC: **How** do we use it?

- **Improved forecasting and budgeting**
  - Understanding LCC allows more effective budgeting of future funds such as O&S costs and disposal costs.
  - Helps prevents budgeting surprises
- **Cost Strategy Support**
  - LCC perspective maximizes the benefit of applying strategies.
    - Cost as an Independent Variable (CAIV)
    - Design to Cost (DTC)
    - Reduced Total Ownership Cost (R-TOC)

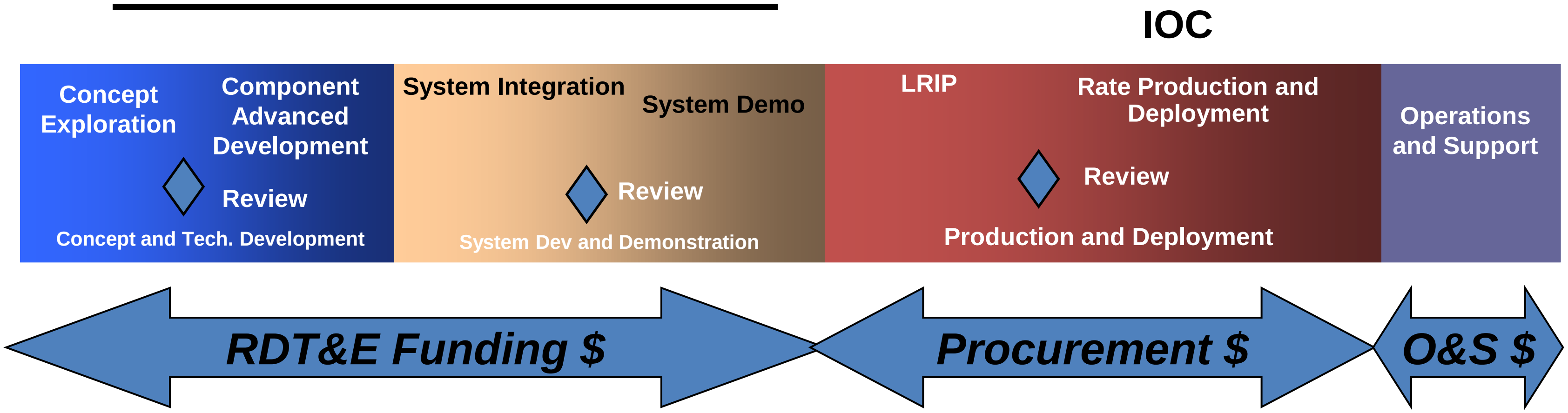


Aircraft Procurement and O&S Costs		
ATTACK	UFAC	DoD Reimb
A-10A	10.7	$3,815
BOMBER		
B001B	254.7	$22,928
B002A	1,041.1	$13,294
B052H	55.4	$13,347
FIGHTER		
F015A/B	29.0	$11,220
F015C/D	31.0	$11,705
F015E	32.3	$11,781
F016A/B	15.2	$5,428
F016C/D	19.5	$4,935
F022A	95.1	$2,462
TANKER		
KC010A	79.8	$9,114
KC135R	17.7	$4,896
RECON/EW		
E003A	121.2	$8,375
E004B	96.3	$49,330
E008C	251.5	$4,037
EC130E	28.0	$2,985
EC135C	41.1	$3,106
CARGO/TRANSPORT		
C005A	119.3	$14,885
C005B	156.8	$10,849
C009A	16.5	$6,256
C009C	21.8	$5,775
C012A/C/J	3.8	$1,911
C020A/B/C	30.5	$3,952
C021A	3.4	$1,523
C130E	12.4	$3,830
C130H	29.2	$3,952
C130J	64.0	$2,536
C141B	43.9	$6,969
HELICOPTER		
HH060D/E	14.1	$3,443
UH001N	2.6	$1,063
TRAINER		
T037A/B/C	1.0	$398
T038A	3.9	$1,353
T041A/C/D	0.1	$11
T043A	21.4	$3,476

UFAC = Unit Fly Away Cost FY 05 $M
oD Reimb= flying hour reimbursement rate

LCC – Phasing and Funding

THE DODI 5000 MODEL



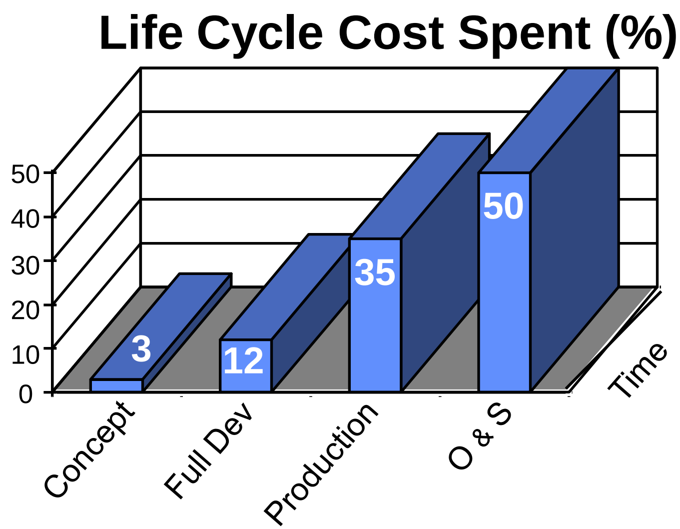
051 Funds (DOD TOA)

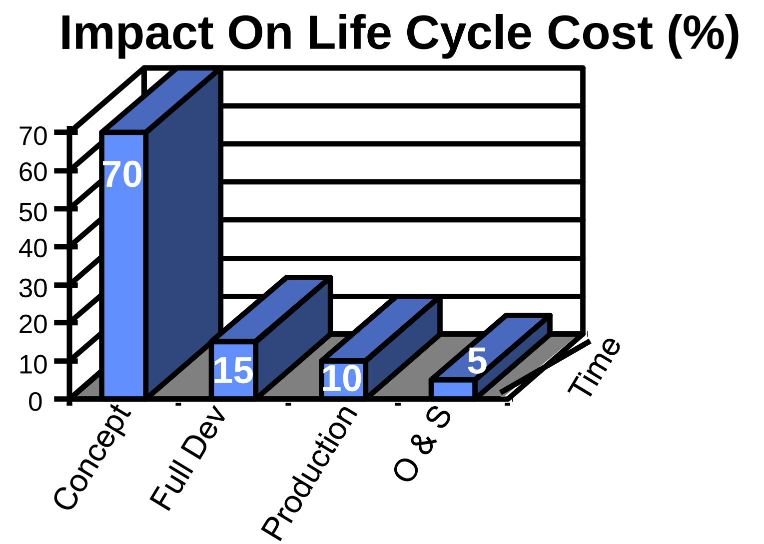
Military Personnel
O&M
Procurement
RDT&E ←
Military Construction
Family Housing
R&M Funds
Defense Wide Contingency
Offsetting Receipts
Trust Funds
Inter-fund Transactions

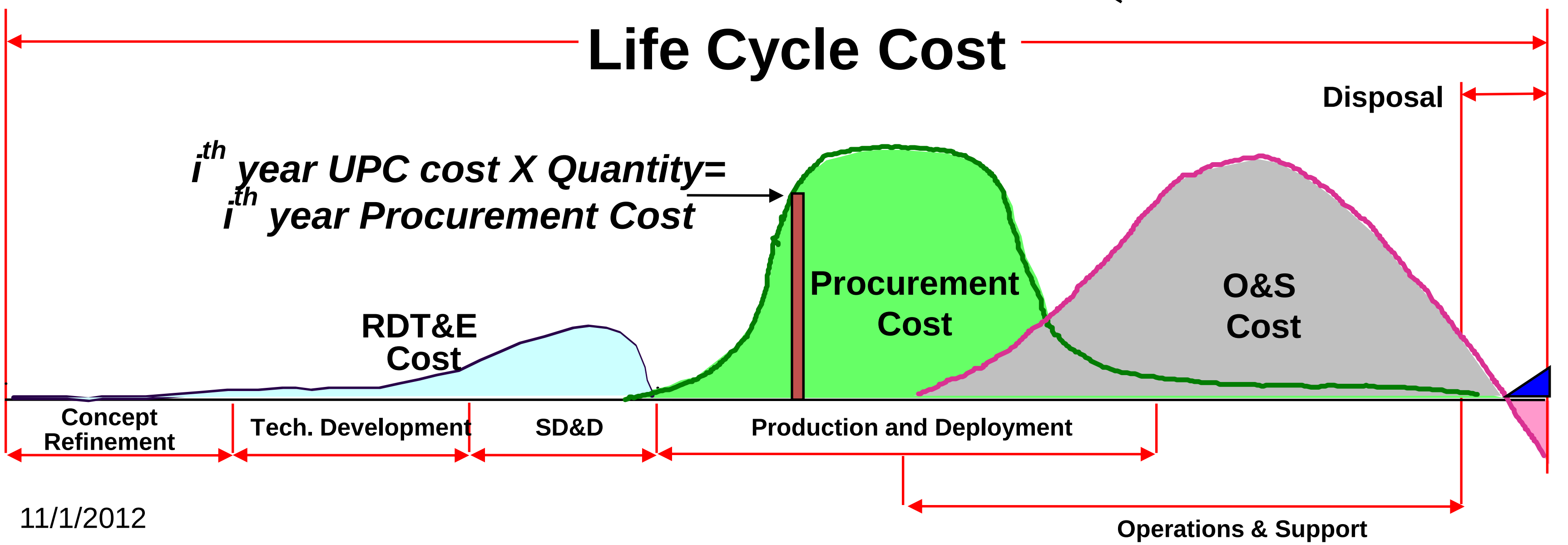
Total Research, Development, Test & Evaluation

6.1 Basic Research
6.2 Applied Research
6.3 Advanced Technology Development
6.3 Advanced Component Development & Prototypes
6.4 System Development & Demonstration
6.4 RDT&E Management Support Operational Systems Development

Trade Space Window Of Opportunity

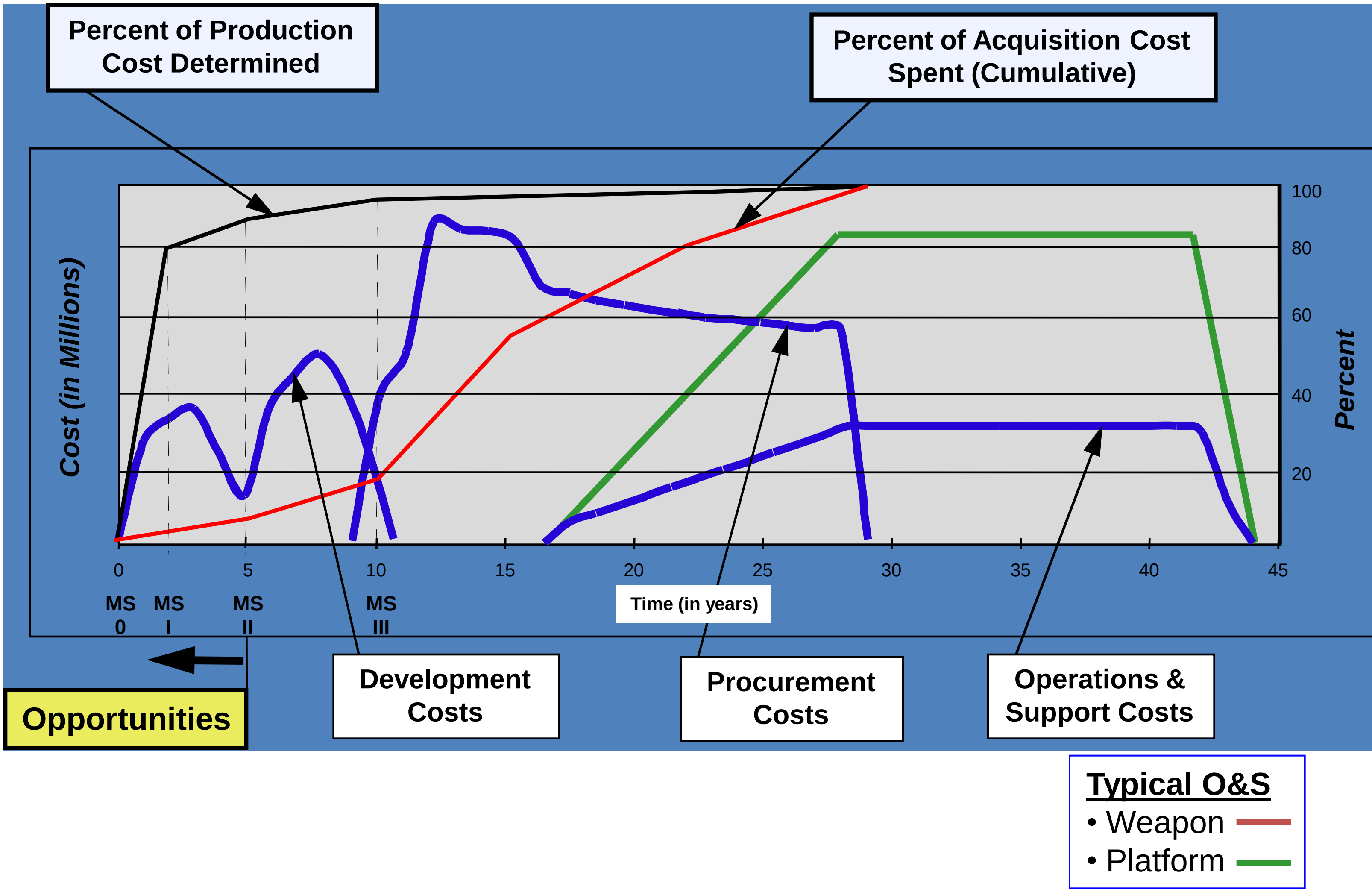






11/1/2012

Missile Cost History



DoD Budgets on a Yearly Basis but Plans on a 5 / 6 Year Cycle

"HOW" Design to LCC IS UTILIZED

1. **Determine the *customer concerns* and understand those concerns**
   - Explicit – States cost goals or operating budgets
   - Implicit – Customer desire to reduce operational staffing
   - Next Phase – Contract contains a limited budget / funding
   - Unit Production – Average unit production cost (AUPC) goals
   - Total Ownership Costs (TOC) – Reduced total ownership costs (RTOC)
   - Life Cycle Costs (LCC) – must be some determine percent (normally 30%) less than the replacement system
2. **Determine how the *competition impacts* affordability**
   - Marketing determines cost time to WIN the contract
   - Existing inventory items with potential modification costs
3. **Set *design goals* (including system cost goals and targets)**
   - Top level system or architecture
   - Subsystems
   - All phases
4. **Understand system *requirements vs. system affordability***
   - Perform economic analysis
   - Establish a cost as an independent variable, design to life cycle costs or design to cost program
5. ***Review* the present estimates against goals often and *react* appropriately and expediently**

Planning the Analysis

- Determine the life cycle
  - System service life: Useful life of the system depends on what the system is.

    (i.e. aircraft – 25 years, ship – 50 years, missile – 20 years, bridge – 100 years, etc.)

  - Planning Horizon: Period of time over which all costs are estimated.

  - May not coincide or may change over time.

Planning the Analysis

- **Cost element structure (CES)**
  - **Estimating LCC requires breaking down the system into its cost elements and time phasing them.**
    - **There is no standard CES for all LCC applications due to the tremendous variation in systems and programs (aircraft, missiles, electronics, ships, infrastructure, etc)**
    - **The CES may be imposed as a requirement**
    - **The level of CES detail will depend on the system as well as the purpose of the analysis. Consider:**
      - **Estimation methodology**
      - **Significant cost generating components.**
      - **Support philosophy**

2.000 Procureme
Production &
2.010 NonRecurring P

3.000 Military Construction Funded Eleme
3.010 Development Construction
3.020 Production Construction
3.030 Operational/Site Activation Construction
3.040 Other Military Construction

4.000 Military Personnel Direct Funded El
4.010 Crew
4.020 Maintenance
4.030 System-Specific Support
4.040 System Engineering/Program Management
4.041 Project management Adminstration
4.042 Other
4.050 Replacement Personnel
4.051 Training
4.052 Permant Change of Station
4.060 Other Military Personnel

5.000 Operations and Maintenence Funde
5.010 Field Maintenance Civilian Labor
5.020 System Specific Base Operations
5.030 Replensihment Depot Level Reparables (Spares)
5.040 Replenishment Consumables (Repair Parts)
5.050 Petroleum, Oil, and Lubricants
5.060 End Item Supply and Maintenance
5.061 Overhaul
5.062 Integrated Materiel Management
5.063 Supply Depot Support
5.064 Industrial Readiness
5.065 Demilitarization
5.070 Transportation
5.080 Software
5.090 System Test and Evaluation, Operational
5.100 System Engineering/Program Management
5.101 Project management Adminstration
5.102 Other
5.110 Training
5.120 Other O&M

6.000 Defence Business Operations Fund Elements
6.010 Class 1X War Reserve
6.020 Other DBOF

Cost Element Structure

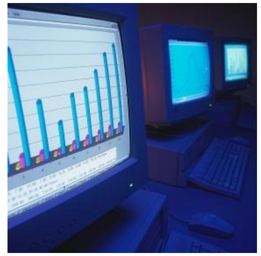
1.000 RTDT&E Funded Elements

Concept & Tech Development
1.010 Development Engineering & Planning
1.020 Producibility Engineering & Planning
1.030 Development Tooling
1.040 Prototype Manufacturing
1.050 System Engineering/Program Management
1.051 Project Management Administration
1.052 Other
1.060 System Test and Evaluation
1.070 Training
1.080 Data
1.090 Support Equipment
1.091 Peculiar
1.092 Common
1.100 Development Facilities
1.110 Other RDT&E

System Dev & Demonstration
1.010 Development Engineering & Planning
1.020 Producibility Engineering & Planning
1.030 Development Tooling
1.040 Prototype Manufacturing
1.050 System Engineering/Program Management
1.051 Project Management Administration
1.052 Other
1.060 System Test and Evaluation
1.061 System Demo
1.070 Training
1.080 Data
1.090 Support Equipment
1.091 Peculiar
1.092 Common
1.100 Development Facilities
1.110 Other RDT&E

Select / Develop the Model

- Some general guidelines
  - Should be responsive to changes in design and operational scenarios.
  - It should clearly incorporate all major cost drivers.
  - Include clear documentation
  - User friendly and should not require special programming support.
  - Allow for adjustment of inflation, discounting, and learning curve where appropriate.
  - Be able to compare and contrast alternatives
  - Identify areas of uncertainty
  - Support sensitivity analysis



HEL Weapon Cost Model - BETA #3 Release Of 5/29/02 - GLS (545-6104)

Notes: User input Cells are in Blue.			Yearly diode buy Quantity: see N4		
Red idenotes key areas					
SOURCE DATA					
Acquisition Scenario			From ASP Study (Can also Use Therman's model		
Development (EMD)	See Cost Distribution Model)		Enter total anticipated production quantity		
Total ADM Protype Quantity	1.5	3	= Years in ADM Phase		
Total SDD Protype Quantity	4	4	= Years in SDD Phase		
SDD Production Occurs From	2007	2011	4		
Production					
Total Production Quantity	344		Enter total anticipated production quantity		
Production Occurs From	2012	2027	15	Years over which this produ	
Production Rate (Yearly even)	22.93		Average Quantity Built Each Year		
O&S			Used Therman's model to calculate this		
Years Operational	10		Estimated Fielded (Operational) Years for each u		
Years from Production to IOC	2		Must be 1 or greater! Includes 1st year of produc		
Net Years of O&S Costs	26		0.692	= Cost factor for each avera	
Fielding	2.5%		Used Therman's model to calculate this		
Annual Sustainment (O&S)	9.0%		Used Therman's model to calculate this		
Economics					
Constant Year Dollars	2002		Model is built using 2002 dollars		
Overhead rates (Composite)	50%		Used to calculate all non HW direct costs		
Learning Curve					
Labor	0.90	-0.152003093			
Commerical Items (diodes)	0.92	-0.120294234	Also used in Cost Distribution model to calculat		
Material & Purchased Parts	0.95	-0.074000581			
Production Parts	0.89	-0.168122759			
	Specifications	Terminology	Unit Cost ($ K)	Factors	
HMMWV Laser WS Concept Unit Production Cost			4,583.47		
Platform (HMMWV) and Shelter			125.94		At 200 Units
HMMWV		From VMADS Study	97.05		101.03
Roof/Structure		From VMADS Study	9.30		9.68
Gyro Support		From VMADS Study	4.65		4.84
Structure IA&T		From VMADS Study	9.99		10.40
HEL Weapon			3,937.22		
Laser Subsystem			1,792.7		
Laser Diodes	15	KW Laser Energy Output	952.0	63.46	AUPC for array - $
2 Watt Diode Cost $	$1,190.00	Est. Unit Cost in low quantity		$153.50	Unit cost (from intel
Adaptive Optics - beam shaping	13.0	cm -Edge Size for Mirror	377.77	Note; this Length is hard wir	
Laser Cavity	Missing (In Adaptive Optics?)		Missing		
Laser Materials (GGG Heat Capacity Ma	13.0	cm -Edge Size for Material	83.71		
Mirors	3	Number	26.99	8.0	Weight Each in LBS
PFM Cards	$10.50	$K for first unit card (T1)	319.79	108	Number of Cards ((
Inter-Cavity Beam Control	Missing (In Adaptive Optics?)		Missing		
Structure - Laser & associated assembli	200.0	Lbs - Assume Steel Rails	32.44		
Diode Current Regulator	Missing (In PFM Cards?)		Missing		
Beam Control Subsystem			1,648.22		
EO Laser Tracker	344	ATFLIR - Learning to Qty	1,088.79		
Tracker	90%	% ATFLIR Cost	826.41		
Illuminator - 30W	35%	% ATFLIR Cost	126.65		
Power	75%	% ATFLIR Cost	12.80		
Video	75%	% ATFLIR Cost	85.98		
Structure	25%	% ATFLIR Cost	36.95		
Telescope	Missing (In Mirrors?)		Missing		
Beam Steering	Missing (In Mirrors?)		Missing		
Main Beam Director	5	Number or Mirrors	181.65	15.0	Edge in cm Mirrors
Adaptive Optics	1	Number or Mirrors	377.77	13.0	cm -Edge Size for M
Beam Clean-up	Missing (In Adaptive Optics?)		Missing		
Power Subsystem	346.42	KW Power to Generate	338.99	280	KW Power VMADS
System Power Generator				4.33%	Efficiency - Input po
Intermediate Power Storage					
Power Processing Unit				75%	Battery Recharge fa
Power Controller Unit				1	0=Lead Acid, 1=Adv
Battery Subsystem (Advanced)	346	KW Stored Energy	211.58	23.09	Scalling Factor to a
Power Conditioning	31%	VMADS % from 100 KW	104.69		Scaled from VMAD
Coll. Supply	*0%*	*VMADS % from 100 KW*	-		*Scaled from VMAD*
Gun Assy	*0%*	*VMADS % from 100 KW*	-		*Scaled from VMAD*
Source Supply	31%	VMADS % from 100 KW	9.35		Scaled from VMAD
Structure	31%	VMADS % from 100 KW	6.35		Scaled from VMAD
Electronics	31%	VMADS % from 100 KW	0.11		Scaled from VMAD
Power Conditioning IA&T	31%	VMADS % from 100 KW	6.92		Scaled from VMAD
Thermal Subsystem	224.89	KW Power to Dissipate	157.35	100	KW Power VMADS

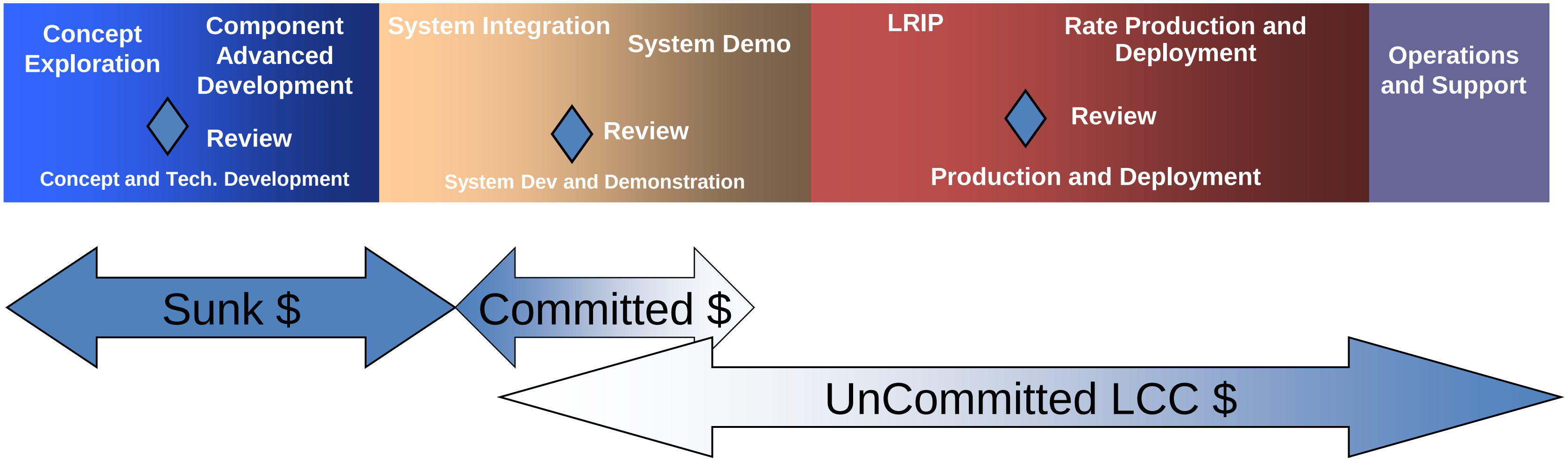
LCC vs. Sunk Cost

LCC = RDT&E $ + Procurement $ + O&S $

Sunk costs are cost already spent

Committed costs are contracted for costs not yet spent (Sunk) - Where in the cost to cancel equals or exceeds the cost to continue the effort.

Therefore, early in SDD, the LCC_a still subject to design trades is:



LCC_a is the LCC still available or subject to be traded

LCC_a = RDT&E $ (Uncommitted SDD $) + Procurement $ + O&S $

where uncommitted SDD $ = RDT&E $ - (Sunk $ + Committed RDT&E $)

Software is included in the "Best Value" Alternative

DECISION POINT

Trade Study Design Alternatives With Physical and Functional Characteristics

Technology, Tools, Existing Products, IR&D, etc.

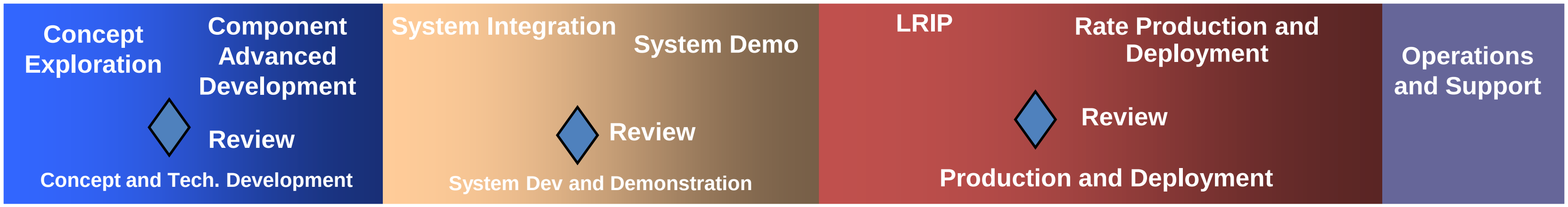
Software Issues
- **Functions Performed**
  - **Lines of code**
  - **Interfaces**
- **Coding Group Capabilities**
- **Environment**
- **Schedule**
- **Existing (mod/reuse/etc)**

Missile Alternative

- Physical and Functional Characteristics
  - Size, Weight, Speed, Range, Payload, etc.
  - Functions Performed (Search, Ballistic Load, etc.)
    - Hardware Resident
      - Seeker Head
      - Propulsion, Warhead, etc.
    - Software Resident
      - Target ID, Tracker, etc.
    - HW/SW Combined
      - Position in Space (IMU and GPS)

Software Alternatives. . .
Consider the Life Cycle

Software DECISION POINT



HW vs. SW Trades

NEW SW Development

- **Requirements (11%)**
- **Design (14%)**
- **Code (24%)**
- **Test (27%)**
  - **Function / Integ / Sim**
  - **SW in the Loop**
  - **HW in the Loop**
  - **Flight Tests (AD, SD)**
  - **Quality**
- **Documentation (10%)**
- **Installation (1%)**
- **Management (13%)**

Enhancement and or Maintenance

Enhancement and or Maintenance

Enhancement and or Maintenance

SW does not age! However, as HW, processes, situations and people change, enhancements (and maintenance) are required. These can either be planned for as a continuous maintenance contract or in separate modification / upgrade contracts. Funding can be through O&S or RDT&E Funds.

SW LCC $s

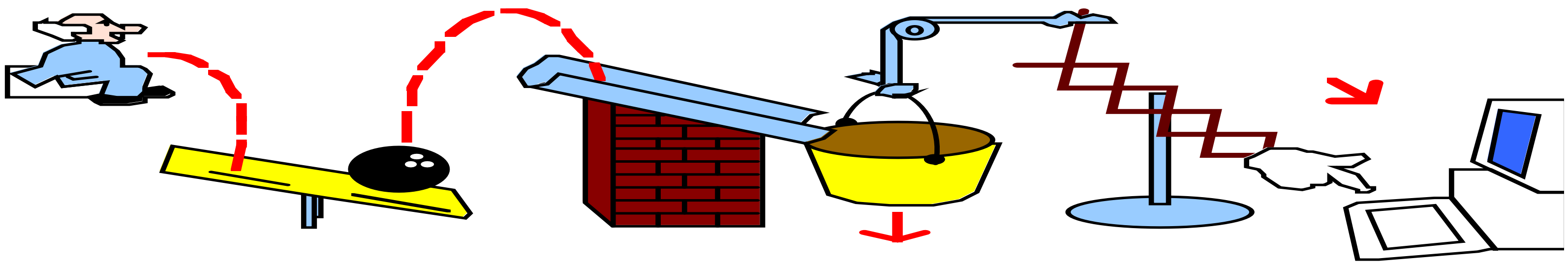
- **RDT&E – Large**
- **Procurement - ≈ Zero**
- **O&S – 50-75% of LCC**
- **Disposal - ≈ Zero**

(avg. Dev to Supt = 47-53%)

Cost Risk and Uncertainty

- **Cost risk and uncertainty refer to the fact that because a cost estimate is a forecast, there is always a chance that the actual cost will differ from the estimate.**
  - **lack of knowledge about the future**
  - **the error resulting from historical data inconsistencies, assumptions, cost estimating equations, and factors that were used to develop the estimate**
  - **biases get into estimating program costs and developing program schedules.**
    - **biases may be cognitive—often based on estimators' inexperience**
    - **or motivational where management intentionally reduces the estimate and/or shortens the schedule to make the project look good to stakeholders.**
  - **Recognizing the potential for error and deciding how best to quantify it is the purpose of risk and uncertainty analysis.**

From GAO Cost Guide, Chapter 14

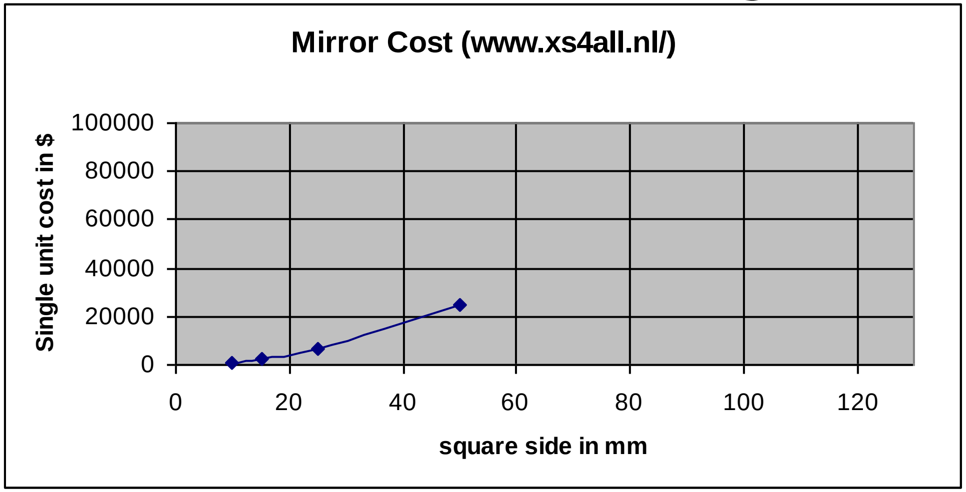


Document and Review Results

- **Review Results**
  - Ground Rules and Assumptions
  - Modeled System
  - Overall LCC
  - Cost Drivers
  - Spikes
  - Measure of Effectiveness
  - Program Risks and Uncertainties

- **Document**
  - If no one can figure out what you did, how you did it, and why you did it ----- It doesn't count!!

  *(Hard truth: The program may last longer than you)



Summary

- **LCC is the total cost to the customer for a program over its full life.**
  - **Cost, including LCC is an engineering design parameter.**
    - **Total cost impact, not just initial near-term cost, must be considered**
    - **Each Phase (Color of Money) estimate is important!**
  - **Early estimates are just estimates! Look at the risks and uncertainty within those estimates. Be prepared for and manage growth.**

- **More customers (especially government) are emphasizing and requiring an LCC perspective AND POTENTIALLY SEQUESTRATION BEING IMPLEMENTED.**
  - **Early design efforts determine LCC. Don't wait!!!!**