Parametric Cost Estimating Training

based on the

ISPA Parametric Estimating Handbook (PEH)

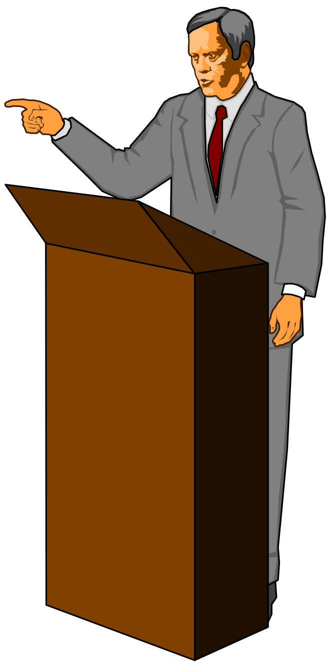
PEH Chapter 4

Company-Developed Complex Models

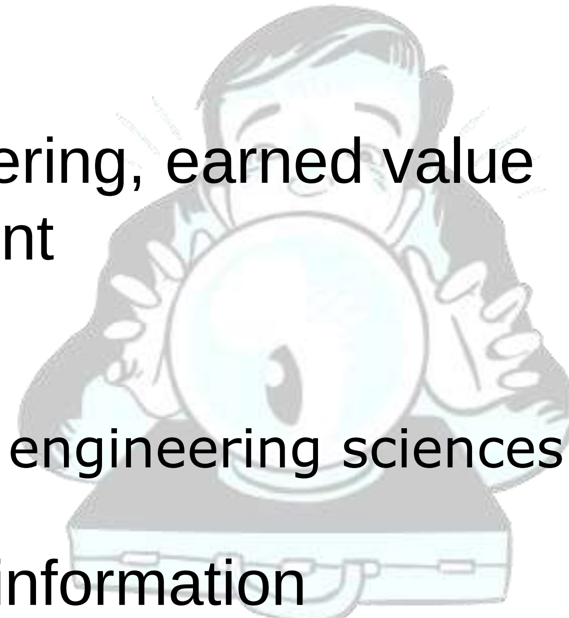
San Diego, CA -- June 2015

Topics

- What Should we Expect from our Cost Models?
- Company-Developed Complex Modeling Process
  - Establishing Objectives
  - Collecting Data
  - Calibrating
  - Establishing Procedures
  - Validating
  - Maintaining
- Final Thoughts
  - Lessons Learned
  - Best Practice



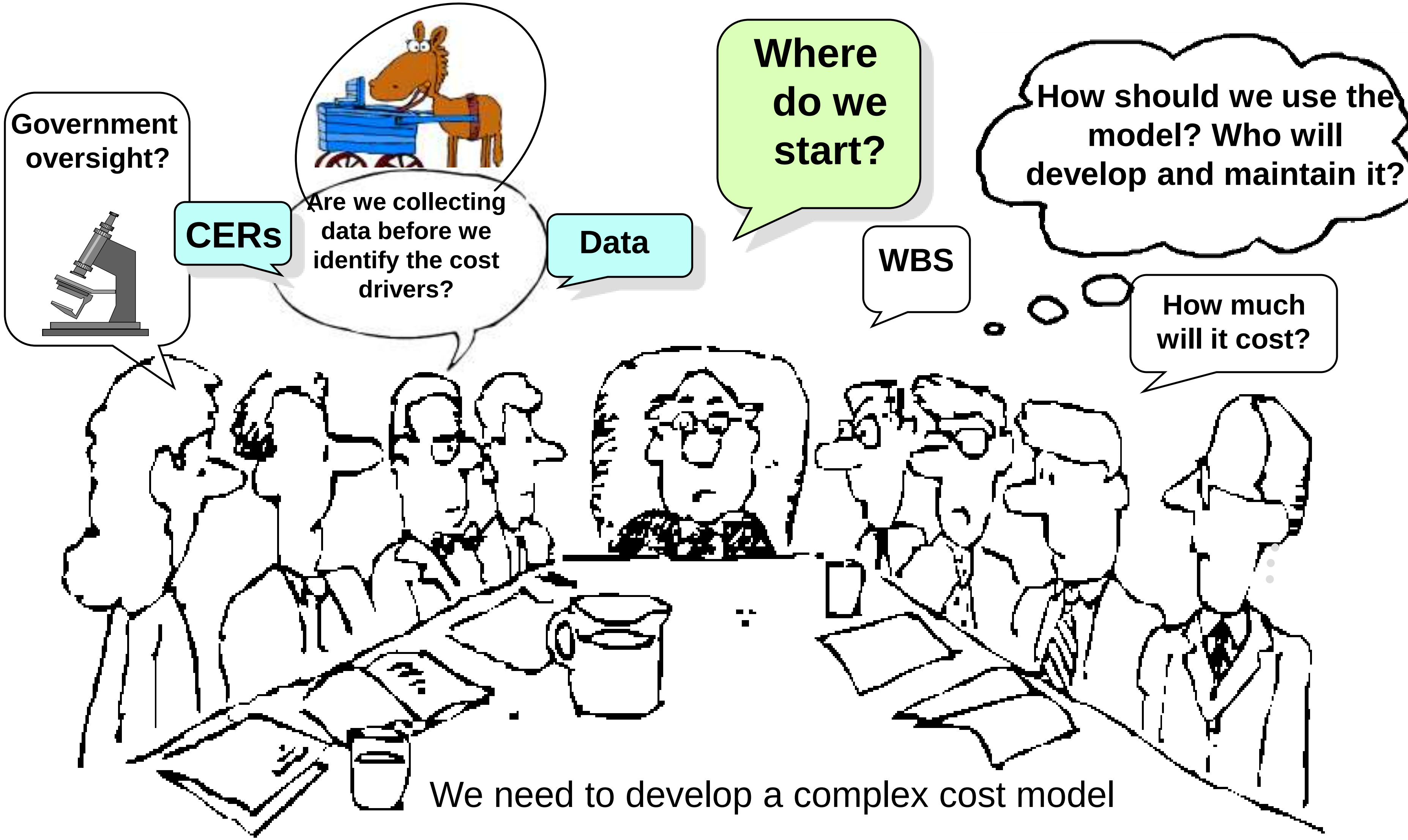
Cost Estimating Is Defined as…



- Predicting the future
- Fundamental to systems engineering, earned value analysis, and project management
- Based on a mixture of:
  - Management expertise
  - Knowledge of the physical and engineering sciences
  - Analytic art
- Almost always based on limited information
- Conducted with a variety of methods and tools
- Supporting decision making

So, how do we emulate this estimating process into a model that will guide others to estimate?

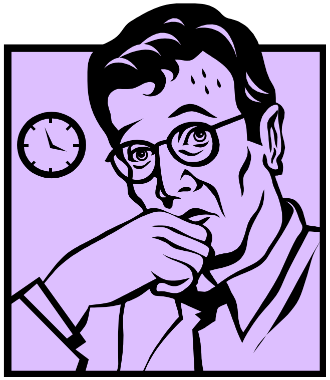
The Modeler's Dilemma



Cost Estimating Concerns

[from a previous class – how many apply to you?]

- Historical data inconsistent (not normalized)
- Previous estimates inconsistent – estimating thread doesn't track over time



- Estimates developed by multiple organizations
  - Different purposes
  - Different groundrules and assumptions
  - Different models
- Not supported by a validated cost database

What's Wrong With this Proposal Estimate?

Work Breakdown Structure (WBS) Element	Proposal Estimate	Basis of Estimate (BOE)
1. New Software	$625,000	Staff of five working one year @$125,000 per year
2. Modified Software	$750,000	Modified 5,000 SLOC from 5,500 original at $150/SLOC
3. Reused Software	Free	No mods, so no cost
4. COTS Software	$25,000	License fee only; no integration or GUI cost
5. Hardware	$140,000	10% of software cost
6. Hardware/Software Integration	Free	Included
7. Total, with risk reserve	$1,540,000	Arithmetic sum

Three Tests for a “Good” Estimate

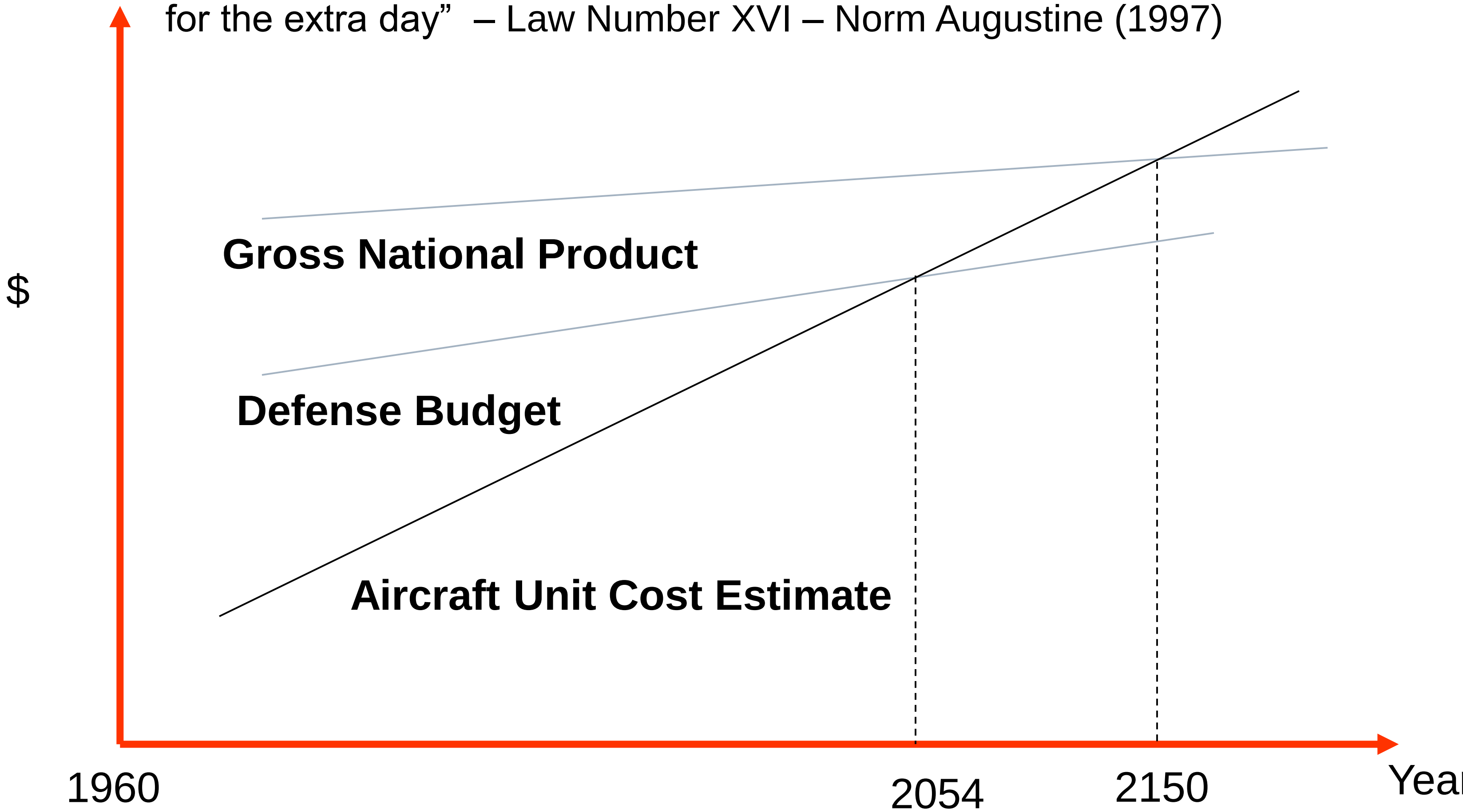
(remember these)

- Realistic [cost realism]
  - Based on reasonable assumptions
  - Derived from previous cost data (normalized, not “cherry picked”)
  - Logical – without bias
  - Untainted by unbundled optimism
- Credible [success probability]
  - Statistically probable of not costing more
- Replicable [by another analyst]
  - From calibrated and validated models
  - Disciplined and documented

The Perception of Estimates

(from Augustine's Laws)

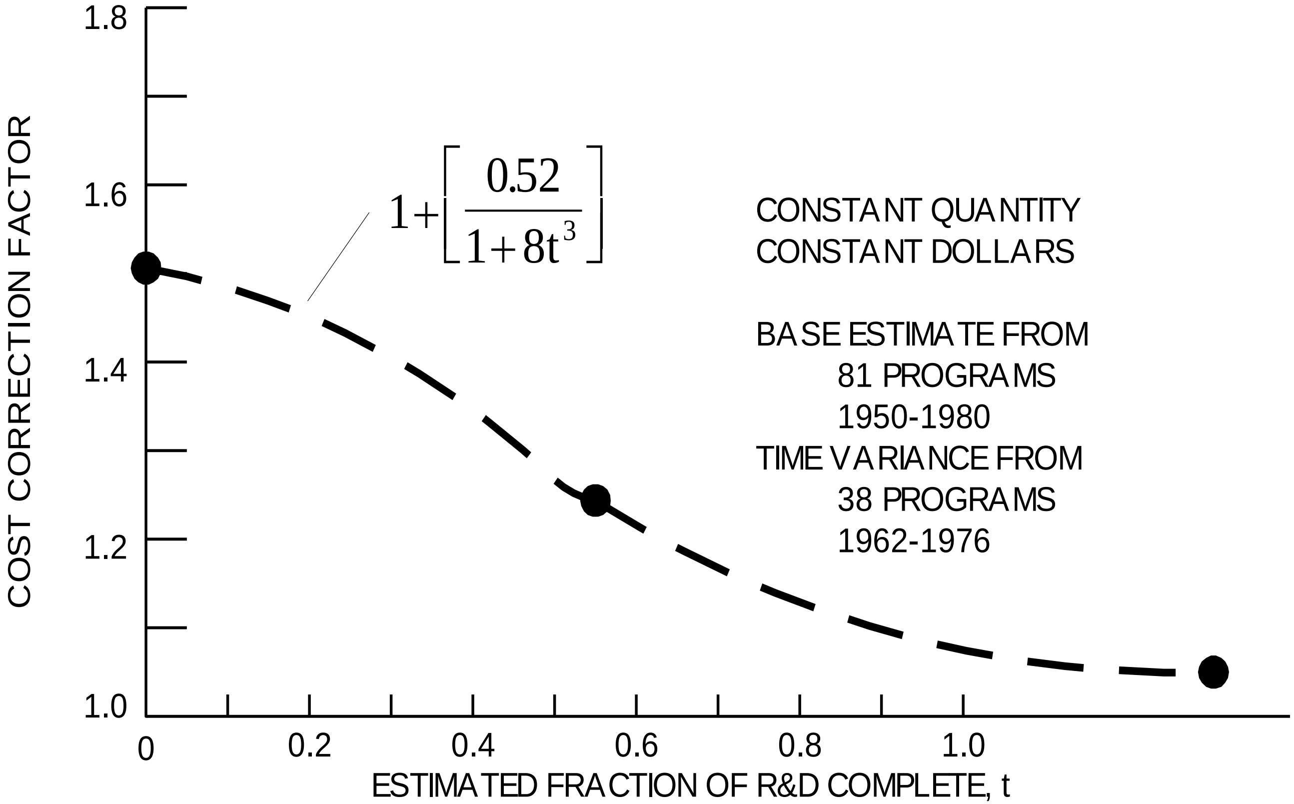
"By 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and Navy 3 ½ days each week except for leap year, when it will be made available to the Marines for the extra day" – Law Number XVI – Norm Augustine (1997)



The Perception of Estimators

(from Augustine's Laws)

"The most unsuccessful three years in the education of many cost estimators appears to have been fifth-grade arithmetic." - Norm Augustine's 23rd Law, the Law of Inestimable Consequences



Brief History of Complex Models

- Rand Corporation
  - Mid 1950's – USAF high-level planning studies
  - Speed, range, attitude drive estimates for missiles, fighters, bombers
  - Adapt to need for reliance on limited inputs (cost drivers)
- RCA PRICE
  - Mid 1970's – internal process for company-developed models
  - Primarily for cost checks, not for BOEs
  - Adapt historical data to future cost predictions
- Parametric Estimating Reinvention Laboratory
  - Mid 1990's – Ten companies plus DCAA/DCMA
  - Now, such models are preferred method for BOEs
  - Adapt to need or quick, traceable, repeatable estimates

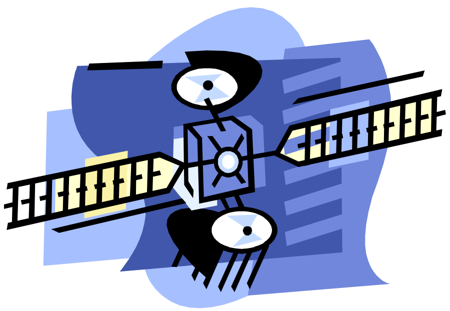
Definitions (for this Handbook)

Company-Developed Complex Models are:

- Also defined as:
  - Company-owned, government-developed, in-house, or proprietary models
  - Typically for special-purpose product, process, platform
- More complex than individual CERs or factors:
  - Typically, emulate complete WBS, multi-phases
  - One variable CERs or more complex CERs
  - Often enhanced with look-up tables
  - Manual or automated, interactive

Complex Model Example

- Computerized, cost prediction tool for competitive or complex product; estimates hardware development cost and T1 production cost according to the way we develop proposals, execute trades, and generate estimates; historic data-based; capable of emulating:
  - Our product
  - Our process
  - Our environment



WBS	Nonrecurring CER (K$)	Recurring CER T1 (K$)
Receiver	2449.5 + 431.9 * Wt	1875.9 + Wt ^ 2.42
Transmitter (SSA)	2385.6 – 75.9 * Wt	933.1 – 103.6 * Wt + 17.9 * Operating Power
Transmitter (TWTA)	5260 (avg value)	1036.2 + 81.9 * Wt
Transponder	2780 (avg value)	- 453 + Wt ^ 2.25
Antenna (Reflector)	1225.6 + 0.41 * Area	573.5 + (Area/Wt) ^ 1.45
Antenna (Horn)	1334 (avg value)	- 199.8 + 94.2 * Wt
Space- borne Electronics	10259 (avg value)	- 1350.9 + 198 * Wt
Waveguides	1353 (avg value)	10.9 + 14.6 * Wt
Power Dividers	1353 (avg value)	192.9 + 47.4 * Wt

Space Communications Payload Cost Model

Institutionalizing Models

- The most successful models get institutionalized – what this means:
- The models are developed, calibrated, validated, and eventually certified by DCAA and/or specific Customers
- They are widely used frequently and routinely by one or more organizations within the business, if not the entire business
- The model calibration is updated regularly based on regular metrics collection within the organization (organizational metrics)
  - Frequently a formal metrics collection system is used to collect and review metrics on a regular basis

Complex Modeling Process

1. Identifying the model purpose
- Feasibility
- Management Support
- Team
- Approaches

2. Preliminary Model Design
- Scope
- Assumptions
- User Requirements
- Interfaces

3. Information Systems Needs
- Defining
- Developing
- Testing
- Maintaining

4. Data Collection and Analysis
- Cost Drivers
- Data Sources
- Collecting
- Normalizing
- Analyzing

5. Model Development
- Refined Scope
- Modeling Approaches
- Estimating Methods

6. Calibration and Validation
- Assume Self-Calibrated
- Frequent Calibration = Continuous Validation

7. Estimating System Policy and Procedures
- Update Policies
- Use as Bid Tool
- Estimating System Manual

8. Internal Approval Process
- Mgmt buy-in
- Technical buy-in
- Training

9. External Approval Process
- Advance Agreements
- Customer Role
- DCMA, DCAA Audit

10. Model Maintenance
- New Data
- Technology or Process Shift
- Periodic Recalibration

Step 1. Identifying the Modeling Purpose

- Investigate feasibility of developing model
  - Satisfy technical needs (save time, be more responsive, satisfy DCAA audit, support proposals, support CAIV trades)
  - Cost effective (cost/benefit analysis)?
  - Have we done anything like this before?
- Gain management support
  - Program(s)
  - Customer
  - DCAA, DCMA
- Establish implementation team (estimator, accountant, programmer, financial analyst, etc)
- Identify model approaches (heuristic, statistical, look-up table, menus, tailorable WBS, documentation, updating, testing, maintenance

Step 2. Preliminary Model Design

- Refine model scope, considering all requirements
  - Program phases: fly-away cost, acquisition cost, O&S cost, life cycle cost (LCC), total ownership cost (TOC)
  - WBS: hardware, software, integration, SE/PM, maintenance, operations, disposal
  - Level of cost: contractor cost, contractor price, government cost – also, do we need visibility into labor and material cost?
- Establish model's groundrules and assumptions
- Reaffirm user requirements (proposal bid decisions, firm proposals, budgetary estimates, engineering trades, backup ICEs, competition modeling, estimates to complete)
- Interfaces to pricing system, other models, databases

Step 3. Information System Needs

- Identify resources for:
  - Defining broad system requirements
  - Information gathering
  - Developing model
  - Testing the model
  - Maintaining the model (configuration management)
  - Providing software support (corrections, revisions, enhancements)

Step 4. Data Collection and Analysis

- Identify primary cost drivers (basis for heuristic CERs)
- Establish data sources (historical or previous estimates; primary or secondary)
- Collect and validate as you go; consistency is key; prepare to document
- Normalize (lot size, escalation, development or production anomalies
- Analyze
  - Are we collecting the right information?
  - Is enough credible data available?

Typical Online Data Collection Form

Data Collection Forms

File Edit Help

Ground Systems | US SPACE COMMAND

0.0 Record Identifier

0.1 Preparer Information

0.1.1	Name	David Patterson
0.1.2	Title	Research Associate
0.1.3	Company/Organization	MCR/ATD
0.1.4	Phone Number	(805) 496-7111
0.1.5	FAX Number	(805) 496-7411
0.1.6	Date Prepared	1/17/96

0.2 Program Information

0.2.1	Program Name	US SPACE COMMAND
0.2.1.1	Prog Element #	35698F
0.2.1.2	O&S Year	1991

0.2.2 Program Function ☐ Navigation ☐ Scientific ☐ Air Defense ☐ Communication ☑ Command and Control ☐ Meteorological ☐ Other

0.2.3 Operating Agency(s) ☑ Air Force ☐ Army ☐ Navy ☐ BMDO ☐ NASA ☐ Other

0.2.4 Operating Contractor(s)

0.2.4.1 Prime Contractor(s)

0.2.4.2 Subcontractor(s)

Record 1 | See Remarks | Page 1 of 10

Step 5. Model Development

- Refine scope
- Confirm modeling approaches
  - Purely statistical
  - Calibrating heuristic CERs
- Confirm estimating methods
  - Presume primarily parametric, but also
    - Historical Factors
    - Database analogies
  - Cookbook?

Time to Expand WBS & Cost Driver List?

WBS Element	Development and Production CERs			
	Engineering	Prototype T1	Production Setup	Flight Unit T1
Focal Plane Array - Monolithic	1936 (avg value)	5 + 5E-07 * D	159 (avg value)	11 + 3.7E-04 * E
Optical Telescope Assy	854 – 1996 * W + 5.61 * AS – 9.7 * AA	253 + 1.13 * AS – 2.22 * AA	184 + 0.16 * ALW + 7.67 * OD	- 63 + 3 * AS – 5.42 * AA
Cryogenic Cooler	1028 + 510 * C	- 142 + 402 * C +3.3 * I	8361 (avg value)	485 (avg value)

D = detector chip area in sq microns

E = Number of active elements per FPA

W = wavelength in microns

C = cooling capacity in watts

I = Input power/cooling capacity in watts/watt

AS = optical area sum in sq cm

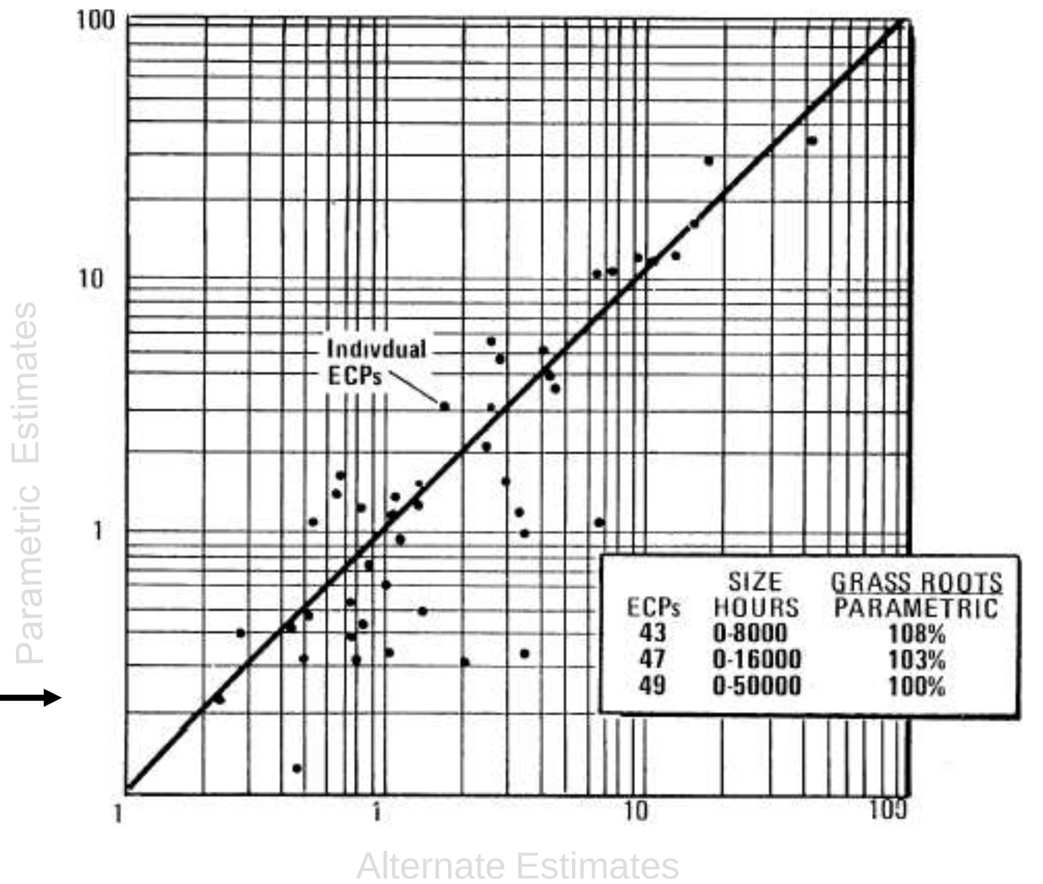
AA = optical area average in sq cm

ALW = area x length / width in sq cm

OD = optical element largest dimension in cm

Step 6. Calibration and Validation

- Assume self-calibrated initially but must update periodically
- Model can be validatec against
  - Withheld data points
  - Alternate estimating methods
  - Actual cost



Step 7. Estimating System Policy & Procedures

- Update company policies and procedures
  - Describe new model use and application as valid bidding tool
  - Update Estimating System Manual
- Inform DCAA of impact on
  - Database
  - Training
  - Validation and recalibration schedule

Step 8. Internal Approval Process

- Time to demonstrate credibility to management and technical staff
  - Reliable budgets to manage projects
  - Adequate and competitive proposal estimates
- Establish training

Typical Findings From Internal Review

Company documents (proposals and manuals) do not adequately describe current estimating process (system); **recommendation**: upda estimating manual; delive to DCAA may initiate review.

Company procedures are weak and lack supporting information; **recommendation**: depe on centralized full-time estimators, make better use of historical data.

Estimators and pricers not familiar with, or not following, company estimating procedures; **recommendation**: train anyone developing estimates.

Step 9. External Approval Process

- Advance agreements critical (but not always binding)
  - Up-front buying activity involvement
  - DCMA and DCAA recommendations important
  - Don't forget primes, also
  - Acceptance of modeling process not same as approval of specific model; sometimes approval not for all WBS elements
- Real examples (from Parametric Estimation Reinvention Laboratory):
  - E-PROMM model - Continuous Improvement Team (CIT)
    - Data from 40 contracts; selection based on team criteria
    - Government approved data accuracy and model application
  - Space Sensor model – Integrated Product Team (IPT)
    - Multiple contractors, multiple government agencies, FFRDC
    - "No surprises" philosophy; understand data, development, application
    - Early agreement on review cycle, ownership, access
- Prepare for Estimating Systems Review (ESR)

Typical Findings from Estimating System Reviews (ESRs)

- Major U S defense contractor
  - Adequate estimating manual but
    - Not updated with respect to new models, etc.
    - Inadequate identification of responsibilities
    - No one reads it
  - Material estimates inadequate
    - Uses old vendor quotes
    - Too many sole-source bids
    - Little or no price justification or analysis
  - Inadequate management oversight
  - Labor hour estimates based on judgment, not history
  - BOEs poor

Typical Findings from Estimating System Reviews (ESRs)

- Multinational Agency Estimating Department
  - Centralized cost estimating staff too small
  - Estimators lack professional respect
  - Estimators lack managerial and operational experience critical to understand product or system to be estimated
  - Outside project organizations sometimes prefer to do their own estimates
  - Estimating procedures not well documented

Typical Findings from Estimating System Reviews (ESRs)

- U S Government Research Lab
  - Lack of internal audit or oversight; no top-level process; many fiefdoms
  - Lack of estimating policy or procedures; consistency is unpredictable
  - No formal training; lack of participation in departmental courses
  - General lack of estimating standards and professional discipline; any reviews occur too late to be effective; historical data ignored or unavailable
  - Pricing data not generally demonstrated to be *current*, *accurate*, or *complete*; judgment prevails

Typical Recommendations from Estimating System Reviews (ESRs)

- Streamline estimating process
  - Centralize responsibility
  - Develop cost database; disseminate
  - Develop BOEs at higher level; reduce detail
  - Establish standard WBS
  - Increase ratio of top-down to bottoms-up estimates
- Implement cost targeting
- Train

External Model Evaluation (DCAA)*

- Relationships must be logical
  - Consider, and disclose, all alternatives, not just the first solution
  - Use the proper cost drivers
- Data must be verifiable
  - Data used in developing model must be accurate and current (and readily available)
- Significant statistical relationship must exist
  - Statistical analysis must be performed, evaluated, and documented
- Model must predict well
  - Show that work to be estimated is comparable to prior work from which the model is derived
- Must be easy to monitor regularly
  - Same as for pricing rates and factors

**Original Guidance from ISPA Journal, Spring 1982*

Assuring TINA* Compliance

- Properly calibrated/validated model fully TINA compliant and so certified.
- Cost or pricing data used to build or to recalibrate the model
  - Technical data (e.g., weights, volume, speed)
  - Programmatic data (e.g., project schedules)
  - Cost data (e.g., labor hours, direct and indirect rates)
  - Management information that could have a significant impact on costs (especially, changes to processes)

* TINA = Truth in Negotiations Act [remember this]

The ~~Problem~~ Perception with Collecting Data

The government are very keen on amassing statistics. They collect them, add them, raise them to the nth power, take the cube root and prepare wonderful diagrams. But, you must never forget that every one of these figures comes from the Village Watchman, who just puts down what he damm pleases.*

* Sir Joseph Stamp; Inland Revenue Department (England), 1896-1919

Step 10. Model Maintenance

- How often to update?
  - New data (TINA requires current, accurate, complete data)
  - Technical shift (recalibration)
- Real examples (from Parametric Estimation Reinvention Laboratory):
  - Follow-on Production Model – Pricing Organization responsible
    - Annual update to cost data used for CER development
    - Purchasing, Manufacturing, Engineering departments update technical
  - Space Communications Payload and Space Sensor Modles – Developing Organization responsible
    - New data provides basis for update
    - User feedback influences development
    - Developer available to answer questions

Complex Modeling Process - Review

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Lessons Learned

From the Parametric Estimating Reinvention Laboratory

- Be willing to change current business operations
- Establish the cost modeling process
  - Set goals
  - Commit resources
  - Understand interfaces (pricing)
  - Establish management support
  - Strive to become the Honest Broker

- Communicate
  - Customer
  - Auditor (DCMA, DCAA)
  - Other company departments (pricing, legal, contracts)

The ultimate goal is not just to develop a model; the goal is to establish a more efficient and credible estimating system

Best Practice*

1. Estimates are made by people, not by models
   - Critique model behavior, not its accuracy
   - Use model to establish credibility, consistency, and auditability

2. Relevant Information is required to estimate anything
   - You can't estimate what you don't understand
   - Use the model itself as a learning mechanism

3. All estimates are based on comparisons
   - Based on prior experience
   - The key is consistent judgment

*Thanks to Peter Korda, 1927-2011