Total Engineering Estimation –
Data Collection Needs Demand Data Collection Processes

Alex Shernoff

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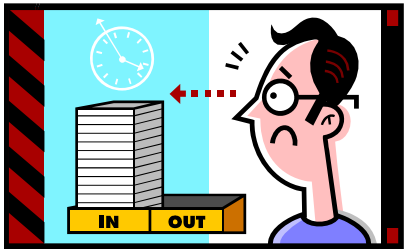
Data Collection Needs – The Problem

- Do you recognize these scenarios?
  - You receive an urgent call from Business Development. They need you to develop a Rough Order of Magnitude (ROM) estimate in 24 hours
  - You are working a proposal and are asked to develop 100 Basis of Estimates (BOEs) to put in the cost volume
  - You get a call from your Program Manager asking you to estimate a portion of an Engineering Change Request from your customer

- How do you currently solve them?
  - Contact the “expert”?
  - WAG?
  - Detailed bottoms-up estimates?
  - Parametric estimates?



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Data Collection Needs – Historical Data Issues

- To solve the previous issues parametric modeling has become popular, BUT…
- Lack of useful historical data is all too common in our industry
  - No funding to do program post-mortems
  - Critical personnel are quickly moved to other programs
  - Diverse Lines of Businesses present a data collection problem
- Historical data that has been collected has many problems:
  - Inconsistent
  - Unreliable
  - Sparse
  - Gaps/Overlaps

Historical data collection CANNOT be an ad-hoc process!

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The Catalyst – BAE Systems SEEMaP/TEEMaP Initiatives

- EI&S Operating Group wide strategic initiatives
  - Estimating systems engineering and total engineering efforts in developing a system or executing a program that delivers a system
  - Products
    - SEEMaP™ – Systems Engineering Estimation Model and Process
    - TEEMaP™ – Total Engineering Estimation Model and Process
  - Applied to ROM, Engineering bid & proposal, Trade studies
  - Improve engineering estimation maturity, confidence, and credibility
- Data collection is the cornerstone for estimating tools
  - Parametric estimation is all about data
  - Launched activities in LoBs systematically collection
  - Collected over 50 past programs

One Model – One Process – Multiple Calibrations

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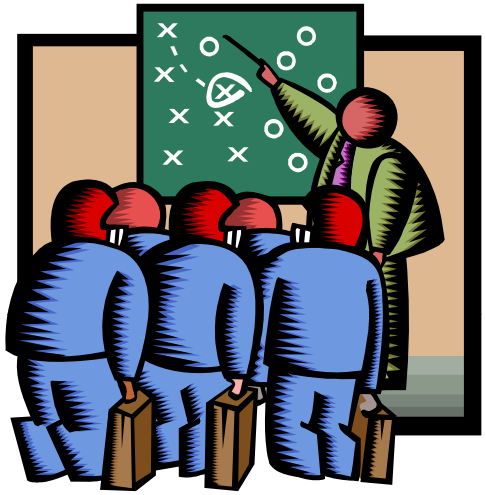
Multi-year Data Collection Process

- Objectives: collect historical data for
  - Supporting tool development
  - Bid & proposal estimating
  - Productivity and Efficiency (P&E) measurement (later)
- What to Collect:
  - Completed programs
  - New estimates
  - In-progress program
- Who to Collect:
  - Development team + Stakeholder group + Program personnel
- Where to Collect:
  - All major sites
- When:
  - Over 3 years and still on going, managed at the yearly basis
- How to Collect:
  - Process
  - Tools (DCT + database + Workbooks)
  - Training



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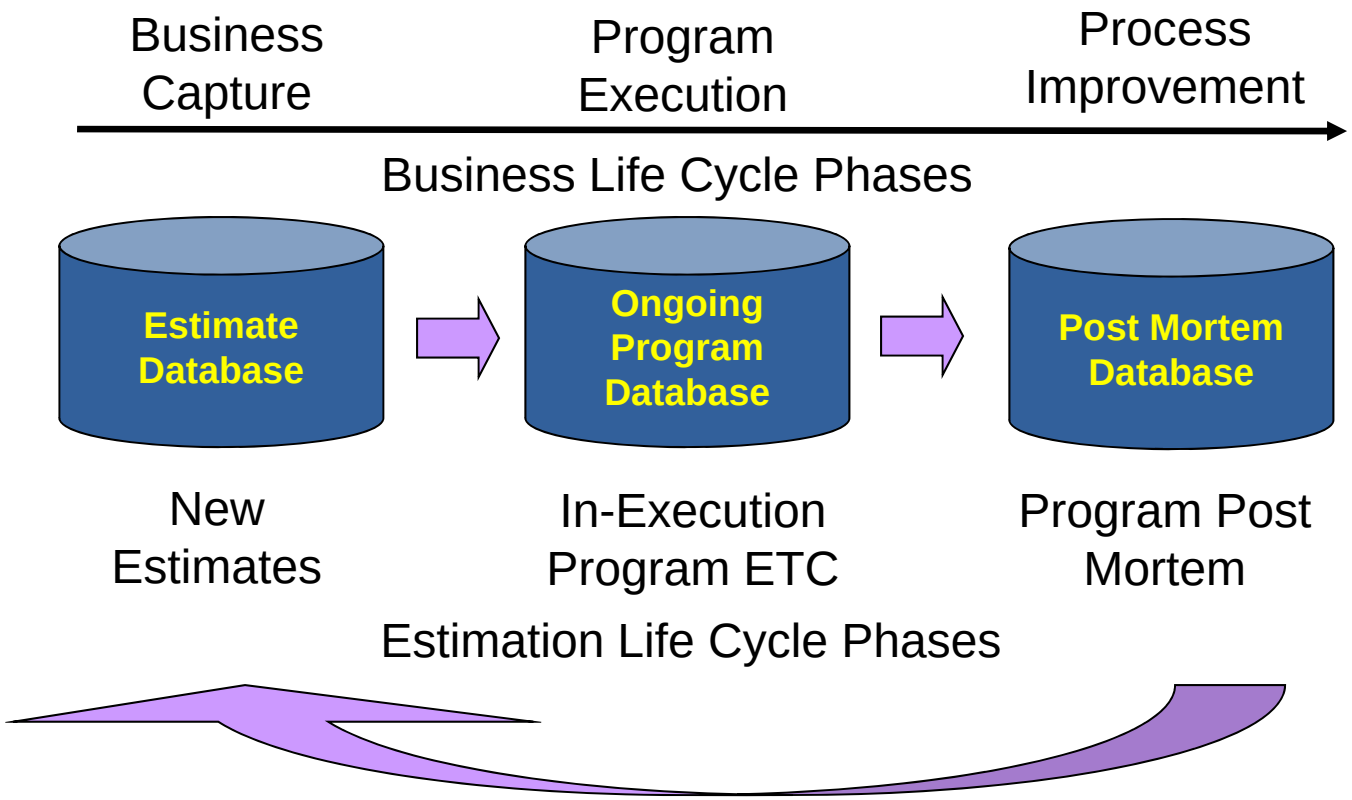
Three Stage Data Collection



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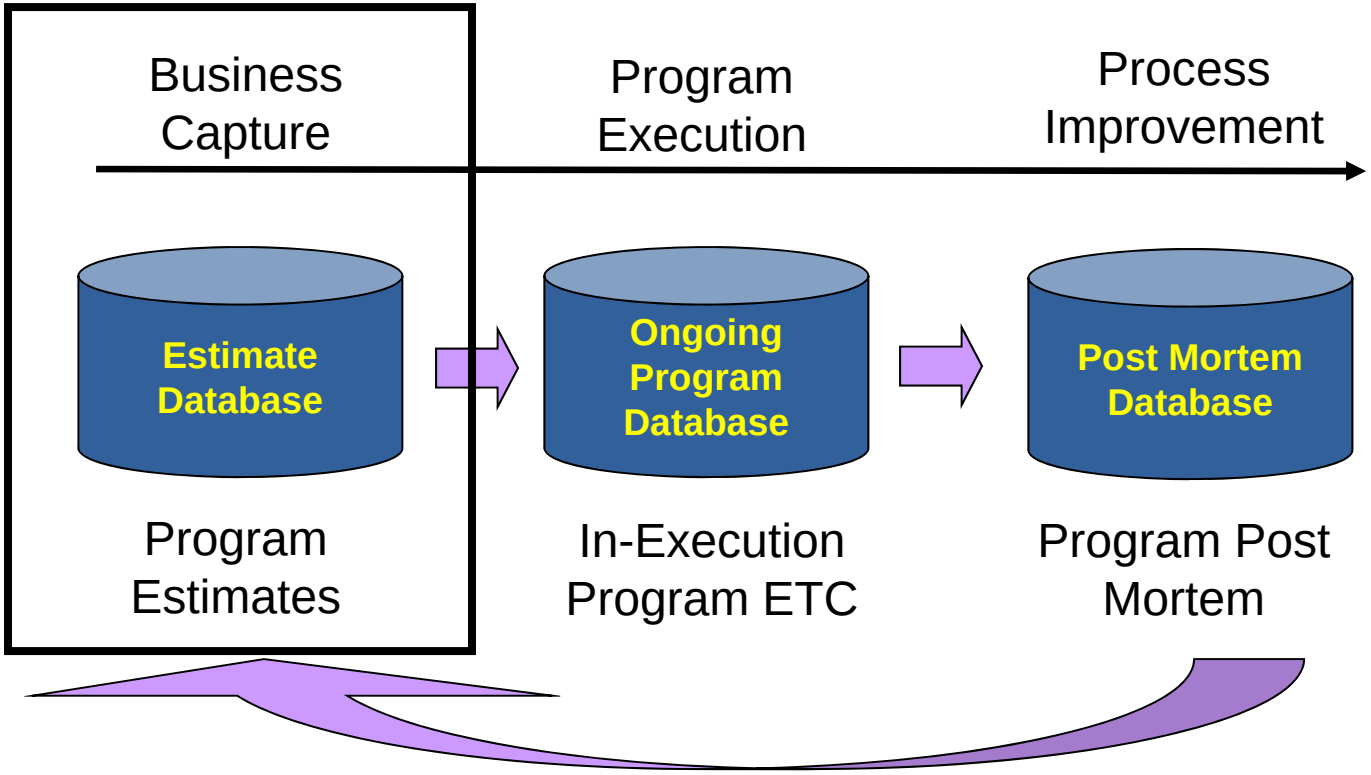
New Estimate Data Collection



Past Results Predict Future Performance

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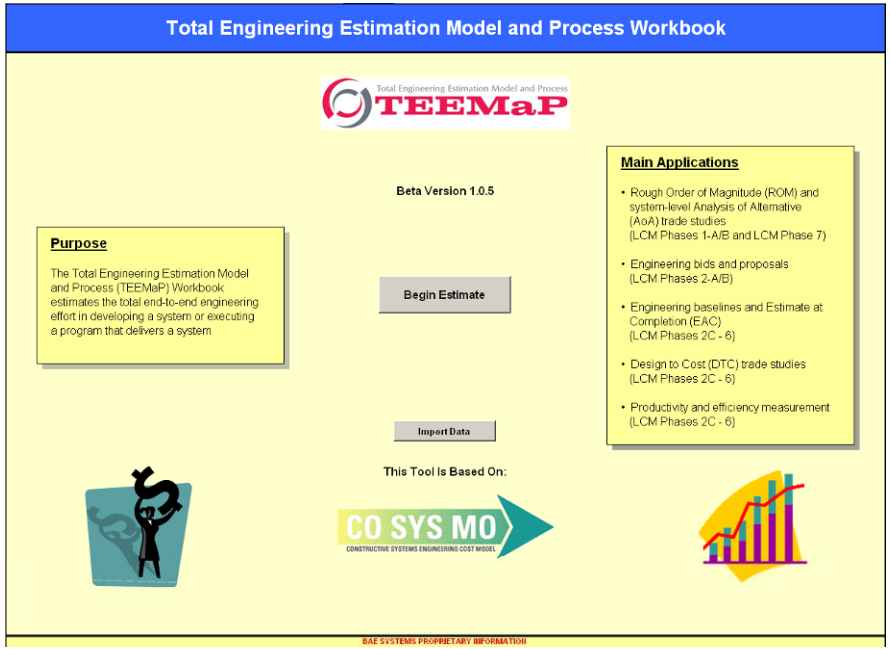
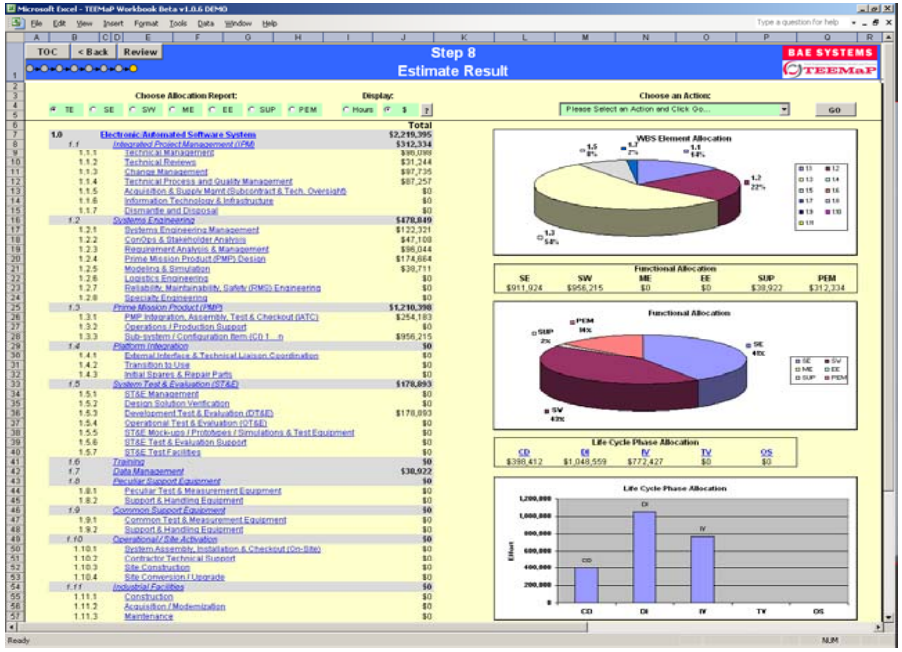
Collecting New Estimate Data

- Proposal Data Collected
  - Newly developed estimates
    - Basic Program and Estimate Information
    - TEEMaP/SEEMaP estimate results
  - Estimates based on other methods (e.g., bottom-up)
  - Questionnaire filled out by individuals developed estimates
- Data intended for
  - Basis of analogy for future Bids/Proposals estimation
  - Reference for contract negotiations
  - Validation of the estimating tool
- Tools used
  - TEEMaP & SEEMaP Workbooks
  - Central database
  - Statistical analyses

TEEMaP Workbook

- TEEMaP Workbook
  - Internal engineering estimation tool deployed across the organization
  - Process driven - follows the “Turbo Tax®” methodology
  - Model based on extended COSYSMO
  - Create estimate based on organization specific calibrations





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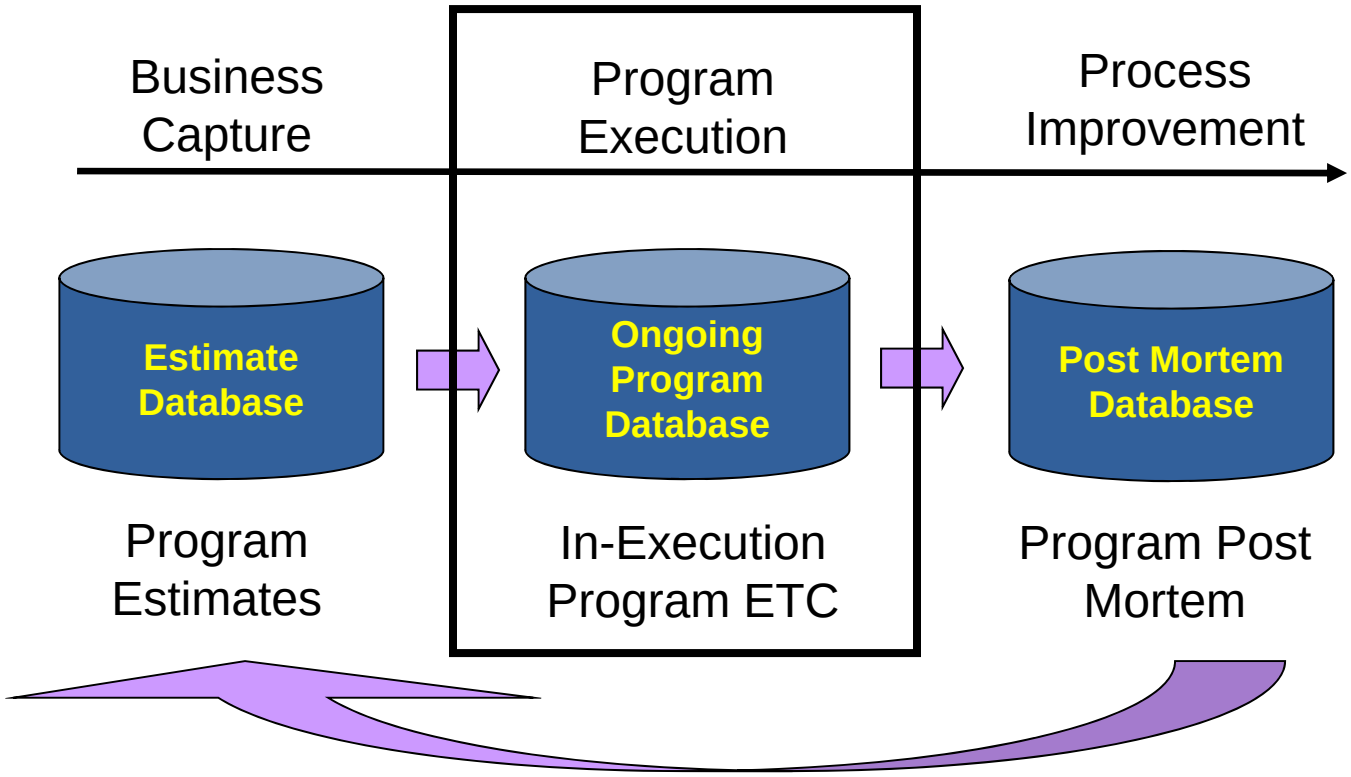
In-Execution Program Data Collection



Past Results Predict Future Performance

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Collecting In-Execution Program Data

- Program data collected periodically (6-month cycles)
  - Actuals (by WBS, Life Cycle Phase, and Function)
  - Estimate to Completion (ETC) (by WBS, Life Cycle Phase, and Function)
  - Revised estimates
    - Basic Program and Estimate Information
    - TEEMaP/SEEMaP estimate results
  - Other Engineering Data (SW Rqmts, ME/EE Rqmts, eSLOC, HW SWAP, Supportability metrics)
- Data intended to
  - Monitor program Productivity & Efficiency (P&E) trends
  - Look at program progress and status
  - Assess ECPs, Requirement changes, etc
- Tools used
  - TEEMaP Data Collection Template
  - Central database
  - Statistical analyses

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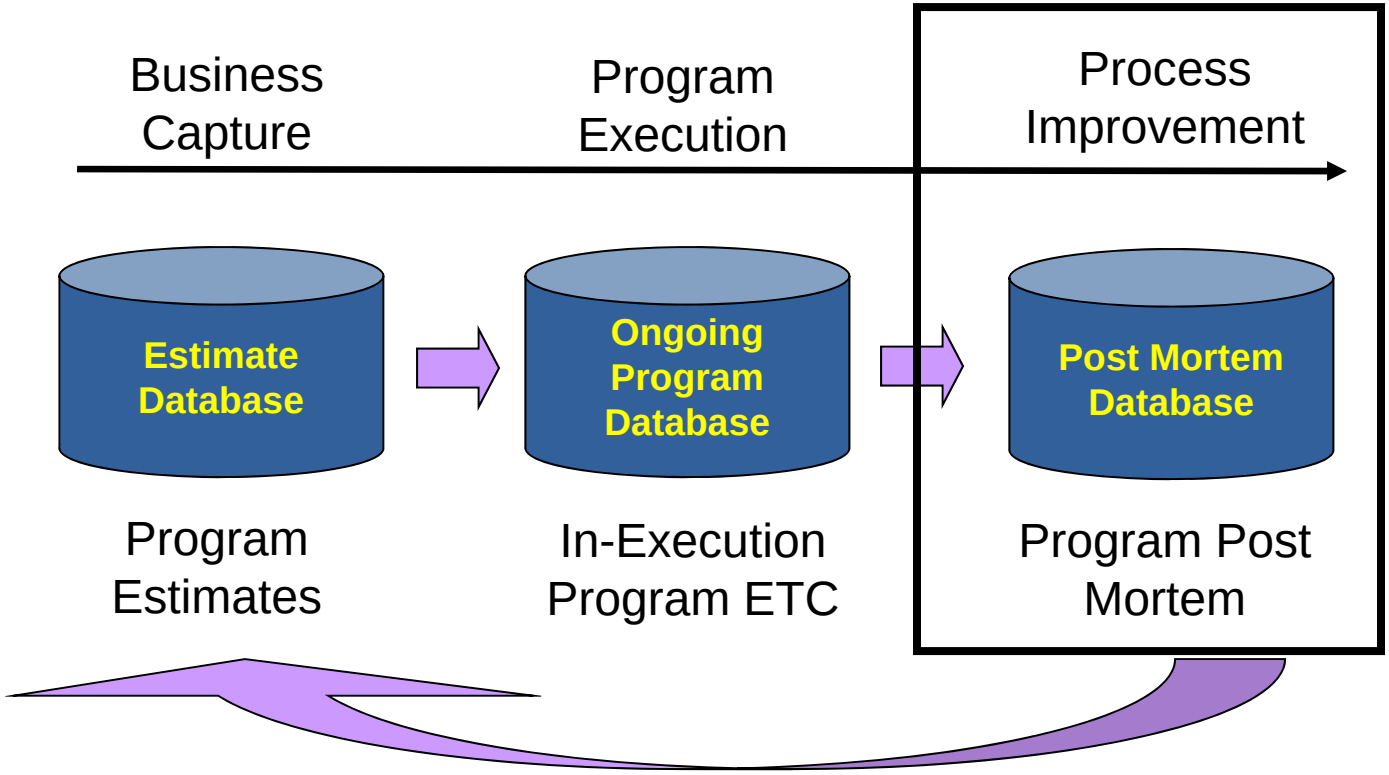
Post Mortem Program Data Collection



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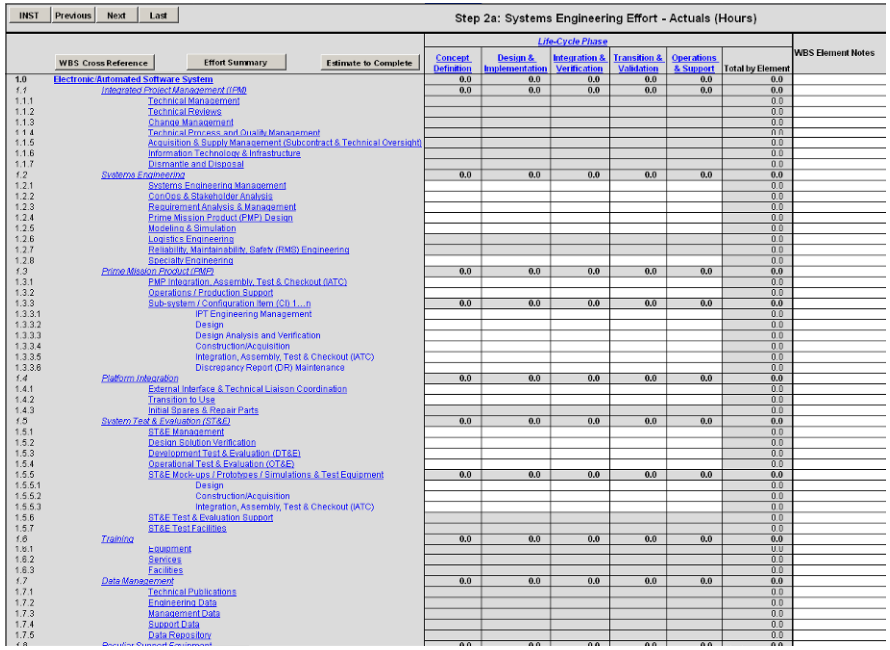
Collecting Post Mortem Program Data

- Program data at completion (or historical programs)
  - Program Information (Type, Duration, Contacts, etc.)
  - Actuals (by WBS, Life Cycle Phase, and Function)
  - COSYSMO-based Size and Cost Drivers
  - Other Engineering Data (SW Rqmts, ME/EE Rqmts, eSLOC, HW SWAP, Supportability metrics)
  - Rationales and justifications
- Data intended for
  - Calibration development
  - Program validation (if the program was previously estimated)
- Tools used
  - TEEMaP Data Collection Template
  - Central database
  - Statistical analysis tools

TEEMaP Data Collection Template

- Data Collection Template (DCT)
  - Actuals and ETCs
  - Standard WBS, engineering functions, life cycle phases
  - COSYSMO-based size and cost drivers
  - Functional oriented Data (SW Rqmts, ME/EE Rqmts, eSLOC, HW SWAP, Supportability metrics)
  - Rationales and justifications



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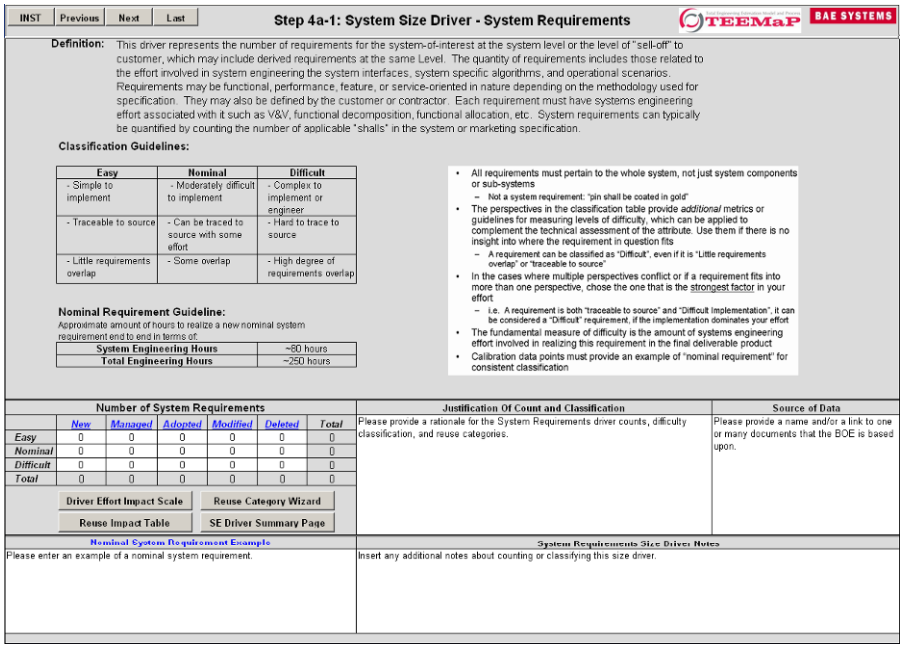
Step 2a: Systems Engineering Effort - Actuals (Hours)

WBS Cross Reference	Effort Summary	Estimate to Complete	Life-Cycle Phase: Concept Definition	Design & Implementation	Integration & Verification	Transition & Validation	Operations & Support	Total by Element	WBS Element Notes
1.0	Electronic/Automated Software System		0.0	0.0	0.0	0.0	0.0	0.0	
1.1	Integrated Project Management (IPM)		0.0	0.0	0.0	0.0	0.0	0.0	
1.1.1	Technical Management							0.0	
1.1.2	Technical Reviews							0.0	
1.1.3	Change Management							0.0	
1.1.4	Technical Process and Quality Management							0.0	
1.1.5	Acquisition & Supply Management (Subcontract & Technical Oversight)							0.0	
1.1.6	Information Technology & Infrastructure							0.0	
1.1.7	Dismantle and Disposal							0.0	
1.2	Systems Engineering		0.0	0.0	0.0	0.0	0.0	0.0	
1.2.1	Systems Engineering Management							0.0	
1.2.2	ConOps & Stakeholder Analysis							0.0	
1.2.3	Requirement Analysis & Management							0.0	
1.2.4	Prime Mission Product (PMP) Design							0.0	
1.2.5	Modeling & Simulation							0.0	
1.2.6	Logistics Engineering							0.0	
1.2.7	Reliability, Maintainability, Safety (RMS) Engineering							0.0	
1.2.8	Specialty Engineering							0.0	
1.3	Prime Mission Product (PMP)		0.0	0.0	0.0	0.0	0.0	0.0	
1.3.1	PMP Integration, Assembly, Test & Checkout (IATC)							0.0	
1.3.2	Operations / Production Support							0.0	
1.3.3	Sub-system / Configuration Item (CI) 1…n		0.0	0.0	0.0	0.0	0.0	0.0	
1.3.3.1	IPT Engineering Management							0.0	
1.3.3.2	Design							0.0	
1.3.3.3	Design Analysis and Verification							0.0	
1.3.3.4	Construction/Acquisition							0.0	
1.3.3.5	Integration, Assembly, Test & Checkout (IATC)							0.0	
1.3.3.6	Discrepancy Report (DR) Maintenance							0.0	
1.4	Platform Integration		0.0	0.0	0.0	0.0	0.0	0.0	
1.4.1	External Interface & Technical Liaison Coordination							0.0	
1.4.2	Transition to Use							0.0	
1.4.3	Initial Spares & Repair Parts							0.0	
1.5	System Test & Evaluation (ST&E)		0.0	0.0	0.0	0.0	0.0	0.0	
1.5.1	ST&E Management							0.0	
1.5.2	Design Solution Verification							0.0	
1.5.3	Development Test & Evaluation (DT&E)							0.0	
1.5.4	Operational Test & Evaluation (OT&E)							0.0	
1.5.5	ST&E Mock-ups / Prototypes / Simulations & Test Equipment		0.0	0.0	0.0	0.0	0.0	0.0	
1.5.5.1	Design							0.0	
1.5.5.2	Construction/Acquisition							0.0	
1.5.5.3	Integration, Assembly, Test & Checkout (IATC)							0.0	
1.5.6	ST&E Test & Evaluation Support							0.0	
1.5.7	ST&E Test Facilities							0.0	
1.6	Training		0.0	0.0	0.0	0.0	0.0	0.0	
1.6.1	Equipment							0.0	
1.6.2	Services							0.0	
1.6.3	Facilities							0.0	
1.7	Data Management		0.0	0.0	0.0	0.0	0.0	0.0	
1.7.1	Technical Publications							0.0	
1.7.2	Engineering Data							0.0	
1.7.3	Management Data							0.0	
1.7.4	Support Data							0.0	
1.7.5	Data Repository							0.0	
1.8	Peculiar Support Equipment		0.0	0.0	0.0	0.0	0.0	0.0	



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Step 4a-1: System Size Driver - System Requirements

TEEMaP | BAE SYSTEMS

Definition: This driver represents the number of requirements for the system-of-interest at the system level or the level of "sell-off" to customer, which may include derived requirements at the same Level. The quantity of requirements includes those related to the effort involved in system engineering the system interfaces, system specific algorithms, and operational scenarios. Requirements may be functional, performance, feature, or service-oriented in nature depending on the methodology used for specification. They may also be defined by the customer or contractor. Each requirement must have systems engineering effort associated with it such as V&V, functional decomposition, functional allocation, etc. System requirements can typically be quantified by counting the number of applicable "shalls" in the system or marketing specification.

Classification Guidelines:

Easy	Nominal	Difficult
- Simple to implement	- Moderately difficult to implement	- Complex to implement or engineer
- Traceable to source	- Can be traced to source with some effort	- Hard to trace to source
- Little requirements overlap	- Some overlap	- High degree of requirements overlap

- All requirements must pertain to the whole system, not just system components or sub-systems
  - Not a system requirement: "pin shall be coated in gold"
- The perspectives in the classification table provide *additional* metrics or guidelines for measuring levels of difficulty, which can be applied to complement the technical assessment of the attribute. Use them if there is no insight into where the requirement in question fits
  - A requirement can be classified as "Difficult", even if it is "Little requirements overlap" or "traceable to source"
- In the cases where multiple perspectives conflict or if a requirement fits into more than one perspective, chose the one that is the strongest factor in your effort
  - i.e. A requirement is both "traceable to source" and "Difficult Implementation", it can be considered a "Difficult" requirement, if the implementation dominates your effort
- The fundamental measure of difficulty is the amount of systems engineering effort involved in realizing this requirement in the final deliverable product
- Calibration data points must provide an example of "nominal requirement" for consistent classification

Nominal Requirement Guideline:

Approximate amount of hours to realize a new nominal system requirement end to end in terms of:

System Engineering Hours	~80 hours
Total Engineering Hours	~250 hours

Number of System Requirements	New	Managed	Adopted	Modified	Deleted	Total
Easy	0	0	0	0	0	0
Nominal	0	0	0	0	0	0
Difficult	0	0	0	0	0	0
Total	0	0	0	0	0	0

Driver Effort Impact Scale | Reuse Category Wizard | Reuse Impact Table | SE Driver Summary Page

Justification Of Count and Classification	Source of Data
Please provide a rationale for the System Requirements driver counts, difficulty classification, and reuse categories.	Please provide a name and/or a link to one or many documents that the BOE is based upon.

Nominal System Requirement Example	System Requirements Size Driver Notes
Please enter an example of a nominal system requirement.	Insert any additional notes about counting or classifying this size driver.

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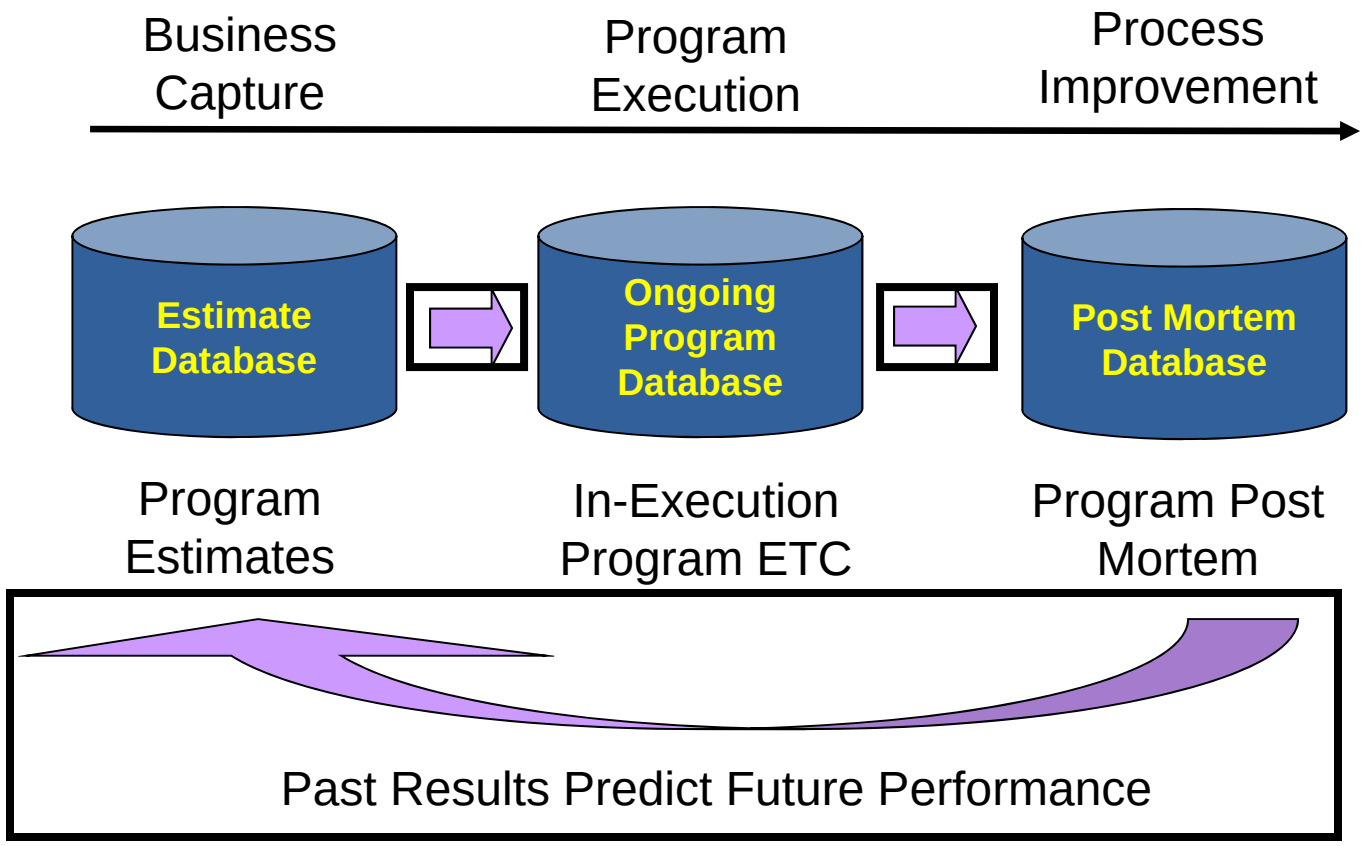
Data Relationship – Life Cycle Perspective



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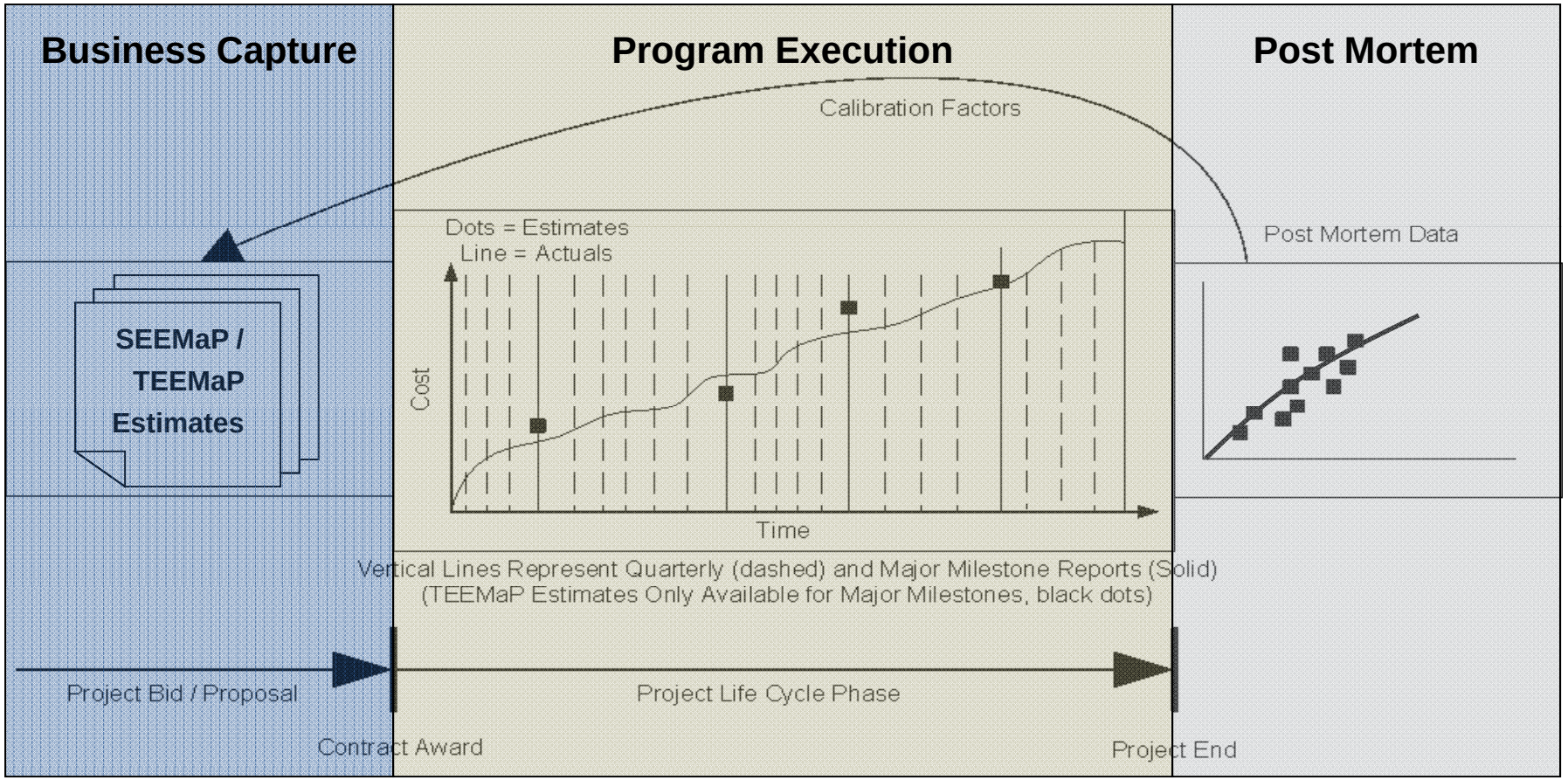
Data Migration in Program Life Cycle



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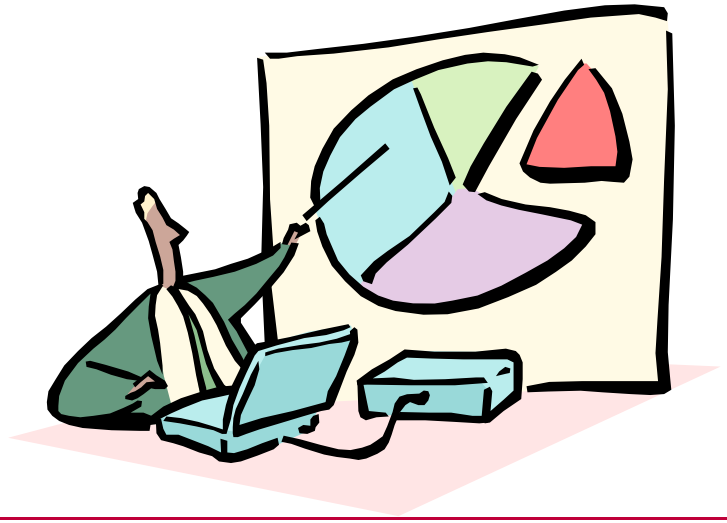
Creating Calibrations with Historical Data

- Historical data needs to go one step further
  - Data Analysis bridges the gap between past performance and future business
  - Group “like programs” to discover productivity patterns
  - Calibrating your historical data is the key to tying the end of the data collection life cycle to the beginning of the data collection life cycle



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Data Collection is a hands-on process

1. Identify historical programs and establish program technical and financial points of contact (POCs) and Data Collectors (DCs)
2. Conduct initial data collection training session (face to face preferred)
   - Learn the TEEMAP Data Collection Template
   - Learn metrics definitions
3. Initial data collection performed by the program POCs
   - Engineering actuals by WBS, life cycle phase, and functions
   - System drivers
   - SW & HW drivers
4. Interview session with TEEMaP team to review the program data
5. Iterate
   - Recollect questionable data
   - Additional interview sessions
6. Finalize the data point
   - Upload into the SQL Database
   - Move on to analysis and calibration…

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Identifying Relevant Data

- Identifying candidate programs eliminates headaches upfront
  1. Completed Program
     - Does the program have clear start and completion, and clean funding lines?
     - There can be exceptions for strategic areas
  2. Relevance of Future Bids
     - Do we have the right kinds of programs to support future bids? Example: similarity of programs, age of programs, process changes, etc
  3. Point of Contact
     - Can we identify the individual(s) who really know the project in detail, e.g., PEM/Engineering Leads, and who we can interview to collect data?
  4. Supporting Data
     - Can we find the engineering documentation, e.g., Metrics, etc, from which to derive important program attributes (i.e., the size drivers: requirements, interfaces, LOC, # drawings, # circuit boards, etc.)?

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Data Collection Challenges

- Time
  - Data Collection is a time consuming process
- Money
  - Data Collection takes investment, which is hard to get
- Personnel Setbacks
  - Core Team, Program Data Collector, Stakeholder
  - Personnel issues can stop data collection in its tracks!
- It's a problem solving process
  - After the first pass, data may look bad – don't get discouraged
  - Requires personnel internal to program
  - Training is necessary
  - Data reviews are necessary
- Consistency, consistency, consistency!
  - Program Data Collector is set in his/her ways
  - Same definition different interpretation
  - Diverse products and product lines
  - What is "the system"?
- Management championship is key

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Summary

- 3-year data collection effort at BAE Systems to support:
  - Estimation process improvement drove data collection and tool development
  - P&E measurement
- Three pillars to support large scale data collection
  - People + Process + Tools
- Data Collection is hard work!
  - Consistency is key but requires effort to achieve
  - It's a problem solving exercise
  - Defined process helps
- **It is worth it!**
  - Metrics are useful in more ways than one
  - Capture it while you can… If you wait until you need it – it's already too late

People, Process, and Tools are the foundation of successful data collection

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Questions and Contact Info

QUESTIONS?

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