NAVAL
POSTGRADUATE
SCHOOL

EXECUTABLE BEHAVIORAL MODELING OF SYSTEM-AND SOFTWARE-ARCHITECTURE SPECIFICATIONS TO INFORM RESOURCING DECISIONS

Monica Farah-Stapleton, PhD

Ray Madachy, PhD

Mikhail Auguston, PhD

Kristin Giammarco, PhD

Monterey, California

WWW.NPS.EDU

Overview

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- Research Objectives
- Summary of Results and Findings
- ThreeMetrics Methodology
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Statement of Problem

- Information Technology (IT) systems are large, complicated, and represent a significant investment in time and resources
  - Operational and financial impacts are often assessed after the fact
  - Resourcing decisions and precise architectural descriptions of the system and environment are often minimally related

- Precise modeling of architectures highlights design details and offers an early cost estimate for the system design
  - Assists in assessing architectural design decisions and their impacts prior to, during, and after implementation and deployment
  - Descriptions of interactions are related to function point transactional and data functions, and offer a way to estimate effort and cost of design decisions early in the process
  - Provides foundation for supporting unadjusted function point (UFP) count with automated tools

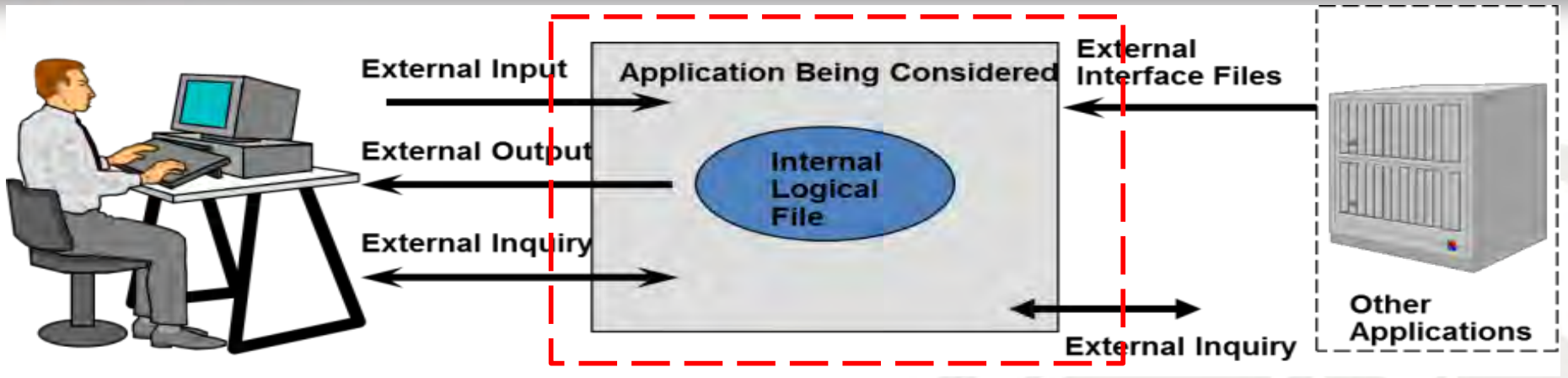
Research Objectives

This research developed a methodology to extract unadjusted function point (UFP) counts from executable architectural behavioral models, for use in cost estimation models such as COCOMO II, in order to inform effort estimates early in the life cycle

Summary of Results and Findings

- The ThreeMetrics methodology is able to extract an unadjusted function point (UFP) count from Monterey Phoenix's (MP) executable architecture models for use in software cost estimation
- The ThreeMetrics methodology leverages precise behavioral modeling using MP and the MP Analyzer on Firebird to assess architecture design decisions and their impacts
- The ThreeMetrics methodology relates architecture modeling to resourcing through UFP counts
- The COCOMO II tool is used to input the UFP count to determine cost estimates
- The ThreeMetrics methodology uses event traces to inform integration test estimates and decision making
- Each step of the ThreeMetrics methodology provides meaningful information to stakeholders

Function Point Analysis
Functionality From User's Perspective



Determine the Type of Count and Boundary:
Development Project, Enhancement Project, Application

Terminology:

- External Inputs (EI): Data that is entering the system
- External Outputs (EO) and External Inquiries (EQ): Data that is leaving the system
- Internal Logical Files (ILF): Data that is processed and stored within the system
- External Interface Files (EIF): Data that is maintained outside the system but is necessary to satisfy a particular process requirement

Function Point Analysis Practice

1. Count Data and Transactional Function Types
2. Determine UFP Count
3. Determine the Value Adjustment Factor
4. Calculate final Adjusted FP Count

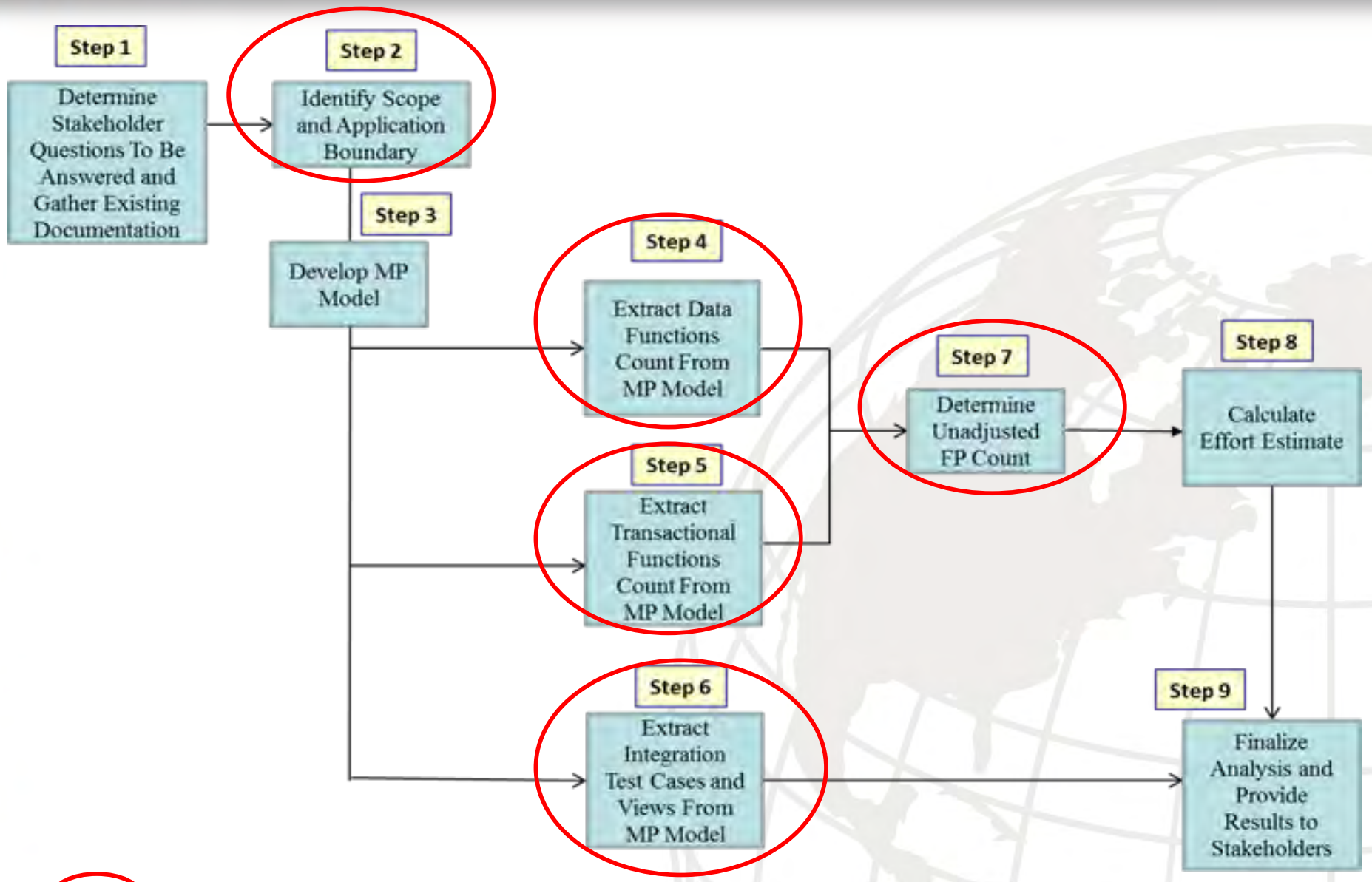
Steps 1 and 2 Result in UFP

Function Points:

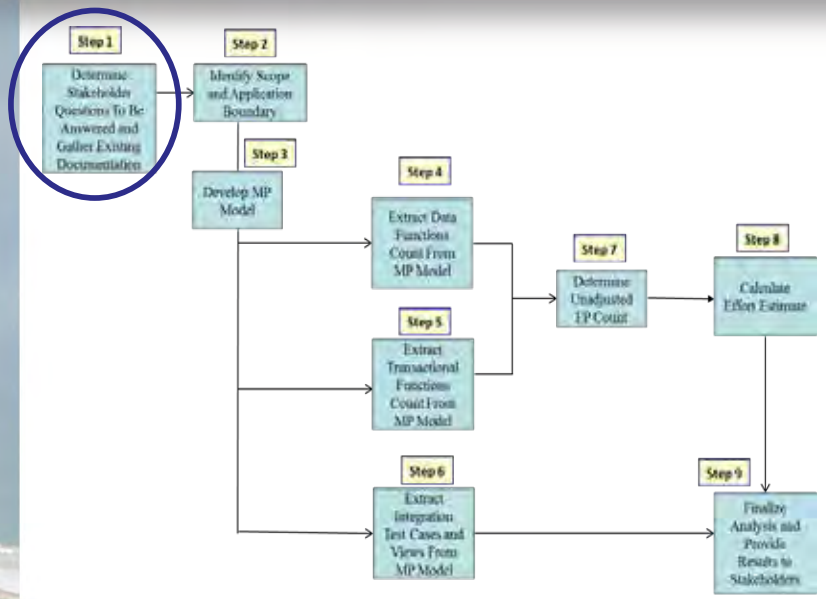
- Normalized *metric* used to evaluate software deliverables
- Measure size based on well-defined functional characteristics of the software system
- Must be defined around components that can be identified in a well-written specification

Source: International Function Point User Group (IFPUG)

ThreeMetrics Methodology



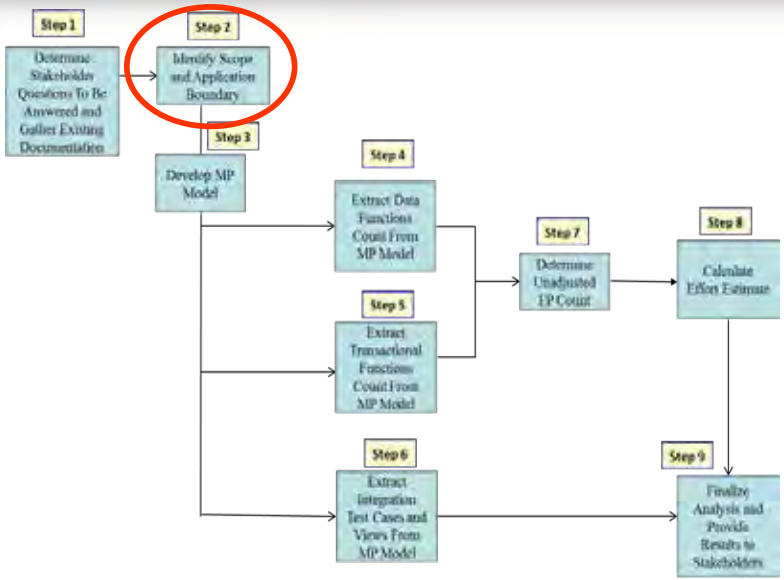
Step 1: Determine Stakeholder Questions To Be Answered and Gather Existing Documentation

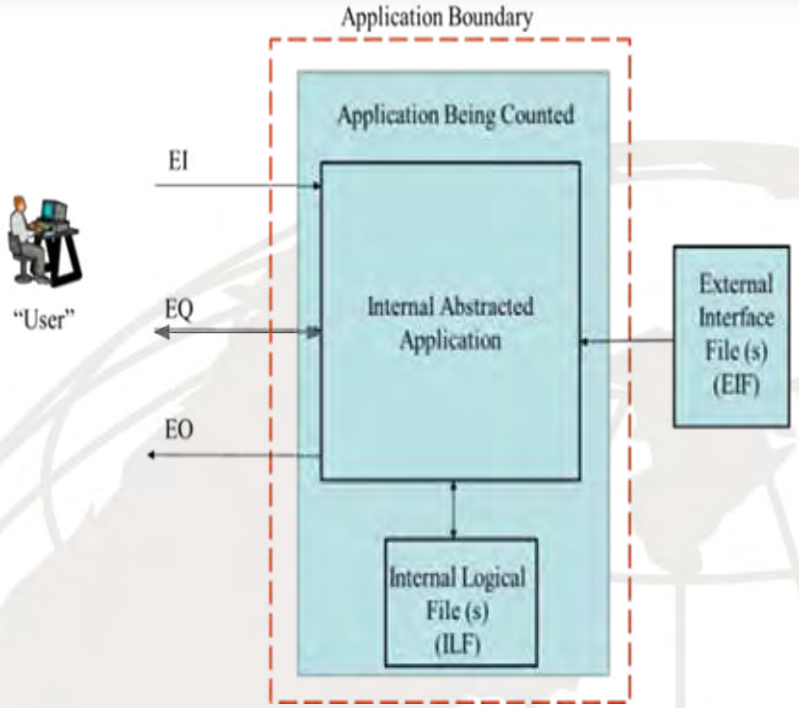


- Identify questions of stakeholders (e.g., customers, users, testers, engineers, designers, cost analysts)
- Gather documentation and subject matter expert input
- Determine if the application is new or an enhancement to an exsiting application

Step 2: Identify Scope and Application Boundary

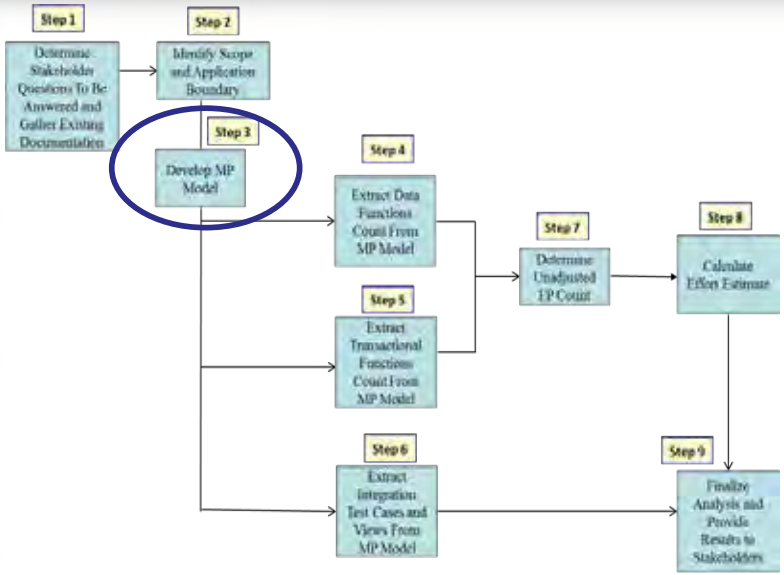
ThreeMetrics Box and Arrow View





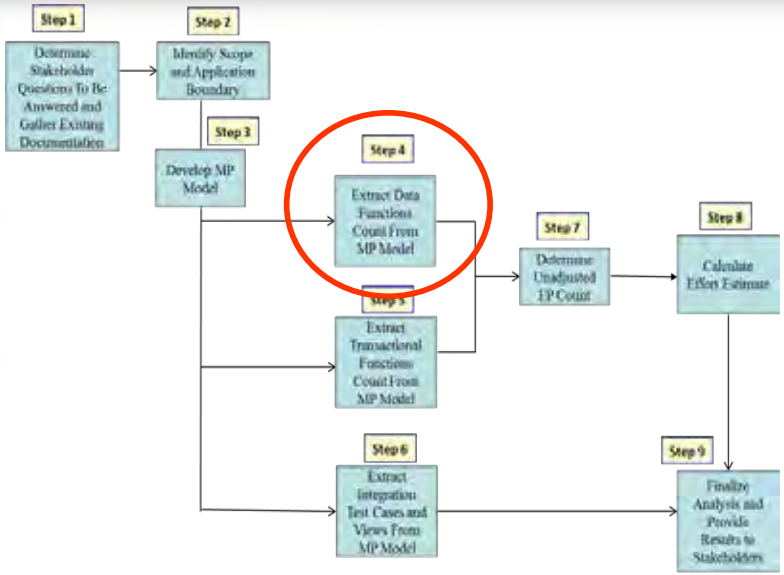
- Identify boundaries of application to be counted
  - Interactions mark the boundaries
  - If there is an interaction, there is a dependency in one or both directions
  - Capture interactions in separate parts of MP model
- Identify data functions (ILF, EIF)
- Identify transactional functions (EI, EQ, EO)
- Identify Internal Abstracted Application (IAA)
- Environment
  - Everything but the application under assessment
  - Interactions with the application

Step 3: Develop MP Model



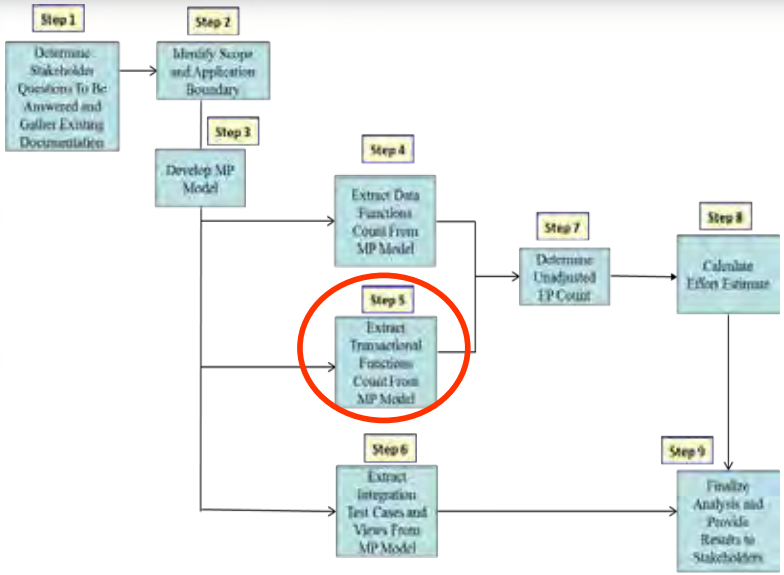
- MP operates in the event space
  - Behaviors of processes and data are uniquely distinguished events
- Describe ROOTs
  - Actors
- Represent data functions and data element types as actors
- Describe interactions between actors using COORDINATE and SHARE ALL composition operations
  - Transactional functions
  - Data functions

Step 4: Extract Data Functions Count From MP Model



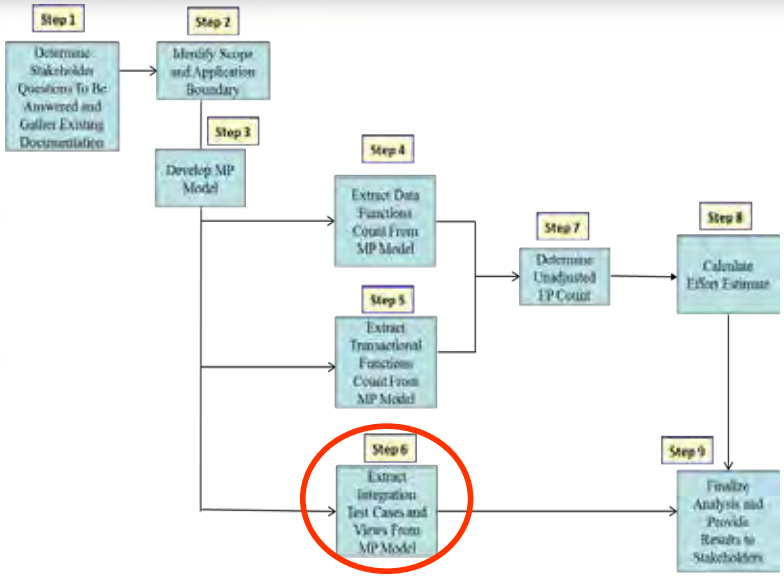
- Inspect MP model for number of interactions for data functions (ILF, EIF)
- Count number of SHARE ALLs, for each data function
- Count number of COORDINATEs and number of ADDs if detailed source information is available, for each data function

Step 5: Extract Transactional Functions Count From MP Model



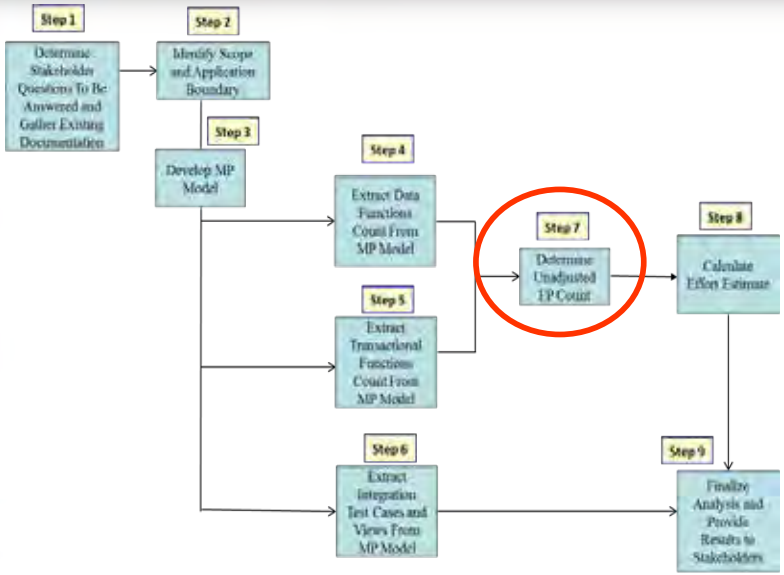
- Inspect MP model for interactions between processes (EI, EO, EQ)
- Count number of COORDINATEs for each transactional function
- Count number of COORDINATEs and number of ADDs if detailed source information is available, for each transactional function

Step 6: Extract Integration Test Cases and Views From MP Model



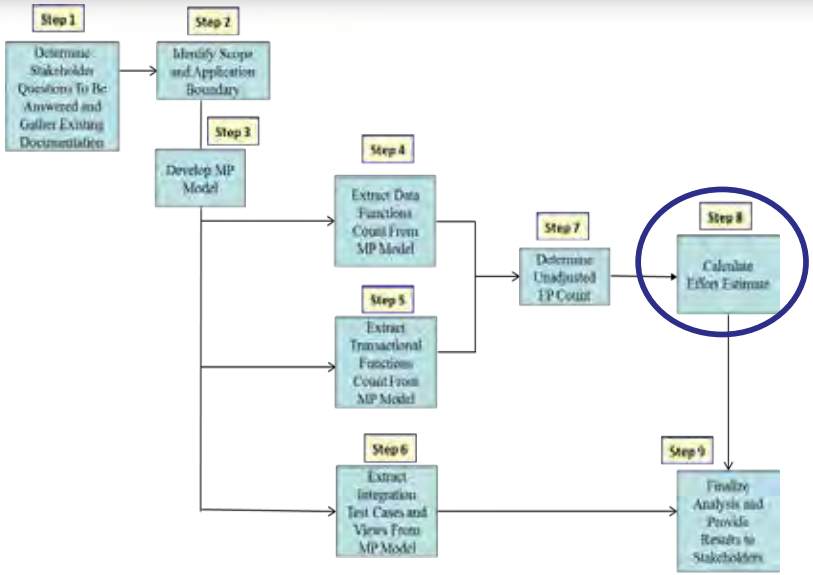
- Event traces (i.e., use cases) are automatically generated by MP Analyzer on Firebird
- MP Analyzer provides exhaustive set of use cases for given scope
- According to Brooks, integration testing comprises up to ¼ of effort
- Inspect event traces and identify which ones can be used as a blueprint for integration test case design

Step 7: Determine UFP Count



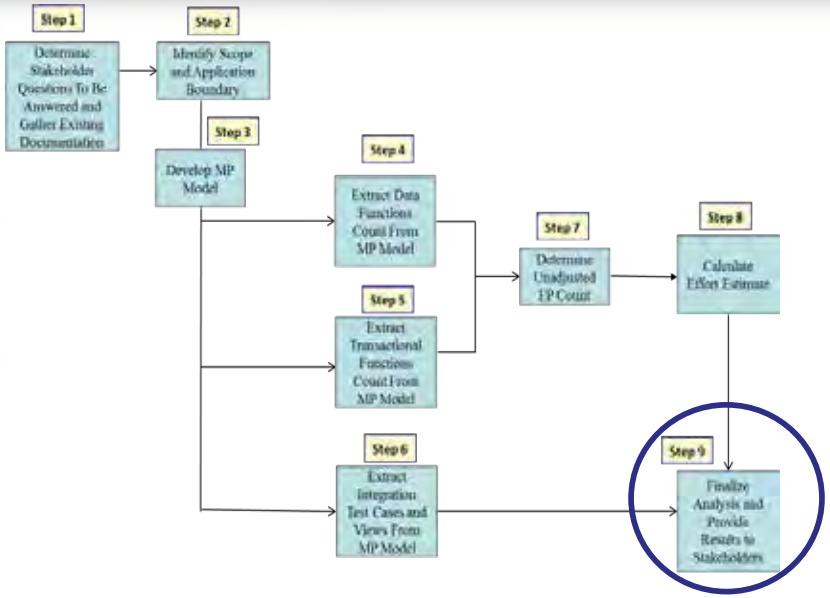
- Use IFPUG tables
  - Functional complexity
  - Functional size values are associated with functional complexity
- Complexity in MP model is determined by number of ADDs counted in COORDINATE composition operation
- For minimal source information, initially assume Average functional complexity and size to calculate the total UFP count
- Total UFP count is summation of UFP count for each data function and UFP for each transactional function

Step 8: Determine Effort Estimate



- Manually insert UFP into COCOMO II calculator tool or import .mp file
- Select
  - Sizing method (e.g., function points)
  - Input method (e.g., direct)
  - Language (e.g., Java)
  - Insert cost per person-month (e.g., 20,000 dollars)
  - Nominal options
- Interpret results for effort, schedule, and cost

Step 9: Finalize Analysis and Present Results to Stakeholders



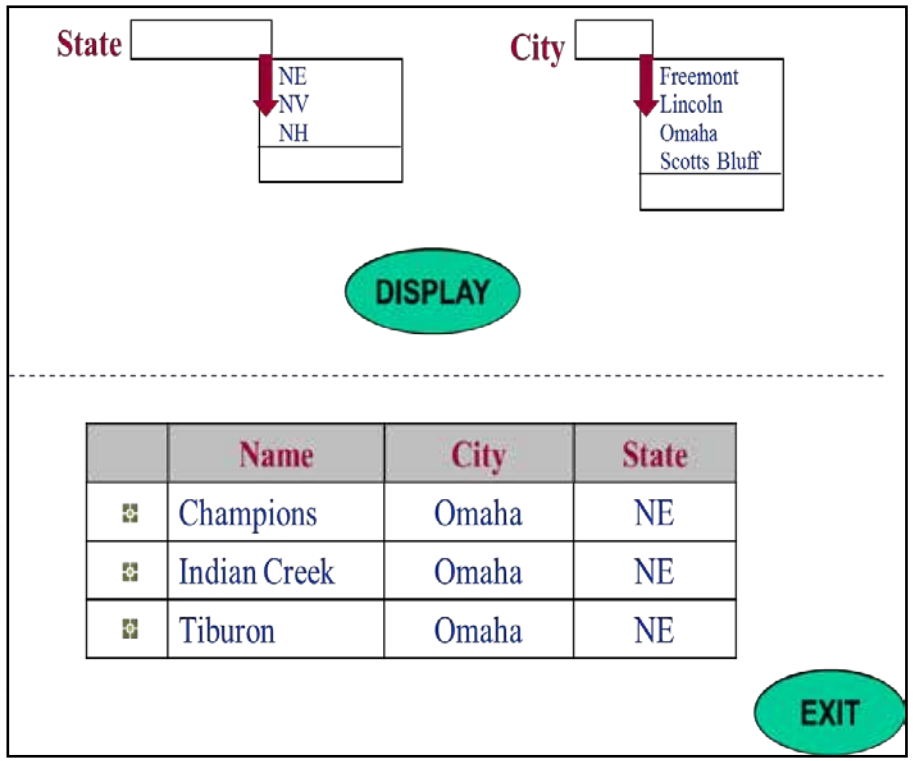
- Provide analysis results and views of information in formats for each group of stakeholders, including
  - Box and arrow diagrams
  - Sequence diagrams
  - High-level pseudocode
  - Cost/schedule/effort values

Methodology Applied to Examples

The ThreeMetrics methodology was applied to 3 FP counting examples:

1. Spell Checker
   - Limited source information. Use Average functional complexity and size values for transactional and data functions. Inspect model for COORDINATE and SHARE ALL.
2. Course Marks
   - Limited source information. Use functional complexity and size values provided in source information, for transactional and data functions. Inspect model for COORDINATE and SHARE ALL.
3. It's Tee Time
   - Detailed source information available, explore 4 courses of action (COAs) to determine UFP count.
   - COA 1: Inspect model for COORDINATE and SHARE ALL. Assume Average functional complexity and size values.
   - COA 2: Inspect model for EI, EO, and EQ descriptive terms with COORDINATE and SHARE ALL. Assume Average functional complexity and size values.
   - COA 3: Inspect model for COORDINATE and ADD to determine functional complexity and size for transactional functions. Inspect model for SHARE ALL assuming Average functional complexity and size for data functions.
   - COA 4: Inspect model for COORDINATE and ADD for both transactional and data function functional complexity and size.

Step 1: Determine Stakeholder Questions To Be Answered and Gather Existing Documentation



Source: It's TeeTime FP counting example, protected by copyright, Q/P Management Group Inc.

Transactional Function: EQ (View or Display Retrieval of Data)

- Click Button from Main Screen, navigate to Golf Courses list;
- Exit button: Navigation

EQ -- View/Display State Drop Down

- **Click on state arrow**
- **State list display returned**
- **Stop**
- **1 FTR (Golf Courses ILF), 2 DET (Arrow Click, State field)**

EQ – View/Display City Drop Down

- State data entered
- Click on City arrow
- City list display returned
- Stop
- 1 FTR (Golf Courses ILF), 3 DET (State data, Arrow Click, City field)

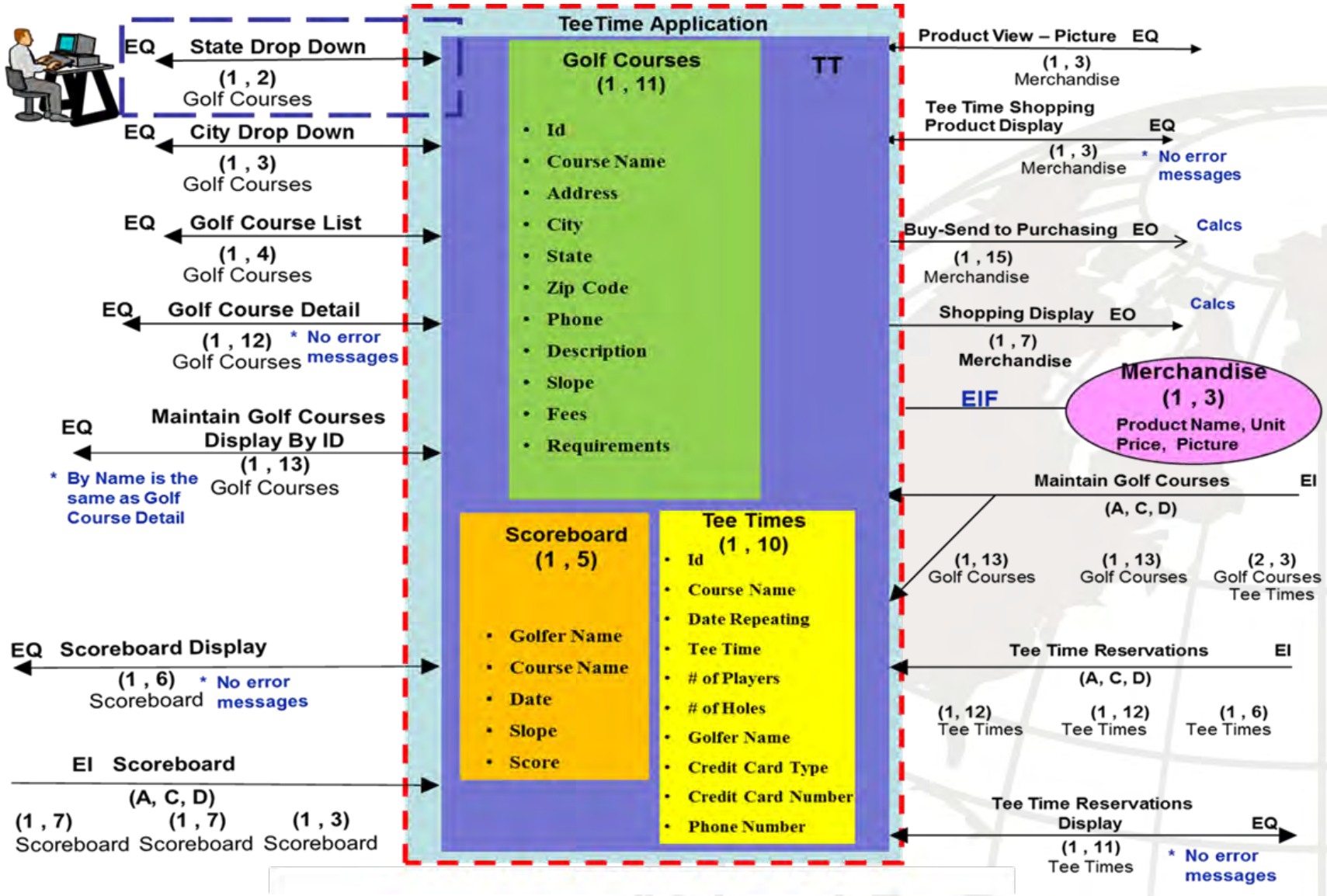
EQ – View/Display Golf Courses List

- Enter State and City
- Click Display button
- Name displayed back, don't count State, City
- Stop
- 1 FTR (Golf Course ILF), 4 DET(State, City, Name, Click Display)

EP	Description	ILF/EIF	FTR/DET	Complex	UFP
EQ	State Drop Down	Golf Courses (I)	(1,2)	Low	3

Step 2: Identify Scope and Application Boundary

ThreeMetrics Box and Arrow View



Source: Derived from the It's TeeTime FP counting example, a registered trademark, provided by Q/P Management Group Inc. for this research

Step 3: Develop MP Model

EQ State Drop Down Transactional Function Example

Line 01 Schema Name for EQ

Lines 02-05 represent the behaviors of ROOTs (Actors)

Lines 06-17 represent the behaviors of the COORDINATE for EQ: State Drop Down

Lines 09 -16 represent behaviors of nested COORDINATE, DETs and FTRs. The number of ADDs determines the weight of this EQ

```
01  SCHEMA It_Is_Tee_Time_EQ
02  ROOT User_GCL:  Inquire_on_state_data  something_else;
03       Inquire_on_state_data: Click_state_arrow_dropdown  Receive_state_list_display;
04  ROOT Golfcourses_ILF: Get_result     anything_else;
05       Get_result: Receive_state_arrow_prompt     Send_state_list_display;

06  COORDINATE $x: Inquire_on_state_data      FROM User_GCL,
07                 $y: Get_result             FROM  Golfcourses_ILF
08   DO
09  COORDINATE $xx: Click_state_arrow_dropdown  FROM $x,
10                  $yy: Receive_state_arrow_prompt   FROM $y,
11                  $x11: Receive_state_list_display FROM $x,
12                  $y11:  Send_state_list_display FROM $y
13  DO
14                  ADD $xx PRECEDES $yy;
15                  ADD $y11 PRECEDES $x11;
16  OD;
17  OD;
```

MP Calculation

- **1 FTR and 1 nested COORDINATE (COORDINATE & 2 ADDs) correspond to 1 FTR and 2 DETs and a functional complexity weighting of 3**
- **EQ State Drop Down = (1 COORDINATE) * 3 UFP/COORDINATE = 3 UFPs**

Step 3: Develop MP Model, con't
Golf Courses ILF Data Function Example

Data function behavior is represented using either

- SHARE ALL, if minimal ILF or EIF source information is available
- COORDINATE, if more detailed ILF or EIF source information is available

SHARE ALL

Line 01 Schema Name for data function

Lines 02-03 represent the behaviors of ROOTs (Actors)

Lines 03 represents behaviors of Golfcourses ILF and TT IAA using SHARE ALL

```
01 SCHEMA Data_Function_Example_SHARE_ALL
02 ROOT TT: (* ( writing | reading) *);
03 ROOT GC_ILF: (+writing+) ( * sending *);
04 TT, GC_ILF SHARE ALL writing;
```

COORDINATE

Line 01 Schema Name for data function

Lines 02-03 represent the behaviors of ROOTs (Actors)

Lines 04-06 represent the behaviors of Golfcourses ILF and TT IAA using COORDINATE

```
01 SCHEMA Data_Function_Example_COORDINATE
02 ROOT TT: (* ( start_writing | reading) *);
03 ROOT GC_ILF: (+finish_writing+) ( * sending *);
04   COORDINATE  $a: start_writing      FROM TT,
05               $b: finish_writing     FROM GC_ILF
06    DO         ADD $a PRECEDES $b; OD;
```

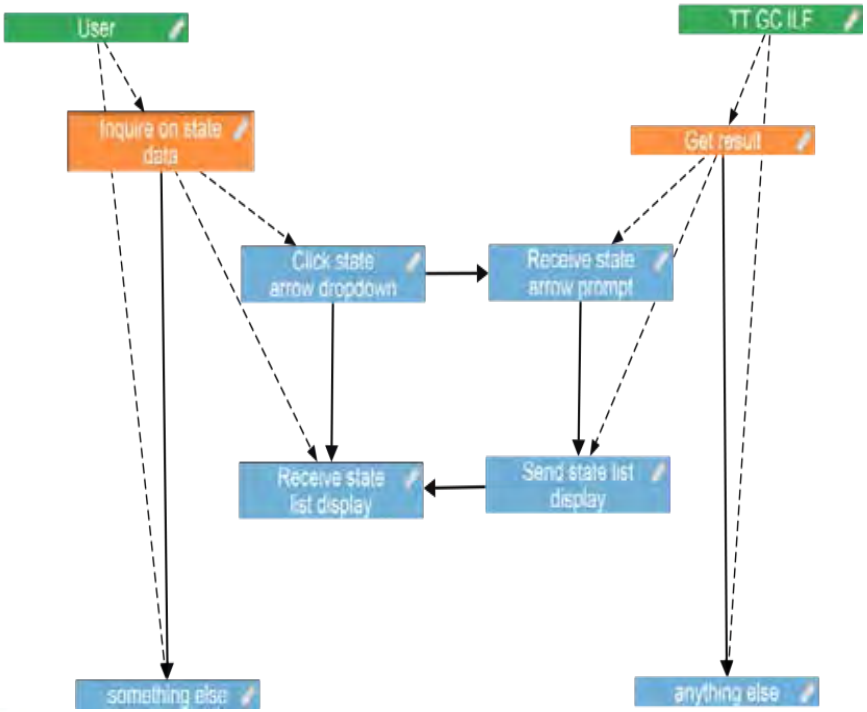
Step 4: Extract Data Functions Count From MP Model

- Inspect MP model for SHARE ALL or COORDINATE
- MP Schema, Tee Time COA 3
  - Count number of data function SHARE ALLs (4)
- MP Schema, Tee Time COA 4
  - Count number of data function COORDINATEs (4)
  - Count number of ADDs in each COORDINATE to determine complexity

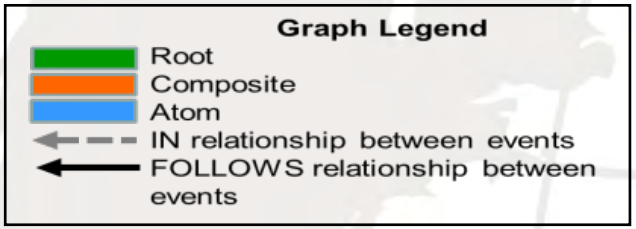
Step 5: Extract Transactional Functions Count From MP Model

- Inspect MP model for COORDINATE
- MP Schema, Tee Time COA 4
  - Count number of transactional function COORDINATEs (20)
  - Count number of ADDs in each COORDINATE to determine complexity

Step 6: Extract Integration Test Cases and Views From MP Model



- Extract Views
  - Expresses dependencies between parts of the system
  - Highlight modifications to the system
  - Event traces (use cases) generated by Firebird
  - Inspect and use to inform test case generation



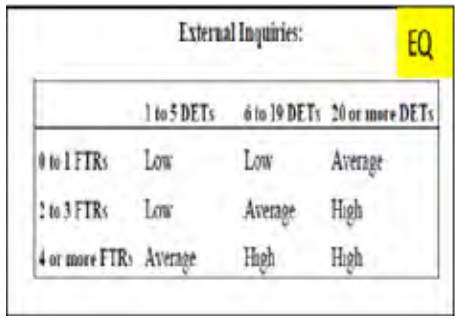
- Extract Integration Test Cases
  - Integration test case creation + execution = Estimate for integration testing
  - Brooks "1/3 planning, 1/6 coding, 1/4 component test and early system test, 1/4 system test, all components in hand."
  - .25 x Total effort = Estimate for integration testing
  - Wolff suggests 6 integration test cases can be executed per day for a large application (e.g., large commerce system)

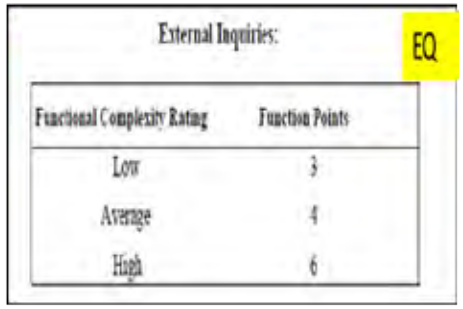
Step 6: Extract Integration Test Cases and Views From MP Model

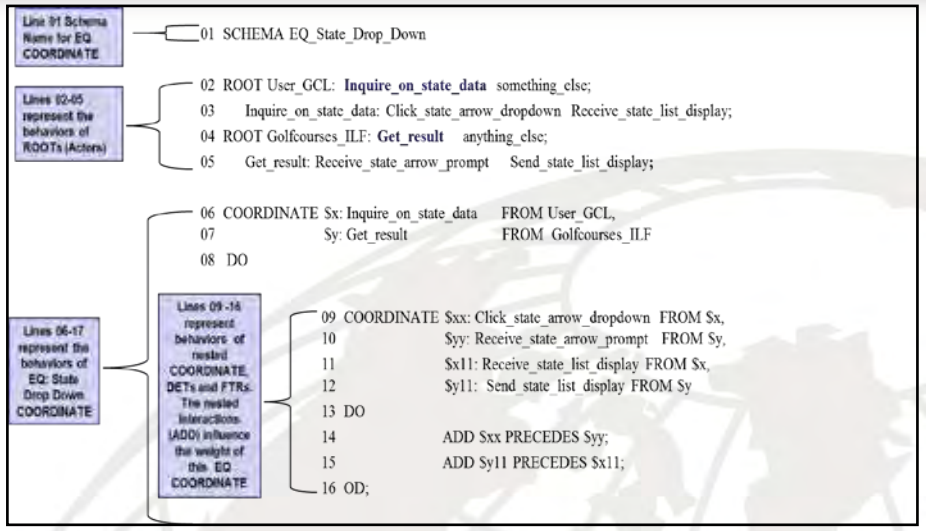
- Integration and Test costs are part of COCOMO II Construction phase effort
  - Construction phase is allocated 6.4 months of schedule
  - 25% of that time is 1.6 months
  - Assume 5 days per week and 8 hours per day for each staff person
- Assume execution of 6 test cases per day
  - 192 test cases can be executed in the allocated time
  - Doesn't include creation of test cases
- 864 event traces generated in the MP model for COA 1
  - Require over 144 days to execute all testing
  - Some event traces are significantly less complicated than others, so effort will vary
- Informs next steps for technical and programmatic decision making
  - Revisit the model
  - Determine if there are any additional resources (e.g. schedule relief, staffing)
  - Identify a subset of test cases for creation and execution
    - 144 days is unsupportable given schedule allocation
    - 192 test cases do not account for creation and analysis, only execution

Step 7: Determine UFP Count
EQ State_Drop_Down

EP	Description	ILF/EIF	FTR / DET	Complex	UFP
EQ	State Drop Down	Golf Courses (I)	(1,2)	Low	3







UFP Calculation: FP Counting

- 1 FTR and 2 DETs identified from the behavior of EQ State_Drop_Down
- 0-1 FTRs and 1-5 DETs correspond to a Low functional complexity rating
- A Low functional complexity rating corresponds to **3 UFPs**

UFP Calculation: Extracted From MP

- 1 COORDINATE interaction associated with State Drop Down EQ behaviors
- State Drop down EQ COORDINATE contains a nested COORDINATE (2 ADDs)
- The 2 ADDs relate to 2 DETs
- ROOT Golfcourses_ILF relates to 1 FTR
- 0 -1 FTRs and 1-5 DETs correspond to a Low functional complexity rating
- A Low functional complexity rating corresponds to 3 UFPs
- EQ State Drop Down is equal to 1 COORDINATE with a weight of 3 or **3 UFPs**

Step 7: Determine Unadjusted FP Count, con't

EP	Description	ILF/EIF	FTR/DET	MP Schema COA 3 COORDINATE #	Complexity	UFP
EQ	State Drop Down	Golf Courses (I)	(1,2)	1	Low	3
EQ	City Drop Down	Golf Courses (I)	(1,3)	2	Low	3
EQ	Golf Course List	Golf Courses (I)	(1,4)	3	Low	3
EQ	Golf Course Detail	Golf Courses (I)	(1,12)	4	Low	3
EQ	Scoreboard Display	Scoreboard (I)	(1,6)	13	Low	3
EQ	Maintain Golf Course Display (by ID)	Golf Courses (I)	(1,13)	9	Low	3
EQ	Tee Times Reservation Display	Tee Times (I)	(1,11)	5	Low	3
EQ	Tee Times Shopping Product Display	Merchandise (E)	(1,3)	17	Low	3
EQ	Product View Picture	Merchandise (E)	(1,3)	18	Low	3

EP	Description	ILF/EIF	FTR/DET	MP Schema COA 3 COORDINATE #	Complexity	UFP
EI	Scoreboard (ADD)	Scoreboard (I)	(1,7)	14	Low	3
EI	Scoreboard (CHANGE)	Scoreboard (I)	(1,7)	15	Low	3
EI	Scoreboard (DELETE)	Scoreboard (I)	(1,3)	16	Low	3
EI	Maintain Golf Course (ADD)	Golf Courses (I)	(1,13)	10	Low	3
EI	Maintain Golf Course (CHANGE)	Golf Courses (I)	(1,13)	11	Low	3
EI	Maintain Golf Course (DELETE)	Golf Courses (I) Tee Times	(2,3)	12	Low	3
EI	Tee Times Reservations (ADD)	Tee Times (I)	(1,12)	6	Low	3
EI	Tee Times Reservations (CHANGE)	Tee Times (I)	(1,12)	7	Low	3
EI	Tee Times Reservations (DELETE)	Tee Times (I)	(1,6)	8	Low	3

EP	Description	ILF/EIF	FTR/DET	MP Schema COA 3 COORDINATE #	Complexity	UFP
EO	Shopping Display (Calculation)	Merchandise	(1,7)	19	Low	4
EO	Buy – Send to Purchasing (Calculation)	Merchandise	(1,15)	20	Low	4

Description	ILF/EIF	RET/DET	MP Schema COA 4 COORDINATE #	Complexity	UFP
Golf Course	ILF	(1,11)	21	Low	7
Tee Times	ILF	(1,10)	22	Low	7
Scoreboard	ILF	(1,5)	23	Low	7
Merchandise	EIF	(1,3)	24	Low	5

- This table contains the results of the UFP count extracted from the It's Tee Time MP model, using the ThreeMetrics
- Total UFP count is summation of UFP count for each data function and UFP for each transactional function
- UFP for Tee Time
  - 62 UFPs for transactional functions (EI, EO, EQ) (COAs 3 and 4)
  - 26 UFPs for data functions (ILF, EIF)
  - Total UFP count = 62 + 26 = 88 UFPs (COA 4)

UFP Summation for Examples

Example Name	Representation of Data Function Types in MP	Total # Data Function Type UFP	Representation of Transactional Function Type in MP	Total # Transactional Function Type UFP	ThreeMetrics Total UFP Count	Source Info Total Key UFP Count
Spell Checker	SHARE ALL	24	COORDINATE	31	55	58
Course Marks	SHARE ALL	15	COORDINATE	24	39	35 or 34
It's Tee Time						
- COA 1	SHARE ALL	34	COORDINATE	86	120	88
- COA 2	SHARE ALL with ILF and EIF keywords	37	COORDINATE with EI, EO, EQ keywords	82	119	88
- COA 3	SHARE ALL with ILF and EIF keywords	37	Nested COORDINATE and ADD, with EI, EO, EQ keywords	62	99	88
- COA 4	COORDINATE with ILF and EIF keywords	26	Nested COORDINATE and ADD, with EI, EO, EQ keywords	62	88	88

Step 8: Determine Effort Estimate

Tee Time COA 4 COCOMO II Nominal Effort Options

COCOMO II - Constructive Cost Model

Software Size Sizing Method: Function Points | Input Method: Direct

Unadjusted Function Points: 88 | Language: Java

Software Scale Drivers

Precedentedness	Nominal	Architecture / Risk Resolution	Nominal	Process Maturity	Nominal
Development Flexibility	Nominal	Team Cohesion	Nominal		

Software Cost Drivers

Product		Personnel		Platform	
Required Software Reliability	Nominal	Analyst Capability	Nominal	Time Constraint	Nominal
Data Base Size	Nominal	Programmer Capability	Nominal	Storage Constraint	Nominal
Product Complexity	Nominal	Personnel Continuity	Nominal	Platform Volatility	Nominal
Developed for Reusability	Nominal	Application Experience	Nominal	**Project**	
Documentation Match to Lifecycle Needs	Nominal	Platform Experience	Nominal	Use of Software Tools	Nominal
		Language and Toolset Experience	Nominal	Multisite Development	Nominal
				Required Development Schedule	Nominal

Maintenance Off

Software Labor Rates

Cost per Person-Month (Dollars): 20000

Calculate

Cost per Person-Month:

$20,000 selected as average labor rate

Reviewed GSA rates for several projects

MP/COCOMO tool created by Dr. Ray Madachy, NPS
rjmadach@nps.edu

Step 8: Determine Effort Estimate, con't

Tee Time COA 4 COCOMO II Nominal Effort Options

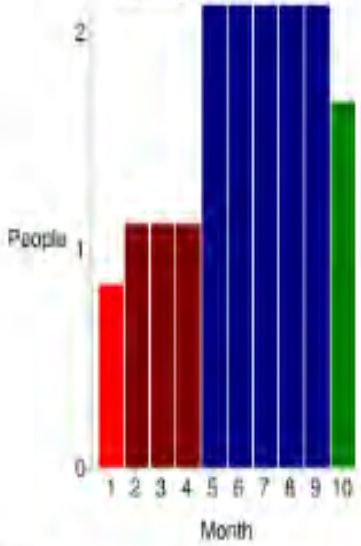
Results

Software Development (Elaboration and Construction)

Effort = 16.0 Person-months
Schedule = 9.2 Months
Cost = $319750

Total Equivalent Size = 4664 SLOC

Staffing Profile



Acquisition Phase Distribution

Phase	Effort (Person-months)	Schedule (Months)	Average Staff	Cost (Dollars)
Inception	1.0	1.1	0.8	$19185
Elaboration	3.8	3.4	1.1	$76740
Construction	12.2	5.7	2.1	$243010
Transition	1.9	1.1	1.7	$38370

Software Effort Distribution for RUP/MBASE (Person-Months)

Phase/Activity	Inception	Elaboration	Construction	Transition
Management	0.1	0.5	1.2	0.3
Environment/CM	0.1	0.3	0.6	0.1
Requirements	0.4	0.7	1.0	0.1
Design	0.2	1.4	1.9	0.1
Implementation	0.1	0.5	4.1	0.4
Assessment	0.1	0.4	2.9	0.5
Deployment	0.0	0.1	0.4	0.6

Your output file is http://csse.usc.edu/tools/MP_COCOMO/data/COCOMO_July_31_2016_20_05_02_278573.txt

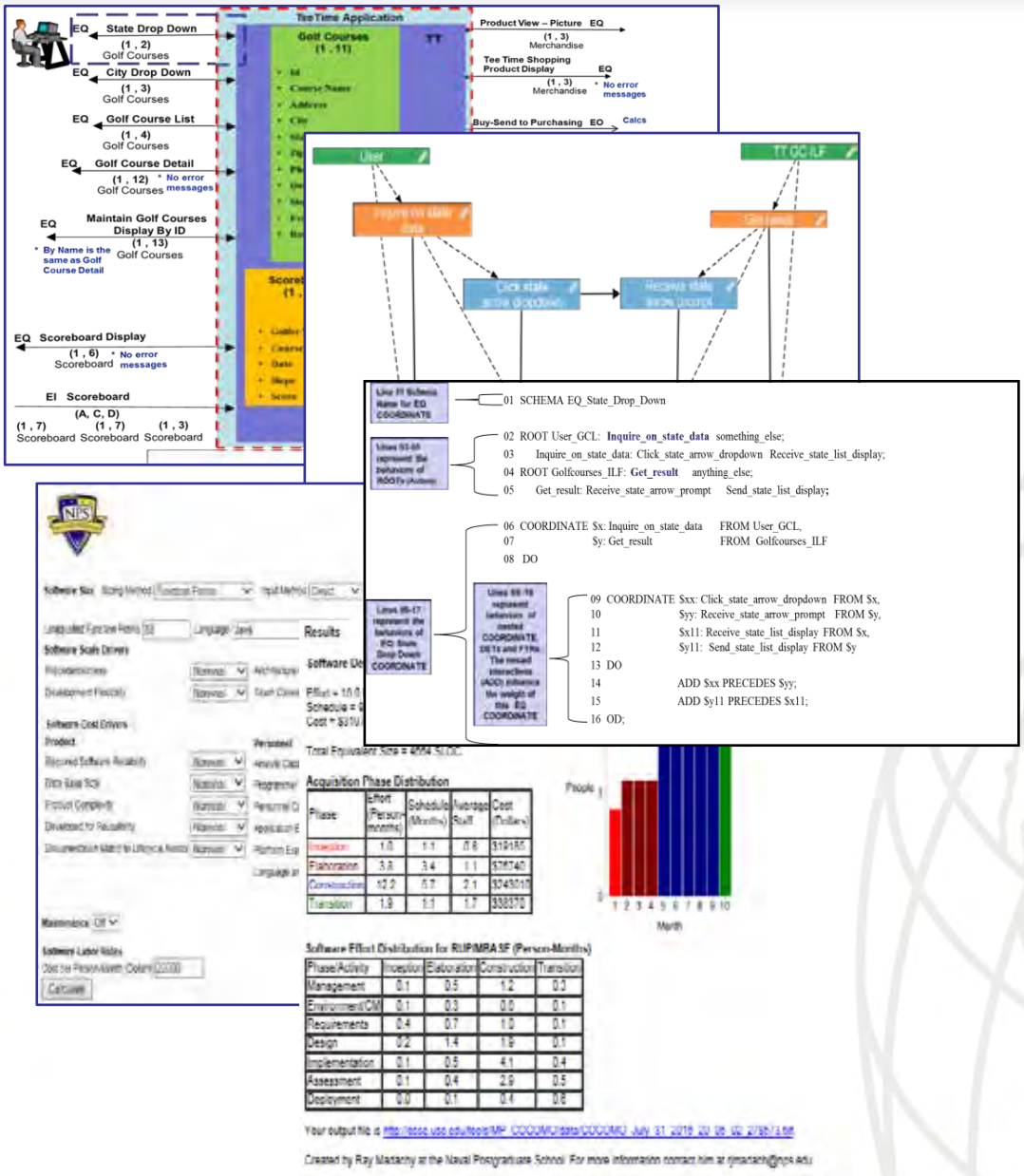
Created by Ray Madachy at the Naval Postgraduate School. For more information contact him at rjmadach@nps.edu

- Sizing Method: Function Points
- UFP: 88
- Nominal options
- Software Development
  - Elaboration and Construction Phases
  - Effort: 16.0 Person-months
  - Schedule: 9.2 Months
  - Cost: $319,750
- Total Equivalent Size: 4664 SLOC
  - SLOC = (# UFP) x (language SLOC/UFP)
  - Java language conversion ratio for UFP to SLOC is 53
  - 4664 SLOC = (88 UFP) x (53 conversion ratio)

*SLOC Source Lines of Code

MP/COCOMO tool Created by Dr. Ray Madachy, NPS, rjmadach@nps.edu/

Step 9: Finalize Analysis and Present Results to Stakeholders



- Each step of the ThreeMetrics methodology provides meaningful information to stakeholders
- High-level pseudocode
- Resourcing requirements presented with each instance of architecture model
- Views extracted from architecture model
  - Use cases (event traces)
  - Sequence diagrams

Contributions

- The ThreeMetrics methodology does relate function point counting, COCOMO II cost estimates, and executable behavioral modeling of system and software architecture specifications.

- The ThreeMetrics methodology, based on MP architecture model, provides a way of establishing internal and external boundaries for function point counting.

- The use of the MP language and framework significantly simplified otherwise complex relationships. The ability to execute the model using MP Analyzer on Firebird, inspect it, and debug it, provided confidence in the results of the model.

- The ThreeMetrics methodology successfully unifies the two distinct function point counting concepts of data function types and transactional function types.

Future Work

- Determine criteria for selection of integration test cases from set of available MP event traces, leveraging Jackson's small scope hypothesis
- Determine selection of COCOMO II formula coefficients based on MP metrics
- Consider how to use all the information in an MP model, particularly the event grammar ("pseudo code"), to inform cost estimates
- Integrate with other MBSE research on System Qualities Ontology, Tradespace and Affordability (SQOTA) Project with DoD Systems Engineering Research Center (SERC)

Discussion

Back Up

Published Papers and Presentations

Peer Reviewed Conference Papers and Presentations

1. M. Farah-Stapleton, M. Auguston, R. Madachy, and K. Giammarco, "Executable behavioral modeling of system- and software-architecture specifications to inform resourcing decisions," in 31st International Forum on COCOMO and Systems/Software Cost Modeling, Los Angeles, CA , Oct 2016. (Abstract Submitted) http://csse.usc.edu/new/events/event/31st-international-forum-on-cocomo-and-systemssoftware-cost-modeling
2. M. Farah-Stapleton, M. Auguston, and K. Giammarco, "Executable behavioral modeling of system and software architecture specifications to inform resourcing decisions," Complex Adaptive Systems (CAS) Conference, Los Angeles, CA, Nov 2016. (Paper Accepted)
3. M. Farah-Stapleton, M. Auguston, K. Giammarco, "Behavioral Modeling of Software Intensive System Architectures" at the Complex Adaptive Systems (CAS) Conference, Baltimore, MD, 2013, pp. 204-209.
4. K. Giammarco, M. Auguston, C. Baldwin, J. Crump, and M. Farah-Stapleton, "Controlling Design Complexity with the Monterey Phoenix Approach," Complex Adaptive Systems (CAS) Conference, Philadelphia, PA, 2014, Volume 36, pp. 204-209.
5. M. Farah-Stapleton, Resource Analysis Based On System Architecture Behavior, Technical Presentation, 30th International Forum on COCOMO and Systems/Software Cost Modeling, November 2015. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0ahUKEwiXuuGLzoXMAhWHuBoKHTXbBTsQFggsMAI&url=http%3A%2F%2Fcsse.usc.edu%2Fnew%2Fwp-content%2Fuploads%2F2015%2F11%2FCOCOMO_Farah-Stapleton__November-2015-DRAFT9_MFS.pptx&usg=AFQjCNEcSGfu3opnpKfOYG9LAfAfChKthA&sig2=y3COAQP5B4QsGwi4kvvXyg

Published Papers and Presentations Con't

Invited Presentations

1. M. Farah-Stapleton, "Behavioral Modeling of Software System Architectures and Verification & Validation," FAA 10th Annual Verification & Validation Summit, Sep 2015. https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/library/v&vsummit/v&vsummit2015/presentations/V%20and%20V%20and%20Behavorial%20Modeling_Monica%20Farah-Stapleton.pdf
2. M. Farah-Stapleton, and K. Giammarco, "Behavioral Modeling of System Architectures", INCOSE SoS WG Webinar series, Jan 2014.
3. M. Farah-Stapleton, and K. Giammarco, "Behavioral Modeling of Software Intensive System of System Architectures and Emergence," International Forum, OSD Systems Engineering, TTCP TP4 SoS Workstream, May 2014.

Peer Reviewed Technical Posters

1. M. Farah-Stapleton, Technical poster, 2015 SERC Doctoral Students Forum & SERC Sponsor Research Review, Dec 2015.

Invited Article

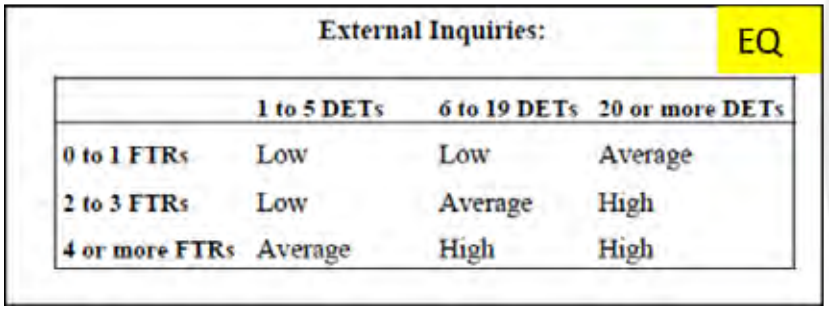
1. M. Farah-Stapleton, Behavioral Modeling of Software Intensive System Architectures Using Monterey Phoenix, CRUSER Newsletter, Dec 2013.

Acronym List

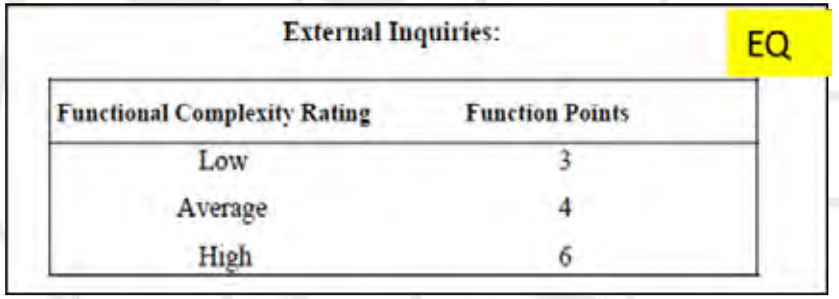
COA	Course of Action
COCOMO II	Constructive Cost Model II
DET	Data Element Type
DOD	Department of Defense
DODAF	DoD Architecture Framework
EI	External Input
EIF	External Interface File
EO	External Output
EQ	External Inquiry
FP	Function Point
FPA	Function Point Analysis
FPC	Function Point Counting
FTR	File Type Referenced
IAA	Internal Abstracted Application
IFPUG	International Function Point User Group
ILF	Internal Logical File
RET	Record Element Type

FPA Calculation
External Inquiry (EQ)

EP	Description	ILF/EIF	FTR/DET	Complexity	UFP
EQ	State Drop Down	Golf Courses (I)	(1,2)	Low	3
EQ	City Drop Down	Golf Courses (I)	(1,3)	Low	3
EQ	Golf Course List	Golf Courses (I)	(1,4)	Low	3
EQ	Golf Course Detail	Golf Courses (I)	(1,12)	Low	3
EQ	Scoreboard Display	Scoreboard (I)	(1,6)	Low	3
EQ	Maintain Golf Course Display (by ID)	Golf Courses (I)	(1,13)	Low	3
EQ	Tee Times Reservation Display	Tee Times (I)	(1,11)	Low	3
EQ	Tee Times Shopping Display	Merchandise (E)	(1,3)	Low	3
EQ	Product View Picture	Merchandise (E)	(1,3)	Low	3


External Inquiries: EQ

	1 to 5 DETs	6 to 19 DETs	20 or more DETs
0 to 1 FTRs	Low	Low	Average
2 to 3 FTRs	Low	Average	High
4 or more FTRs	Average	High	High


External Inquiries: EQ

Functional Complexity Rating	Function Points
Low	3
Average	4
High	6

Source IFPUG Counting Manual Part 2, p.7-19

FPA Calculation
External Input (EI)

EP	Description	ILF/EIF	FTR/DET	Complexity	UFP
EI	Scoreboard (ADD)	Scoreboard (I)	(1,7)	Low	3
EI	Scoreboard (CHANGE)	Scoreboard (I)	(1,7)	Low	3
EI	Scoreboard (DELETE)	Scoreboard (I)	(1,3)	Low	3
EI	Maintain Golf Course (ADD)	Golf Courses (I)	(1,13)	Low	3
EI	Maintain Golf Course (CHANGE)	Golf Courses (I)	(1,13)	Low	3
EI	Maintain Golf Course (DELETE)	Golf Courses (I) Tee Times	(2,3)	Low	3
EI	Tee Times Reservations (ADD)	Tee Times (I)	(1,12)	Low	3
EI	Tee Times Reservations (CHANGE)	Tee Times (I)	(1,12)	Low	3
EI	Tee Times Reservations (DELETE)	Tee Times (I)	(1,6)	Low	3

External Inputs: EI

	1 to 4 DETs	5 to 15 DETs	16 or more DETs
0 to 1 FTRs	Low	Low	Average
2 FTRs	Low	Average	High
3 or more FTRs	Average	High	High

External Inputs EI

Functional Complexity Rating	Function Points
Low	3
Average	4
High	6

Source IFPUG Counting Manual Part 2, p.7-19

FPA Calculation
External Output (EO)

EP	Description	ILF/EIF	FTR/DET	Complexity	UFP
EO	Shopping Display (Calculation)	Merchandise	(1,7)	Low	4
EO	Buy – Send to Purchasing (Calculation)	Merchandise	(1,15)	Low	4

External Outputs : EO

	1 to 5 DETs	6 to 19 DETs	20 or more DETs
0 to 1 FTRs	Low	Low	Average
2 to 3 FTRs	Low	Average	High
4 or more FTRs	Average	High	High

External Outputs: EO

Functional Complexity Rating	Function Points
Low	4
Average	5
High	7

Source IFPUG Counting Manual Part 2, p.7-19

FPA Calculation
Data Functions

Description	ILF/EIF	RET/DET	Complexity	UFP
Golf Course	ILF	(1,11)	Low	7
Tee Times	ILF	(1,10)	Low	7
Scoreboard	ILF	(1,5)	Low	7
Merchandise	EIF	(1,3)	Low	5

Functional Complexity of Each Data Function

	1 to 19 DETs	20 to 50 DETs	51 or more DETs
1 RET	Low	Low	Average
2 to 5 RETs	Low	Average	High
6 or more RETs	Average	High	High

Functional Size of Each Data Function

ILF Translation Table: Use the following table to assign a functional size to each ILF.

Functional Complexity Rating	Function Points
Low	7
Average	10
High	15

ILF

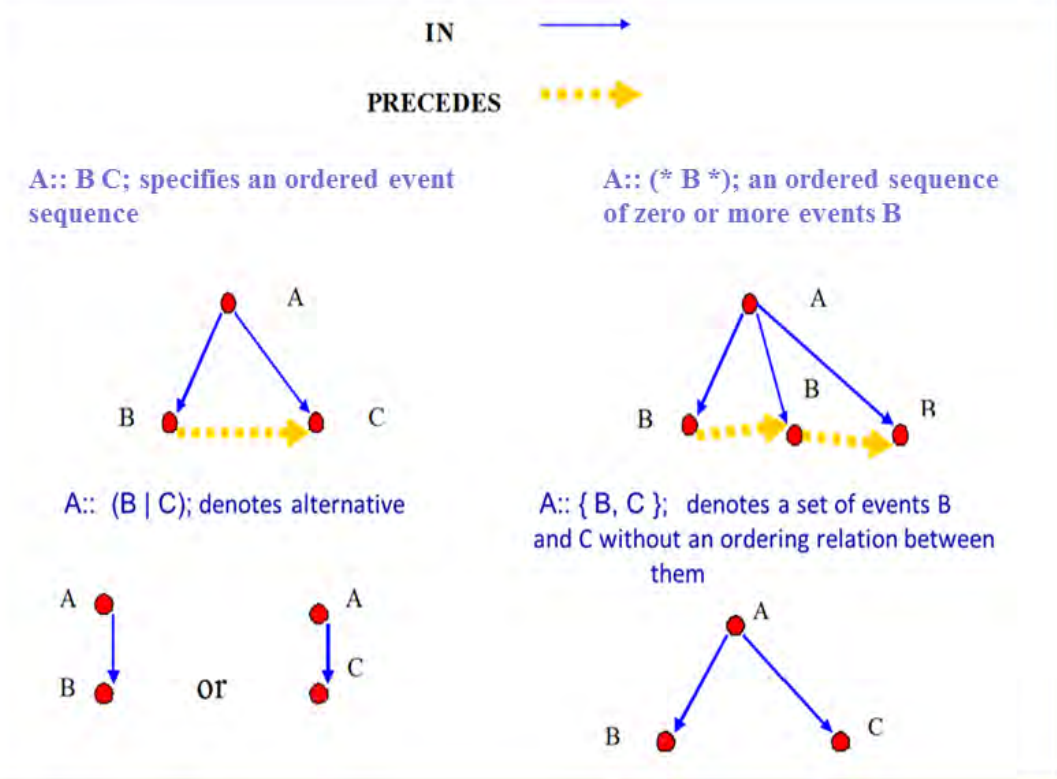
EIF Translation Table: Use the following table to assign a functional size to each EIF.

Functional Complexity Rating	Function Points
Low	5
Average	7
High	10

EIF

Source IFPUG Counting Manual Part 2, p.7-19

Basic Concepts for Monterey Phoenix (MP) Behavioral Modeling



- **Event** - any detectable action in system's or environment's behavior
- **Event trace** - set of events with two basic partial ordering relations, *precedence* (PRECEDES) and *inclusion* (IN)
- **Event grammar** - specifies the structure of possible event traces

Innovations:

- **Uniform Framework:** Describe behaviors and interactions of the system AND environment using the same framework
- **Leverage Small Scope Hypothesis:** Exhaustive search through all possible scenarios (up to the scope limit), expecting that most flaws in models can be demonstrated on small counterexamples
- **Separation of System Interaction from System Behavior**: Specify behavior of each system's components separately from interactions between those components