Ogden Air Logistics Complex

U.S. AIR FORCE

A Software Estimating Model Using Tagged Requirements

Hill Air Force Base

309th Software Maintenance Group

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Objectives

- Determine the Relationship Between Software Requirements and Schedule

- Comprehend Requirement Tags
  - How to isolate and tag requirements
  - How to identify and utilize traceable tags

- Comprehend Process Modeling
  - Reasoning for using models
  - How to get started
  - How to improve and refine models
  - Benefits provided by modeling

Historical Background

- **309th Software Maintenance Group**
  - **Over 1100 engineers, scientists and support personnel**
  - **Providing software support for dozens of weapons and information systems**
- **Created a Successful Software Estimating Model**
  - **Initially for a single weapon system**
  - **Now being deployed on several programs**
  - **Requires historical data – many projects using data collected IAW the Software Engineering Institute's Team Software Process[SM] (TSP[SM])**

SM Team Software Process and TSP are service marks of Carnegie Mellon University

Development Process

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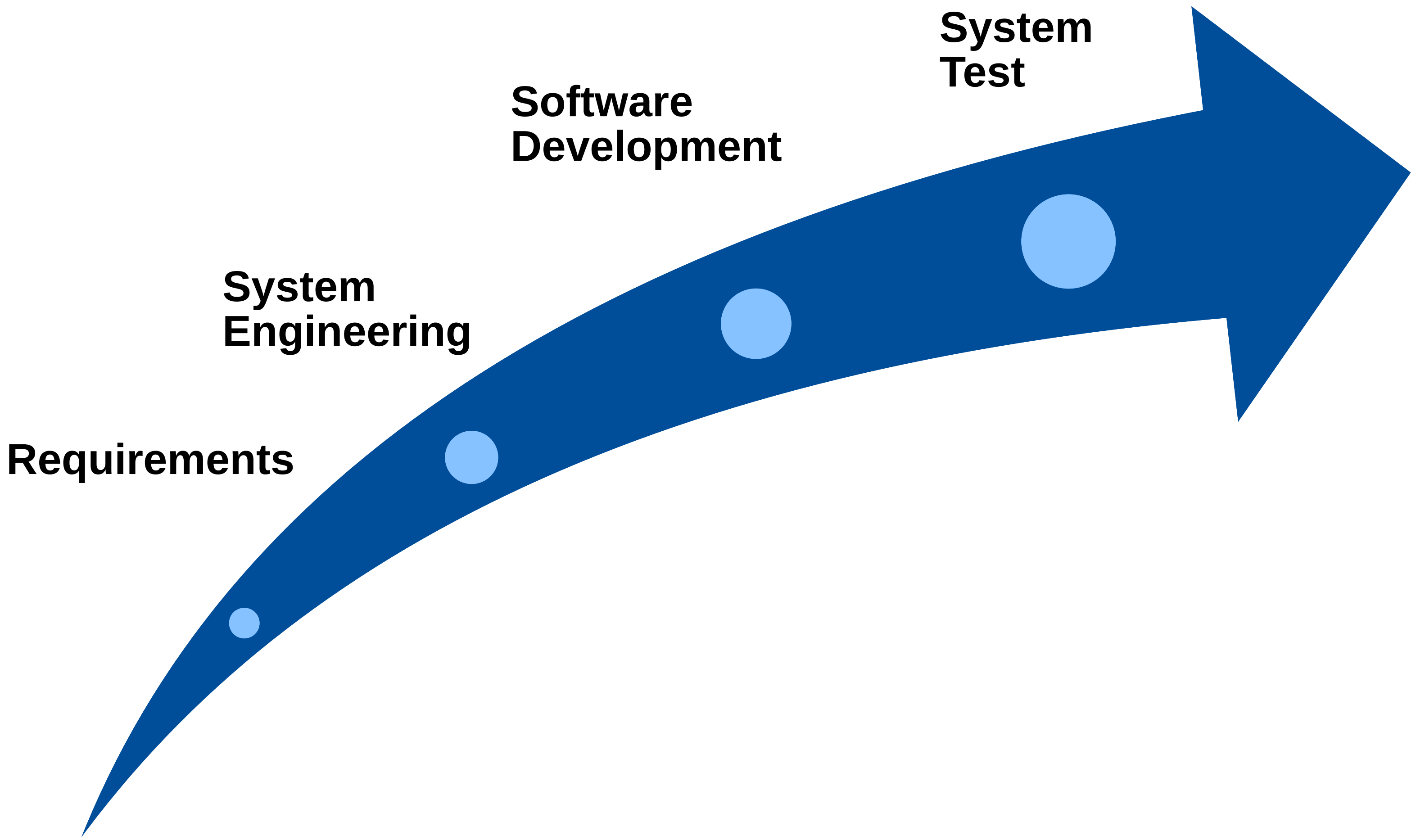

Management Desire

- Provide Accurate Estimates
  - Engineering EFFORT
  - Release SCHEDULE
  - Customer COST

- Establish Estimation Model
  - Utilize objective factors as input
  - Determine key objective factor(s)
  - Keep it simple, quick and accurate

Initial Focus

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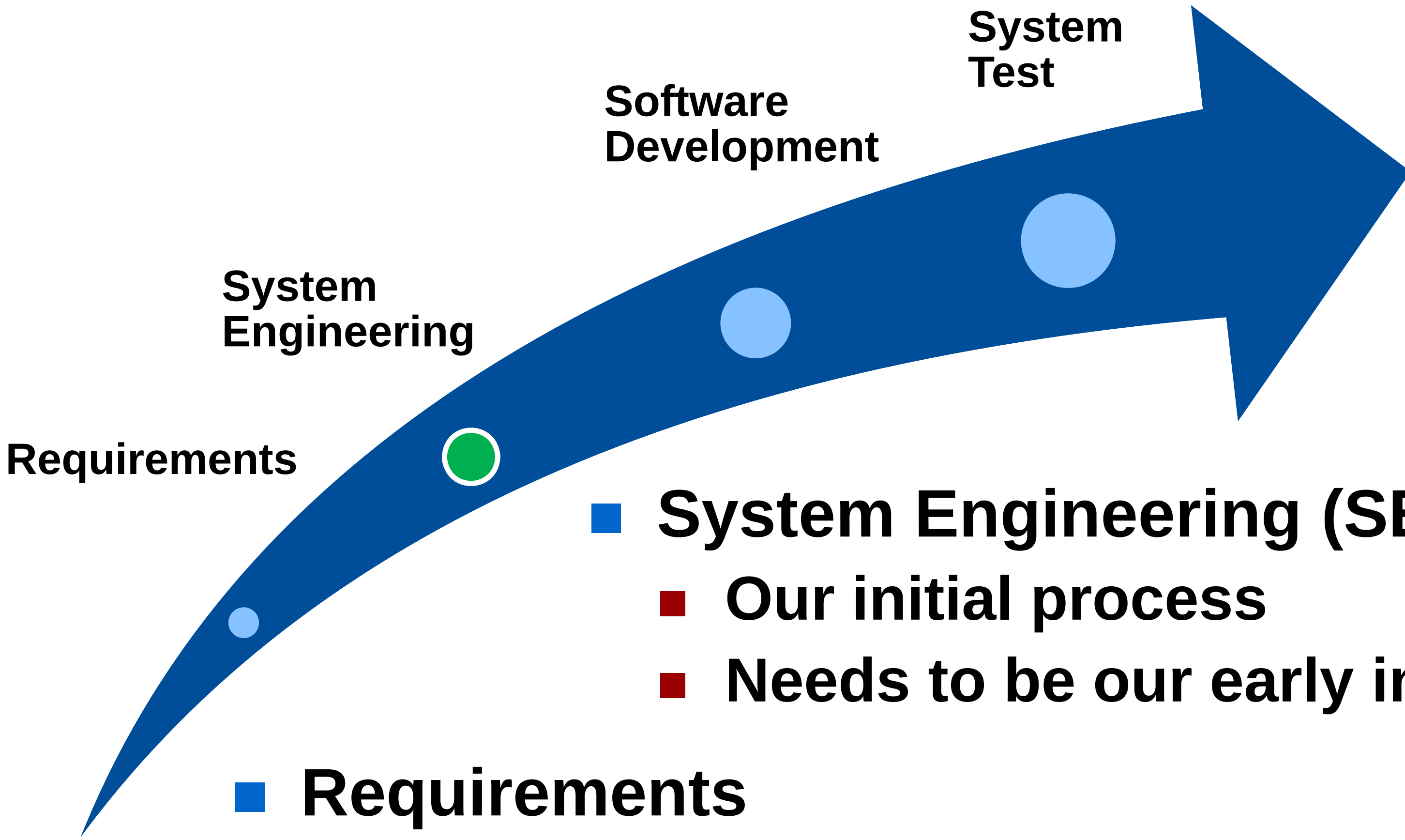

- System Engineering (SE)
  - Our initial process
  - Needs to be our early indicator
- Requirements
  - Provided by the customer/prime contractor
  - Outside of our immediate control

Our Advantages

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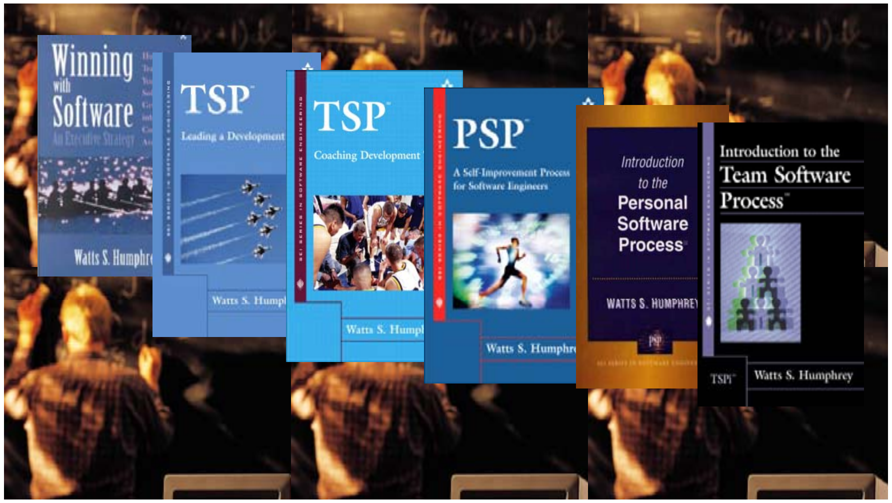
- **Team Software Process℠ (TSP℠)**
  - **In use by the team**
  - **Tools in place to consistently collect data**
  - **Team had historical data**



- **Mature processes**
  - **Organization was CMMI Level 5 certified**
  - **Well defined metrics**
    - **Earned Value Management (EVM)**
    - **Earned Hours: referred to as Task Hours**

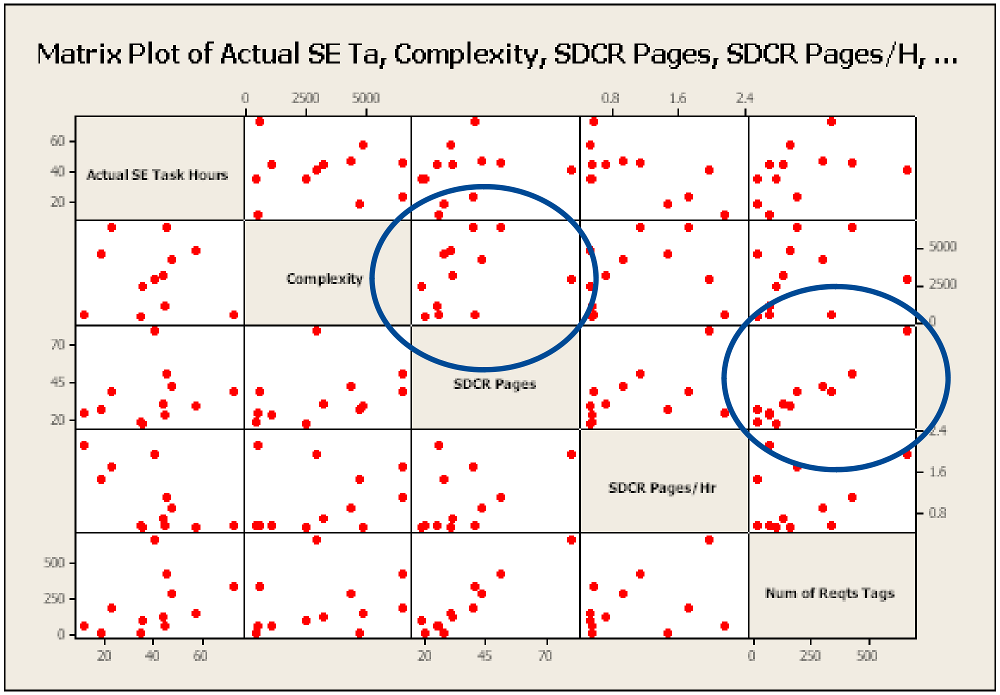
℠ Team Software Process and TSP are service marks of Carnegie Mellon University

SE Historical Data

Build	Candidate	Actual SE Task Hours	Complexity	SDCR Pages	SDCR Hours/Page	Num of Reqts Tags
8.0.3	Control External Cooling Fans	58.00	4875	30	1.93333	154
8.0.3	Control Throttle Override	44.20	1681.0924	31	1.42581	136
8.0.3	Manage SSPC	47.50	4325	43	1.10465	710
8.0.3	Power Up (Initial)	45.77	6500	51	0.89739	638
8.0.3	Power Down (Initial)	22.78	954.8526	39	0.58419	317
8.0.3	Provide Throttle	35.68	1875.2162	18	1.98241	100
8.0.3	Perform Self Test Update	73.23	3451.8562	40	1.83083	385
8.0.4	Manage Hydraullics with Engine Power	34.88	5575.3932	65	0.53667	383
8.0.4	Control Automotive Steering	120.77	3990.87	33	3.6596	140
8.0.4	Control Shifting	111.90	2445	55	2.03455	302
8.0.4	Display Drive Train Data	18.52	4709	27	0.6858	15
8.0.4	Provide ECS Vent	53.27	5575.3932	35	1.5219	205
8.0.4	Control Horn	10.28	295.62	16	0.64271	19
8.0.4	Raise-Lower Ramp	56.67	2813.317	50	1.13333	138
8.0.4	Control Mobility Transition	40.67	2915	80	0.50833	669
8.0.4	Control Bow Flap Lock	35.07	415	19	1.84561	14

Data Relationships

- Several Relationships Looked Intriguing
  - Centered around System Design Change Request (SDCR) pages
  - Found potential



- Key Relationships?
  - Complexity vs. SDCR Pages
  - SDCR Pages vs. Requirements Tags

Complexity Vs. SDCR Pages

- Poor Correlation
  - 14.6% - Low R
  - 8.5% - Low R^2
  - 0.144 - High p

Regression Analysis: Complexity versus SDCR Pages

The regression equation is

Complexity = 1622 + 41.8 SDCR Pages

S = 1835.42   R-Sq = 14.6%   R-Sq(adj) = 8.5% ← *Poor correlation*

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	8055337	8055337	2.39	0.144

- Not suited for estimating purposes

SDCR Pages Vs. Tags

- **Moderate Correlation**
  - **55.1% - Moderate R**
  - **51.9% - Moderate R^2**
  - **0.001 - Low p**

Regression Analysis: SDCR Pages versus Num of Reqts Tags

The regression equation is

SDCR Pages = 24.4 + 0.0560 Num of Reqts Tags

S = 12.1462 R-Sq = 55.1% R-Sq(adj) = 51.9% ← *May be useful for estimating*

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2536.6	2536.6	17.19	0.001

- **May be useful for estimating**

Tags Vs. Hours/Page

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- Regression Analysis Gave Better Correlation
  - 75.6% - Good R
  - 71.8% - Good R^2
  - 0.000 - Excellent p

Regression Analysis: Actual SE Ta versus SDCR Hours/P, Num of Reqts

The regression equation is

*SE Task Hours = - 8.9 + 33.2 *SDCR Hours/Page + 0.0486 *Num of Reqts Tags*

S = 15.9883 R-Sq = 75.6% R-Sq(adj) = 71.8% ← *Much better correlation*

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	10280.8	5140.4	20.11	0.000

- Much better for estimating

Tagging Requirements

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Tag **Requirement**

DOORS ID	UCD Requirements - Lower Ramp
SD450-2370	**2 Flow of Events**
SD450-2371	**2.1 Basic Flow - Lower Ramp**
SD450-2372	**2.1.1 Assumptions**
SD450-2373	Vehicle is not in Water mode or performing a Reconfiguration
SD450-2374	The Engine or APU is running
SD450-2375	**2.1.2 Operator Lowers Vehicle Ramp (SAFETY CRITICAL)**
SD450-2376	**1. Operator selects Lower Ramp**
SD450-2377	The Use Case begins when the Operator selects the Lower Ramp control as defined in the MMI Screen document.
SD450-2378	The System deasserts system fault: RAMP_LOCK_FAILED_TO_UNLOCK**.**
SD450-2379	**2. System checks Vehicle mode**
SD450-2380	The System determines the vehicle is not in Water mode and the Reconfiguration function is not active.
SD450-2381	**3. System checks current ramp state**
SD450-2382	The System determines the current ramp state is Locked. Extends **Monitor Hatches** at **Extension Point: Current Ramp State**.

Traceable Requirements

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Tag

Requirement

Configured Item
Verification Method

Traceable

DOORS ID	UCD Requirements - Lower Ramp	CI	VM
SD450-2370	**2 Flow of Events**		
SD450-2371	**2.1 Basic Flow - Lower Ramp**		
SD450-2372	**2.1.1 Assumptions**		
SD450-2373	Vehicle is not in Water mode or performing a Reconfiguration		
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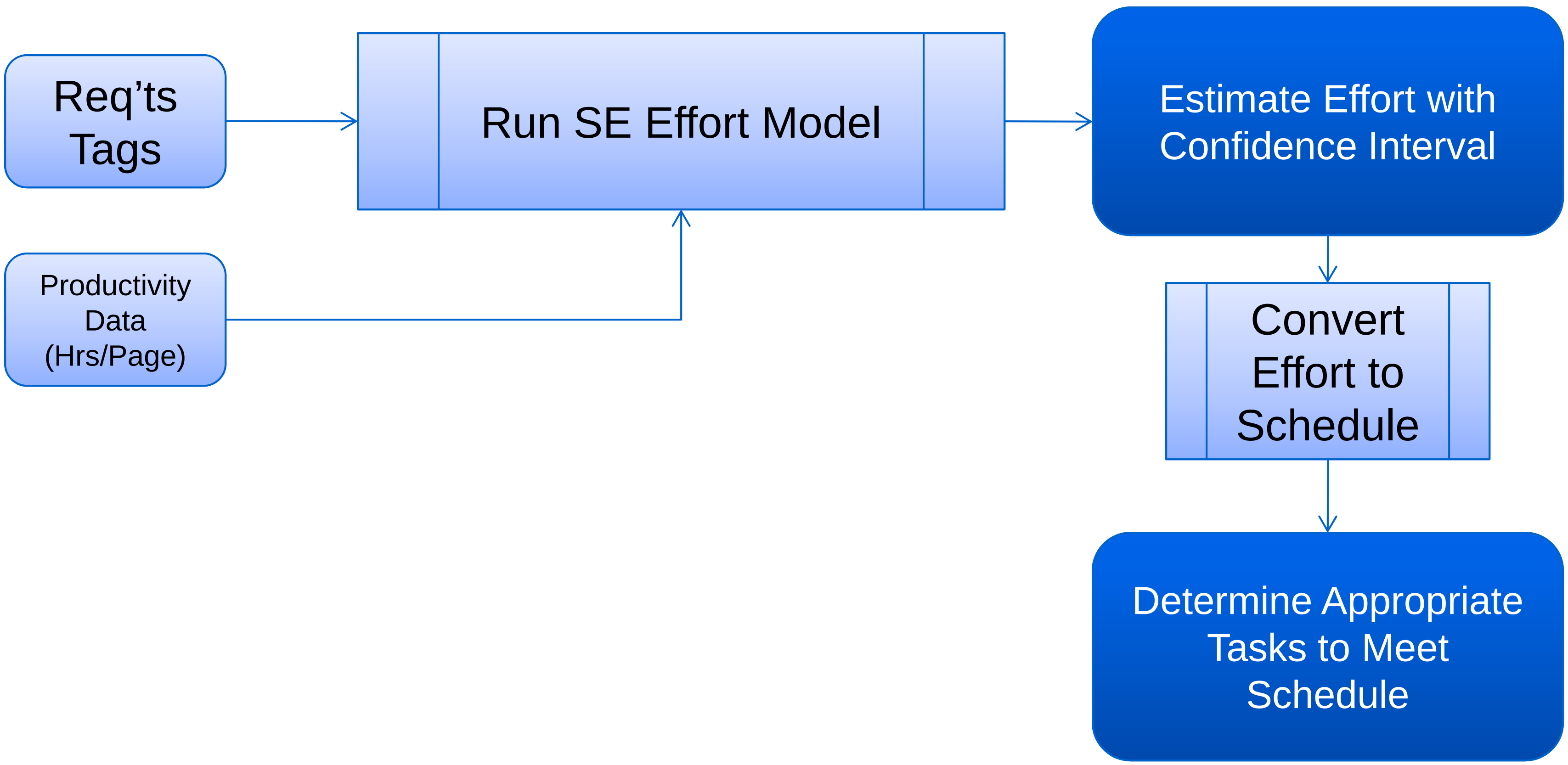
Modeling Effort

- **Establish Model**
  - **Estimate EFFORT in SE task hours**
  - **Use historical SE task hours**
  - **Determine SCHEDULE on SE task hours per week**

- **Adjust For Variation**
  - **Model has an inherent variation**
  - **Use variation to determine confidence**
  - **Provide confident intervals in EFFORT and SCHEDULE**

- **Improve & Refine Model**
  - **Track candidate progress against estimates**
  - **Compare progress with group control limits**
  - **Analyze and adjust**

Determining Effort



Initial Model Failed

- **Model's Performance During Next SE Cycle**
  - **Every SDCR was estimated at 24 task hours!**
  - **Model was overwhelmed**
    - **Average hours/page productivity numbers**
    - **Low initial value and low coefficient value of tags**
  - **Initial model failed the "sniff test"**
- **Model Was Refined**
  - **Used a two-step model, first determining SDCR Pages using Requirements Tags, then calculating hours using productivity (Hours/Page)**
  - **The *Monte Carlo Method* was used to calculate the Hours/Page input, taking into account variability of historical data**
  - **A new and improved model was established:**

Found a great correlation between tagged requirements and design pages

SDCR Pages = 21.8 + 0.0724*Num of Reqts Tags

SE Task Hours = SDCR Hours/Page * SDCR Pages

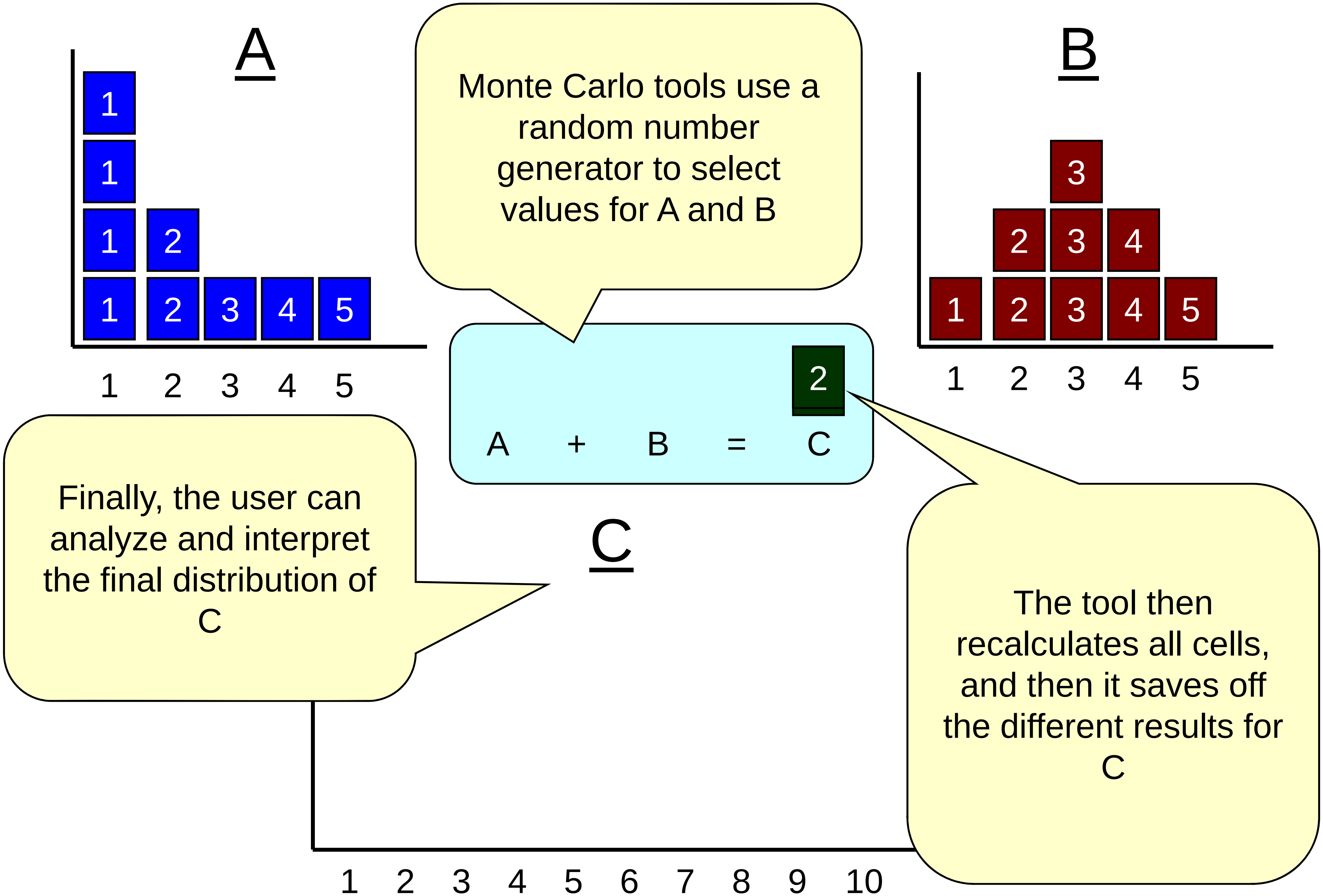
Replaced average productivity with historical distribution

What is the Monte Carlo Method?

- **A technique using random numbers and probability distributions to solve problems**
- **Uses "brute force" computational power to overcome situations where solving a problem analytically would be difficult**
  - **Iteratively applies random numbers to the probability distributions in a behavior model for hundreds or thousands of times to determine an expected solution**
  - **First extensively studied during the Manhattan project, where it was used to model neutron behavior**

How Does Monte Carlo Work?

- **Monte Carlo Steps**
  1. **Create a parametric model**
  2. **Generate random inputs**
  3. **Evaluate the model and store the results**
  4. **Repeat steps 2 and 3 (x-1) more times**
  5. **Analyze the results of the x runs**



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Refined Model Data

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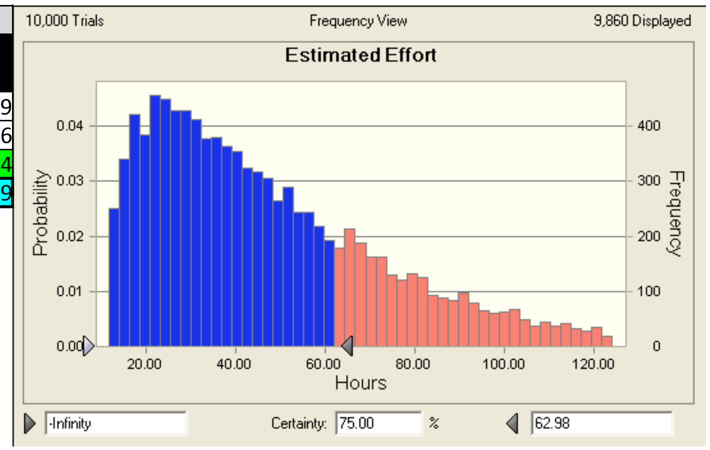
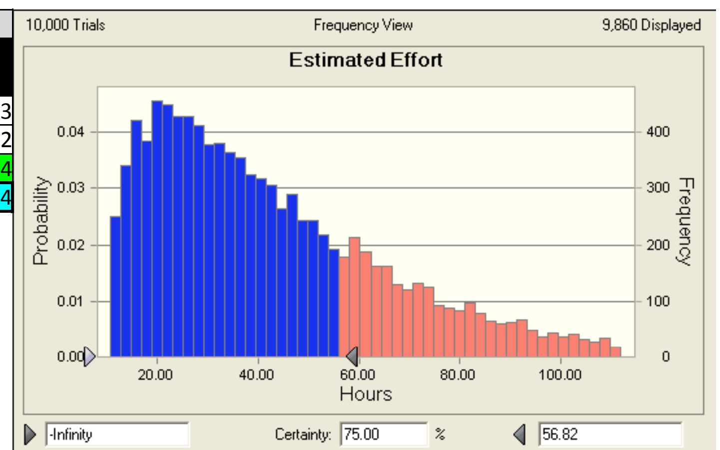
Parameters	Coefficients	Inputs
Candidate Name:	Control Auto Bilge	
Constant	21.8	
Number of Requirements Tags	0.0724	169
Est. SDCR Pages		34.0356
SDCR Hour/Pages		1.395444
Estimated SE Effort		47.49479

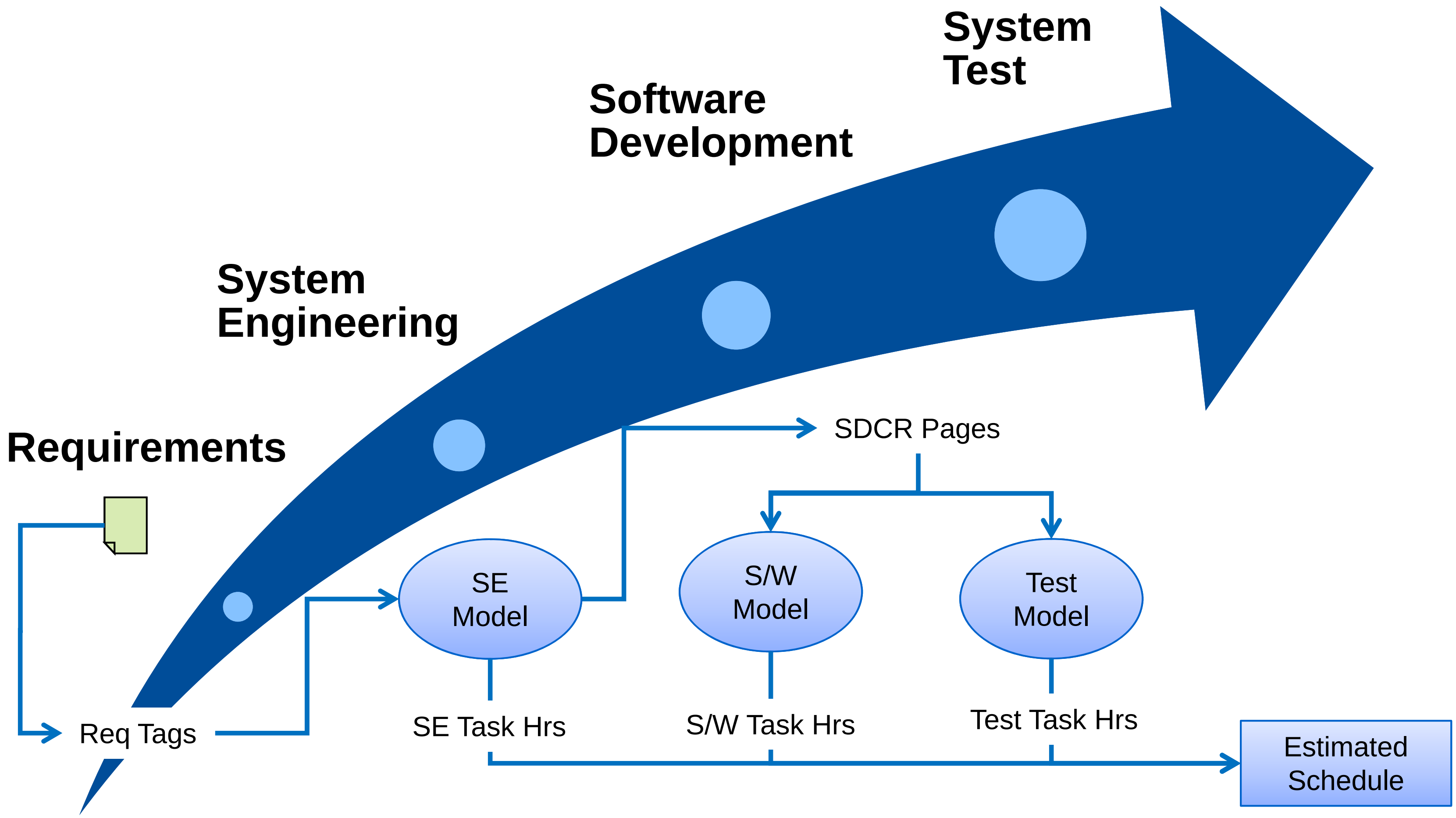


Variable input from historical Hrs/Page distribution

Parameters	Coefficients	Inputs
Candidate Name:	Control Manual Bilge	
Constant	21.8	
Number of Requirements Tags	0.0724	123
Est. SDCR Pages		30.7052
SDCR Hour/Pages		1.395444
Estimated SE Effort		42.8474



Early Process Correlation



Early Process Findings

- Collecting the metrics from previous build, compared the calculated effort to the actual effort.
  - Found that for the easier candidates that the level of effort was good.
  - As the requirements became more complex, it was taking more effort that model predicted.
- Determined that more refinement was needed to model.

Continuous Model Refinement

To refine the size of SE work for a release, the following was taken into consideration:

- **The number of traceable requirements to be implemented**
- **The SDCR size based upon the number of requirements to be implemented**

  (range: 1=small to 3=large)
- **The maturity of the requirements**

  (range: 1=low to 3= high)
- **Complexity of the requirements**

  (range: 1=low to 5=high)

Adjusting for Complexity

- **Complexity is Non-linear**
  - **Data analysis of historical data determined that the complexity factor determined above had a non-linear relationship to the SE Task Hours**
  - **Using the previous candidates, the new model was applied and the complexity multiplier determined as follows:**

Complexity Factor	Complexity Multiplier
1	1
2	0.9375
3	0.875
4	0.8125
5	0.75

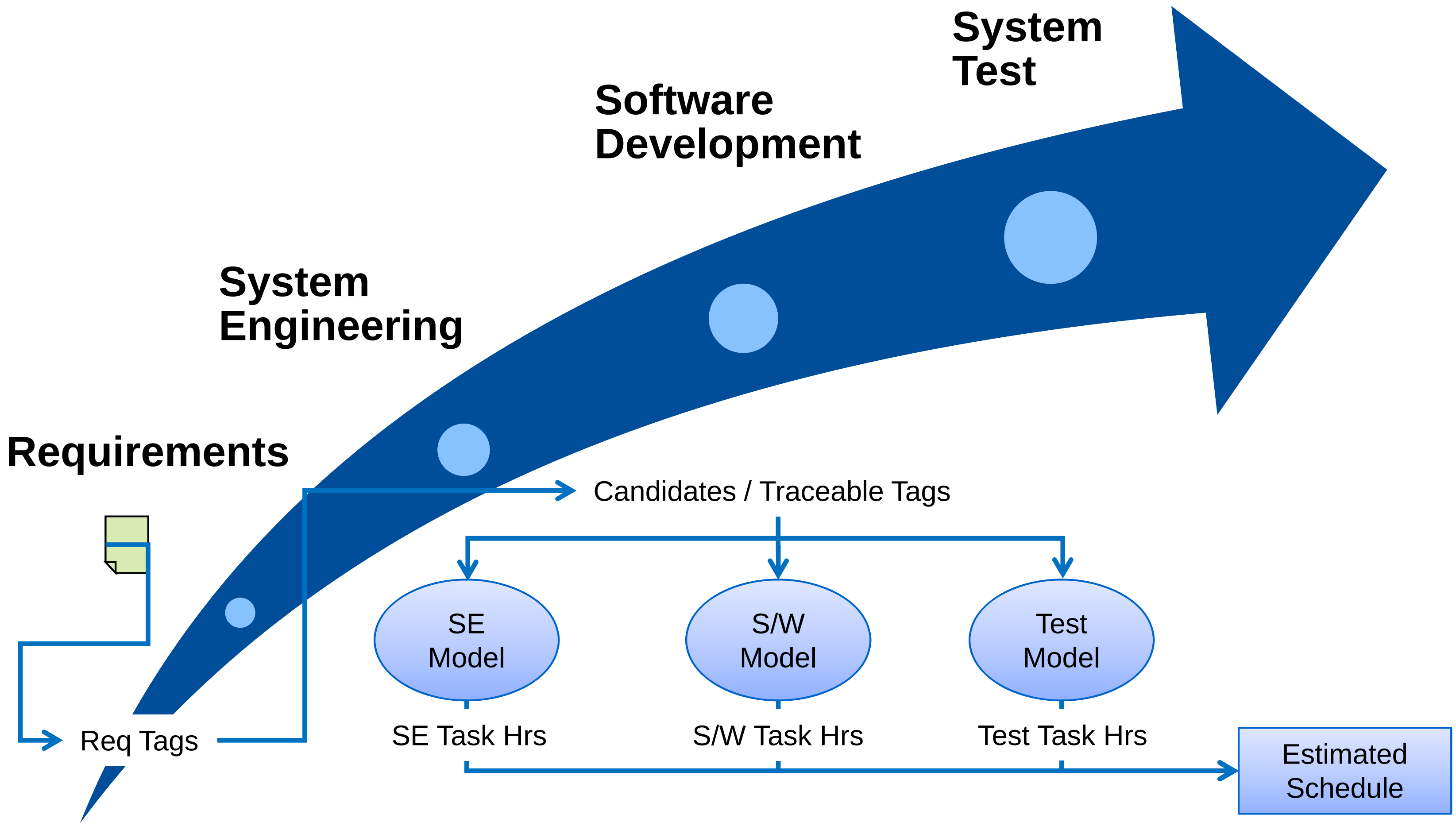
Current Model

- **Using the Complexity Multiplier and the Maturity provided the most accurate Task Hours estimate for SE**

Size	Maturity	SE Effort
1	1	(12.5 x 1.5 x 1.5)/Complexity Multiplier
2	1	(12.5 x 2 x 1.5)/Complexity Multiplier
3	1	(12.5 x 2.5 x 1.5)/Complexity Multiplier
N/A*	2	(15 + Number of requirements to implement)/(3.67 X Complexity Multiplier)
N/A*	3	(10 + Number of requirements to implement)/(3.67 x Complexity Multiplier)

*Size was not a factor for those items with Maturity 2 or 3

Refined Process Correlation



Development Process Estimates – Task Hours

- **Development Task Hours**
  - **Development Task Hours were estimated using SE Task Hours**
  - **Historical data analysis indicated that SE Task Hours had a linear correlation to Software Development Task Hours**

  *DEV Task Hours = SE Task Hours *(7/3)*

- **System Test Task Hours**
  - **System Test Task Hours were estimated using traceable requirements tags (just like SE)**
  - **Historical data analysis determined a linear relationship using a "complexity multiplier"**

  *ST Task Hours = (((0.12 * Traceable Requirements)/Complexity Multiplier) + 20)*

Development Process Estimates – Schedule

- **Schedule Directly Correlated to Task Hours**
  - **Historical data showed that Task Hours accounted for about 30% of the overall effort**
  - **Scheduled Person Hours were estimated for each group by adding all the Task Hours for a group and then dividing by 0.3**

  Scheduled Person Hours = Total Task Hours / 0.3

  - **A simple calculation dividing the resulting Scheduled Person Hours by 40 hours per week per person provided the Schedule Weeks**

  Schedule Weeks = Scheduled Person Hours / 40

Final Estimating Model

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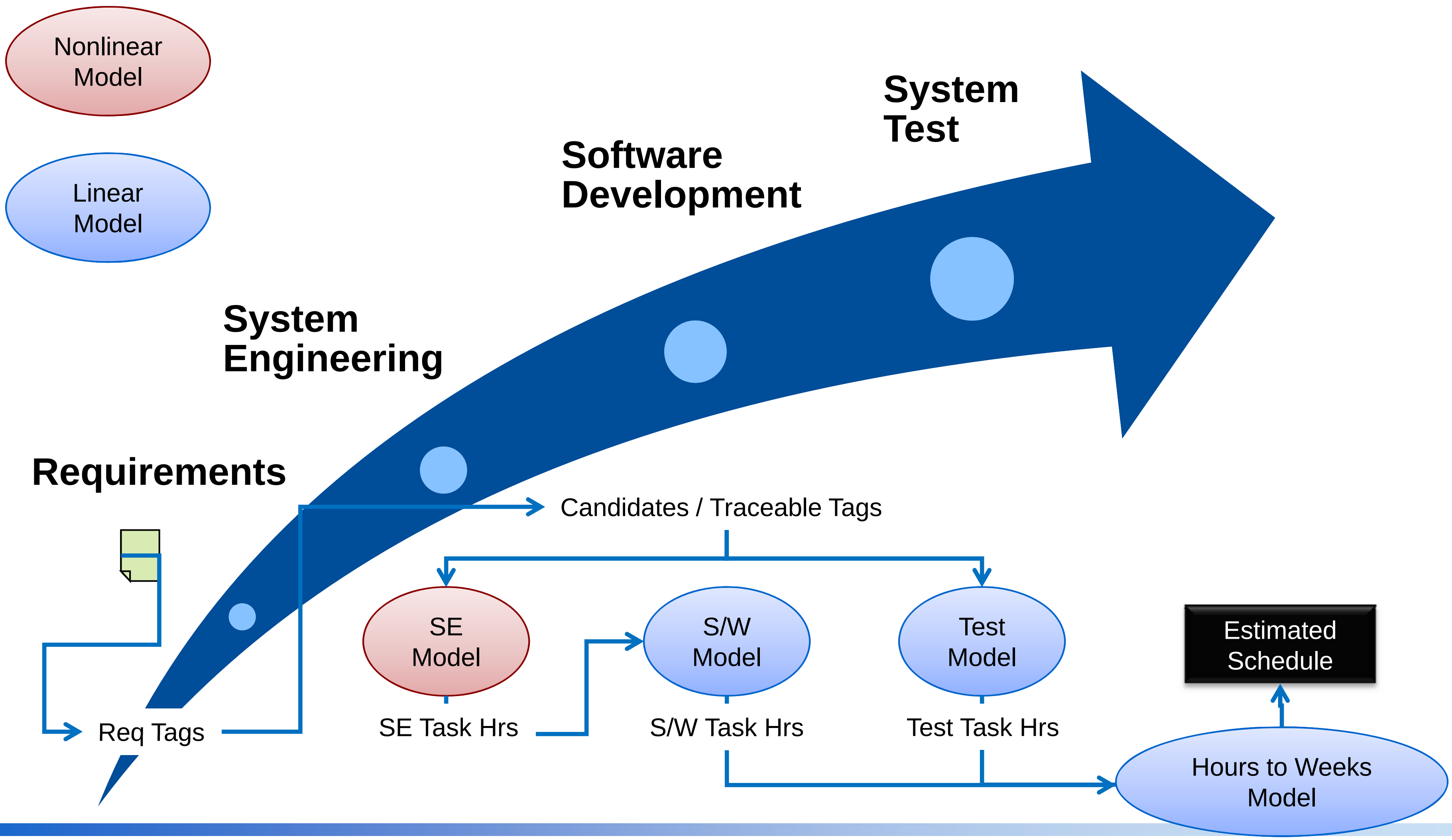

Summary

- **Hill Air Force Base Created a Successful Software Development / Maintenance Estimating Model**
  - **Determined by examining historical data**
  - **Initial model failed**
  - **Iterative refinements improved accuracy**
- **Effort Estimates Could be Determined Early On**
  - **Used tagged requirements**
  - **Linear and nonlinear models with confidence intervals developed**
- **Schedule Estimates Derived from Effort Estimates**

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