



Secure Software Development Levels and Costs

Barry Boehm

Elaine Venson

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Outline

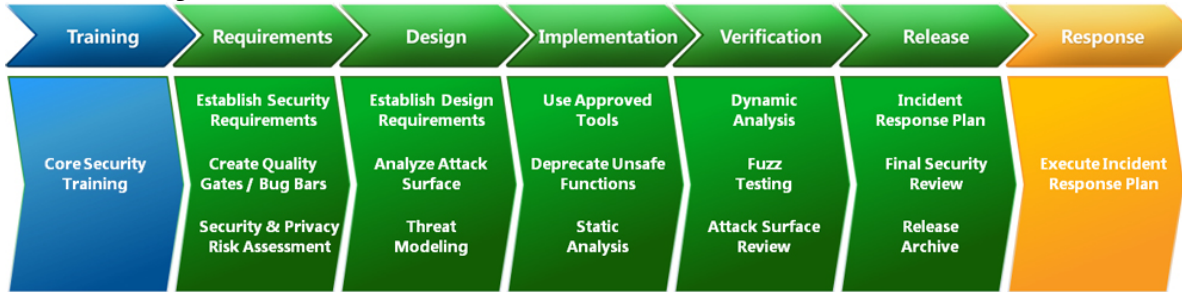
- Secure Software Development Costs
- Scale Development
- Resulting Estimates from Security Experts
- Next Steps

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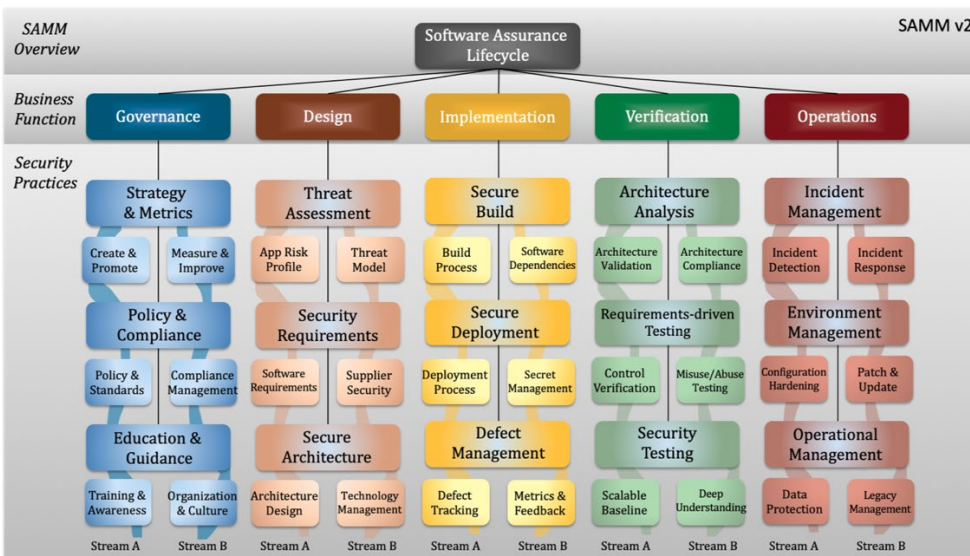
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Secure Software Development

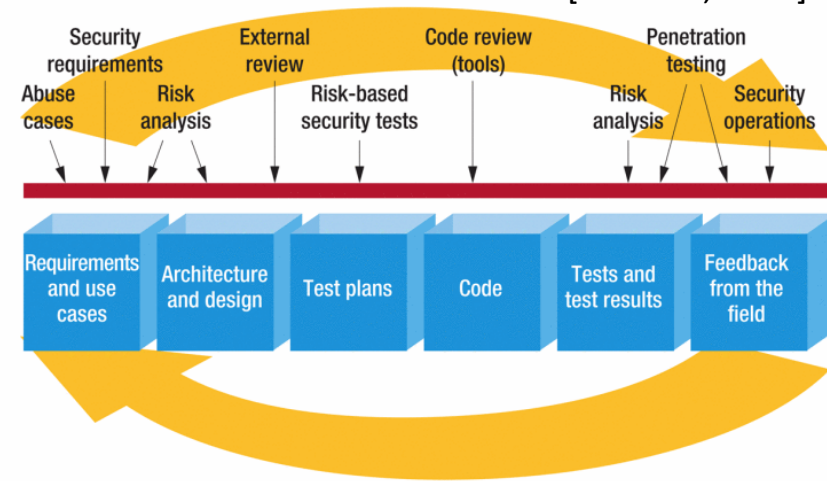
Microsoft SDL <https://www.microsoft.com/>



OWASP SAMM <https://owasp samm.org/>



Touchpoints
[McGraw, 2011]



Software Security as a Trade-off



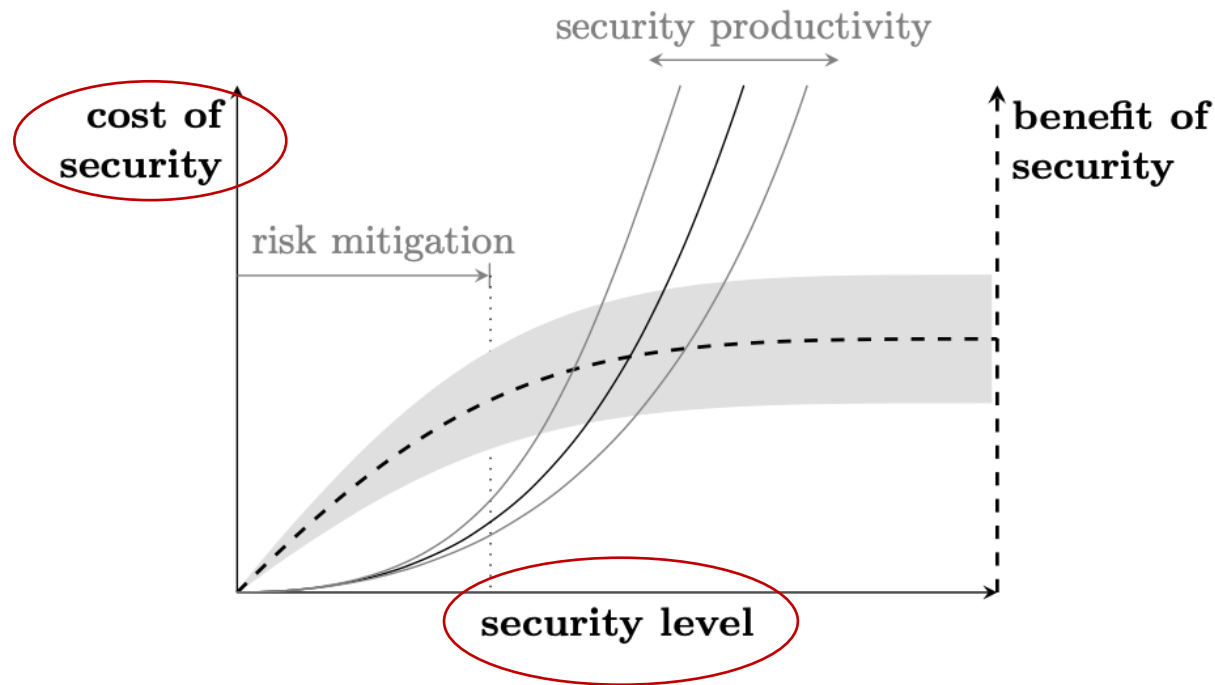
Costs

- Higher fixing costs
- Patching
- Down-time
- Recovery costs
- Reputation loss
- Expertise
- Tools
- Training
- Improving processes
- Investment in early phases

Benefits

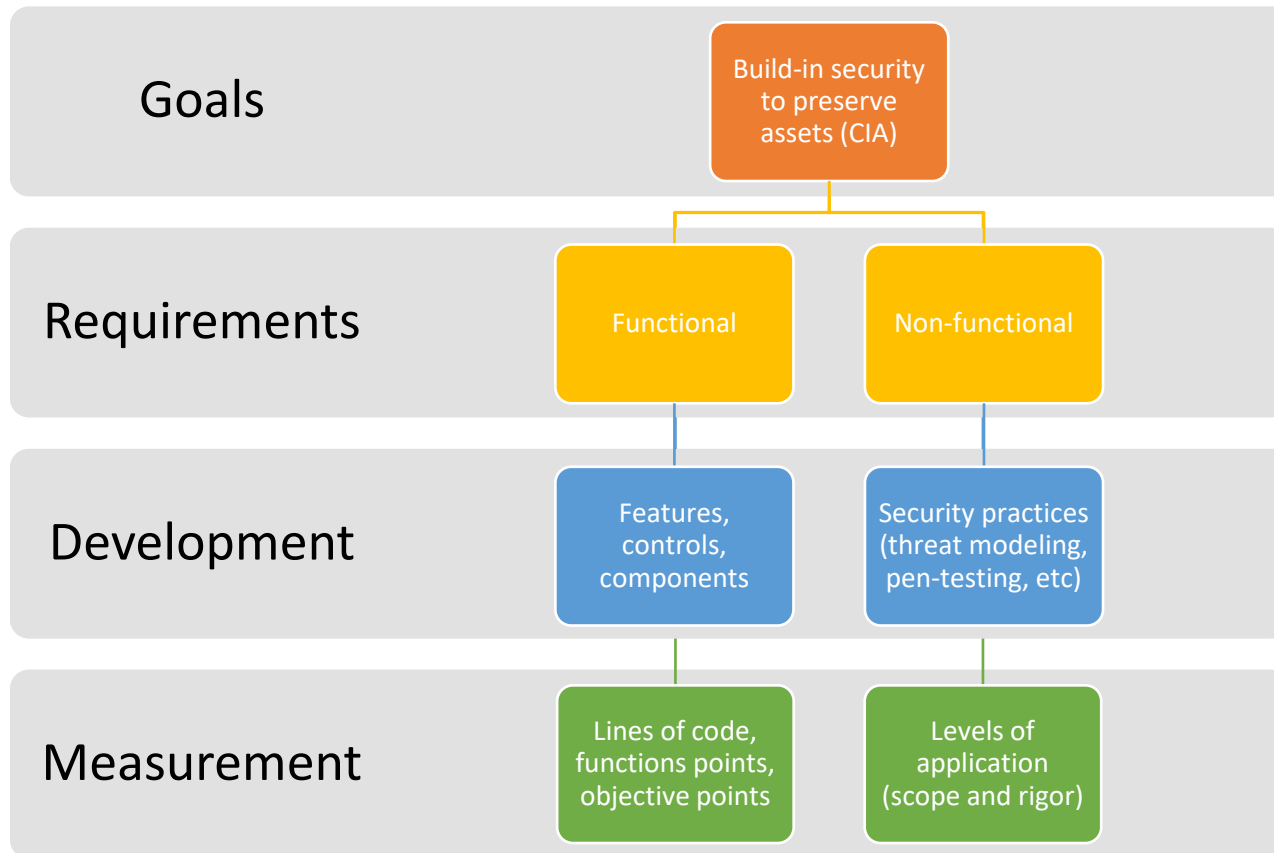
- Priority to features
- Better time to market
- Vulnerabilities prevention/detection
- Avoided risks
- Reduced total cost

The right amount of security



Böhme, R., 2010. Security Metrics and Security Investment Models, in: Echizen, I., Kunihiro, N., Sasaki, R. (Eds.), Advances in Information and Computer Security.

Costs of SecSw Development



Measuring SecSw Development

Measurement	Lines of code, functions points, objective points	Levels of application (scope and rigor)
	<p><i>Security Features Size:</i></p> <ul style="list-style-type: none">• Directly estimated using sw sizing methods, or• Estimated using a Security Sizing Factor	<p><i>Secure Sw Dev Level:</i></p> <ul style="list-style-type: none">• Development of an <i>ordinal scale</i> based on application of software security practices – Secure Software Development Scale

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Secure Software Development Scale

- Ordinal scale defining degrees of application of security practices
- Scale items development based on:
 - Literature
 - BSIMM (Building Security in Maturity Model)
 - OWASP SAMM (Software Assurance Maturity Model)
 - COCOMO descriptors of attribute levels

Software Security Practices

Apply Security Requirements	Consider and document security concerns prior to implementation of software features.
Apply Data Classification Scheme	Maintain and apply a Data Classification Scheme. Identify and document security-sensitive data, personal information, financial information, system credentials.
Apply Threat Modeling	Anticipate, analyze, and document how and why attackers may attempt to misuse the software.
Document Technical Stack	Document the components used to build, test, deploy, and operate the software. Keep components up to date on security patches.
Apply Secure Coding Standards	Apply (and define, if necessary) security-focused coding standards for each language and component used in building the software.
Apply Security Tooling	Use security-focused verification tool support (e.g. static analysis, dynamic analysis, coverage analysis) during development and testing.
Perform Security Testing	Consider security requirements, threat models, and all other available security-related information and tooling when designing and executing the software's test plan.
Perform Penetration Testing	Arrange for security-focused stress testing of the project's software in its production environment. Engage testers from outside the software's project team.
Perform Security Review	Perform security-focused review of all deliverables, including, for example, design, source code, software release, and documentation. Include reviewers who did not produce the deliverable being reviewed.
Publish Operations Guide	Document security concerns applicable to administrators and users, supporting how they configure and operate the software.
Track Vulnerabilities	Track software vulnerabilities detected in the software and prioritize their resolution.
Improve Development Process	Incorporate "lessons learned" from security vulnerabilities and their resolutions into the project's software development process.
Perform Security Training	Ensure project staff are trained in security concepts, and in role-specific security techniques.

Morrison, P., Smith, B.H., Williams, L., 2017. Surveying Security Practice Adherence in Software Development, in: Proceedings of the Hot Topics in Science of Security: Symposium and Bootcamp, HoTSoS. ACM, New York, NY, USA, pp. 85–94.

Scale Development

Practices Levels' Description

Practices Grouping

Practices Summarization

Tasks, Practice & Activities	Characteristics for SECU ratings	Degree	Address nature coding	Address common vulnerabilities	Address common and/or control vulnerabilities	Address all known vulnerabilities and weaknesses
Apply Vulnerability Scanning	Standards coverage	Basic (not performed), moderate, extensive (proper use of APIs, memory addresses, control flow)	Address nature coding	Address common vulnerabilities	Address all known vulnerabilities and weaknesses	Coding to address all known vulnerabilities and weaknesses
Perform Security Testing	Testing rigor and coverage	Basic testing (single edge cases, and boundary conditions), low testing (derived from requirements and security features), moderate (in-line analysis with security coverage, comprehensive tests derived from abuse cases, compliance and threat derived from abuse cases)	Ad-hoc security testing	Basic adversarial testing	Moderate adversarial testing (derived from security risks)	Extensive adversarial testing (derived from security risks and attack patterns)
Apply Security Testing	Test suite	Basic test configurations, customized test suites, able to detect malicious code	Basic use of static analysis and penetration testing tools to identify security defects	Use of static analysis, penetration testing and security testing tools with standard tests	Extensive use of static analysis, penetration testing and security testing tools with standard tests	Rigorous use of static analysis, penetration testing and security testing tools with standard tests
Perform Security Review	Review rigor and coverage	Ad-hoc (not done), moderate (high risk code, systematic code review for high risk code, systematic code review for high risk code, systematic code review for high risk code, systematic code review for high risk code)	Ad-hoc security feature code review	Moderate security code review	Systematic security code review	Extensive security code review
Task Vulnerability Management	Resolution coverage	Ad-hoc (not done), moderate (high risk code, systematic code review for high risk code, systematic code review for high risk code, systematic code review for high risk code)	Ad-hoc vulnerability tracking and fixing	Regular vulnerability tracking and fixing	Systematic vulnerability tracking and fixing	Extensive vulnerability tracking and fixing
Apply Security Requirements	Requirements specification	General, based on business functionality, based on known risks, based on specific threat models	Basic security requirements derived from business functionality and compliance drivers	Comprehensive security requirements derived from business functionality, compliance drivers and known risks	Extensive security requirements derived from business functionality, compliance drivers and known risks	Systematic security requirements derived from business functionality, compliance drivers and known risks
Improve Software Development Process	Improvement frequency	Ad-hoc (not done), moderate (high risk code, systematic code review for high risk code, systematic code review for high risk code, systematic code review for high risk code)	Regular improvements driven by vulnerability reduction	Systematic improvements driven by vulnerability reduction	Extensive improvements driven by vulnerability reduction	Systematic improvements driven by vulnerability reduction
Perform Penetration Testing	Penetration testing frequency	Before shipping, for each release, periodic	Ad-hoc penetration testing	Regular penetration testing (each release)	Frequent penetration testing (each release)	Deep-dive analysis and regular penetration testing
Document Technical Skills	Control security of third components	Basic (identify and test third components), moderate (identify and test third components), extensive (identify and test third components)	Ad-hoc technical skills documentation	Moderate technical skills documentation	Systematic technical skills documentation	Extensive technical skills documentation
Apply Threat Modeling	Attack information	Based on general attack profiles, with specific adversarial modeling (e.g. adversarial modeling based on known risks)	Ad-hoc threat modeling	Regular threat modeling	Frequent threat modeling	Deep-dive analysis and regular threat modeling
Apply Data Classification Scheme	Data classification scheme	Single data classification scheme (high risk data)	Single data classification scheme	Multiple data classification schemes	Comprehensive data classification schemes	Extensive data classification schemes
Perform Security Training	Training level and coverage	General awareness, role-specific, advanced (role-specific, operational and security certified training)	Security awareness training	Role-specific training	Advanced (role-specific, operational and security certified training)	Extensive (role-specific, operational and security certified training)
Publish Operations Guide	Coverage	Basic (critical security information for deployment), moderate (operational and security information for deployment), extensive (operational and security information for deployment)	Regular operations guide with critical security information for deployment	Moderate operations guide with critical security information for deployment	Extensive operations guide with critical security information for deployment	Systematic operations guide with critical security information for deployment

Task	Practices	Characteristics for SECU ratings	Low	Nominal	High	Very High	Extra High
Requirements and Design	Apply Security Requirements	Requirements specification	Ad-hoc security requirements	Basic security requirements derived from business functionality	Moderate security requirements derived from business functionality, compliance drivers and known risks	Complex security requirements derived from business functionality, compliance drivers and application-specific security risks	Extreme security requirements derived from business functionality, compliance drivers and application-specific security risks
	Security Features	Scope and rigor	None	Build basic security features (authentication, role management, key management, audit/log, cryptography, protocols)	Build additional security features (authentication, role management, key management, audit/log, cryptography, protocols)	Build secure-by-design middleware for security features (authentication, role management, key management, audit/log, cryptography, protocols)	Build container-based approaches for security features (authentication, role management, key management, audit/log, cryptography, protocols)
Coding	Apply Threat Modeling	Attack information	None	Ad-hoc threat modeling	Apply threat modeling with generic attack profiles	Apply threat modeling using new attack models developed with a science team	Apply threat modeling using new attack models developed with a science team
	Apply Secure Coding Standards	Standards coverage	Ad-hoc secure coding	Address common and off-nominal vulnerabilities	Address all vulnerabilities and some weaknesses	Coding to address all known vulnerabilities and weaknesses	Rigorous use of static analysis, penetration testing and black-box security testing tools with tailored rules
Verification and Validation	Perform Security Testing	Testing rigor and coverage	Ad-hoc security testing	Basic adversarial testing	Moderate adversarial testing driven by security risks and security features	Extensive adversarial testing driven by security risks and attack patterns	Rigorous adversarial testing driven by security risks and attack patterns
	Perform Security Review	Review rigor and coverage	Ad-hoc security features code review	Basic security features code review	Moderate security code review	Systematic security code and design review	Systematic security code and design review
Coding	Apply Security Tooling	Tools usage	Casual use of standard static analysis tool to identify security defects	Basic use of static analysis tool to identify security defects	Routine use of static analysis and penetration testing tools to identify security defects	Extensive use of static analysis, penetration testing and black-box security testing tools with tailored rules	Rigorous use of static analysis, penetration testing and black-box security testing tools with tailored rules
	Perform Penetration Testing	Penetration testing	Ad-hoc penetration testing	Basic penetration testing (each release)	Frequent penetration testing (each release)	Deep-dive analysis and regular penetration testing	Systematic penetration testing (each release)

Practices Type	Practices	Characteristics for SECU ratings	Low	Nominal	High	Very High	Extra High
Requirements and Design	Security requirements (derived from business functionality)	Security requirements (derived from business functionality)	Ad-hoc security requirements	Basic security requirements derived from business functionality	Moderate security requirements derived from business functionality, compliance drivers and known risks	Complex security requirements derived from business functionality, compliance drivers and application-specific security risks	Extreme security requirements derived from business functionality, compliance drivers and application-specific security risks
Other	None	None	None	None	None	None	None
Coding and Tooling	Secure coding standards	Standards coverage	Ad-hoc secure coding	Address common and off-nominal vulnerabilities	Address all vulnerabilities and some weaknesses	Coding to address all known vulnerabilities and weaknesses	Rigorous use of static analysis, penetration testing and black-box security testing tools with tailored rules
Verification and Validation	Security testing	Testing rigor and coverage	Ad-hoc security testing	Basic adversarial testing	Moderate adversarial testing driven by security risks and security features	Extensive adversarial testing driven by security risks and attack patterns	Rigorous adversarial testing driven by security risks and attack patterns
Summary	Security requirements, secure coding standards, security testing, security review, security training, security operations guide	Security requirements, secure coding standards, security testing, security review, security training, security operations guide	Ad-hoc security requirements, security testing, security review, security training, security operations guide	Basic security requirements, secure coding standards, security testing, security review, security training, security operations guide	Moderate security requirements, secure coding standards, security testing, security review, security training, security operations guide	Complex security requirements, secure coding standards, security testing, security review, security training, security operations guide	Extreme security requirements, secure coding standards, security testing, security review, security training, security operations guide

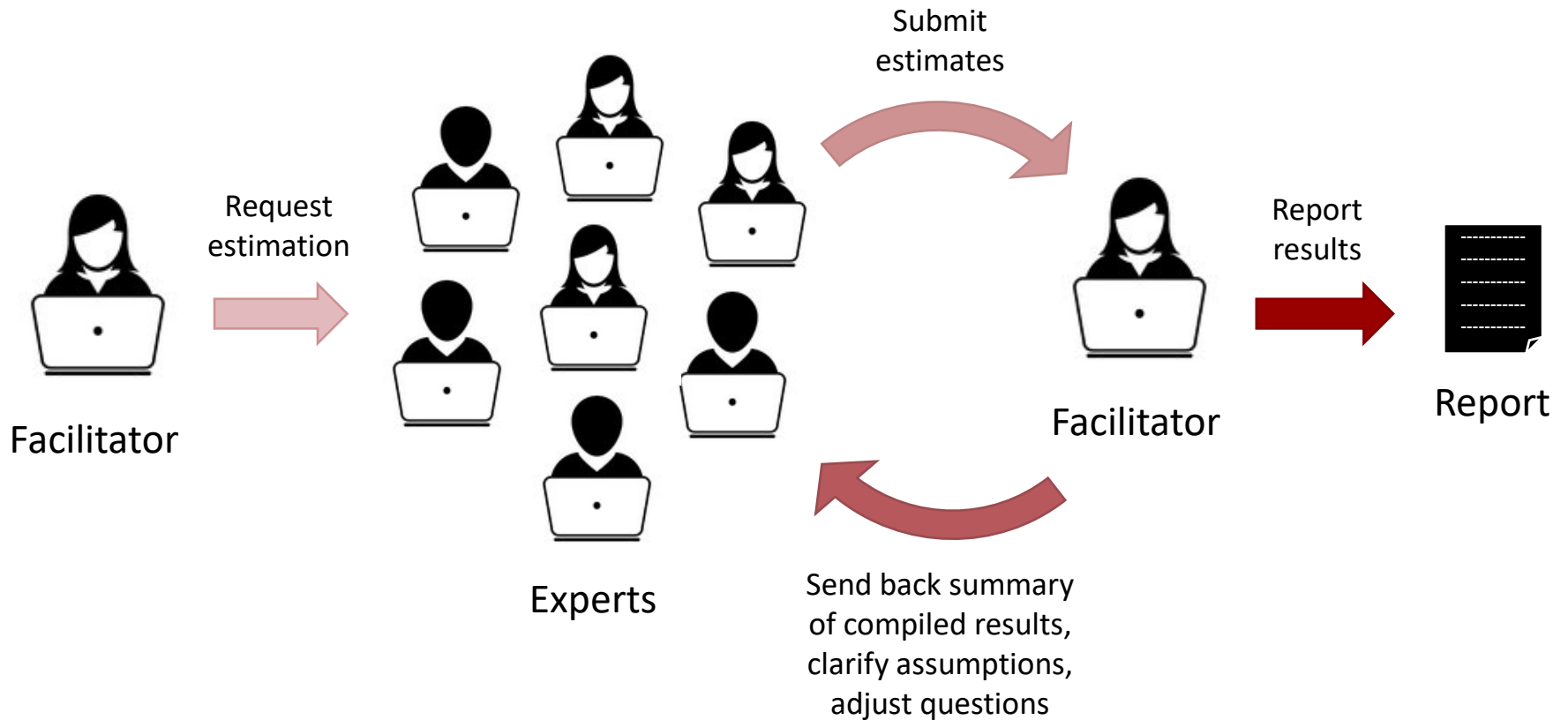
Resulting Rating Scale

Security Requirements and Security Design	Secure Coding and Security Tools	Security Verification and Validation (V&V)
LEVEL 0 None	LEVEL 0 No secure coding and no use of static analysis tool.	LEVEL 0 None
LEVEL 1 Basic analysis to identify security requirements. Basic threat modeling.	LEVEL 1 Basic vulnerabilities applicable to the software will be prevented with secure coding standards and/or detected through basic use of static analysis tools.	LEVEL 1 Basic adversarial testing and security code review. Basic penetration testing. Security V&V activities conducted within the project.
LEVEL 2 Additional analysis to identify security requirements such as audit/log, cryptography, etc. Moderate threat modeling.	LEVEL 2 Known and critical vulnerabilities applicable to the software will be prevented with secure coding standards and/or detected through routine use of static analysis tools.	LEVEL 2 Moderate adversarial testing and security code review. Routine penetration testing. Security V&V activities conducted by an independent group.
LEVEL 3 Thorough analysis to identify security requirements, advanced secure-by-design needs. Threat modeling with specific attack strategies.	LEVEL 3 Extensive list of vulnerabilities and weaknesses applicable to the software will be prevented with secure coding standards and/or detected through extensive use of static analysis and black-box tools.	LEVEL 3 Extensive adversarial testing and security design/code review. Frequent and specialized penetration testing. Security V&V activities conducted by an independent group at the organizational level.
LEVEL 4 Extensive analysis to identify security requirements, including off-nominal cases, container-based approaches for advanced security features development. Rigorous threat modeling.	LEVEL 4 Very extensive list of vulnerabilities and weaknesses applicable to the software will be prevented with secure coding standards and/or detected through rigorous use of static analysis and black-box security testing tools with tailored rules. Employ formal methods in coding.	LEVEL 4 Rigorous adversarial testing and security design/code review. Exhaustive deep-dive analysis penetration testing. Use of formal verification and custom developed V&V tools. Security V&V activities conducted by an outside certified company.

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Online Delphi

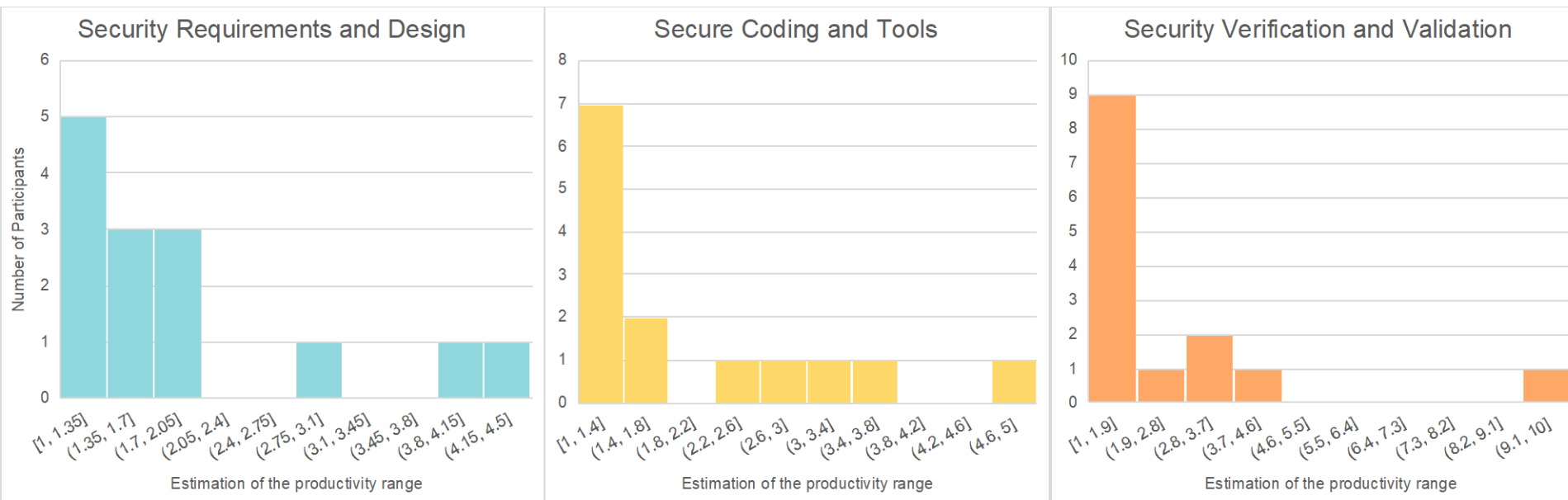


Results from online Delphi

- September 2020
- Participants invited from the Software Security Group on LinkedIn
- 2 rounds
 - 17 participants
 - 14 participants
- 10.88 years average experience with Secure Software Development
- 11.06 years average experience with Software Estimation

Productivity Range*

Histograms for each group of security practices



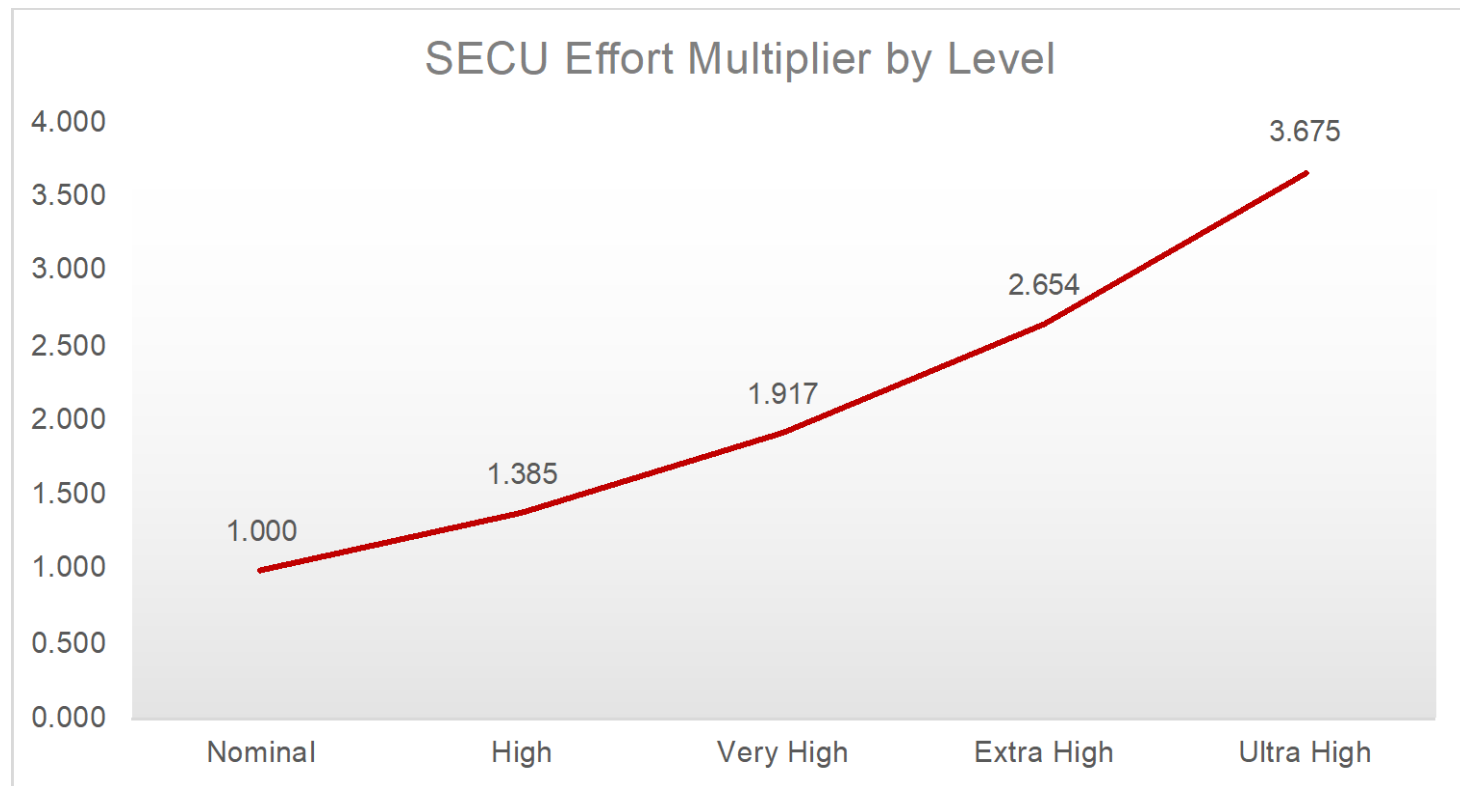
* Productivity range is the ratio between the highest level (Level 4) and the lowest level of the scale (Level 0).

Productivity Range

Group	Average	Median	Standard Deviation	Coefficient of Variation
Requirements and Design	1.957	1.5	1.093	56%
Coding and Tools	2.046	1.4	1.193	58%
Verification and Validation	2.561	1.75	2.335	91%
Productivity Range	10.256	3.675		

Added Effort by Security Level

Based on median productivity range



Increase in Application Size

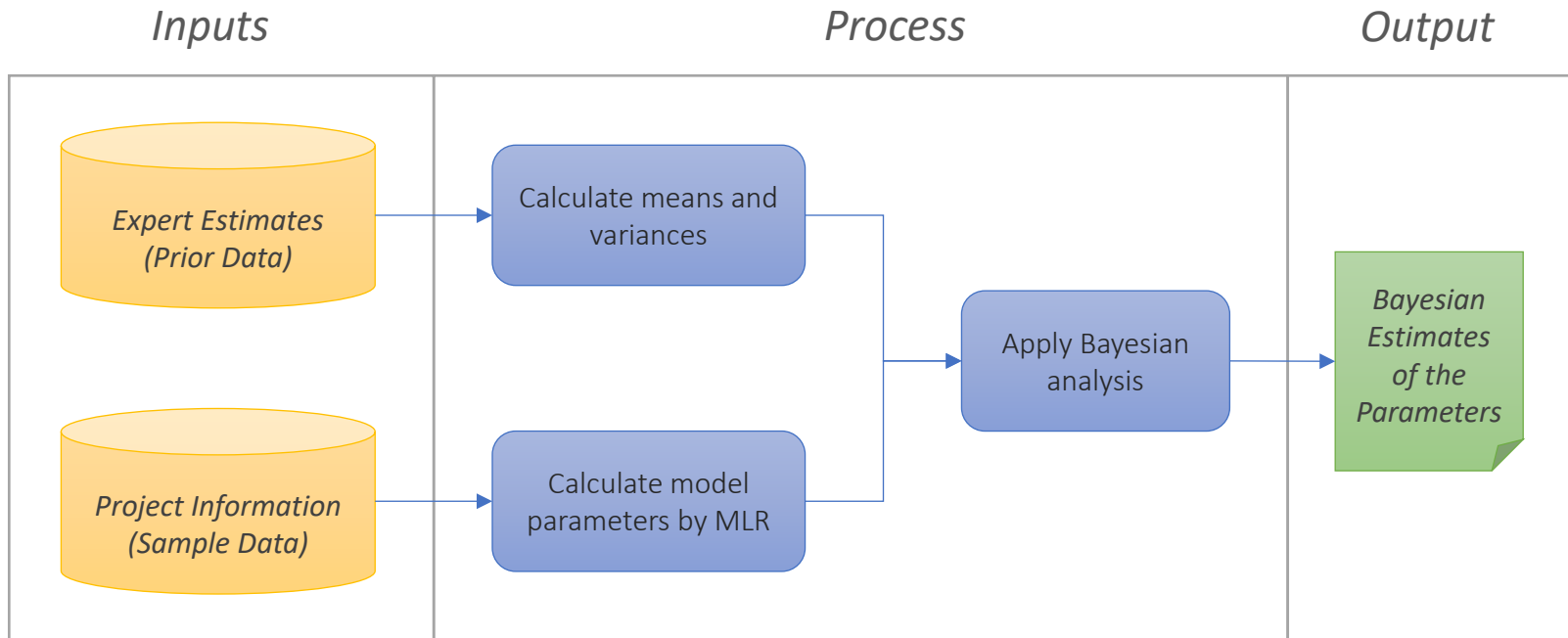
Estimates from 14 participants (only in 2nd round)

	L1 High	L2 Very High	L3 Extra High	L4 Ultra High
Average	1.170	1.393	1.668	1.914
Median	1.100	1.250	1.500	1.675
Std Deviation	0.125	0.366	0.590	0.839
Coefficient of Variation	11%	26%	35%	44%

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Cost Estimation Model Building



Proposed Cost Model Form

- Original COCOMO II equation

$$Effort = A \cdot Size^E \cdot \prod_{i=1}^n EM_i$$

- Addition of the parameter for secure software development level, and adjusted size:

$$Effort = A \cdot \textit{Size}^E \cdot \textit{SECU} \cdot \prod_{i=1}^n EM_i$$

Includes Security
Functional Features

Effort multiplier for secure
software development level

Data Collection



Security experts' estimates for the security parameter



Estimation experts' estimates for the security parameter



Wideband Delphi



Projects' Data



Manual Data Collection Form



Projects' Data



Automated Data Collection



Projects' Data



Survey OSS developers

Poll - Get involved!

- 1) Participate in an online Delphi study
 - Share your estimates and assumptions anonymously
 - Compare your your estimates with other participants
- 2) Participate in data collection
 - Provide sanitized data
 - Receive a version of the model calibrated for your organization

Contact: Elaine Venson
venson@usc.edu

Contact: Brad Clark (COCOMO III Project Coordinator)
clarkbk@usc.edu



Thank you!

Barry Boehm
boehm@usc.edu

Elaine Venson
venson@usc.edu

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