A CER-Based Software Cost Estimating Model For Space Applications

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Contents

- Objective
- Data Base Development
- Model Development
- Summary

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Purpose

- In-House Understanding of Costs of Space-Related Software Aids Management Decision Making
- CER-Based Models Overcome Disadvantage of Relying Solely on Commercially Available Models into Whose Data Bases the User has No Visibility
- FY94 Task Funded by Corporate Internal Research Program to
  - Develop data base of historical cost, schedule data on space-related software
  - Identify software cost, schedule drivers
  - Apply data base to derive cost, schedule estimating relationships

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Data Base Development

- Evaluate Existing Software Development Data from
  - AF Space and Missile Systems Center (SMC) Software Development Data Base (SDDB), maintained by MCR Federal, Inc.
  - Space Systems Cost Analysis Group (SSCAG - Joint AF/NASA/ESA Working Group)
  - Institute for Defense Analyses
- Establish Data Fields Defining Data Base Structure
- Construct Historical-Cost Data Base, Including
  - Technical characteristics of software projects
  - Costs
  - Schedules
- Assimilate New Data

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Functional Classifications

- **Operational Environment**
  - **Military Ground**
  - **Avionics**
  - **Military Mobile**
  - **Unmanned Space**
  - **–**

- **Software Applications**
  - **Command/Control**
  - **Signal Processing**
  - **–**
  - **Data Base**
  - **Simulation**
  - **–**
  - **Mission Planning**
  - **Support**
  - **–**
  - **Operating System (OS) / Executive**
  - **Test**
  - **–**

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Data Base Format

RECORD	SOURCE	SLOC	LANG	EFFORT (DM)	SCHEDULE (MONTHS)	OPR ENV	APPL
1	SDDB 9	128200	JOV	2254	40.8	G	CMD/CNTL
2	SDDB18	70143	FORT	1093	32.0	G	CMD/CNTL
3	SDDB50	71676	FORT	1122	32.3	G	CMD/CNTL
4	SDDB55	96059	JOV	1544	36.3	G	CMD/CNTL
5	•	•	•	•	•	•	•
6	•	•	•	•	•	•	•
7	•	•	•	•	•	•	•
8							
9							
10							
11							
12							
13							
14							
15							

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Data Record Summary

APPLICATION	ENVIRONMENT			
	MILITARY GROUND	MILITARY MOBILE	MIL-SPEC AVIONICS	UNMANNED SPACE
Command/Control	30	6	4	19
Data Base	5	1		6
Mission Planning	7			3
OS/Executive	2			1
Signal/Processing	17	2	2	10
Simulation	8			
Support	22	2		
Test	11	1		7
Sub-Totals	102	12	6	46
Total Data Base Size = 166				

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Effort vs. Source Code Size

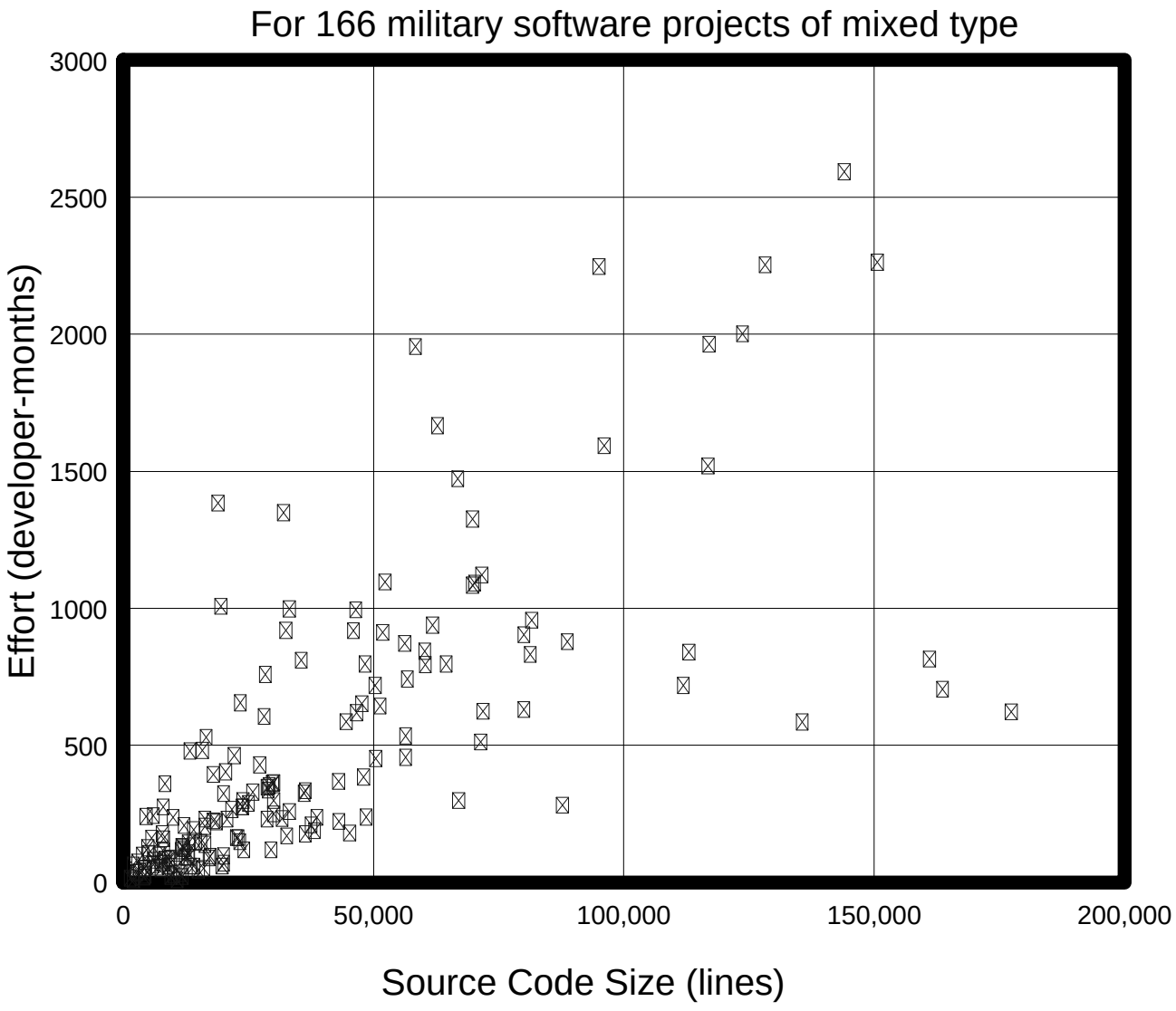

Chart date 11/3/95
Based on 166 military software projects.

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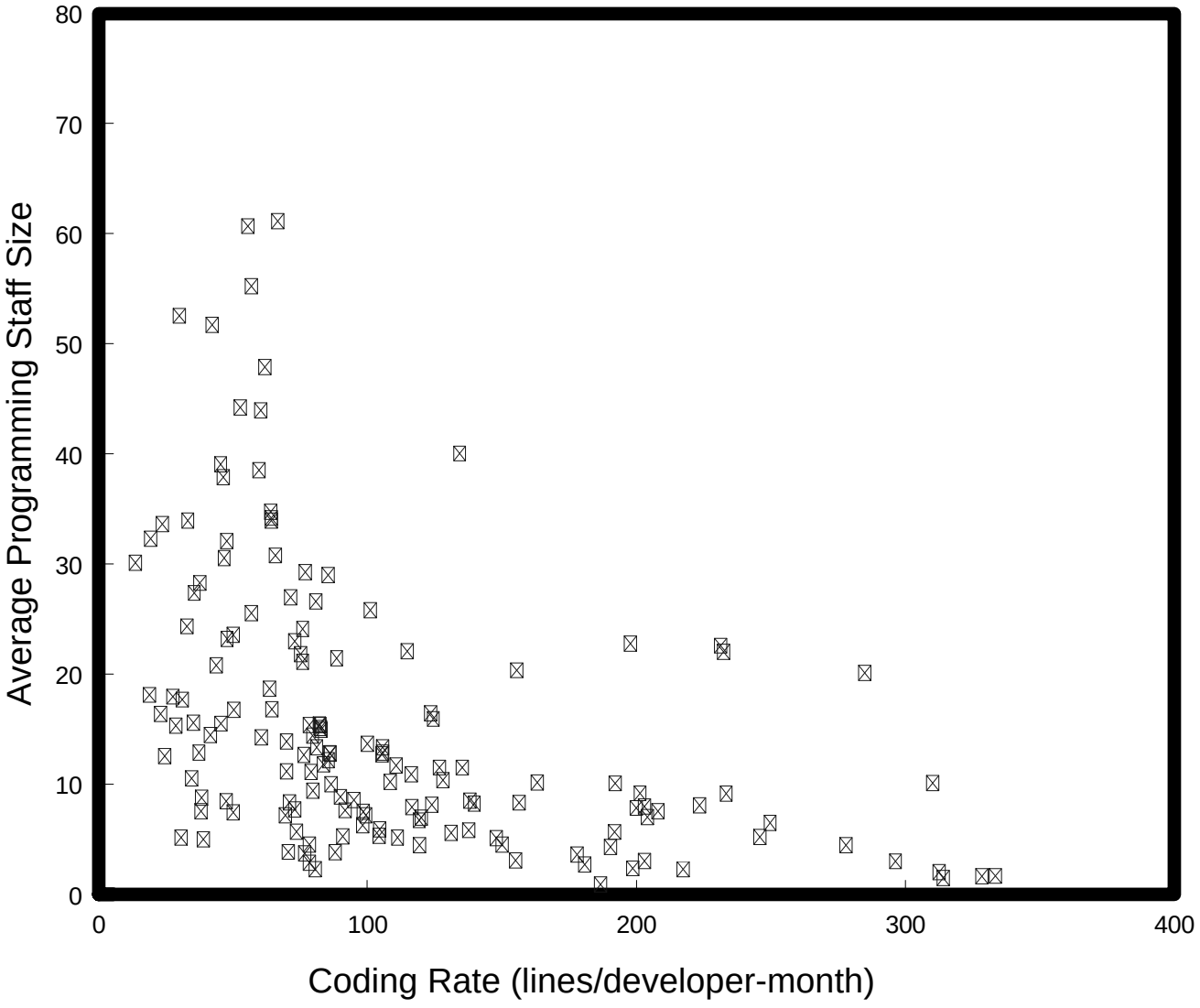
Staff Size vs. Coding Rate



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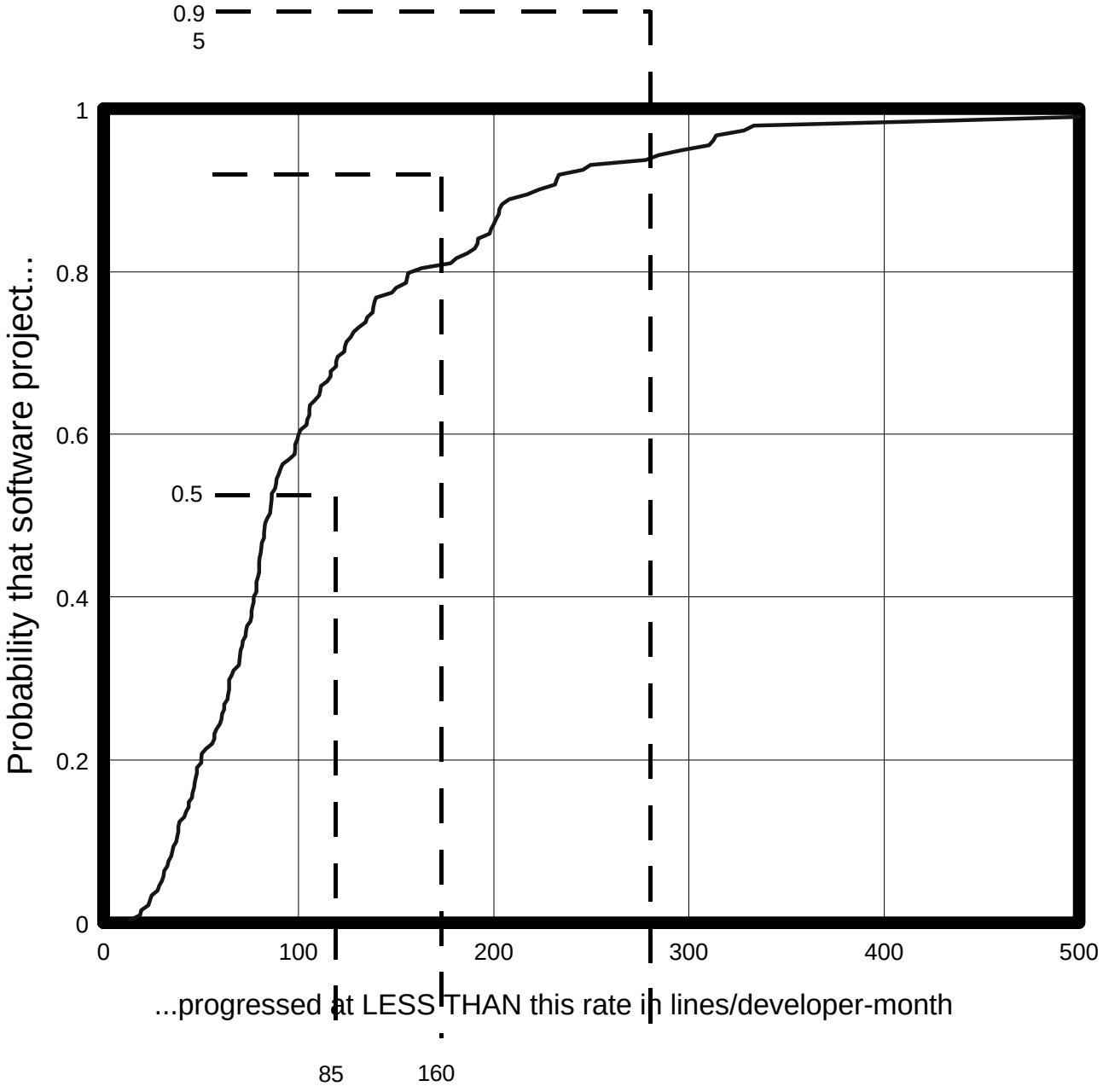
Distribution of Software Coding Rates



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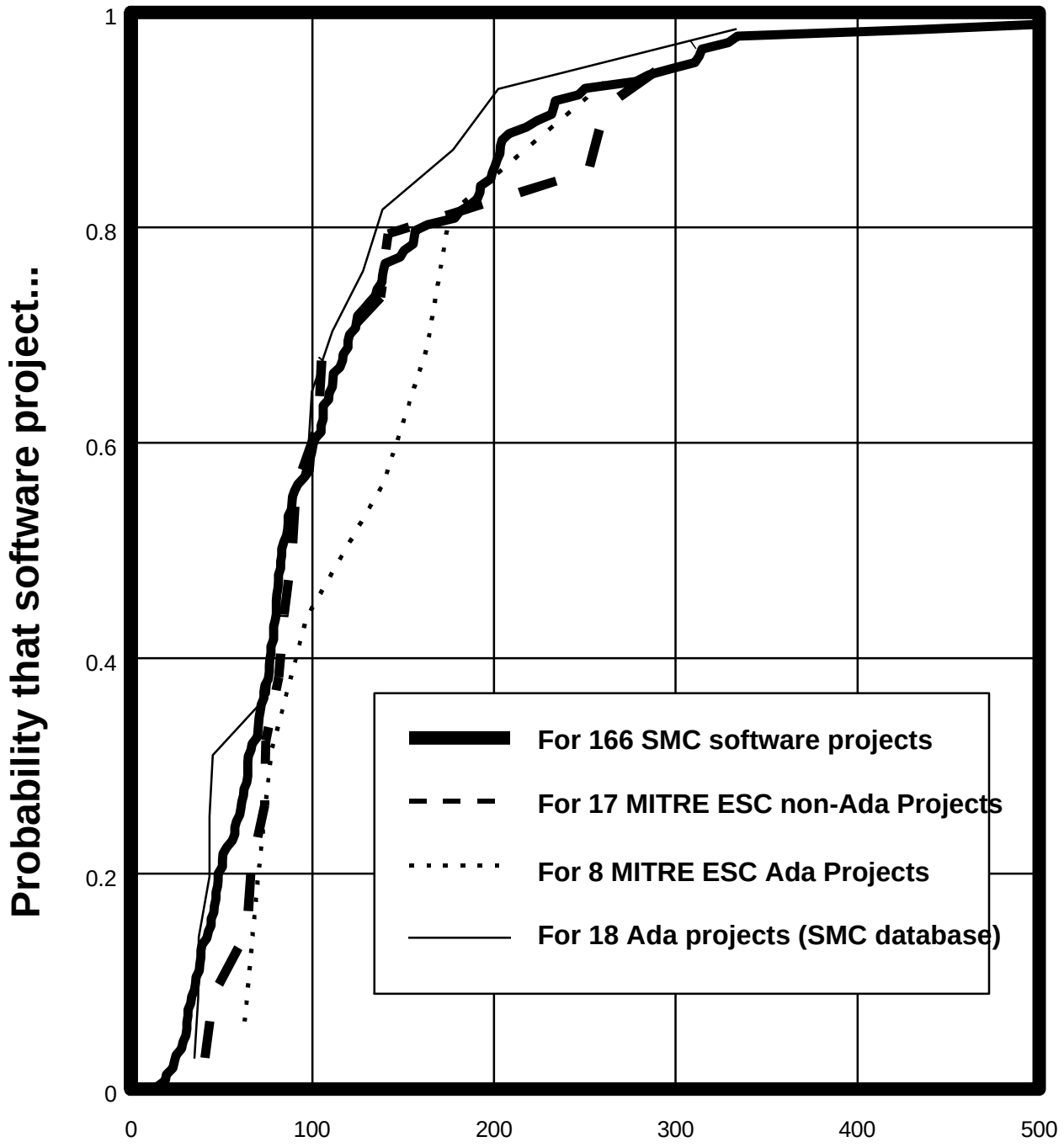
Comparison of Software Coding Rates



...progressed at LESS THAN this rate in lines/developer-month

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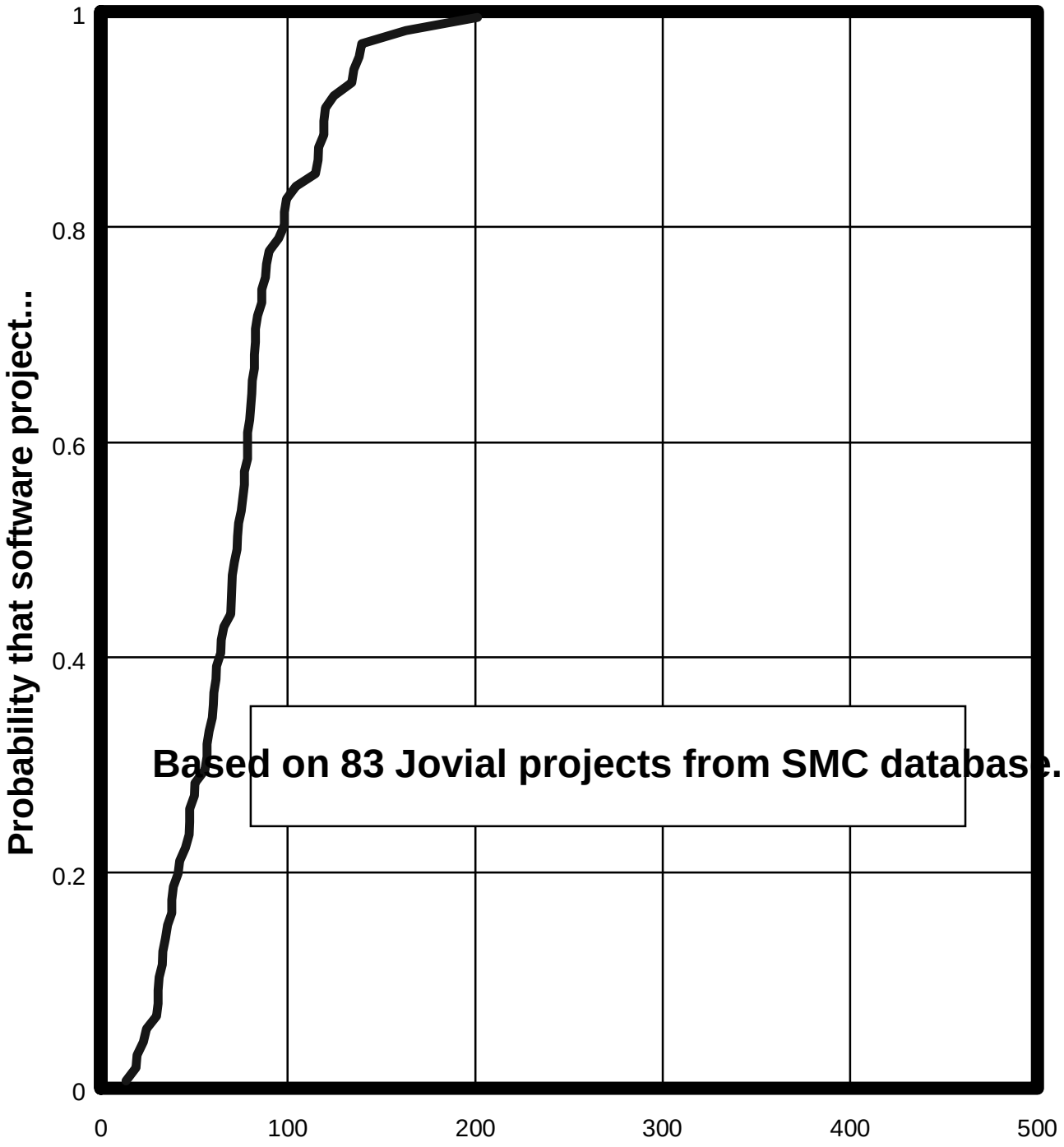
Jovial Coding Rates



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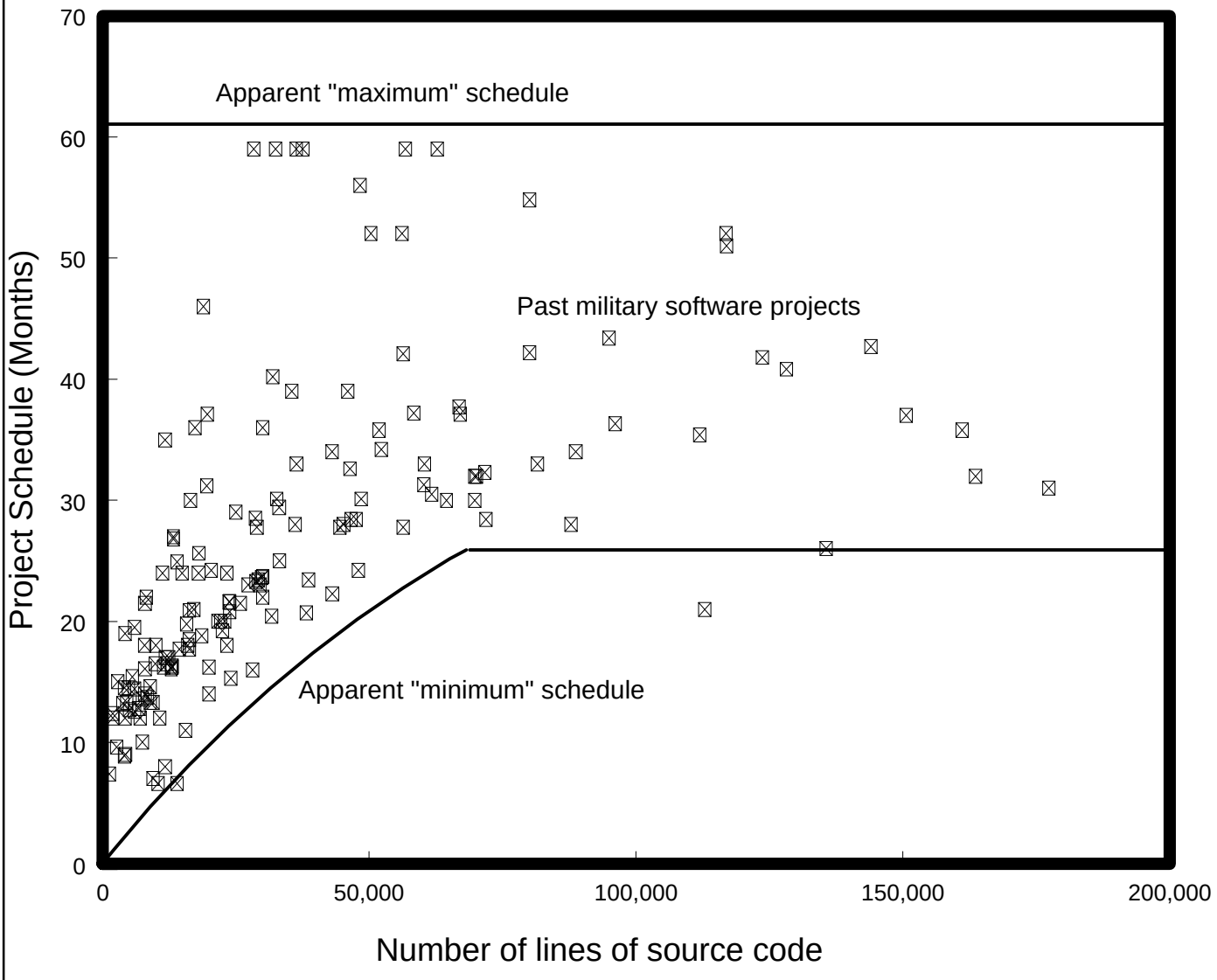
Achievable Software Development Schedules



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Model Development

- **Conduct Extensive Analysis of the Data**
  - **Plot data on graphs**
  - **Seek relationships between drivers and cost**
- **Derive Initial Set of CERs for Categories With Viable Statistical Sample (Rule of Thumb: Seven Data Points or More)**
- **Validate CERs**
  - **Use preliminary CERs to estimate known costs**
  - **Present CERs to DoD cost community for testing and comments***

***We are doing this right now!**

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CER Table (Chart 1 of 2)

			Environment		
Application		Military Ground	Military Mobile	Mil-Spec Avionics	Unmanned Space
Command	# pts	30	6	4	19
Control	CER	$DM=23.8+.00092 \cdot LOC^{1.24}$	$DM=286+2.6\times10^{-7} \cdot LOC^{1.98}$		$DM=100+.023 \cdot LOC$
	SEE	24%	65%		58%
	Bias	5%	22%		0%
	R^2	0.952	0.585		0.511
Database	# pts	5	1		6
	CER	$DM=.0146 \cdot LOC$			$DM=.0289 \cdot LOC$
	SEE	53%			42%
	Bias	23%			0%
	R^2	0.337			0.700
Mission	# pts	7			3
Planning	CER	$DM=6.09+.00813 \cdot LOC^{1.005}$			
	SEE	19%			
	Bias	2.1%			
	R^2	0.956			
OS/	# pts	2			1
Executive	CER				
	SEE				
	Bias				
	R^2				

DM = Developer-Months
LOC = Lines of Code

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CER Table (Chart 2 of 2)

			Environment		
Application		Military Ground	Military Mobile	Mil-Spec Avionics	Unmanned Space
Signal	# pts	17	2	2	10
Processing	CER	$DM=4.82+.002 \cdot LOC^{1.17}$			$DM=68.2+.0006 \cdot LOC^{1.32}$
	SEE	17%			28%
	Bias	25%			5.5%
	R^2	0.934			0.998
Simulation	# pts	8			
	CER	$DM=8.5+.00037 \cdot LOC^{1.27}$			
	SEE	60%			
	Bias	23%			
	R^2	0.679			
Support	# pts	22	2		
	CER	$DM=20.4+.0048 \cdot LOC$			
	SEE	52%			
	Bias	0%			
	R^2	0.881			
Test	# pts	11	1		7
	CER	$DM=17+9.11\times10^{-8} \cdot LOC^{2.14}$			$DM=3.1+.00049 \cdot LOC^{1.40}$
	SEE	61%			21%
	Bias	0%			2.5%
	R^2	0.353			0.935

DM = Developer-Months
LOC = Lines of Code

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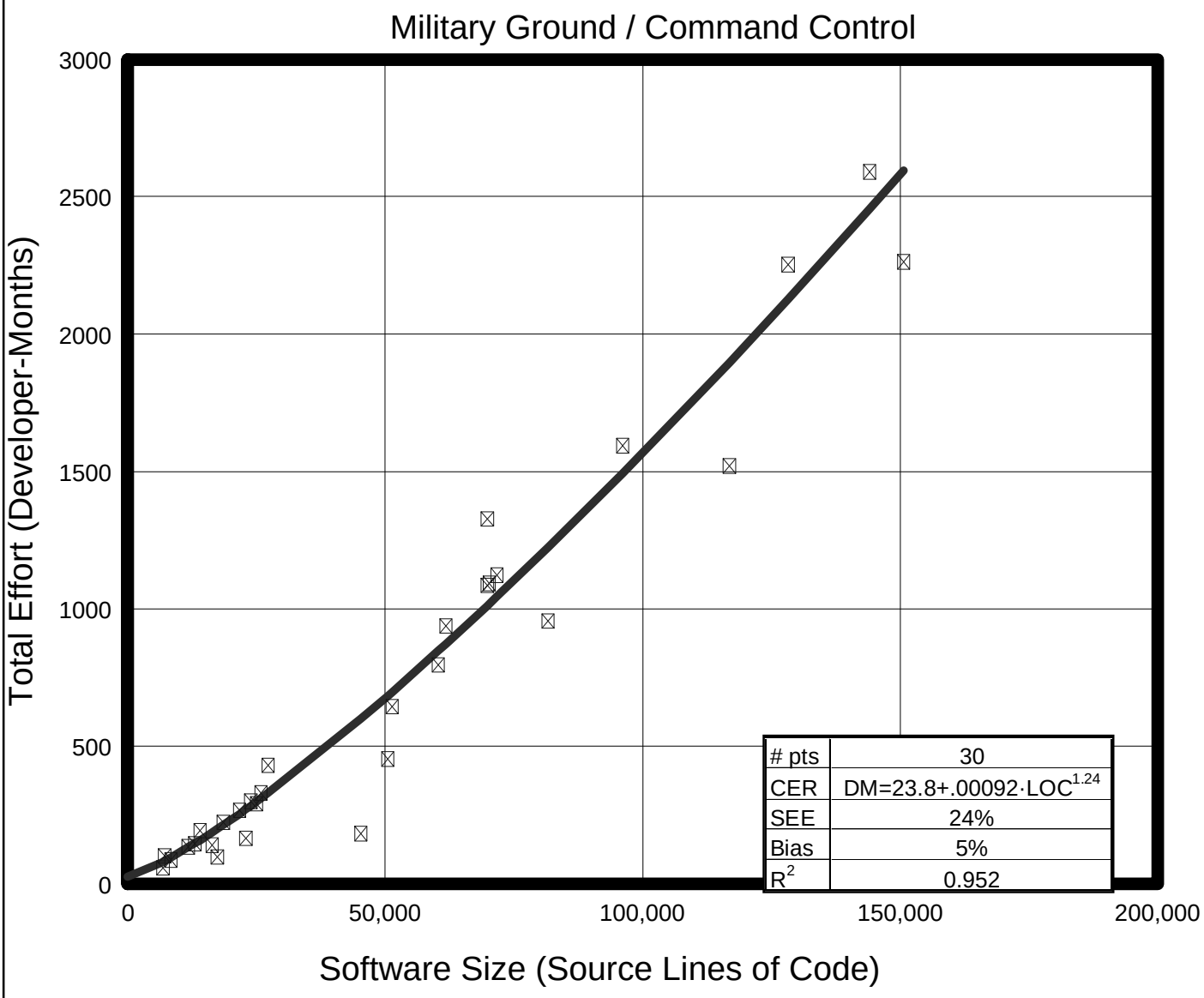
Development Effort vs. Source Code Size



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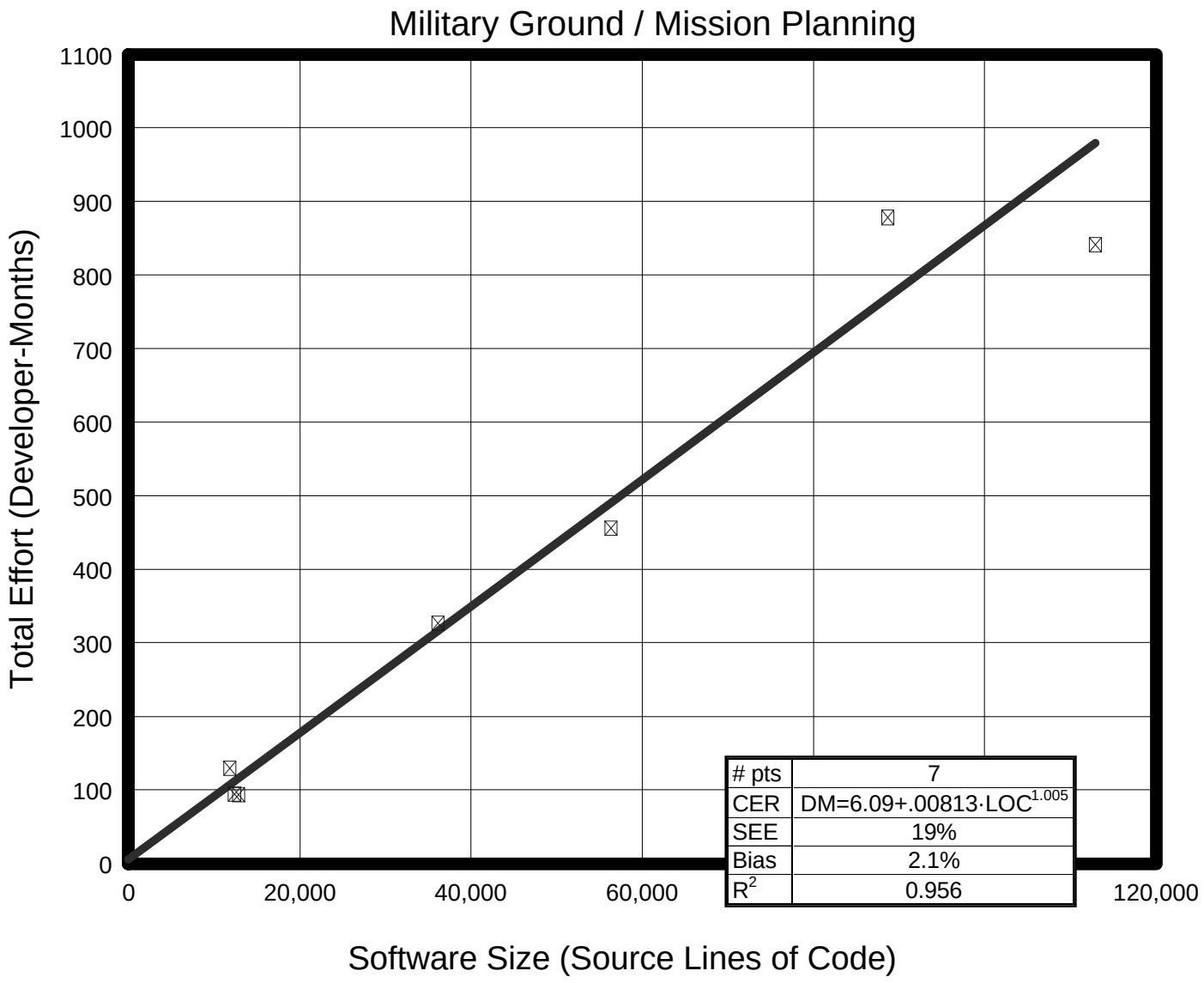
Development Effort vs. Source Code Size



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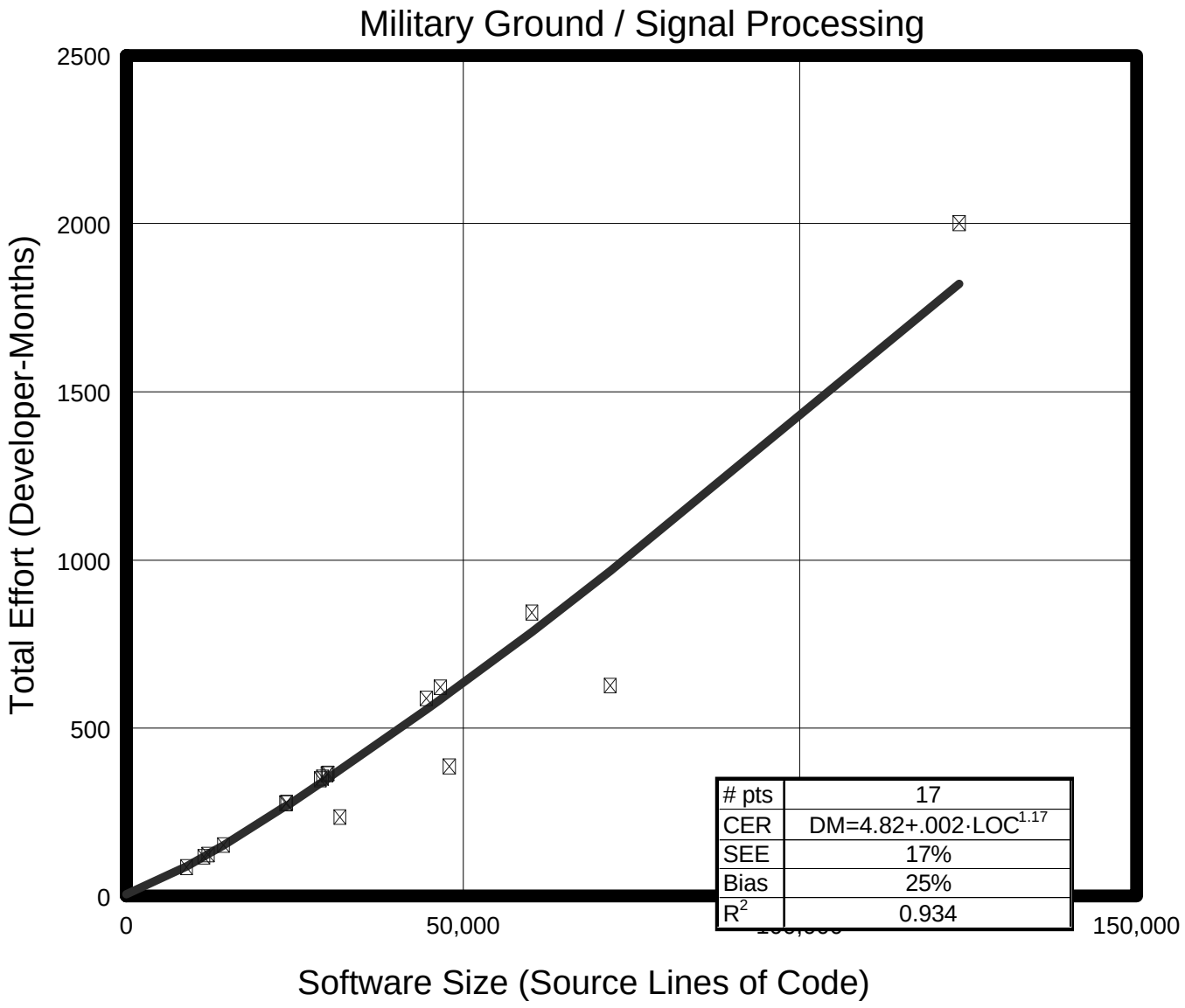

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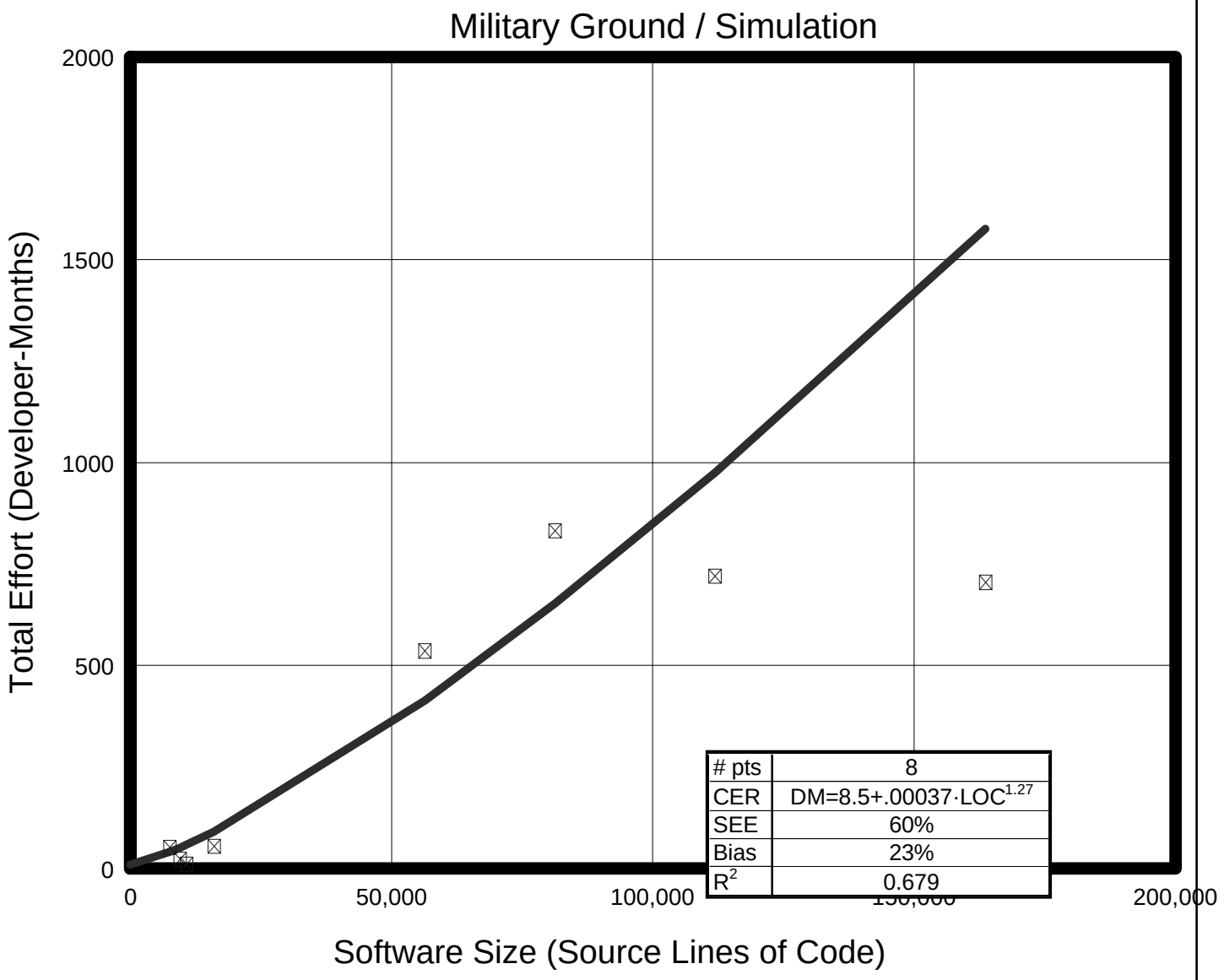

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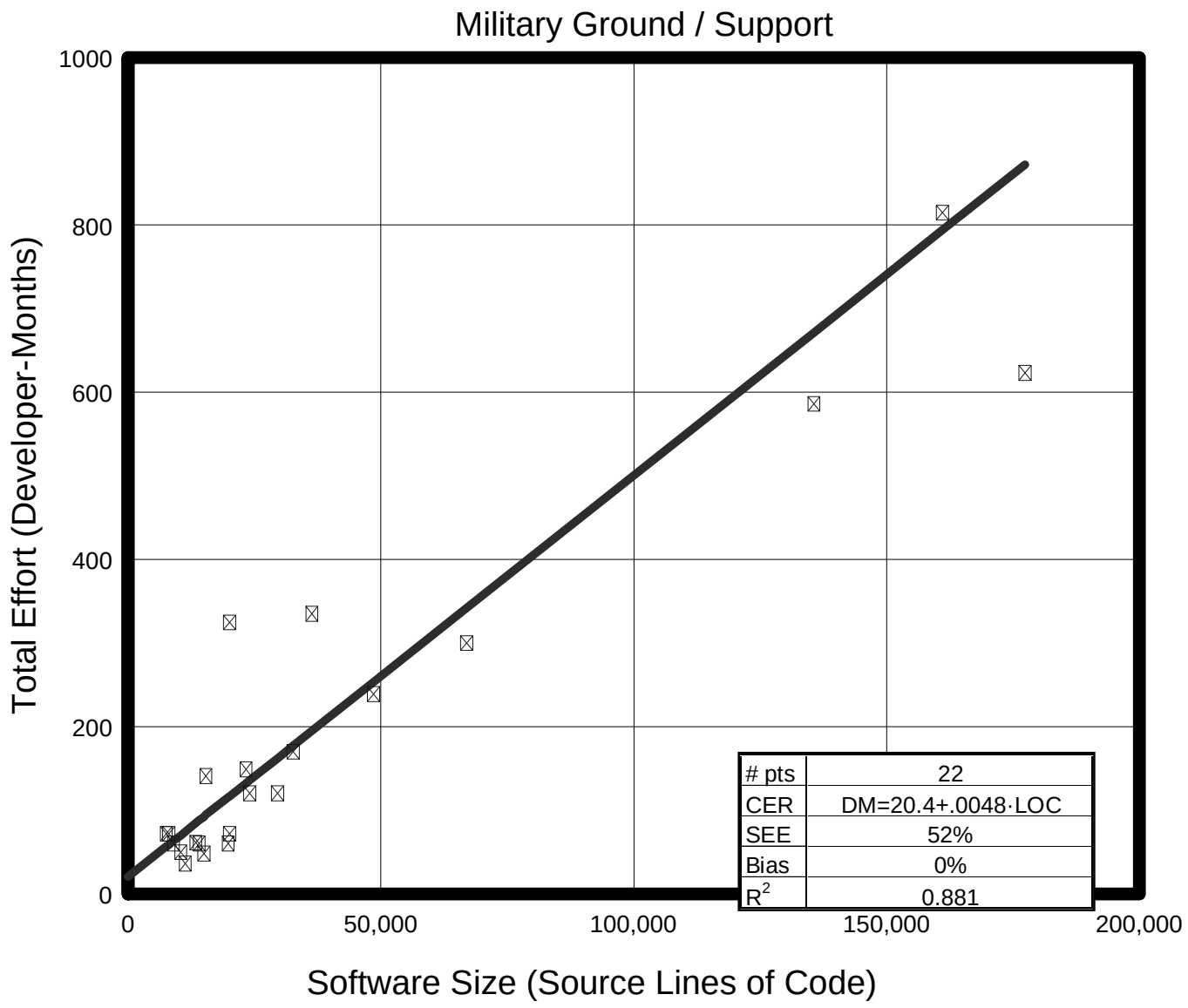

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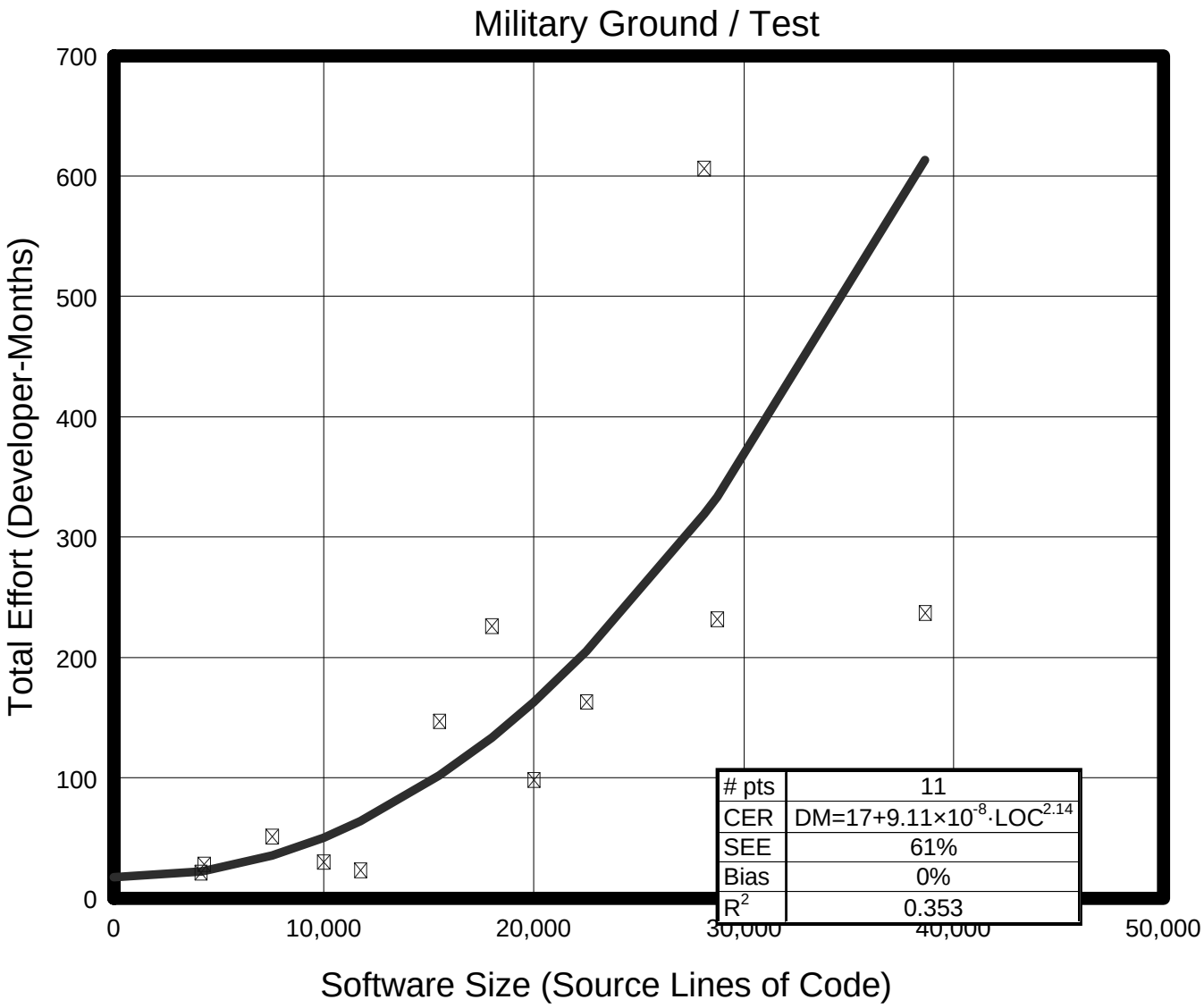

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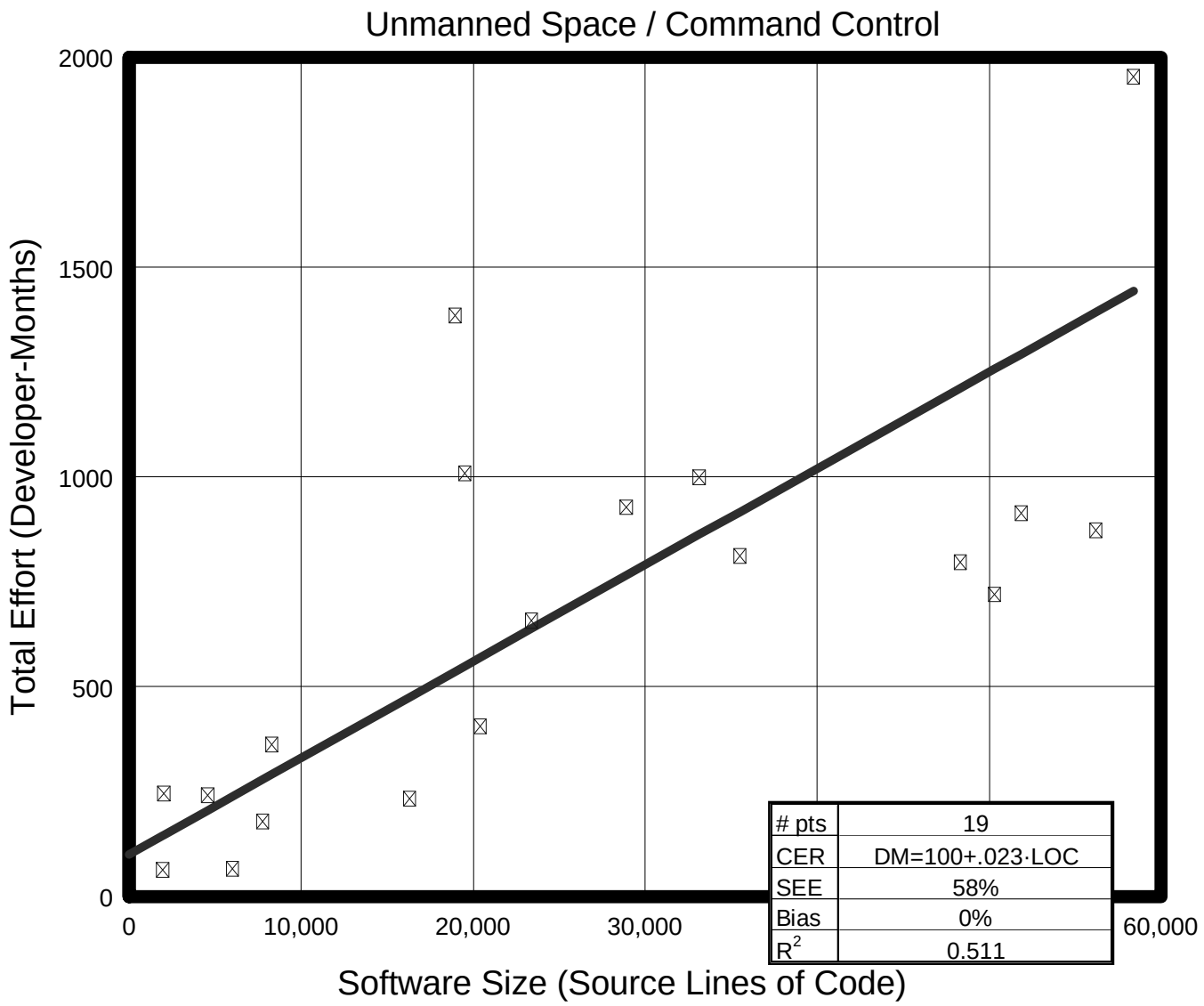

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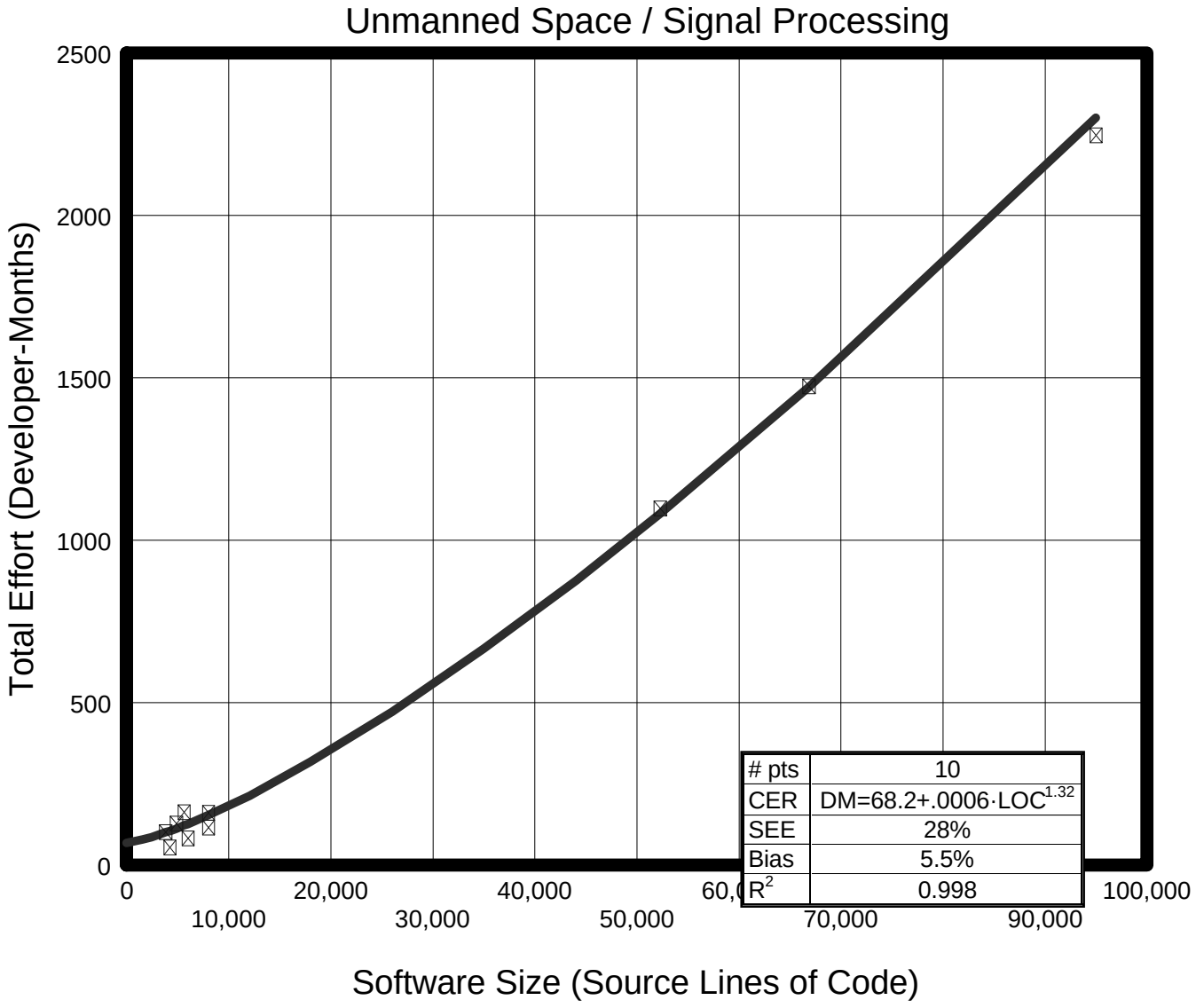

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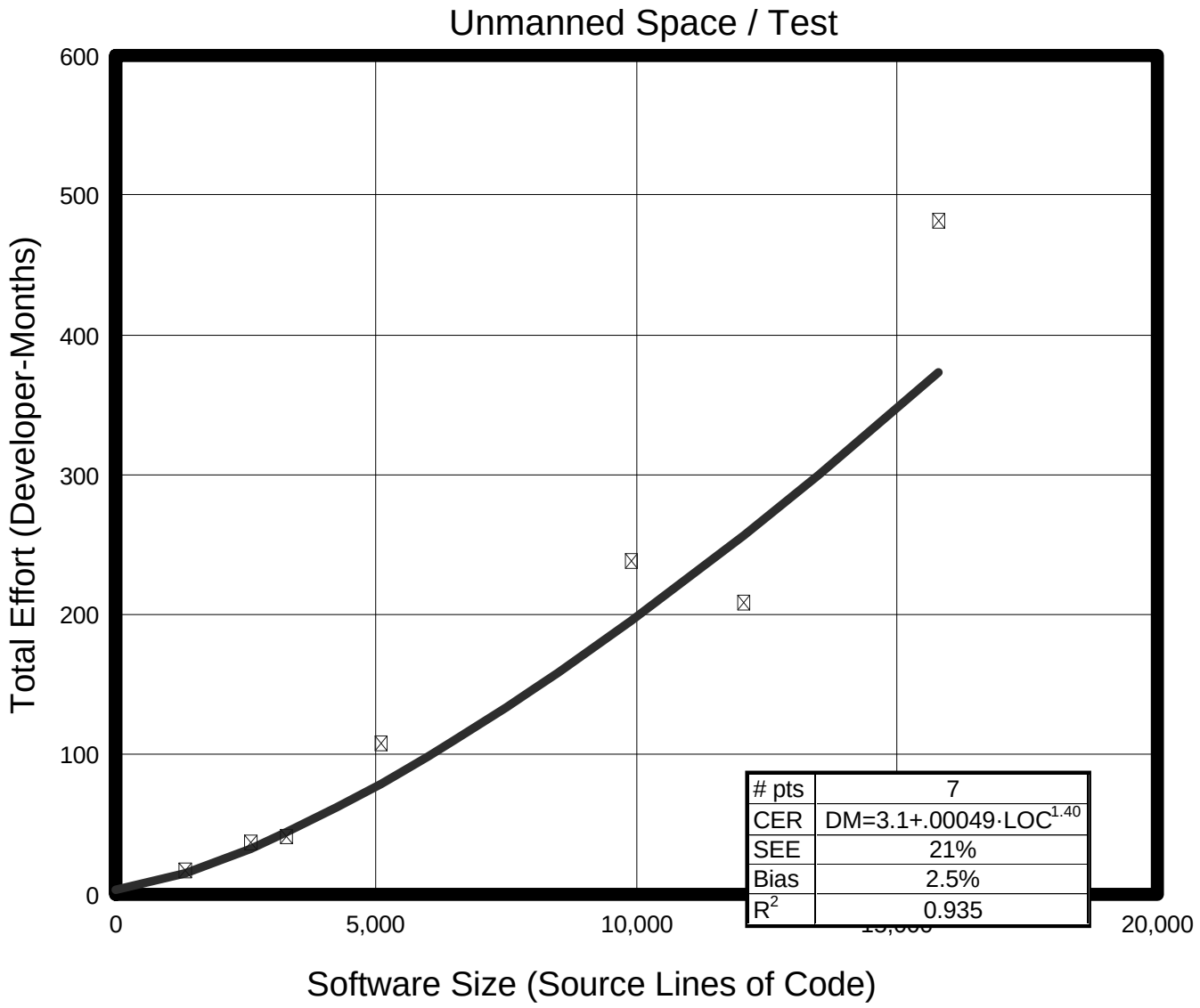

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Summary

- Gained Better Understanding of Factors that Determine Cost of Software
- Established Historical-Cost Data Base for Space Systems
- Begin Initial Development of In-House Software-Cost Model
- Possess Tool that is Independent of Available Commercial Packages and Strictly Space-Related

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Acronyms

AF	Air Force
APPL	Application
CER	Cost Estimating Relationship
DM	Developer Months
ESA	European Space Agency
FORT	Fortran
JOV	Jovial
LANG	Language
LOC	Lines of Code
NASA	National Aeronautics and Space Administration
OPR ENV	Operational Environment
OS	Operating System
SDDB	Software Development Data Base
SLOC	Source Lines of Code
SMC	Space and Missile Systems Center
SSCAG	Space Systems Cost Analysis Group

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Back-Up Charts

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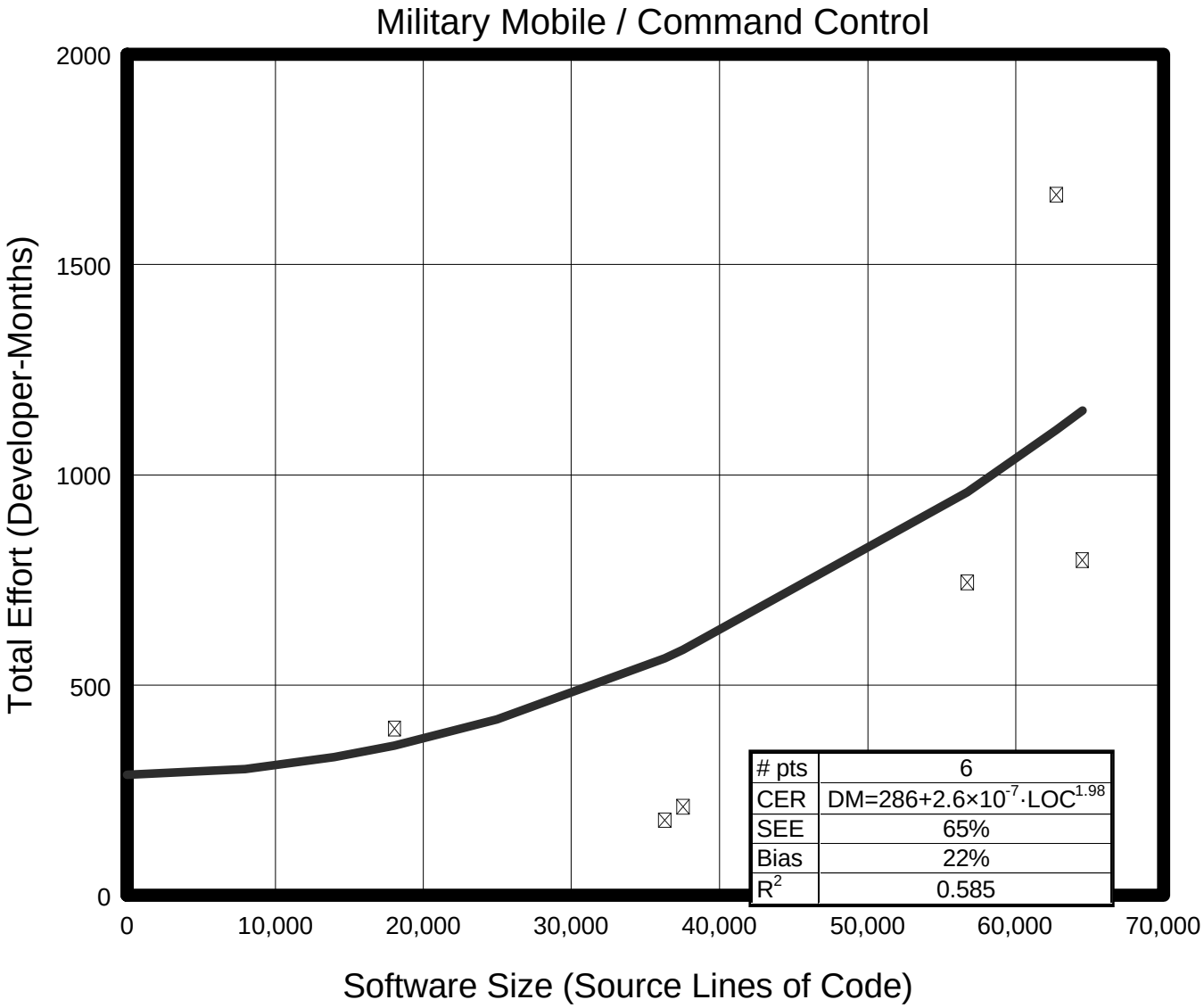
Development Effort vs. Source Code Size



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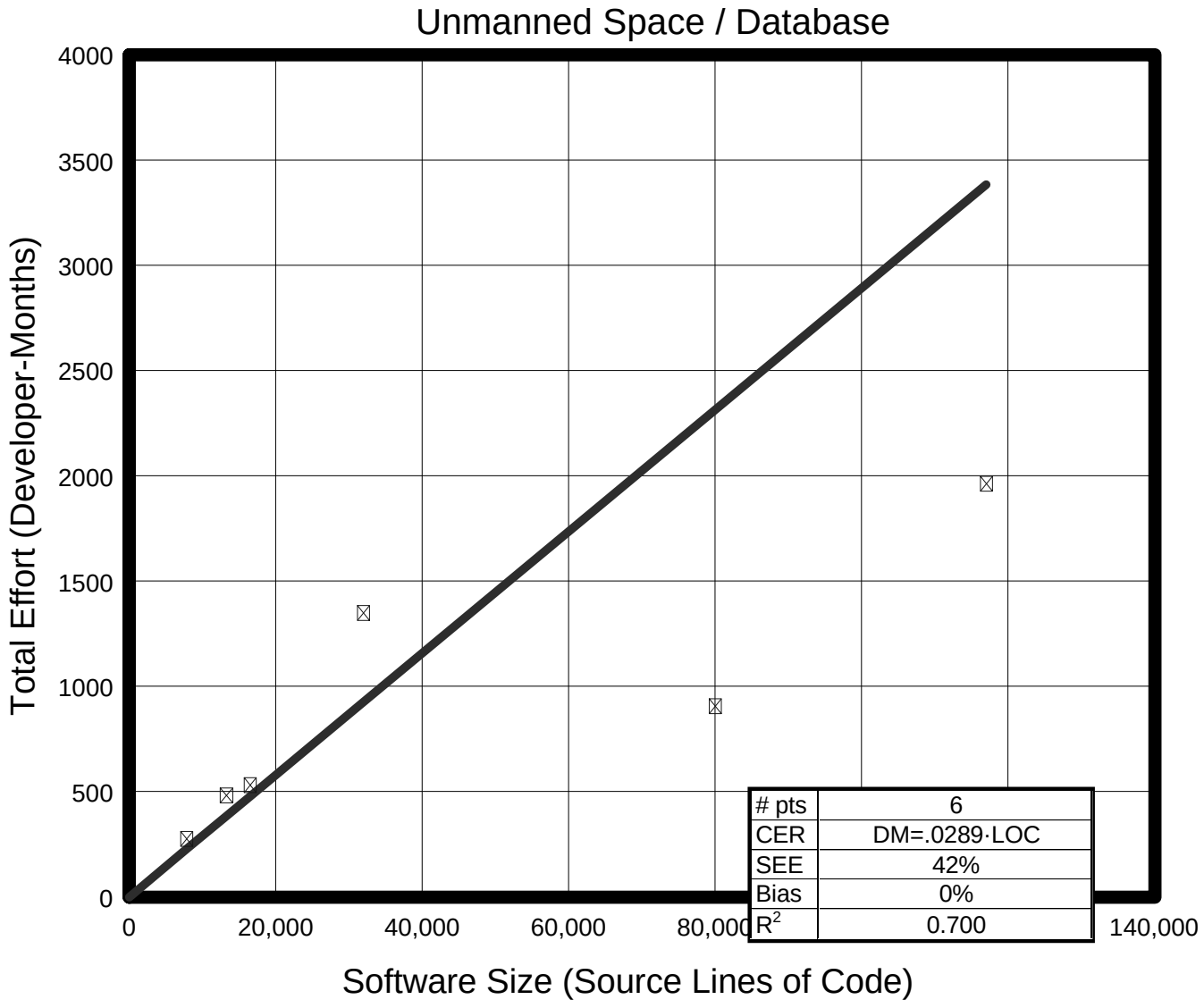
Development Effort vs. Source Code Size



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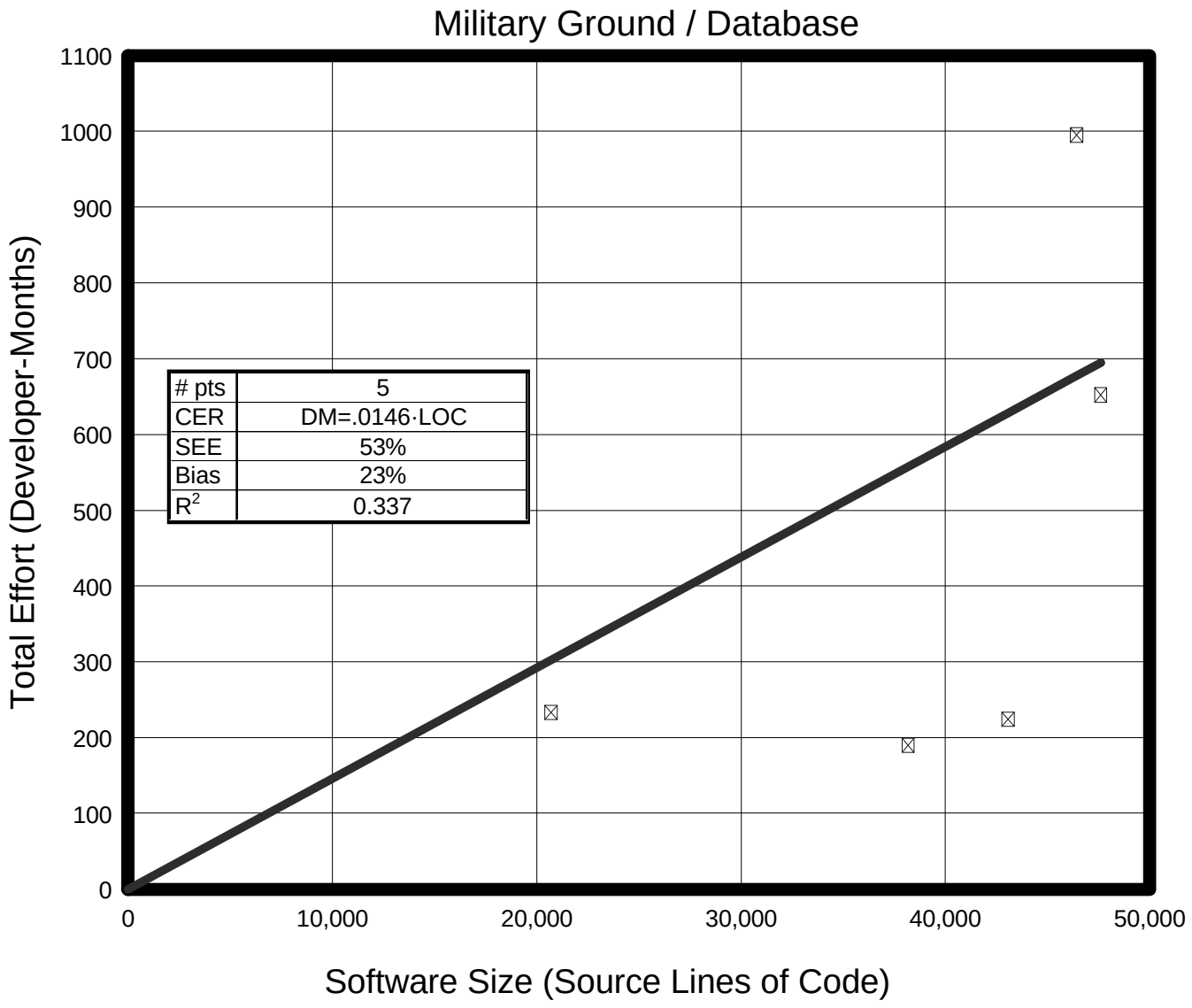

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