Web-Based Advisory Tool: Updated Proposal

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Problems

There are two primary engineering-related issues in the development of products, and both lead to unsatisfactory results. The first is that many engineering teams estimate poorly both development effort and schedule. The second is that many teams skip good practices during development by thinking they can shorten delivery time or budget. The result is that products often either go over budget and schedule or have latent faults and failure modes.

The Barr Group has surveyed developers of embedded systems for several years and found that between 20% and 35% of companies skip good practices, such as code review, defect tracking, and adherence to coding standards [1]. Some do not even have version control. These problems almost guarantee that design errors will go undetected.

Studies, including a NASA report from 2007, show the relative cost of not finding design errors [2][3]. Design errors that are undetected and uncorrected can cost a factor of 1500 times more than if they were fixed early in development.

Solution

We propose a solution to address these problems: the IEEE Systems Council will provide an easy-to-use advisory tool to systems engineers and engineering teams. The tool would give estimates of development effort and schedule, as well as provide a means to illuminate potential problems. The advisory tool would be a free website, hosted by the IEEE Systems Council, where a client or an engineering team can submit a description of the product to be developed; the website would then respond with a short report.

The website-based advisory tool is unique in that it not only is preprogrammed with established estimation tools, it also would use crowdsourcing, previously called the “wisdom of crowds,” to supply a statistical aggregation of results for comparisons of the estimated schedule and budget.

Important Concerns

This proposal is for a free tool that ***ONLY*** provide estimates. IEEE Systems Council ***NEITHER*** endorses results ***NOR*** claims any liability. A disclaimer statement will be prominent in the tool and will have a form like:

> This is a free website that does not guarantee its advice to you or to your company. Your use of this website and its tools is solely your responsibility. IEEE, the Systems Council, and all members of the IEEE and its societies are not liable for any advice it delivers to you.

The need for this sort of tool is to help people with avoiding making mistakes in estimating schedule, budget, and cost-of-goods-sold (COGS). It is unique in that it provides complementary estimates and uses crowdsourcing. Commercial tools are either expensive or not as broad-based as crowdsourcing.

Benefits accrue all around. Clients receive unbiased estimates quickly and cheaply. IEEE gains higher visibility among industry colleagues. Kim Fowler gets credit for developing the tool.

Initially, the focus of tool for the first 4 to 6 years would be embedded systems and products. The focus would not be large vehicles or plants or system-of-systems. Examples of embedded projects may include:

- medical devices
- military equipment
- mechatronics
- smaller, restricted networks of sensors
- smaller, non-distributed software systems
- control systems for:
  - appliances
  - instruments
  - engines
  - industrial processes

Implementation

The IEEE Systems Council will establish a free, easy-to-use website to advise systems engineers and engineering teams with estimates of development effort and schedule, as well as indicate potential problem areas. The website will operate as follows:

1. A client will submit a description of a proposed development through a web page. The client will also answer questions in a simple format to clarify potential issues. (NOTE: The client's input to the website will be worded to avoid intellectual property issues and maintain the confidentiality and anonymity of the clients.)
2. The website will have a database, which will randomly select a group of engineers from a database of volunteers, to submit anonymous survey responses to that project. Each volunteer will reply with these three actions:
   - fill boxes in a simple spreadsheet with estimates of effort for each development phase (conceptual, preliminary, critical, test and integration, production handoff)
   - click "radio buttons" to indicate potential problems or fill in a textbox
   - fill boxes in a simple spreadsheet to estimate the cost of goods sold (COGS)
3. The website will compile the results of the surveys and present them to the client. This will be a crowdsourcing approach.

4. The website will also provide the results of several other tools for immediate comparison. Examples may include:
    - Heuristic or empirical estimation
    - Function-point estimation
    - Lines-of-code estimation
    - Comparison to previous projects
5. The website could provide advertisements or URLs of commercial tools to aid the client. (This could be a source of income for the website.)

The client will receive free advice in exchange for agreeing to do the following:

- Participate in one short survey for someone else's project, or at most two surveys, on the IEEE website over the next year. Each survey should take less than 12 minutes of time to complete.
- Provide a confidential debrief of actual schedule and effort and COGS at the end of development. The debrief can be a simple template to complete on the website. Again, this should take less than 12 minutes of time for the client to complete.
- Failing to comply will bar the client from receiving additional reports for two years.

To prepare this website-based advisory tool requires some research upfront. Kim Fowler will provide this research. He will develop surveys and resources for the database for the website; the surveys will address several current issues that are not fully covered by literature. He will prepare three surveys for distribution by the IEEE Systems Council (in fact, Kim has already prepared these surveys but not yet distributed them). The surveys will cover the following:

- Engineering-team motivations
- "Wisdom of crowds" estimates for projects
- Buy-vs.-build heuristics

Kim will then analyze the results of the surveys and provide the resulting data to the website-based advisory tool. To motivate respondents to complete the surveys, Kim will provide up to US$750 at ten US$25 gift cards, or US$250, per survey. Furthermore, Kim will spend up to US$1000 to prepare a prototype website and pilot-test its functionality.

For the website hosted by the IEEE Systems Council, Kim will develop algorithms for the other estimation tools and pilot test the algorithms on his prototype website. These estimation tools may include the following:

- Heuristic estimation
- Function-point estimation

- Lines-of-code estimation
- Comparison to previous projects

After the pilot test of the prototype website, Kim will provide the initial requirements for the website to be hosted by the IEEE Systems Council. He will support the remaining development of the requirements with advice and data.

To support Kim's efforts, the IEEE Systems Council will distribute three email requests, each containing the URL of one of the three surveys, to the constituent societies within the Systems Council. The importance of this avenue is that it has a reasonable probability for developing statistically significant results for the "wisdom of crowds" methodology and for the various heuristics that the website might use.

Benefit

This project would have mutual benefits for the IEEE, the IEEE Systems Council, and the authors of this proposal. For the IEEE and the IEEE Systems Council, hosting the website becomes an asset. It helps raise the visibility of IEEE as a valuable professional organization to support good engineering. It may become a source of funding from advertisements. It also provides another avenue to gain new IEEE members.

The benefit to Kim Fowler is that he obtains statistically significant survey data for publication in his PhD dissertation and in journal articles. He will develop a tool that might be the basis for follow-on research. Finally, he gains recognition for being a coauthor of the website tool.

Schedule and Budget

We estimate the schedule and budget the IEEE Systems Council as follows:

- Year 1 and 2: US$0 to distribute surveys for data sources, pilot test the prototype website, develop initial requirements for the IEEE website. The Systems Council may terminate after year 2 if it is dissatisfied with the results.
- Year 3: < US$12,000 for professional development of website and hosting
- Year 4: < US$2,000 for revisions to website and hosting
- Year 5: < US$1,000 for hosting
- Year 6: < US$1,000 for hosting

Previous experience with developing websites indicates that these estimates can be reasonable. The IEEE Systems Council would provide the funds to develop and host the website-based advisory tool.

References

[1] "Embedded Systems Safety & Security Survey," Barr Group, 2017, www.barrgroup.com.

[2] Jonette M Stecklein et. al. (2004). *Error Cost Escalation Through the Project Life Cycle*, Report Number: JSC-CN-8435, 14th Annual International Symposium, Toulouse; 19–24 Jun. 2004, France. Accessed on 18 January 2014: http://ntrs.nasa.gov/search.jsp?R=20100036670

[3] *Systems Engineering Handbook*, NASA/SP-2007-6105 Rev1, December 2007. Accessed on 18 January 2014: http://www.acq.osd.mil/se/docs/NASA-SP-2007-6105-Rev-1-Final-31Dec2007.pdf

Proposal: Estimation Tool Hosted by IEEE Systems Council

By Kim Fowler and Stephen Dyer

October 2017

Important Concerns

- Free tool to provide estimates **ONLY**
  - IEEE Systems Council **NEITHER** endorses results **NOR** claims any liability!
  - See disclaimer statement that will be prominent in the tool
- Why is it needed?
  - Development teams keep committing the same mistakes in estimating:
    - schedule
    - budget
    - Cost of goods sold (COGS)
- Why is it unique?
  - It provides complementary estimates and uses crowdsourcing
  - Commercial tools are either expensive or not as broad-based as crowdsourcing
- Who benefits?
  - Clients receive unbiased estimates quickly and cheaply (tool would be free)
  - IEEE gains higher visibility among industry colleagues

Focus of tool

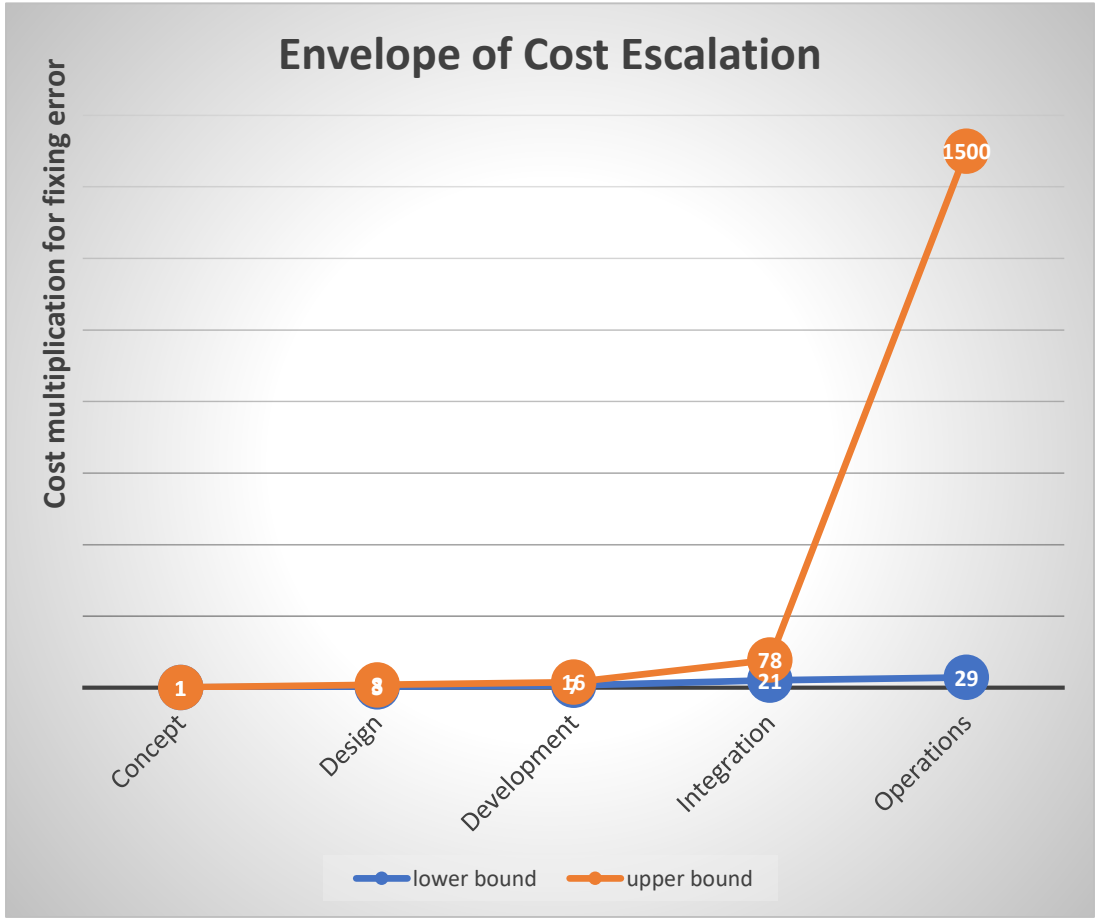
- Initially (first 4 to 6 years)
  - embedded systems and products
  - not large vehicles or plants or system-of-systems
- Examples may include
  - medical devices
  - military equipment
  - mechatronics
  - smaller, restricted networks of sensors
  - smaller, non-distributed software systems
  - control systems for
    - appliances
    - instruments
    - engines
    - industrial processes

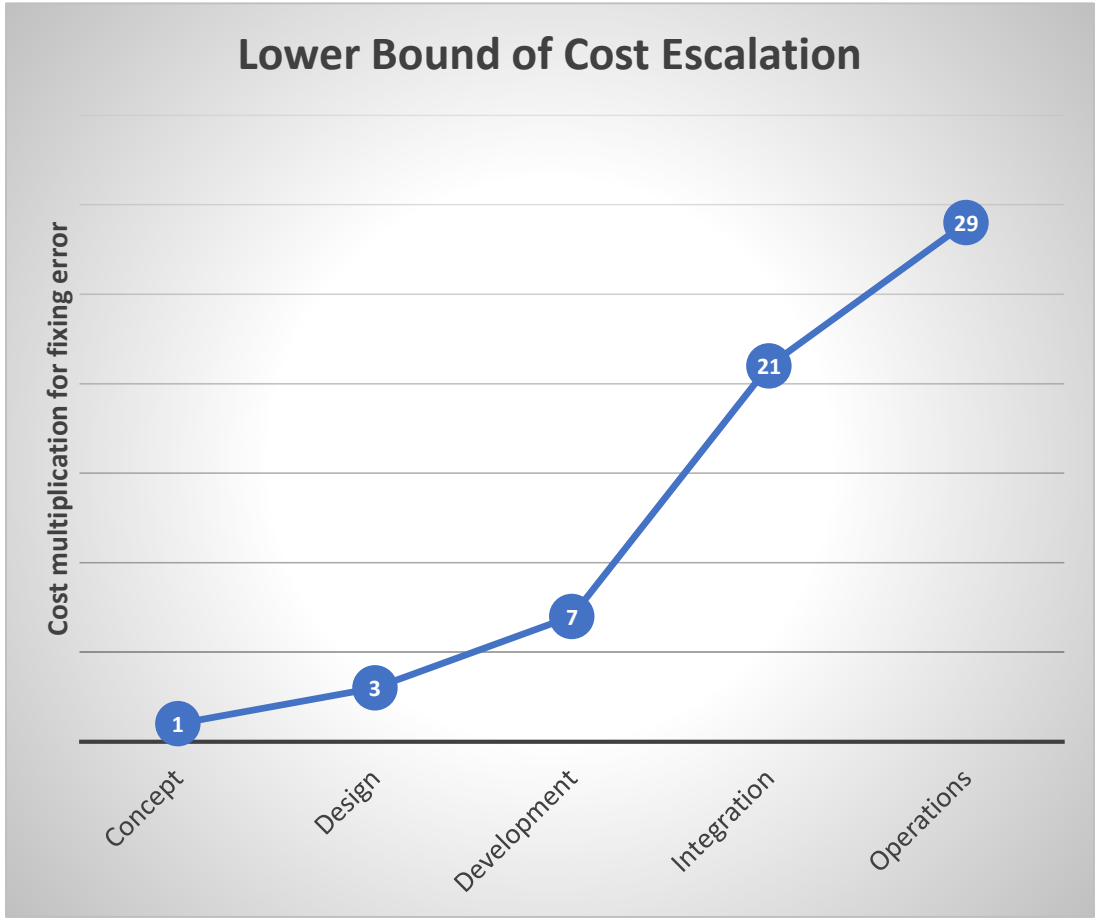
Problems Suffered by Development Teams

- Poor estimates:
  - Effort
  - Schedule
- 20% and 35% of companies (in safety-critical applications) skip good practices*
  - code review,
  - defect tracking,
  - adherence to coding standards, and
  - some do not even have version control.

* Survey report by Gerson and Barr, 2016 and 2017, “Embedded Systems Safety & Security Survey”

Cost escalation for fixing errors in requirements (INCOSE report)





Solution

- Easy-to-use advisory tool for engineering teams
  - ➢give estimates of effort and schedule
  - ➢illuminate potential problems
  - ➢part of advice from crowdsourcing survey
- IEEE Systems Council to host a free website
  - ➢Clients will get a report of estimates
    - effort,
    - schedule, and
    - COGS
    - Each client will agree to participate in one estimate/year for other clients until project is finished
    - each survey estimate will only take < 8 minutes/participant
    - provide a debrief summary at the end of project

Implementation – Overview

- Operation
  - ➢through website, client submits description of the product to be developed
  - ➢website responds with a short report
    - summary of various estimates
    - preprogrammed with established estimation tools
    - use crowdsourcing (wisdom of crowds) to supply an cumulative aggregation of the estimated schedule and budget

Implementation – What We Contribute

- Provide research to develop website
- Kim Fowler provides surveys and resources for the website
  - Engineering-team motivations
  - "Wisdom of crowds" estimates for projects
  - Buy-vs.-build heuristics
- Over the first two years, Kim will
  - Analyze the results of the surveys
  - Use data in website-based advisory tool
  - Provide US$750 @US$25 gift cards, or US$250/survey
  - Spend up to US$1000 to pilot-test a prototype website

Implementation – What Systems Council Does

- Distribute three email requests to the constituent societies
  - each contains URL for one survey
  - probability for statistically significant results
- Host and observe results from pilot website
  - No cost to IEEE
  - *Can use as a decision point* to
    - make modifications to operation, or
    - Terminate if not satisfied with results
- Host website when implemented
  - Pay for final development
  - Provide maintenance

Tool's Advice NOT Endorsed by IEEE

- This is a free tool with low liability to IEEE
- Addresses a problem within industry
- Only estimates; not a contract
- Disclaimers will be prominently displayed on tool and reports:

This is a free website that does not guarantee its advice to you or to your company. Your use of this website and its tools is solely your responsibility. IEEE, the IEEE Systems Council, and all members of the IEEE and its societies are not liable for any advice it delivers to you.

Benefits

- IEEE System Council
  - raise visibility of IEEE as a valuable professional organization, and the Systems Council in particular
  - advertisements could provide funding (if you want them)
  - recruitment tools for new IEEE members
- Authors
  - Kim Fowler obtains data for his Ph.D. dissertation
  - tool may be basis for follow-on research
  - recognition as co-authors of the website tool
- Clients
  - receive unbiased advice while planning projects for embedded systems
  - no expense or big commitment

Budget and Schedule

- Year 1 and 2: US$0 (System Council may terminate after year 2, if dissatisfied)
  - ➢to distribute surveys for data sources
  - ➢pilot test the prototype website
  - ➢develop initial requirements for the IEEE website
- Year 3: < US$12,000 for professional development of website
- Year 4: < US$2,000 for revisions to website, and hosting
- Year 5: < US$1,000 for hosting
- Year 6: < US$1,000 for hosting

End

Surveys

- Topics
  - Motivation
  - Estimation (testing for feasibility of wisdom-of-crowds)
  - Buy versus Build
- Literature replete with *ad hoc* and anecdotal reports, but no statistically significant reports for engineering development
- Samples available for inspection

Implementation – What a Client Does

- Submit a description of a proposed development through a web page
- Participate in two surveys for another clients' projects over the next year.
- Provide a debrief of actual schedule, effort, and COGS at the end of project development.
- Failing to comply bars client from receiving reports for two years.

Implementation – What Website/Volunteers Do

- Randomly select volunteers from a database to submit anonymous responses to each project
- Each volunteer will reply with these three actions:
  - fill boxes in a spreadsheet with estimates of effort for each phase (see next slide)
  - click “radio buttons” to indicate potential problems or fill in a textbox
  - fill boxes in a simple spreadsheet to estimate COGS
- Prepare empirical estimates, (e.g., COSYSMO 3, function-point)
- Compile short report for client

Planned Prototype of Website

Project Report – General Format

IEEE Systems Council Estimation and Advisement Tool

Purpose: This website is a free tool to help engineers with some initial systems engineering and estimation of projects.

Function: The tool uses several estimation tools and crowdsourcing to provide you with an estimate of effort, cost of goods sold, and potential problems that your project might encounter.

Types of systems and products:

This tool will focus on embedded systems and products; it will not be large vehicles or plants or system-of-systems. Examples of products may include medical devices, military equipment, mechatronics, smaller, restricted networks of sensors, smaller, non-distributed software systems, and control systems for appliances, instruments, engines, industrial processes.

What it does not do and limitation of liability:

This is a free website that does not guarantee its advice to you or to your company. Your use of this website and its tools is solely your responsibility. IEEE, the Systems Council, and all members of the IEEE and its societies are not liable for any advice it delivers to you.

→ ☐ I agree to these conditions. (You must check this box before proceeding to the menu items below.)

I wish to:

→ ☐ try some basic tradeoffs without submitting a project.

→ ☐ view previous projects and their estimations.

→ ☐ submit a project for estimation and comment.

→ ☐ provide a yearly progress report on a project.

→ ☐ complete a debrief on a completed project.

Project Submission – 1

→ Select the type of submission that you are making. (Pull down menu)

New submission on new project
New submission on a project similar to another
Update to a previous submission

→ Sign in with Project Account or create a new Project Account ID

_____ Project ID

_____ Project password

☐ Create a new Project Account

→ If new submission, then select type of design effort: (Pull down menu)

Clean-sheet, new design
Clean-sheet design of a previous product
Update/modification of current design
Integration of subsystems purchased from vendors to give final product

→ If an update or modification of a current product is selected in the menu above, estimate the percentage of subsystems to be revised and the total percentage revision of the original design of the product:

_____% of subsystems to be revised

_____% revision of the original design

→ Manufacture and production

_____ How many units will be produced over the total production run?

_____ How many units will be produced each year?

Project Submission – 2

1. In what industry(ies) will the project operate? (Check all that apply)

- [ ] Aerospace or Defense
- [ ] Agricultural equipment
- [ ] Automotive
- [ ] Civil construction or monitoring, infrastructure
- [ ] Consumer devices or appliances
- [ ] Government
- [ ] Industrial or manufacturing equipment or process control
- [ ] Medical or pharmaceutical
- [ ] Petrochemical or mining
- [ ] Power generation and distribution
- [ ] Scientific and test equipment
- [ ] Transportation (other than automotive), cargo hauling, materials extraction
- [ ] Other - describe:

2. Are there regulatory environments or standards that your product must meet? Check all that apply:

- [ ] Transportation - FAA, DOT, NHTSA
- [ ] Military - DoD,
- [ ] Medical - FDA
- [ ] Consumer - UL, CE Mark, VDE
- [ ] Space - NASA guidelines
- [ ] National Electrical Code (NEC), fire codes

- [ ] Describe any certifications or approvals you must obtain and any regulations or guidelines you must follow:

Project Submission – 3

3. What is the operational environment in which your product will operate? Check all that apply:

- ☐ Indoors, controlled temperature and humidity
- ☐ Outdoors, uncontrolled
- ☐ Marine
- ☐ Corrosive
- ☐ High pressure
- ☐ High radiation
- ☐ Space - vacuum and radiation
- ☐ Vibration (if checked, then select type from pulldown menu)

Low levels for short-term, e.g., sliding appliance across a counter
Low levels over long-term, e.g., distant manufacturing mildly buzzes table top
High levels for short-term, e.g., missile launch
High levels over long-term, e.g., shaker screen for industrial process

- ☐ Mechanical shock (if checked, then select type from pulldown menu)

Low magnitude, short-term, e.g., bumping an appliance with your elbow
Low magnitude, long-term, e.g., repeated drops of a few millimeters
High magnitude, short-term, e.g., 2 meter high drop to concrete surface
High magnitude, long-term, e.g., large gun repeatedly firing

- ☐ Other - describe:

4. Estimate aspects of your project in each of the following three lines:

Number of subsystems (e.g., circuit boards, power supplies, mechanisms): _____

Number of lines of code (LOC): _____

Number of logical operations or function points: _____

- ☐ Check only if you have no confidence in your numbers.

Project Submission – 4

5. What is the planned longevity of each unit once it goes into service?
   - ☐ less than a year
   - ☐ 1 to 3 years
   - ☐ 4 to 10 years
   - ☐ 11 to 20 years
   - ☐ more than 20 years

6. What is the plan for maintaining and repairing the product?
   - ☐ disposable, no maintenance nor repair
   - ☐ repairable, but no regular maintenance
   - ☐ regular maintenance by customer or operator
   - ☐ highly complex maintenance and repair by very skilled personnel

7. Will the device be connected to the internet?
   - ☐ continuously while operating
   - ☐ intermittently when it calls into a designated control center
   - ☐ only during development or repair or maintenance
   - ☐ not after development, all communications will be secure
   - ☐ never

8. Classify the human interface:
   - ☐ autonomous, very little or no human interaction
   - ☐ simple and intuitive, e.g., like a kitchen appliance
   - ☐ requires some training, e.g., like learning to drive an automobile
   - ☐ requires training and update short courses
   - ☐ only used by a few highly trained operators, e.g., pilots flying an aircraft

Project Submission – 5

9. Describe the data bandwidth into and out of the product in less than 100 words:

10. Describe limits on size, shape, or volume in less than 70 words:

11. Describe limits on weight in less than 50 words:

12. Describe limits on power consumption (or generation) in less than 50 words:

13. Describe the purpose, primary function, and functional limitations of the product in less than 200 words:

14. Describe how you would operate the product in less than 200 words:

Project Submission – 6

☐ By checking this box, I agree to do the following:

- Give a yearly progress report until the project finishes. (Expected 12 min.)
- Give a debriefing report when the project finishes. (Expected 12 min.)
- Participate anonymously in at least one survey each year for other clients until my project is finished. (Expected 8 to 12 min.)

- Failing to complete these three conditions will bar me and my company from using this tool for three years.

Report Format for Crowdsourcing

Purpose, primary function, and functional limitations of the product:

How to operate the product:

Type of project:
(e.g., clean-sheet or update or integration)

If project is an update:
_____% of subsystems to be revised
_____% revision of total product

Manufacturing or production:
_____ total number of units to be produced over market lifetime.
_____ number of units to be produced each year.

Industries in which the product will operate:

Regulations, standards, certifications, or approvals that the product must meet:

Operational environment in which the product will operate:

Estimates of project complexity:
Number of subsystems within product: _____
Number of lines of code within product: _____
Number of logical operations or function points: _____

Planned longevity of each unit once it enters service: _____ years

Maintenance and repair philosophy:

Internet connectivity:

Human interface:

Bandwidth:
Size, shape, volume:
Weight:
Power consumption (or generation):

Spreadsheet for Estimates (Crowdsourcing)

	Estimates of effort in FTEs (person-months) per phase			
	Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Transfer to Production**
Engineers, developers (e.g., software, elect., mech., indust., mfg.)				
Technicians, assemblers, fabricators, logistic support				
Management, administrative				
Marketing and sales				
Others, including consultants				

Please fill in these four boxes with your estimate of calendar time (in months) for each phase.

Estimates of effort in FTEs (person-months) per phase			
Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Transfer to Production**

In production, what do you expect the per-unit-cost of the product will be? Cost of Goods Sold (COGS)/unit = $_____

Spreadsheet for Potential Problems (Crowdsourcing), Part 1

	Low - effort, cost, and technology are understood and controlled; e.g., system upgrade to a servomechanism that does not require software changes and only minor differences in the motor and drive.		**Medium** - effort, cost, and technology are understood; e.g., clean-sheet design of a servomechanism that uses available components.		**High** - effort, cost, or technology are new to the team; e.g., clean-sheet design of a spacecraft instrument with new software and autonomy.
	1	2	3	4	5
Software, firmware	☐	☐	☐	☐	☐
User interface and operation	☐	☐	☐	☐	☐
Electrical and electronic hardware	☐	☐	☐	☐	☐
Optics	☐	☐	☐	☐	☐
Mechanisms and mechanical hardware	☐	☐	☐	☐	☐
Data manipulation, flow, and storage	☐	☐	☐	☐	☐
Controls, mechanisms	☐	☐	☐	☐	☐
Verification, validation, compliance (e.g., FDA or FAA or UL or CE)	☐	☐	☐	☐	☐

Spreadsheet for Potential Problems (Crowdsourcing), Part 2

	Low - effort, cost, and technology are understood and controlled; e.g., system upgrade to a servomechanism that does not require software changes and only minor differences in the motor and drive.		**Medium** - effort, cost, and technology are understood; e.g., clean-sheet design of a servomechanism that uses available components.		**High** - effort, cost, or technology are new to the team; e.g., clean-sheet design of a spacecraft instrument with new software and autonomy.
	1	2	3	4	5
Security of operation	☐	☐	☐	☐	☐
Customer or client acceptance	☐	☐	☐	☐	☐
Extreme environments (e.g., temperature or pressure or vibration)	☐	☐	☐	☐	☐
Cost of final product	☐	☐	☐	☐	☐
Cost of development	☐	☐	☐	☐	☐
Time-to-market	☐	☐	☐	☐	☐
Changing requirements	☐	☐	☐	☐	☐

Spreadsheet for Potential Problems (Crowdsourcing), Part 3

	Low - effort, cost, and technology are understood and controlled; e.g., system upgrade to a servomechanism that does not require software changes and only minor differences in the motor and drive.		**Medium** - effort, cost, and technology are understood; e.g., clean-sheet design of a servomechanism that uses available components.		**High** - effort, cost, or technology are new to the team; e.g., clean-sheet design of a spacecraft instrument with new software and autonomy.
	1	2	3	4	5
New technology, paradigm shift, revolutionary	☐	☐	☐	☐	☐
Power consumption or dissipation or handling	☐	☐	☐	☐	☐
Size or weight	☐	☐	☐	☐	☐
Material or mass flow	☐	☐	☐	☐	☐
Competition	☐	☐	☐	☐	☐
Program management, team collaboration	☐	☐	☐	☐	☐
Other:	☐	☐	☐	☐	☐

Report Format for Project Estimates to Client - 1

The COSYSMO model estimates that your project will take: _____ FTEs (person-months)

Crowdsourcing estimates the following:

	Estimates of effort in FTEs (person-months) per phase				
	Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Certification, transfer to Production**	
Engineers, developers	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Technicians, assemblers, fabricators, logistic support	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Management, administrative	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Marketing and sales	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Others, including consultants	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	**Average total effort**
Mean estimate of effort + standard deviation per phase	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.

	Estimates of effort in FTEs (person-months) per phase				
	Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Certification, transfer to Production**	**Average total time**
Mean estimate of time + standard deviation per phase	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.

In production, the estimated per-unit-cost of the product will be: COGS/unit = US$_____μ ± S.D.__

Report Format for Project Estimates to Client - 2

Classification of Problem Areas

Low (1 to 2) - effort, cost, and technology are understood and controlled; e.g., system upgrade to a servomechanism that does not require software changes and only minor differences in the motor and drive.

Medium (2 to 4) - effort, cost, and technology are understood; e.g., clean-sheet design of a servomechanism that uses available components.

High (4 to 5) - effort, cost, or technology are new to the team; e.g., clean-sheet design of a spacecraft instrument with new software and autonomy.

	Estimate
Software, firmware	
User interface and operation	
Electrical and electronic hardware	
Optics	
Mechanisms and mechanical hardware	
Data manipulation, flow, and storage	
Controls, mechanisms	
Verification, validation, compliance (e.g., FDA or FAA or UL or CE)	

Report Format for Project Estimates to Client – 2 (continued)

Security of operation	_____
Customer or client acceptance	_____
Extreme environments (e.g., temperature or pressure or vibration)	_____
Cost of final product	_____
Cost of development	_____
Time-to-market	_____
Changing requirements	_____
New technology, paradigm shift, revolutionary	_____
Power consumption or dissipation or handling	_____
Size or weight	_____
Material or mass flow	_____
Competition	_____
Program management, team collaboration	_____
Other: _____	_____

Web Tools for Providing Advice on Estimation

Overview of Tools

The purpose for these tools is to provide engineers and developers with estimations for the level-of-effort, duration of development, and COGS of the final product. The focus of this tool will be embedded systems and products; it will not be for large vehicles or plants or system-of-systems. Examples of products and systems may include medical devices, military equipment, mechatronics, smaller, restricted networks of sensors, smaller, non-distributed software systems, and control systems for appliances, instruments, engines, industrial processes.

It will use several different methods to generate estimates. One set of methods will be heuristic calculations based on the expected product complexity; we will consider the various model estimators from Barry Boehm and the USC CSSE, such as COCOMO, Agile COCOMO II, COCOTS, COQUALMO, CORADMO, and possibly COSYSMO [65]. Another will be a crowdsource estimate. These will be estimates only, they will not claim accuracy nor liability; clients are not advised to rely on them.

The tool should be free and hosted on a website maintained by a technical society or organization. The website will be visited by clients, prospective clients, contributors, and staff of the hosting organization. A database will support the website and archive the submissions and actions on individual project estimations.

A client will submit a project description through a webpage; it will then generate a short report that client approves before it is submitted for consideration or for archiving. With calculations like heuristic estimations, the tool will generate immediate estimates of level-of-effort and duration of development. The tool will then randomly select and send requests to 400 to 1200 potential crowdsource contributors to provide individual estimates of the level-of-effort, duration of development, and COGS of the final product. The tool will collect the replies from the crowdsource contributors and generate aggregated estimates for a report sent to the client. It will then generate a short report for the client.

The following sections of this appendix contain initial plans for webpages and interactions.

Proposed Client Title Webpage

This webpage is what greets clients and prospective clients. This page should be the last one developed. Some clients may only want to view potential tradeoffs or past histories of projects and estimation efforts.

IEEE Systems Council Estimation and Advisement Tool

Purpose: This website is a free tool to help engineers with some initial systems engineering and estimation of projects.

Function: The tool uses several estimation tools and crowdsourcing to provide you with an estimate of effort, cost of goods sold, and potential problems that your project might encounter.

Types of systems and products:

This tool will focus on embedded systems and products; it will not be large vehicles or plants or system-of-systems. Examples of products may include medical devices, military equipment, mechatronics, smaller, restricted networks of sensors, smaller, non-distributed software systems, and control systems for appliances, instruments, engines, industrial processes.

What it does not do and limitation of liability:

This is a free website that does not guarantee its advice to you or to your company. Your use of this website and its tools is solely your responsibility. IEEE, the Systems Council, and all members of the IEEE and its societies are not liable for any advice it delivers to you.

→ ☐ I agree to these conditions. (You must check this box before proceeding to the menu items below.)

I wish to:

→ ☐ try some basic tradeoffs without submitting a project.

→ ☐ view previous projects and their estimations.

→ ☐ submit a project for estimation and comment.

→ ☐ provide a yearly progress report on a project.

→ ☐ complete a debrief on a completed project.

Proposed Survey for Client to Submit a Project for Estimation

The proposed survey format follows that a client submits a project for estimation. It provides consistent reports to crowdsource participants and minimizes extraneous or biased information. It should minimize time required by crowdsource participants to read and then respond with estimates.

→ Select the type of submission that you are making. (Pull down menu)

New submission on new project
New submission on a project similar to another
Update to a previous submission

→ Sign in with Project Account or create a new Project Account ID

_____ Project ID

_____ Project password

☐ Create a new Project Account

→ If new submission, then select type of design effort: (Pull down menu)

Clean-sheet, new design
Clean-sheet design of a previous product
Update/modification of current design
Integration of subsystems purchased from vendors to give final product

→ If an update or modification of a current product is selected in the menu above, estimate the percentage of subsystems to be revised and the total percentage revision of the original design of the product:

_____% of subsystems to be revised

_____% revision of the original design

→ Manufacture and production

_____ How many units will be produced over the total production run?

_____ How many units will be produced each year?

1. In what industry(ies) will the project operate? (Check all that apply)

- [ ] Aerospace or Defense
- [ ] Agricultural equipment
- [ ] Automotive
- [ ] Civil construction or monitoring, infrastructure
- [ ] Consumer devices or appliances
- [ ] Government
- [ ] Industrial or manufacturing equipment or process control
- [ ] Medical or pharmaceutical
- [ ] Petrochemical or mining
- [ ] Power generation and distribution
- [ ] Scientific and test equipment
- [ ] Transportation (other than automotive), cargo hauling, materials extraction
- [ ] Other - describe:

2. Are there regulatory environments or standards that your product must meet? Check all that apply:

- [ ] Transportation - FAA, DOT, NHTSA
- [ ] Military - DoD,
- [ ] Medical - FDA
- [ ] Consumer - UL, CE Mark, VDE
- [ ] Space - NASA guidelines
- [ ] National Electrical Code (NEC), fire codes

- [ ] Describe any certifications or approvals you must obtain and any regulations or guidelines you must follow:

3. What is the operational environment in which your product will operate? Check all that apply:

- ☐ Indoors, controlled temperature and humidity
- ☐ Outdoors, uncontrolled
- ☐ Marine
- ☐ Corrosive
- ☐ High pressure
- ☐ High radiation
- ☐ Space - vacuum and radiation
- ☐ Vibration (if checked, then select type from pulldown menu)

Low levels for short-term, e.g., sliding appliance across a counter
Low levels over long-term, e.g., distant manufacturing mildly buzzes table top
High levels for short-term, e.g., missile launch
High levels over long-term, e.g., shaker screen for industrial process

- ☐ Mechanical shock (if checked, then select type from pulldown menu)

Low magnitude, short-term, e.g., bumping an appliance with your elbow
Low magnitude, long-term, e.g., repeated drops of a few millimeters
High magnitude, short-term, e.g., 2 meter high drop to concrete surface
High magnitude, long-term, e.g., large gun repeatedly firing

- ☐ Other - describe:

4. Estimate aspects of your project in each of the following three lines:

Number of subsystems (e.g., circuit boards, power supplies, mechanisms): _____

Number of lines of code (LOC): _____

Number of logical operations or function points: _____

- ☐ Check only if you have no confidence in your numbers.

5. What is the planned longevity of each unit once it goes into service?
   - ☐ less than a year
   - ☐ 1 to 3 years
   - ☐ 4 to 10 years
   - ☐ 11 to 20 years
   - ☐ more than 20 years

6. What is the plan for maintaining and repairing the product?
   - ☐ disposable, no maintenance nor repair
   - ☐ repairable, but no regular maintenance
   - ☐ regular maintenance by customer or operator
   - ☐ highly complex maintenance and repair by very skilled personnel

7. Will the device be connected to the internet?
   - ☐ continuously while operating
   - ☐ intermittently when it calls into a designated control center
   - ☐ only during development or repair or maintenance
   - ☐ not after development, all communications will be secure
   - ☐ never

8. Classify the human interface:
   - ☐ autonomous, very little or no human interaction
   - ☐ simple and intuitive, e.g., like a kitchen appliance
   - ☐ requires some training, e.g., like learning to drive an automobile
   - ☐ requires training and update short courses
   - ☐ only used by a few highly trained operators, e.g., pilots flying an aircraft

9. Describe the data bandwidth into and out of the product in less than 100 words:

10. Describe limits on size, shape, or volume in less than 70 words:

11. Describe limits on weight in less than 50 words:

12. Describe limits on power consumption (or generation) in less than 50 words:

13. Describe the purpose, primary function, and functional limitations of the product in less than 200 words:

14. Describe how you would operate the product in less than 200 words:

The report, approved by the client before completing the submission, will have the following look-and-feel to it. This is what crowdsource participants will see:

Purpose, primary function, and functional limitations of the product:

How to operate the product:

Type of project:
(e.g., clean-sheet or update or integration)

If project is an update:
_____% of subsystems to be revised
_____% revision of total product

Manufacturing or production:
_____ total number of units to be produced over market lifetime.
_____ number of units to be produced each year.

Industries in which the product will operate:

Regulations, standards, certifications, or approvals that the product must meet:

Operational environment in which the product will operate:

Estimates of project complexity:
Number of subsystems within product: _____
Number of lines of code within product: _____
Number of logical operations or function points: _____

Planned longevity of each unit once it enters service: _____ years

Maintenance and repair philosophy:

Internet connectivity:

Human interface:

Bandwidth:
Size, shape, volume:
Weight:
Power consumption (or generation):

When the client wishes to submit the project for consideration and estimation, the client must check this box to finalize the submission.

☐ By checking this box, I agree to do the following:

- Give a yearly progress report until the project finishes. (Expected 12 min.)
- Give a debriefing report when the project finishes. (Expected 12 min.)
- Participate anonymously in at least one survey each year for other clients until my project is finished. (Expected 8 to 12 min.)

- Failing to complete these three conditions will bar me and my company from using this tool for three years.

Proposed Survey for Crowdsource Participants to Provide Project Estimation

Crowdsource participants will see and read the report given in the section of the appendix above. They then will respond to the following survey:

	Estimates of effort in FTEs (person-months) per phase			
	Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Transfer to Production**
Engineers, developers (e.g., software, elect., mech., indust., mfg.)				
Technicians, assemblers, fabricators, logistic support				
Management, administrative				
Marketing and sales				
Others, including consultants				

Please fill in these four boxes with your estimate of calendar time (in months) for each phase.

Estimates of effort in FTEs (person-months) per phase			
Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Transfer to Production**

In production, what do you expect the per-unit-cost of the product will be? Cost of Goods Sold (COGS)/unit = $_____

	Low - effort, cost, and technology are understood and controlled; e.g., system upgrade to a servomechanism that does not require software changes and only minor differences in the motor and drive.		**Medium** - effort, cost, and technology are understood; e.g., clean-sheet design of a servomechanism that uses available components.		**High** - effort, cost, or technology are new to the team; e.g., clean-sheet design of a spacecraft instrument with new software and autonomy.
	1	2	3	4	5
Software, firmware	☐	☐	☐	☐	☐
User interface and operation	☐	☐	☐	☐	☐
Electrical and electronic hardware	☐	☐	☐	☐	☐
Optics	☐	☐	☐	☐	☐
Mechanisms and mechanical hardware	☐	☐	☐	☐	☐
Data manipulation, flow, and storage	☐	☐	☐	☐	☐
Controls, mechanisms	☐	☐	☐	☐	☐
Verification, validation, compliance (e.g., FDA or FAA or UL or CE)	☐	☐	☐	☐	☐
Security of operation	☐	☐	☐	☐	☐
Customer or client acceptance	☐	☐	☐	☐	☐
Extreme environments (e.g., temperature or pressure or vibration)	☐	☐	☐	☐	☐
Cost of final product	☐	☐	☐	☐	☐
Cost of development	☐	☐	☐	☐	☐
Time-to-market	☐	☐	☐	☐	☐
Changing requirements	☐	☐	☐	☐	☐
New technology, paradigm shift, revolutionary	☐	☐	☐	☐	☐
Power consumption or dissipation or handling	☐	☐	☐	☐	☐
Size or weight	☐	☐	☐	☐	☐
Material or mass flow	☐	☐	☐	☐	☐
Competition	☐	☐	☐	☐	☐
Program management, team collaboration	☐	☐	☐	☐	☐
Other: _____	☐	☐	☐	☐	☐

Proposed Report Format of the Project Estimation Provided to the Client

The proposed format of the report, supplied to the client, that contains the crowdsource estimates will have the following formats.

The COSYSMO model estimates that your project will take: _____ FTEs (person-months)

Crowdsourcing estimates the following:

	Estimates of effort in FTEs (person-months) per phase				
	Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Certification, transfer to Production**	
Engineers, developers	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Technicians, assemblers, fabricators, logistic support	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Management, administrative	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Marketing and sales	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	
Others, including consultants	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	**Average total effort**
Mean estimate of effort + standard deviation per phase	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.

	Estimates of effort in FTEs (person-months) per phase				
	Concept & Preliminary Design	**Critical Design**	**Test & Integration**	**Certification, transfer to Production**	**Average total time**
Mean estimate of time + standard deviation per phase	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.	μ ± S.D.

In production, the estimated per-unit-cost of the product will be: COGS/unit = US$_____μ ± S.D.__

Classification of Problem Areas

Low (1 to 2) - effort, cost, and technology are understood and controlled; e.g., system upgrade to a servomechanism that does not require software changes and only minor differences in the motor and drive.

Medium (2 to 4) - effort, cost, and technology are understood; e.g., clean-sheet design of a servomechanism that uses available components.

High (4 to 5) - effort, cost, or technology are new to the team; e.g., clean-sheet design of a spacecraft instrument with new software and autonomy.

	Estimate
Software, firmware	
User interface and operation	
Electrical and electronic hardware	
Optics	
Mechanisms and mechanical hardware	
Data manipulation, flow, and storage	
Controls, mechanisms	
Verification, validation, compliance (e.g., FDA or FAA or UL or CE)	
Security of operation	
Customer or client acceptance	
Extreme environments (e.g., temperature or pressure or vibration)	
Cost of final product	
Cost of development	
Time-to-market	
Changing requirements	
New technology, paradigm shift, revolutionary	
Power consumption or dissipation or handling	
Size or weight	
Material or mass flow	
Competition	
Program management, team collaboration	
Other:	