You Can't Wait for ROI for MBSE and Model-Based Analysis

Fred Schenker

Jerome Hugues

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

Document Markings

This material is based upon work funded and supported by the U.S. Army Combat Capabilities Development Command Aviation & Missile Center under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

DM23-0439

Problem Statement

The acquisition of Cyber-Physical Systems (CPS) is notoriously challenging

It is a **“metaphysical certainty”** that the system acquisition will be over budget, late, lacking required capability, or some combination of these three

One of the primary root causes for the delays is that we discover ***in integration and test*** that there are resource constraints (e.g., processing speed, memory, bandwidth) with the embedded computing systems, manifested as system latencies or other observable phenomena

When discovered so late in the development lifecycle, these situations generally require significantly more effort and time to resolve, ***because the design has been completed***

We can do more to leverage model-based development (e.g., MBSE) and model-based analysis to improve the status quo, but we aren’t

Why Are We Not Trying to Get Better at Developing Cyber-Physical Systems?

Embedded Computing and Cyber Physical Systems

Cyber-Physical Systems (CPS) are pervasive in the DoD, their capability is extended by their embedded systems.

Embedded systems are made of software and hardware sub-systems, and are integrated into a larger system, e.g., in charge of monitoring and controlling a physical process such as the trajectory of a vehicle:

- often associated with real-time or safety non-functional requirements: providing a function that must be completed under time constraints, (e.g., respect of deadline, periodicity, etc.)
- while ensuring safety invariants, e.g., avoiding unsafe situations that would create an unbearable risk to the system or its environment.

CPS adds extra complexity to the system because of the greater degrees of coupling between computations and physical processes and was first recognized by the NSF as part of an emerging field of research in late 2006

Model-Based Engineering and Analysis

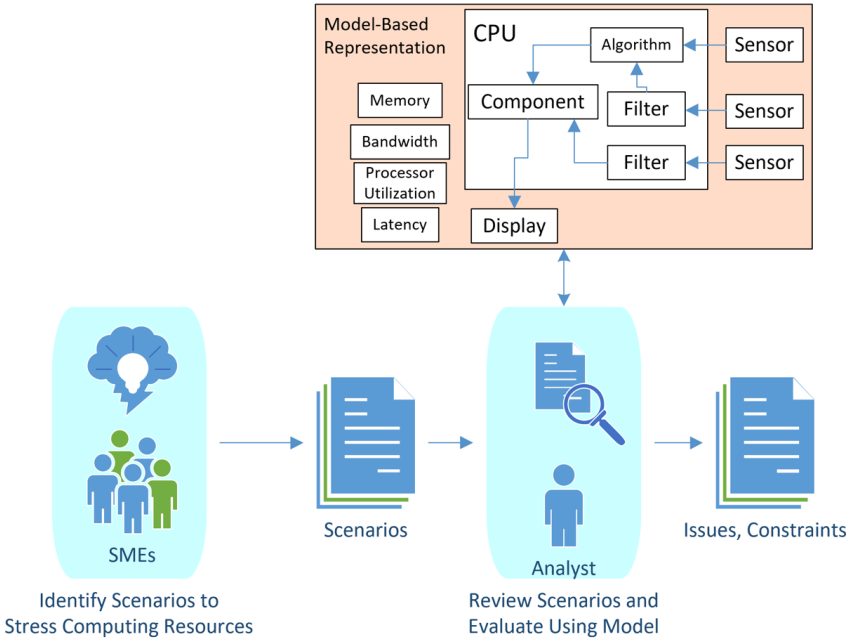
Models have been used to improve engineering design quality **for centuries**, some examples:

- Mechanical structural design and analysis by Da Vinci, Euler, others
- Development of the rail specification in the 19th century

Model-based analysis provides a model-based environment to predict product performance, and identify issues and constraints, some physics-based examples:

- Wind tunnels
- Finite element analysis

Notional Model-Based Analysis Process



Model-Based Engineering and Analysis for Embedded Computing Resources

Goal: *Identify computing resource constraints (and figure out what you're going to do about them) LONG BEFORE you would normally have done this if using "traditional" methods*

1. Develop models of the embedded computing resources, e.g., processor capacity, memory usage, bandwidth of buses
2. Develop models of the components that comprise the systems
   - Start with simple, black box representations
   - Elaborate them, as necessary, to perform specific analyses
3. Develop use cases, or application scenarios, that stress the computing resources
4. Perform model "virtual integration" simulating the physical integration
   - Connect the components to the computing resources and to each other
   - Evaluate the interfaces and build the system messaging infrastructure
5. Perform the model-based analyses, identifying potential issues with the computing resources
6. Iterate the design using the results of the analysis, improving the design quality

Return on Investment (ROI) – Issues

The traditional method for assessing ROI is to do some kind of "**apples to apples**" comparison, looking for process improvement in predictable places, e.g., quality, cost

What's wrong with this type of evaluation for model-based analysis?

- DoD acquisition lifecycle is too long
- Teams of developers will not have equivalent skills
- The new process (model-based analysis) will evolve over the course of the evaluation
- There is no standard criteria for measuring benefits

In addition, there is a problem, that if we apply model-based methods to identify and mitigate issues early, then they never exist. How do you count things that aren't there?

- Referred to as *counterfactual thinking*… "if only we had been doing model-based development and analysis from the beginning"
- Usually applies to not normal behavior, i.e., you only ask the "if only" question when something unusual happens

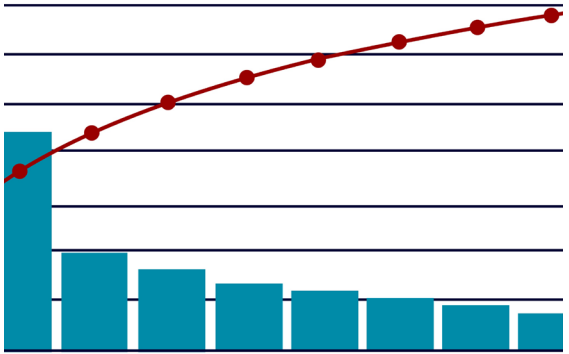
It is very difficult to use ROI to prove the value of model-based methods

Post-Mortem Analysis

Instead of applying a traditional method for assessing ROI, we should investigate other approaches to measuring benefits

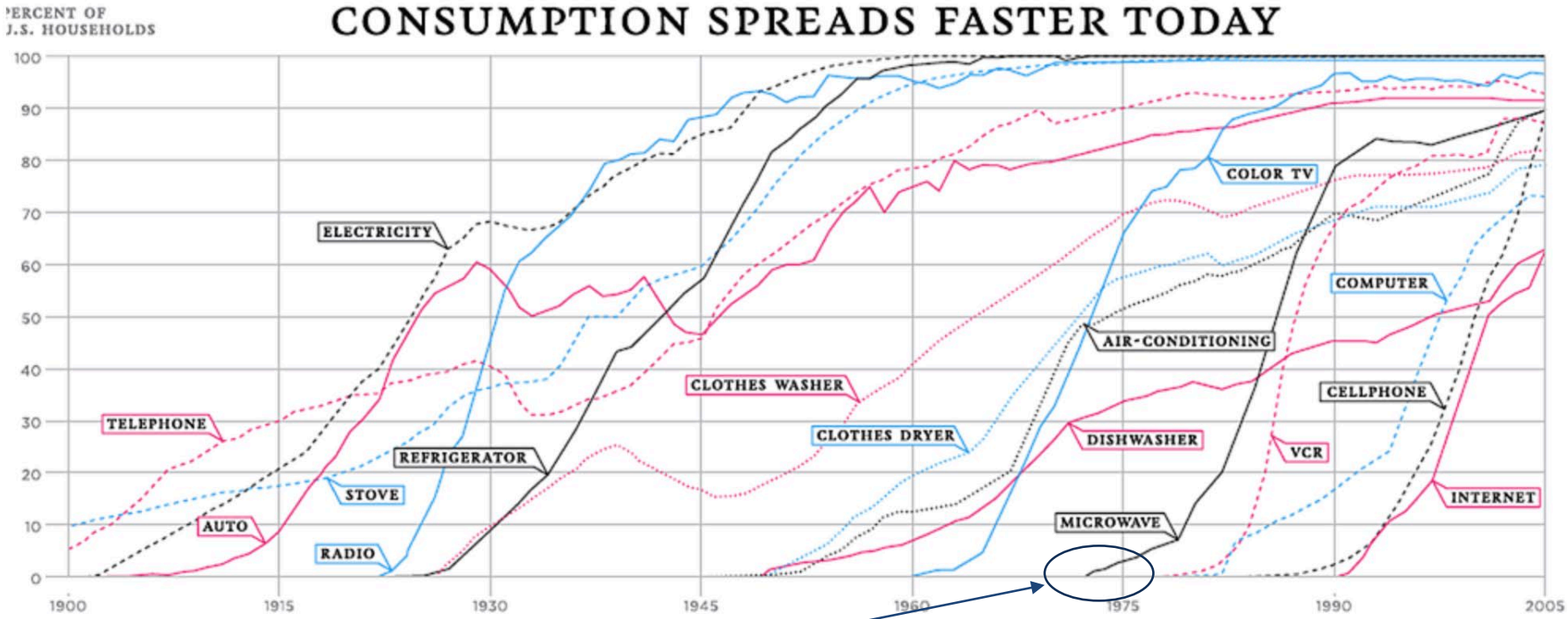
Using prior project data, we can assess whether or not the issues that caused project delays or overruns could have been prevented had model-based methods been used

1. Identify a set of projects to review
2. Examine the defect database, pareto the defects by the amount of time to correct the issue
3. For each of the issues in the top 80%, determine:
   a) How a model-based method could have been used to prevent the issue
   b) How practical it would have been to do this
4. Summarize the benefit that would have been accrued by using the model-based methods, and use this to justify the investment



Note: This type of assessment has not been done (to our knowledge); the SEI would be very interested in working with an organization to demonstrate the method

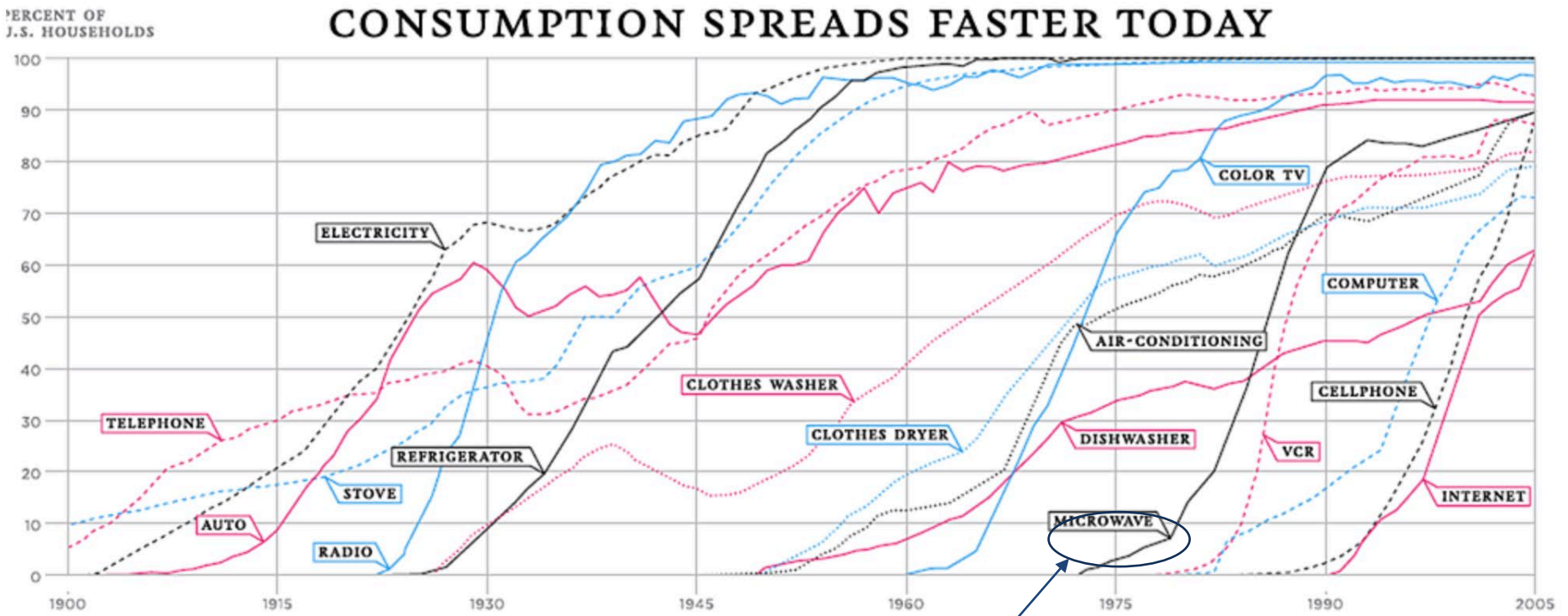
Technology Adoption



Late 60s – Microwave Introduced

graphic reprinted with permission from Nicholas Felton

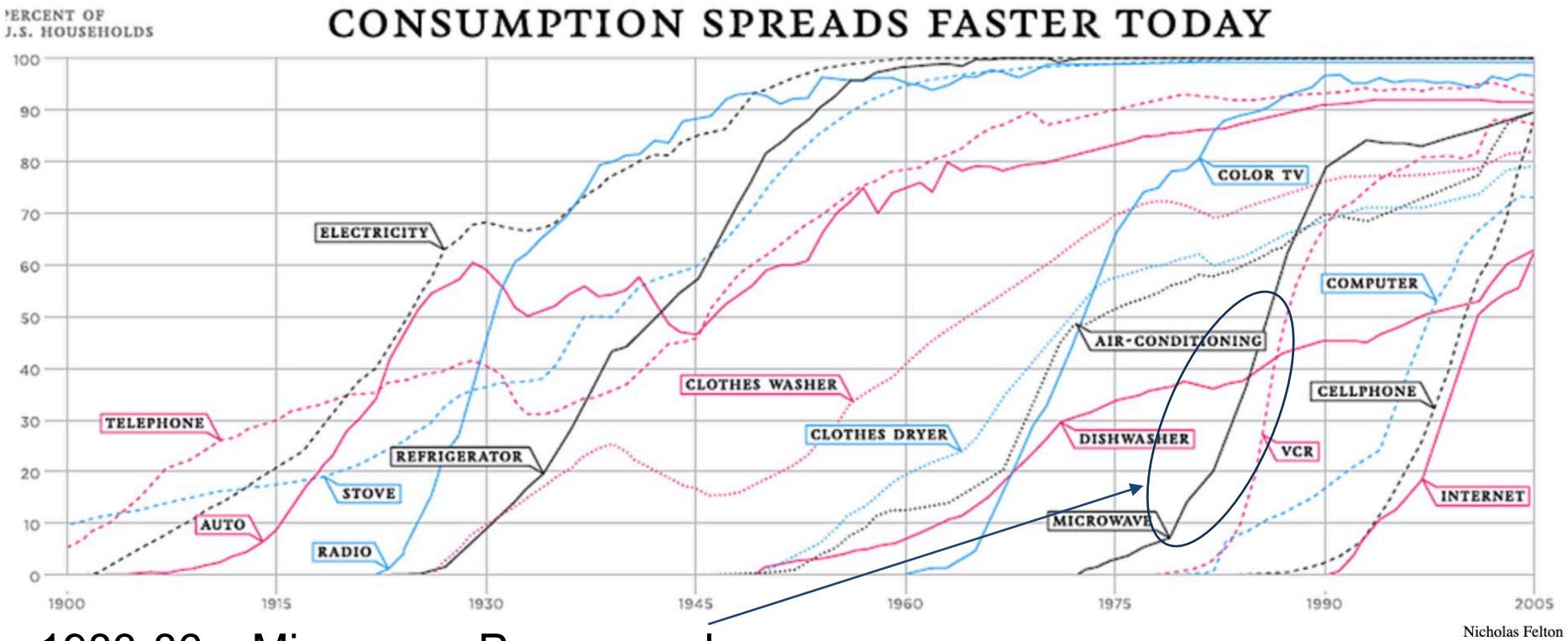
Technology Adoption



Late 60s - Early 80s – Microwave Sales Languish
<10% of US Households in 1982

graphic reprinted with permission from Nicholas Felton

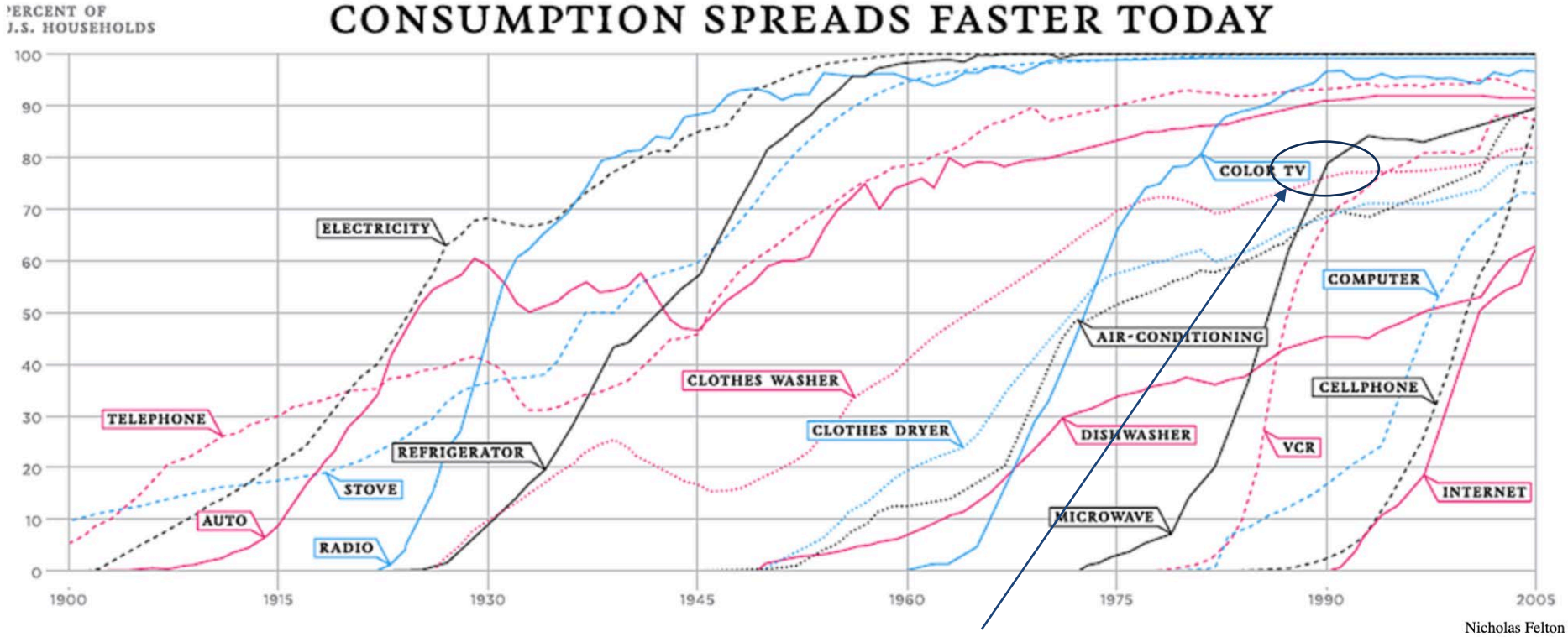
Technology Adoption



1983-86 – Microwave Popcorn sales increase from $53M to $250M

graphic reprinted with permission from Nicholas Felton

Technology Adoption



1990 – Microwaves exist in 80% of US households *graphic reprinted with permission from Nicholas Felton*

Recommendations for Acquirers and Contractors

For Acquirers

1. Continue to set expectations with contractors that model-based design and analysis will be required for current and future acquisitions:
   - Language in SEPs, SOWs, and other acquisition documents
   - RFIs asking contractors to describe their practices for integrating model-based methods into their development practices.
   - **Award fees and other contract incentives for successful application of model-based methods.**
2. **Train staff on how to use the tooling to be able to effectively review, verify, and validate contractor model-based deliverables.**
3. **Build an enterprise-level competency for model-based methods to establish consistency across programs, and collect lessons learned for future process enhancement.**
4. Build the supporting infrastructure (digital engineering environment) to provide the capability to collect and analyze contractor deliverables.

For Contractors

1. **Establish the culture to enable the model-based methods to thrive and add value.**
2. Establish how the model-based methods are to be implemented, i.e., identify the model-based tools, and configure the tools into some kind of toolchain.
3. Train staff on how to perform the new practices.
4. **Develop a strategy for model management for collaboration. Don't assume that it's "my way or the highway." Elements such as where the authoritative source of design information resides needs to be established and communicated with all stakeholders.**
5. **Take a critical look at the defect resolution process.. Use the results of root cause analyses to spur innovation with the model-based development methods.**
6. **Establish a project post-mortem process.**
7. **Establish a plan for how to account for the added costs and measuring the value received from applying model-based methods to the existing process.**

Conclusion

We have made the case that ROI is not a useful way to assess the viability of adopting model-based systems engineering practices, especially for architecting and evaluating the embedded computing resources of CPS.

We have proposed alternative ways, such as post-mortem analysis, analogy, or just a leap of faith to justify the increased usage of MBSE techniques to support these CPS projects.

These findings are informing some of the current engagements performed by the SEI. The SEI is supporting multiple DoD projects in their adoption towards MBSE and will transfer some of these recommendations into practice as part of our transition work.

Contact Info

Alfred (Fred) Schenker
e: ars@sei.cmu.edu
o: (412) 268-9145

Jerome Hugues
e: jjhugues@sei.cmu.edu
o: (703) 247-1380