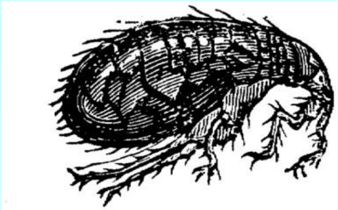

Software Test Architectures and Advanced Support Environments for IoT

Jon D. Hagar, Consultant, Grand Software Testing

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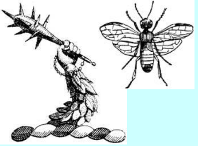
PNSQ Conference



The Test Architectures and Advanced Support Environments Opportunity

- IoT is Hot
- Test Architectures are poorly defined and understood
- Supporting Test Environments are often weak
- IoT is in part an evolution of embedded systems

But devices want to be

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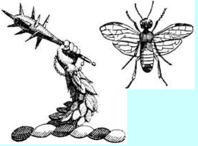

Today's Topics

- Introduction
  - Definition of Software Test Architecture and Environment
  - Classification of IoT Device Architectures for Software Test
- Classification of IoT Device Environments Needing Test
- IoT Test Architecture and Environment Viewpoints
- Sample Risks Caused by Insufficient Test Architectures and Environments
- Example of Current Large Scale Test Architecture-Environment Solutions
- Future research Needs
- Summary

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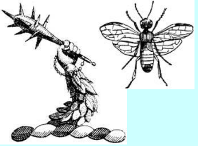
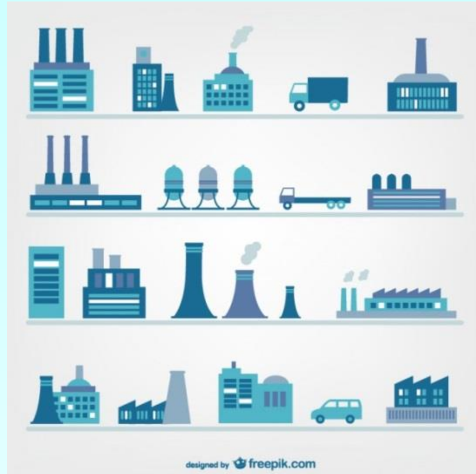
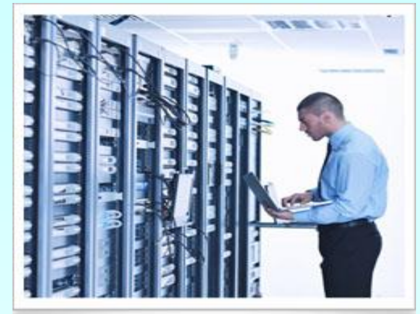


Defining The Technology Space





Cyber

Systems

(1950s)

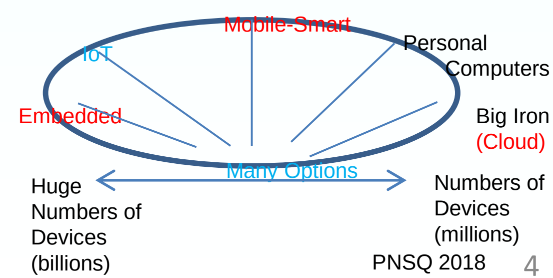
Physical

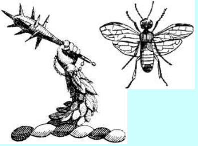
Systems

(circa 100,000 BC)

Cyber-Physical

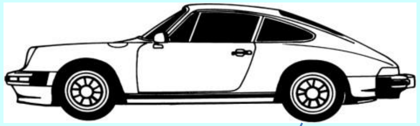
Systems





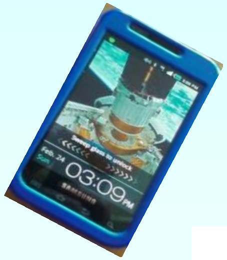
What are These IoT Devices

- Embedded – Software contained in “specialized” hardware…
  - Minimal networking-communications in the beginning
  - But now Networked => IoT and Robotics



Test Brakes

- Mobile and handheld smart devices—small, held in the hand, highly connected (web, cloud, servers,….)



To Drive

- IoT – Internet of Things are “traditional” and new devices with software and communication added

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DEFINITION OF SOFTWARE TEST ARCHITECTURE AND ENVIRONMENT

- ***Software Test Architecture*** *is the process(s) and the product(s) of planning, designing, and constructing tests done with supporting test structures*
  - *Note: supporting test structures include test: tools, environments, documentation, tooling, viewpoints, and analytics*
- ***Computing Environment*** *(to support testing) - The overall structure within which a user, computer, or program operates*
- ***Viewpoint*** *– In systems engineering, a viewpoint is a partitioning or restriction of concerns in a system*
- ***Software User*** *– Typically in software, humans are the only users who interact with the software system, but in IoT, the user of the software is expanded to include*

Defining Software Capabilities

- James Whittaker defines 4 fundamental capabilities that all software possesses
  1. Software accepts inputs from its environment
  2. Software produces output and transmits it to its environment
  3. Software stores data internally in one or more data structures
  4. Software performs computations using input or stored data

- To this, I expand and refine based on IoT context:
  – Performance within time while supporting complex communications
  – Testing with specialized hardware
  – Verifying and validating (V&V) qualities: safety, security and privacy
  – Testing to support different environment contexts and constraints

Early testing   Holistic Testing   Rapid Testing   Field Testing

Last Year's Test Architecture Conferences

- Defining test architecture problem
- No standards really address architectures
- Examples of architectures and environments may be critical for testing success

IoT maturing chaos

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Classification of IoT Device Architectures for Software Test

- IoT differences
  - Hardware
  - Many possible uses/users
  - Billions of products (devices)
  - Software in everything and emergence of AI/Analytics
  - Costs and schedule (really not new, but important)

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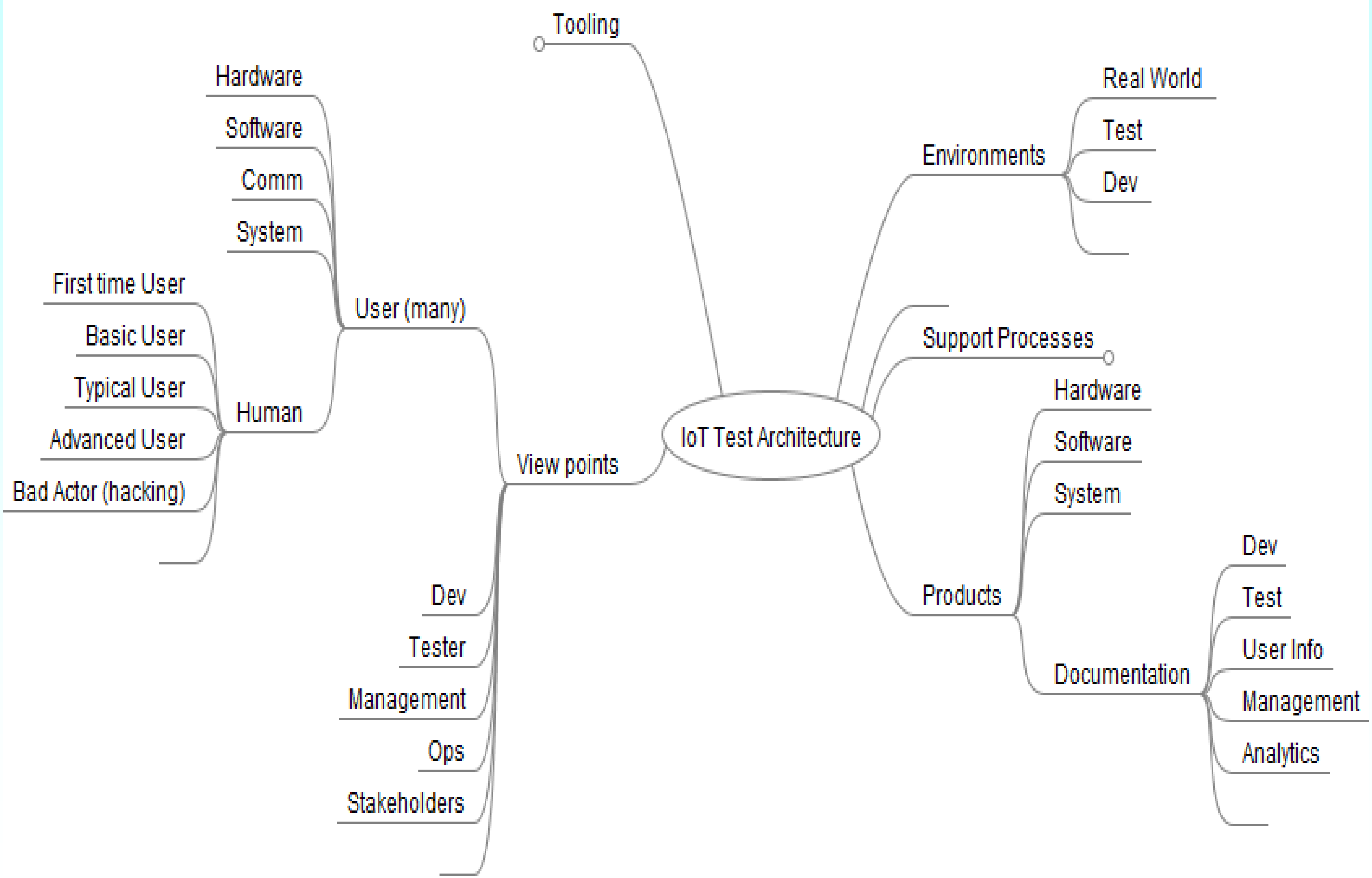
IoT Test Architecture Classification



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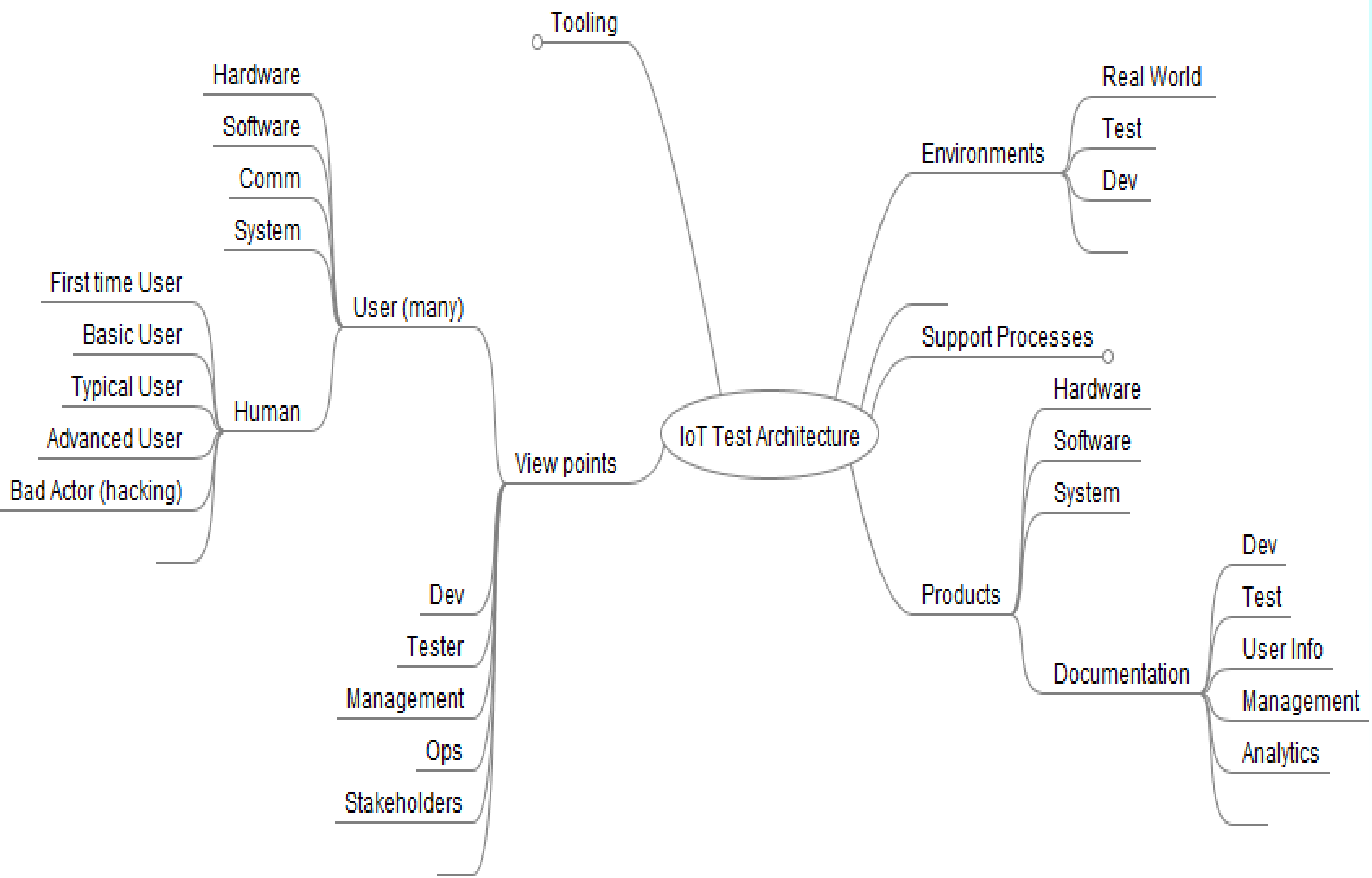
Exercise (not in notes)

- Missing or Added Elements?



Architecture Key Points

- Model is not complete
- Many sub areas under “Tooling”
- Much architecture work needed for test environments
- <u>IoT products are out pacing test processes, standards, architectures, and eironments</u>

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Classification of IoT Device Environments Needing Test

- In IoT test architecture, one critical component will be environments
  - Current IoT project test in “small” isolated environments
  - The World IoT system function in is bigger

Who is responsible for the bigger picture?

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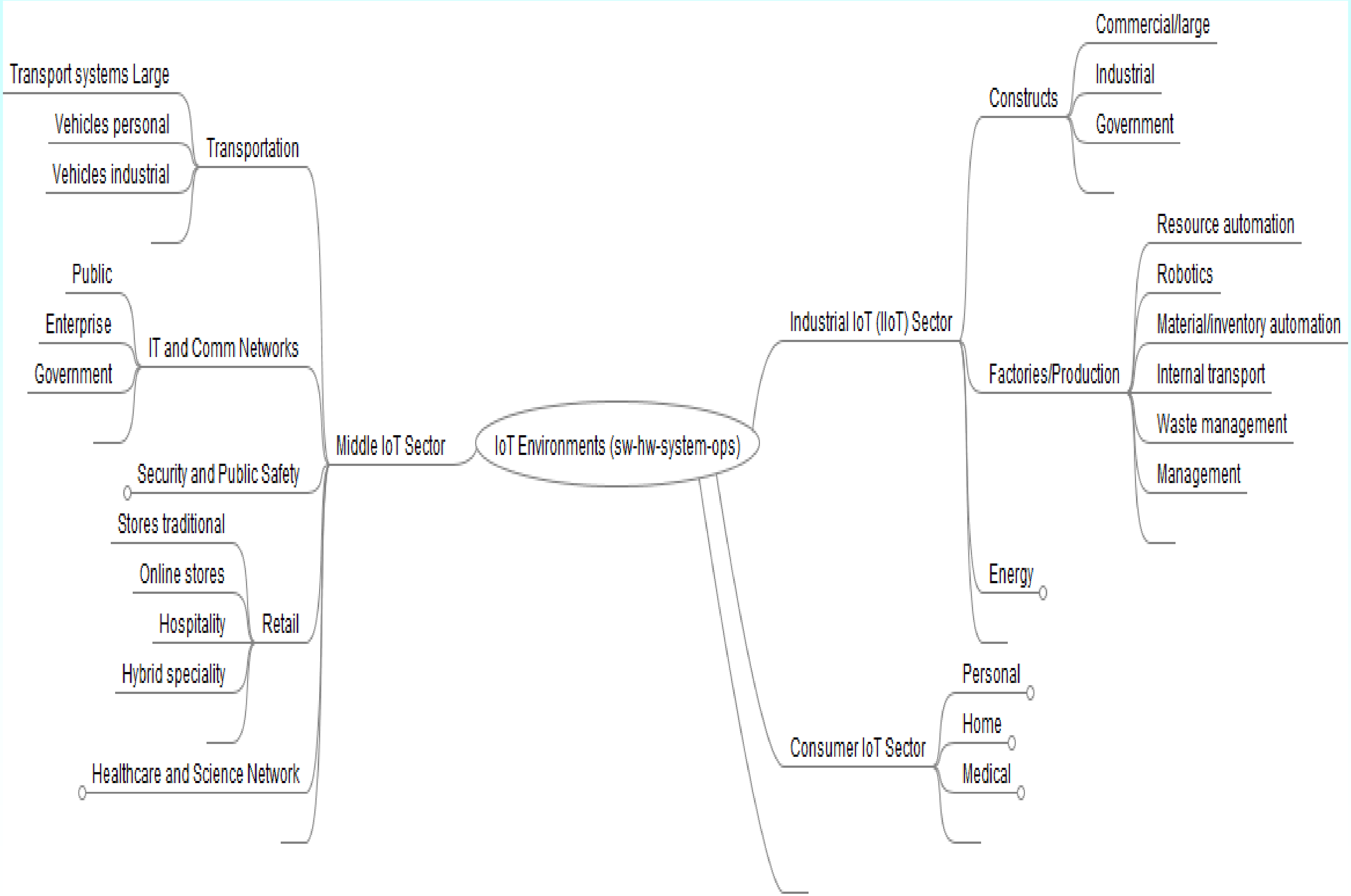
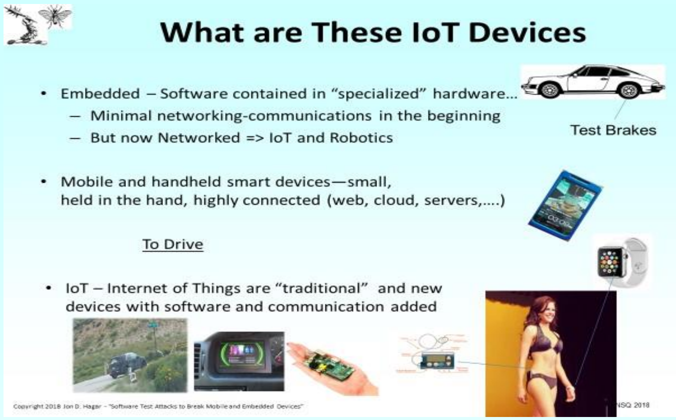
IoT Device Environments Mind Map



Environment Mind Map Considerations

- No agreed to allocation of what is IoT

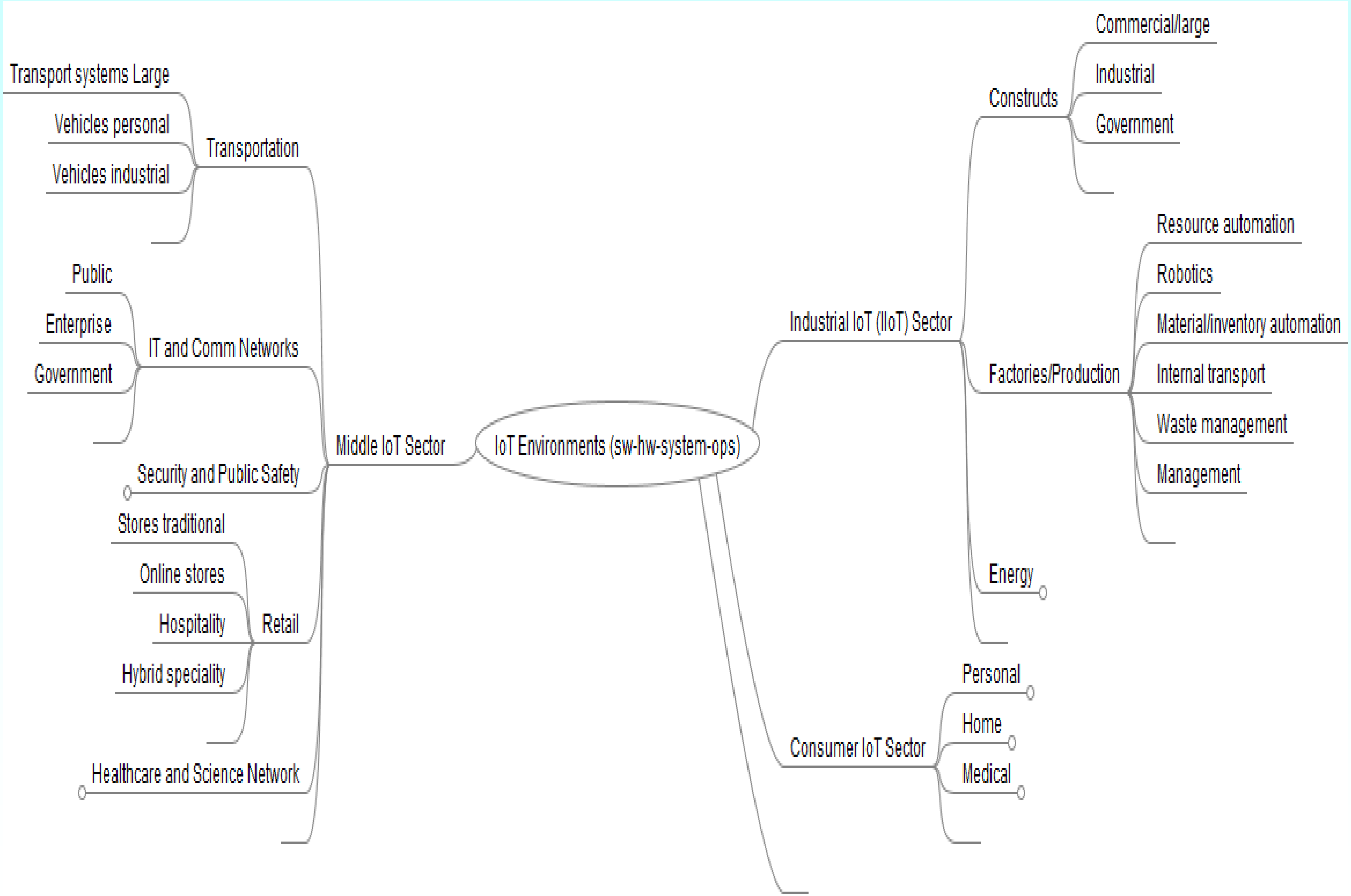


- Much debate over IoT, IIoT, personal devices, cars, robots, etc.

- Test environments still need to be understood and identified within test architectures for products to be successful

- Worse in environments there are many viewpoints which often are not considered during testing

Exercise: What Environments Must We Add?



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Example IoT Test Architecture & Environment Viewpoints

Environment Example	IoT ViewPoint	Sub Target	Examples
Connected Automobile	User (s) - Non Human	Hardware	Controllers, sensors, motors, batteries
		Software	Onboard App, cloud, third party, Operation system
		Comm	Vendor network, Wifi end to end comm, long duration trip/drops
		System	Safety, Security, availablity, reliability
	Human	First time driver	Security set up, limit usages, non techie
		Basic	Average user, disability, user help files
		Typical	Child, adult, techie
		Advanced	Race Car, expert on snow,
		Bad actor	Hacker, cracker, human using malware
	Dev	Structural tests	Coverage, static analysis
	Tester	Test process, planning, design, techniques, documentation	ISO 29119, ISO 26262
	Management	Information on	Cost, schedule, time to ship
	Ops	Failure management	Help desk, predicitive analysis tires
		Analytics	Machine learning, AI, privacy
	Stakeholder (owner)	Benfit	Information, self-drive
		Resoruce	Cost, schedule, savings

IoT Test Architecture & Environment Viewpoint Considerations

- A simple environment for an IoT device in a automobile may miss many viewpoints and targets

- Errors and faults are missed

- Security, reliability, performance and many other qualities are likely to be compromised

  – Consider recent car crash – Tesla in California

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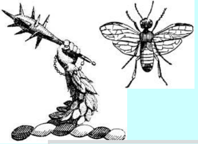
Exercise: View Points (not in notes)

Device	View Point	Target
Smart Watch		



IoT Risk Sampling in Test Environments

Risk Area Example	**Risk Area Example**
The reactive and always-on nature of the devices	Lack of realized benefits promised by IoT vendors
Heterogeneity and diversity at the same time across many systems and devices	Waste (cost or schedule) caused by failures seen in the field
Power/battery usage limitations	Errors and failures impact happiness and quality of life
The massively distributed, highly dynamic, and migratory nature of devices	Disruption in society caused by devices (story of traffic lights)
The need for software fault-tolerant and recovery	Lack of resources (cost and schedule) for test environments
Fragmentation of the market place (many vendors)	Lack of responsibility for quality across the system or system of systems
Configuration management of devices to maintain consistency and qualities	Interoperability and integration across devices and sectors
Current approaches in testing and test architectures do not scale given billions of devices	Software quality characteristics not met, e.g. High availability, relability, safety, security, usability, and functionality
Lack of universal product Comm standards	Hardware quality characteristics not met

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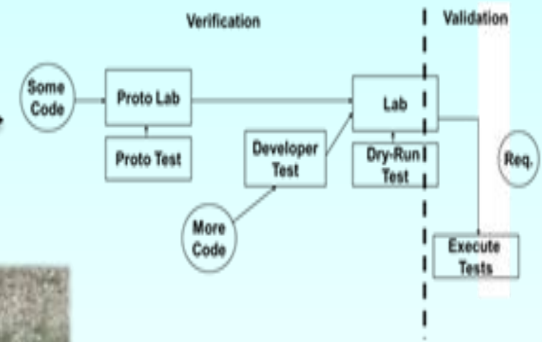
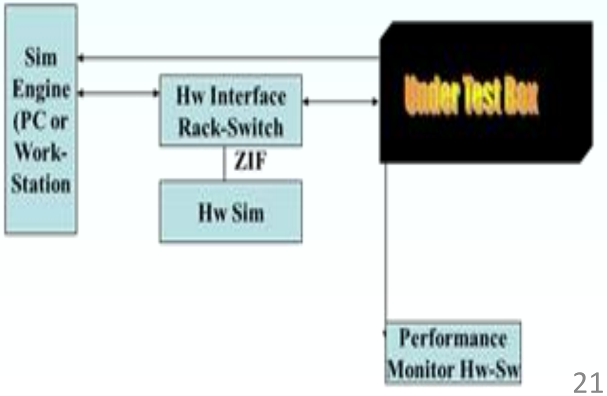
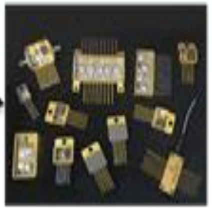
Examples of In-Use Complex Test Architecture-Environments

Example of Complex Test Environment	Refer link	Notes and pictures
Embedded test labs of AreoSpace	17	Software, Hardware, and system integration facilities
Airbus Iron Bird	18	Airplane with all the "parts", but can not ever fly
Auto industry high altitude test lab	19	Test the cars in the real world - picture of drap
Test bed cities and open evaluation platform	20	Real environment, but with what controls and monitor system? How tests and records?
Chaos engineering	21	Test on live systems. Risk
Embedded test environments approaches	4 , 10	Lab with scopes, software,modeling, switch in and out zero force pic
Device hardware qualification levels	22	e.g. space qual'd parts

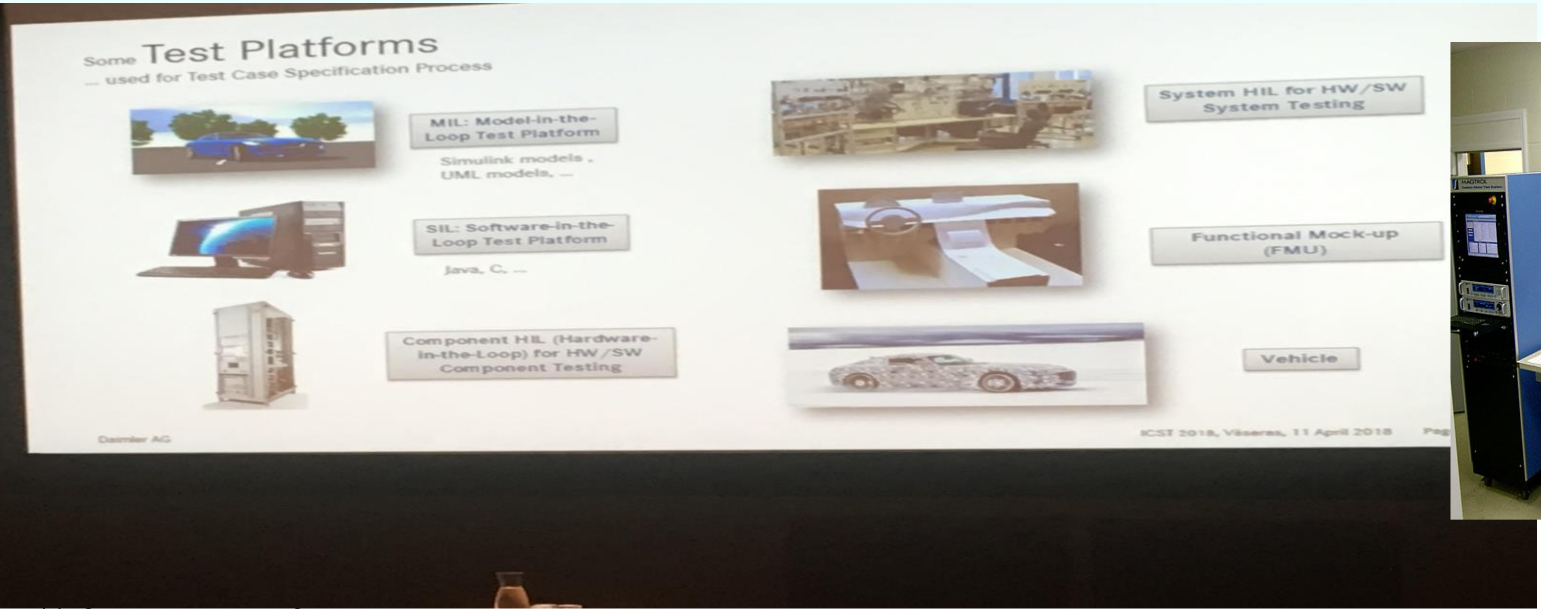






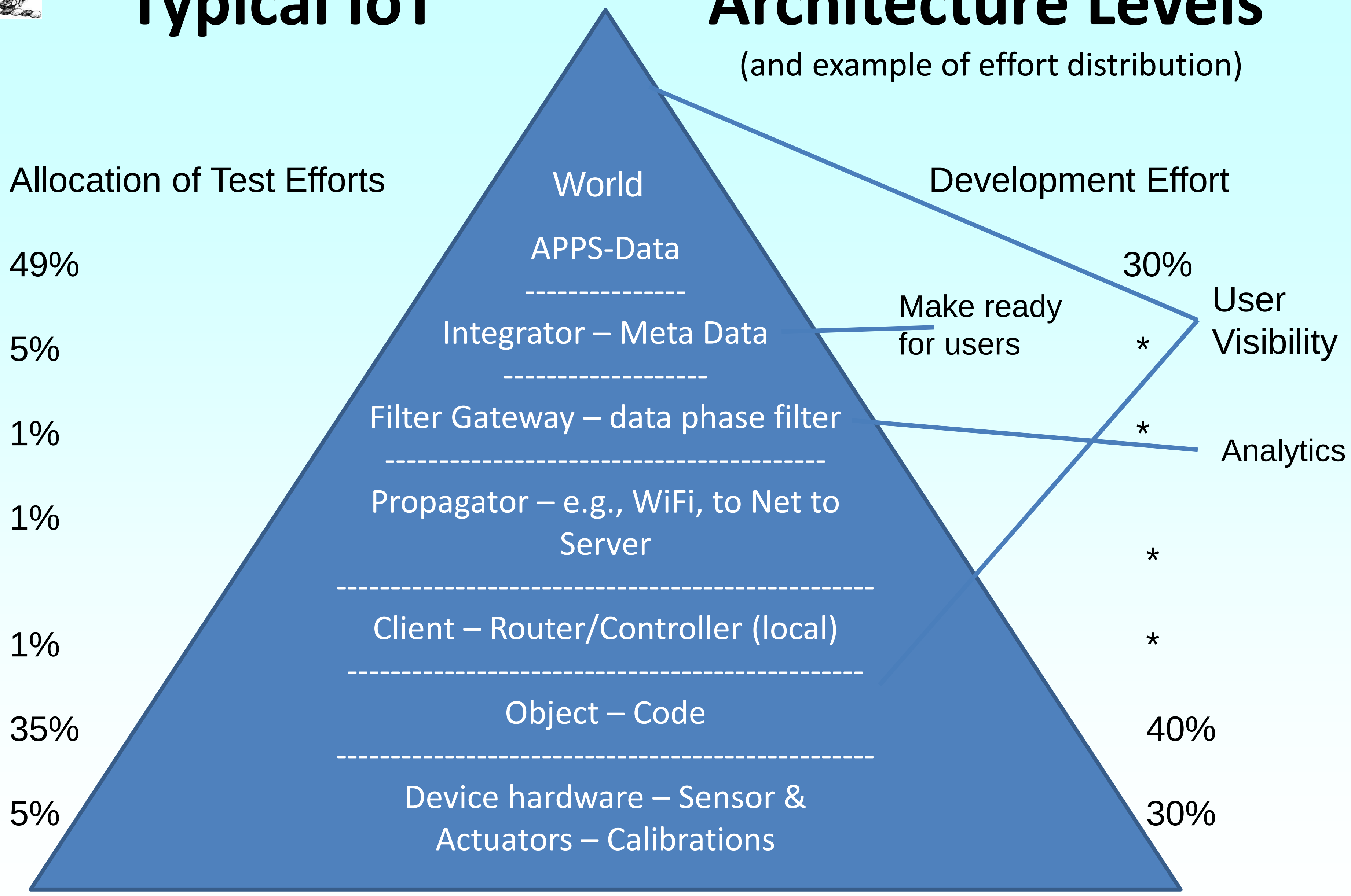
Test Environments and Architectures Needed for Each IoT Type

- Test and project planning problem
- Over simplification is a risk
- Under testing a real possibility
- Project will then to “accept” the risk to get to market
- Test Environment and Architectures needed at each level of IoT Architecture



Typical IoT Architecture Levels

(and example of effort distribution)



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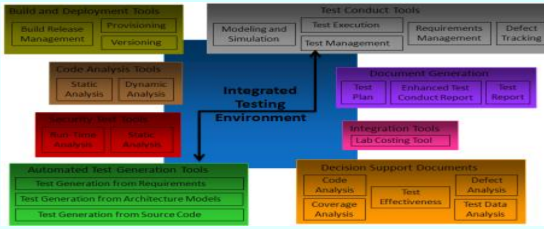
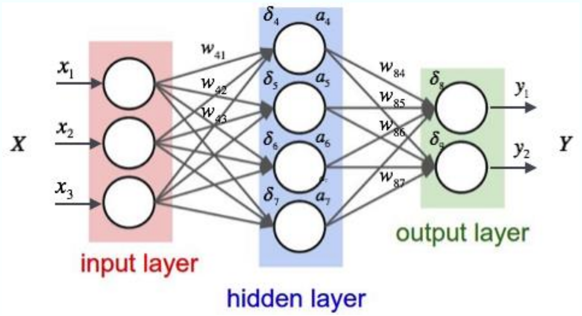
AI/Analytics Enable Many IoT System

- Data modeling analytics, statistical design, AI and deep learning
  - Model based testing leading automation (millions of tests?)



- Designing AI-deep learning
  - Using data from machine learning but watch
    - <u>Neural Net case study: programmers who write more and better comments make fewer errors (not what I expected)</u>

- In statistics we scientifically design experiments and analyze data
  - How to pick training sets?
  - What is important?
  - What is valid?



- Test Analysis => Thinking

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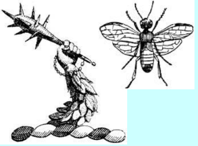
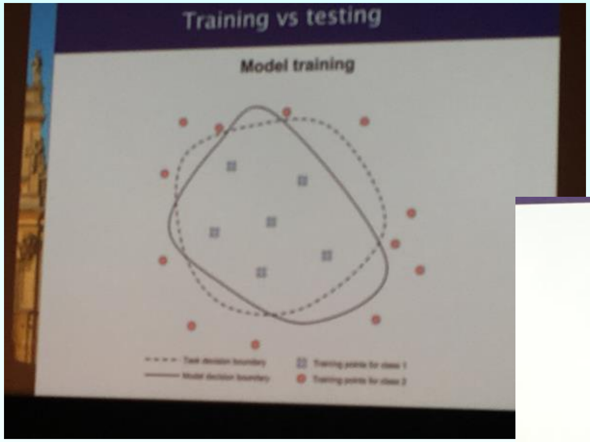


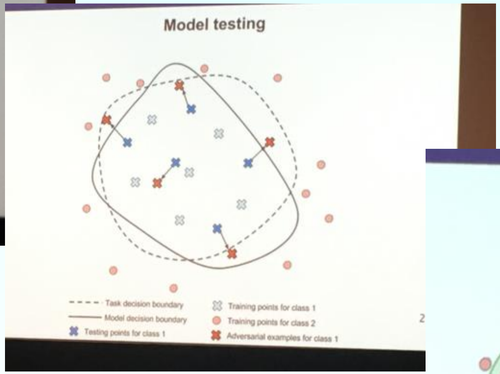
Test Implications of Deep Learning Models

Data Analytics Using AI models may be very useful but thinking humans are still needed
 - Case Study of Early bug Taxonomy

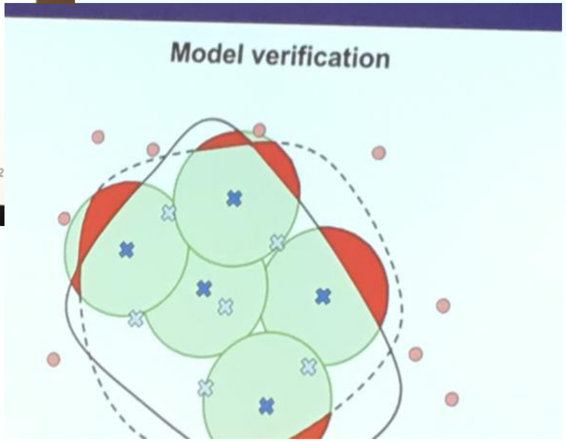
You need Valid Big Data



You Should Test The Learned Model



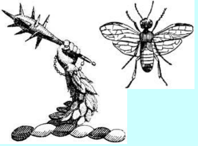
You Should Verify The Model Over The Life of the Device



Credit: IEEE Sweden 2018

Future IoT Work Opportunities

- Specialized IoT IV&V facilities at the full system/system-of-system for IoT
- Data analytics with real-time testing in the field and self-healing systems
- Government departments tasked with the focus on IoT (National testbed)
- Privacy and security regulations and standards
- Model Based Testing (MBT) and simulation driven test beds
- Predictive Maintenance
- Distribution and heterogeneous systems on the Internet
- Industry and government test labs with independence (cost and schedule)
- Testing to address the fragmentation of IoT
- IoT Test support tools
- IoT data analytics and deep learning
- Support process standards e.g., ISO and IEEE

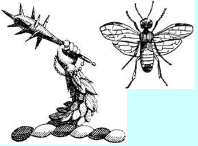


Summary

- The research for this paper has indicated the need for more work in IoT test architecture and environments
  - An IoT classification example for test architecture and environments
  - Demonstrated viewpoint usage in testing

- Existing and successful test facilities from the embedded software device world
- Some projects will make IoT devices just "good enough" to continue
- The lack of being "good enough" will lead to many IoT projects learning by failures in the field
- Risks outlined in this paper are only part of the IoT problem

- IoT, IIoT and IoT of everything are being rushed, implemented and fielded before many of these test architecture and environment issues are even considered, let alone solved and resources will be wasted



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