CS453: Software Verification Techniques

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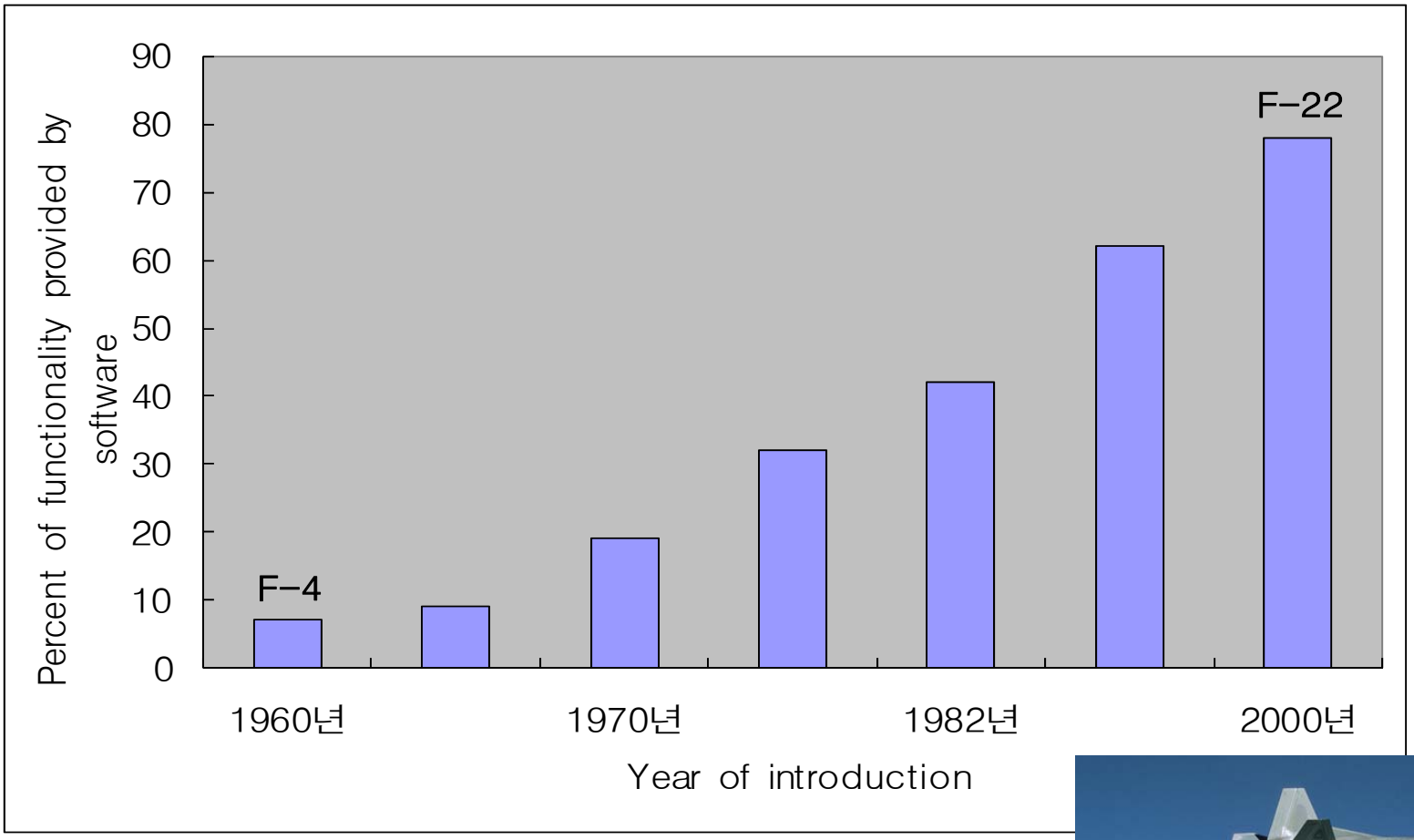
Provable Software Laboratory

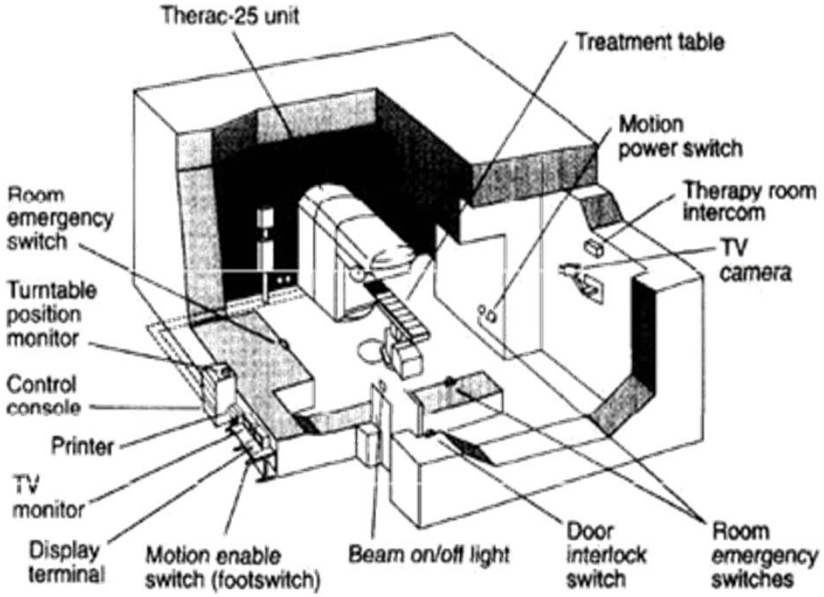
CS Dept. KAIST

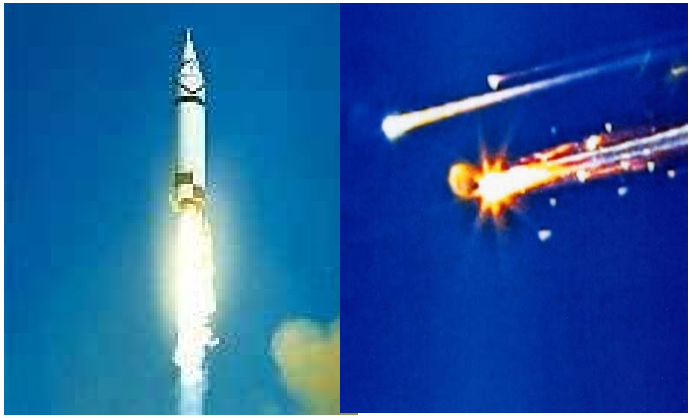
Role of S/W: Increased in Everywhere

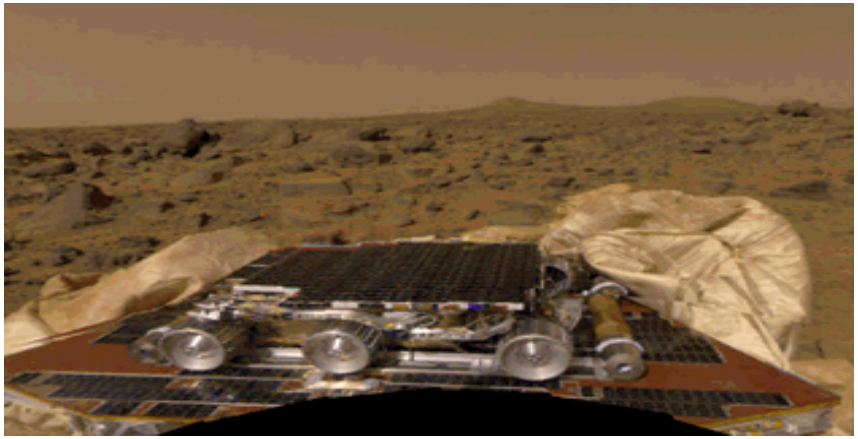


자료출처: Watts Humphrey 2002

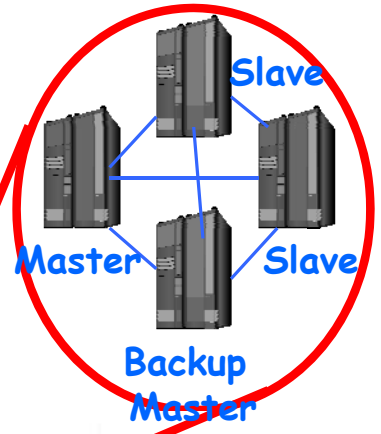
Motivation: Poor Quality of SW

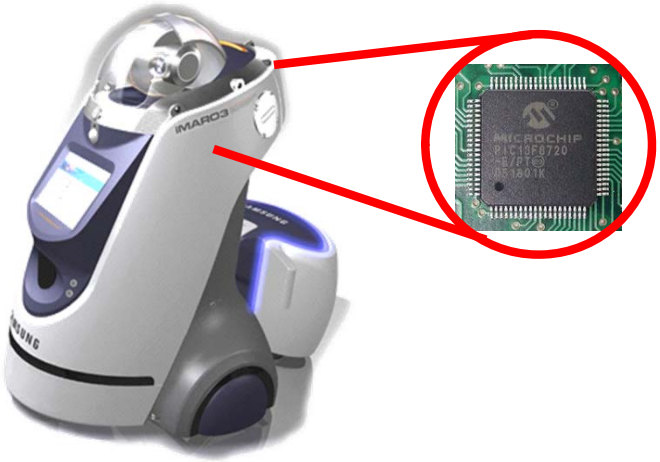


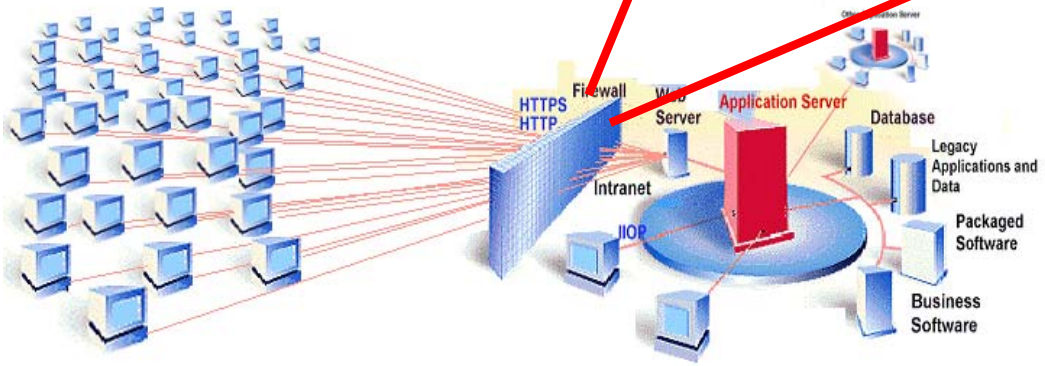




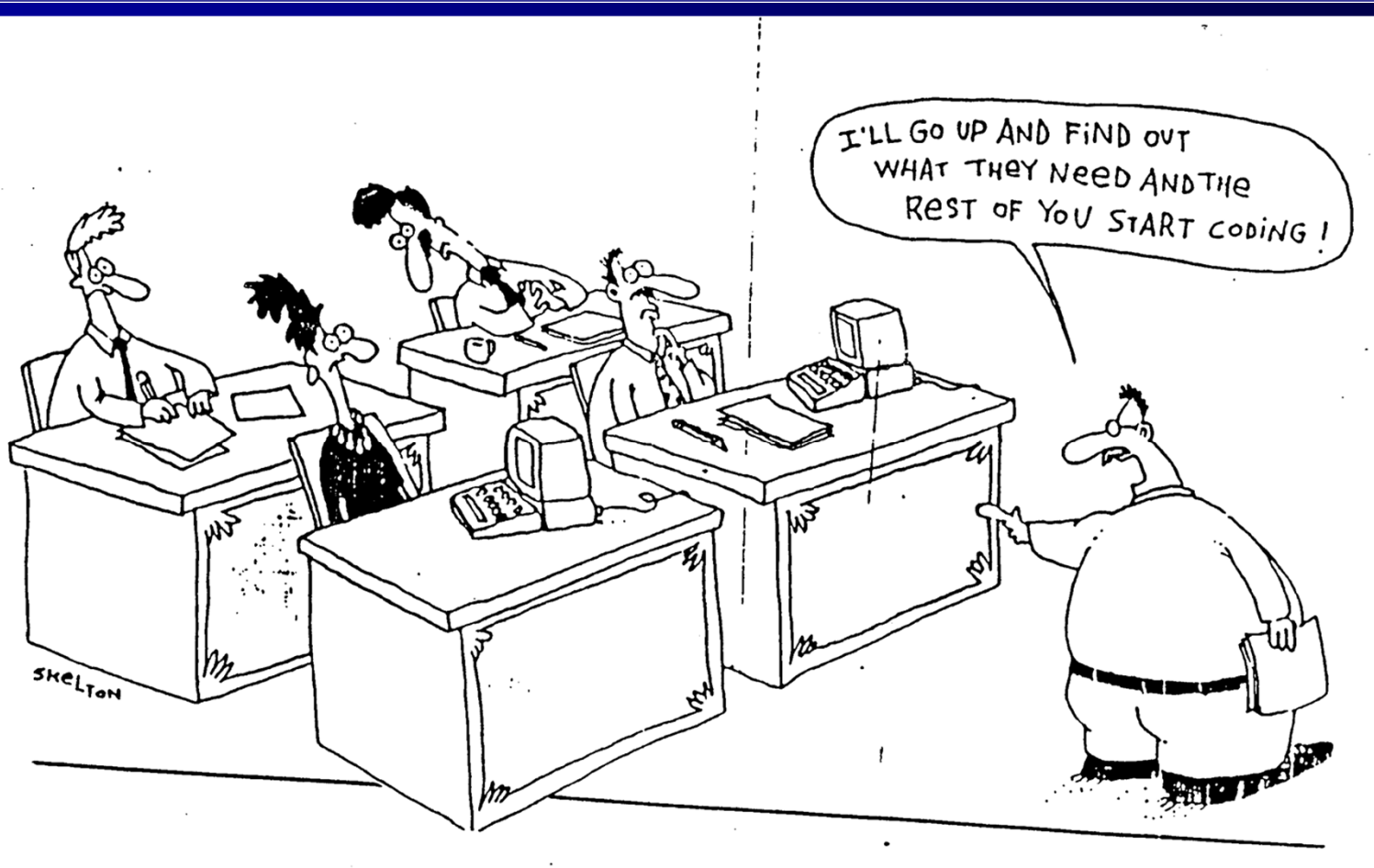
PROVABLE SW LAB







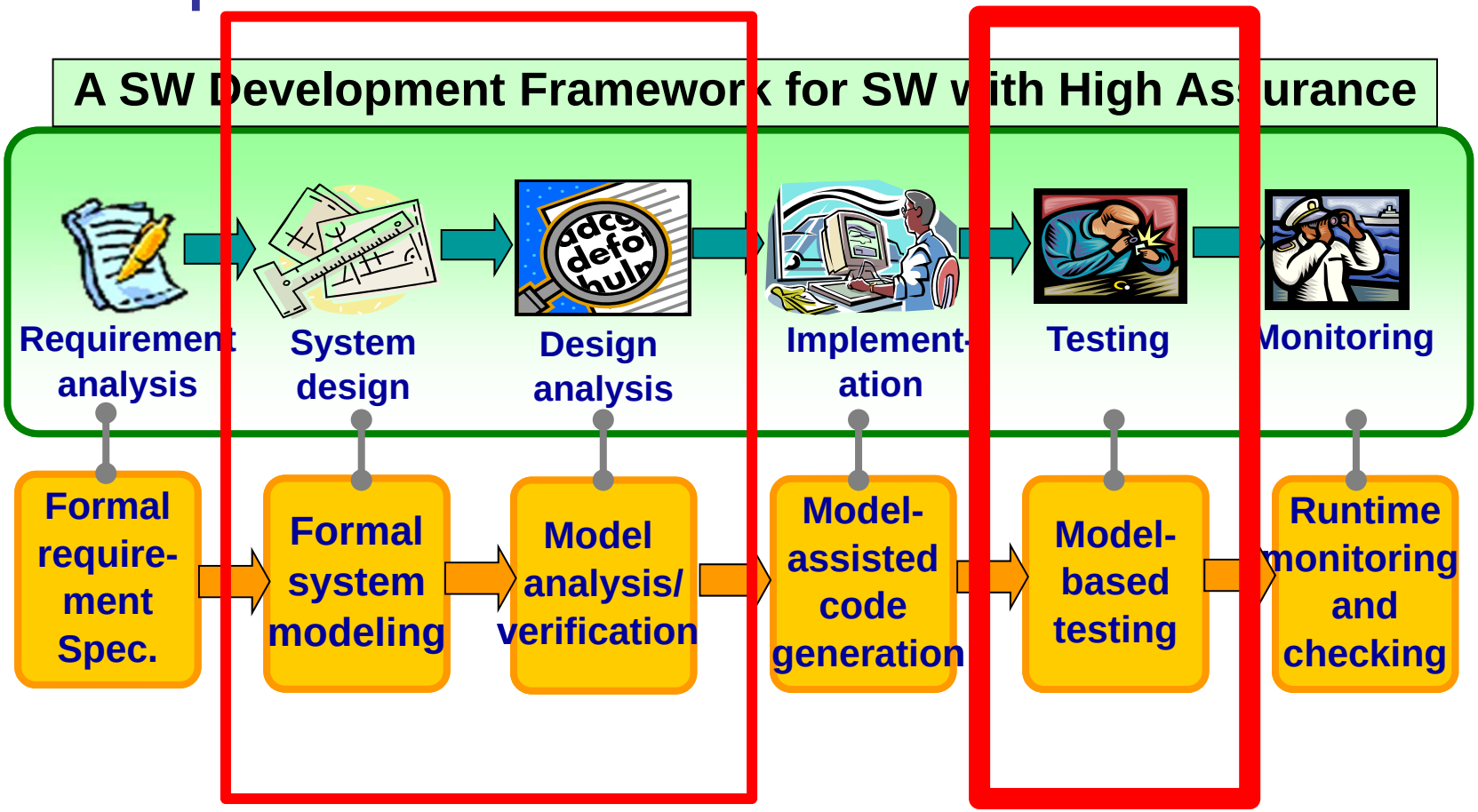
Current Practice for SW



- **SW developers have to follow scientific disciplines for building and analyzing software with high quality**
  - This class focuses on the analysis activities

Software Development Cycle

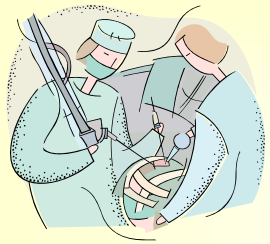
- A practical end-to-end formal framework for software development



Main Target Systems

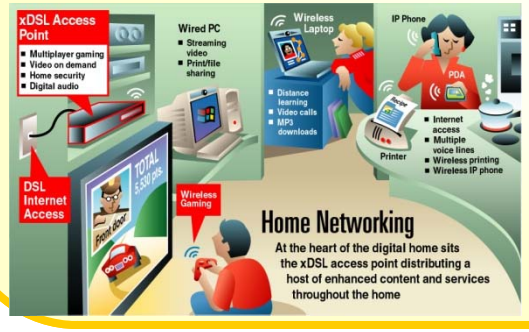
- **Embedded systems where highly reliable SW technology is a key to the success**
  - The portion of SW in commercial embedded devices increases continuously
  - More than 50% of development time is spent on SW testing and debugging

Intelligent Medical Devices



Home Service Robots

Home Network



Highly Reliable Systems

Intelligent Mobile Systems

How to Improve the Quality of SW

1. **Systematic testing**
   - Coverage criteria
   - Mutation analysis

2. **Debugging through automated analysis tools**
   - Scientific treatment of SW with computing power
   - Useful tools are available

3. **Formal verification**
   - Guarantee the absence of bugs!!!

Questions???

- **Is formal analysis really beneficial in industry?**
  - Yes, dozens of success stories at Samsung
- **Is formal analysis academically significant?**
  - Yes, 3 Turing awardees in ‘07
- **Is formal analysis too hard to learn and use?**
  - No, there are tools available

Companies Working on Software Verification

Microsoft

SAMSUNG

INRIA

cadence

IBM

ESTEREL Technologies

Sparrow The Early Bird

NEC Empowered by Innovation

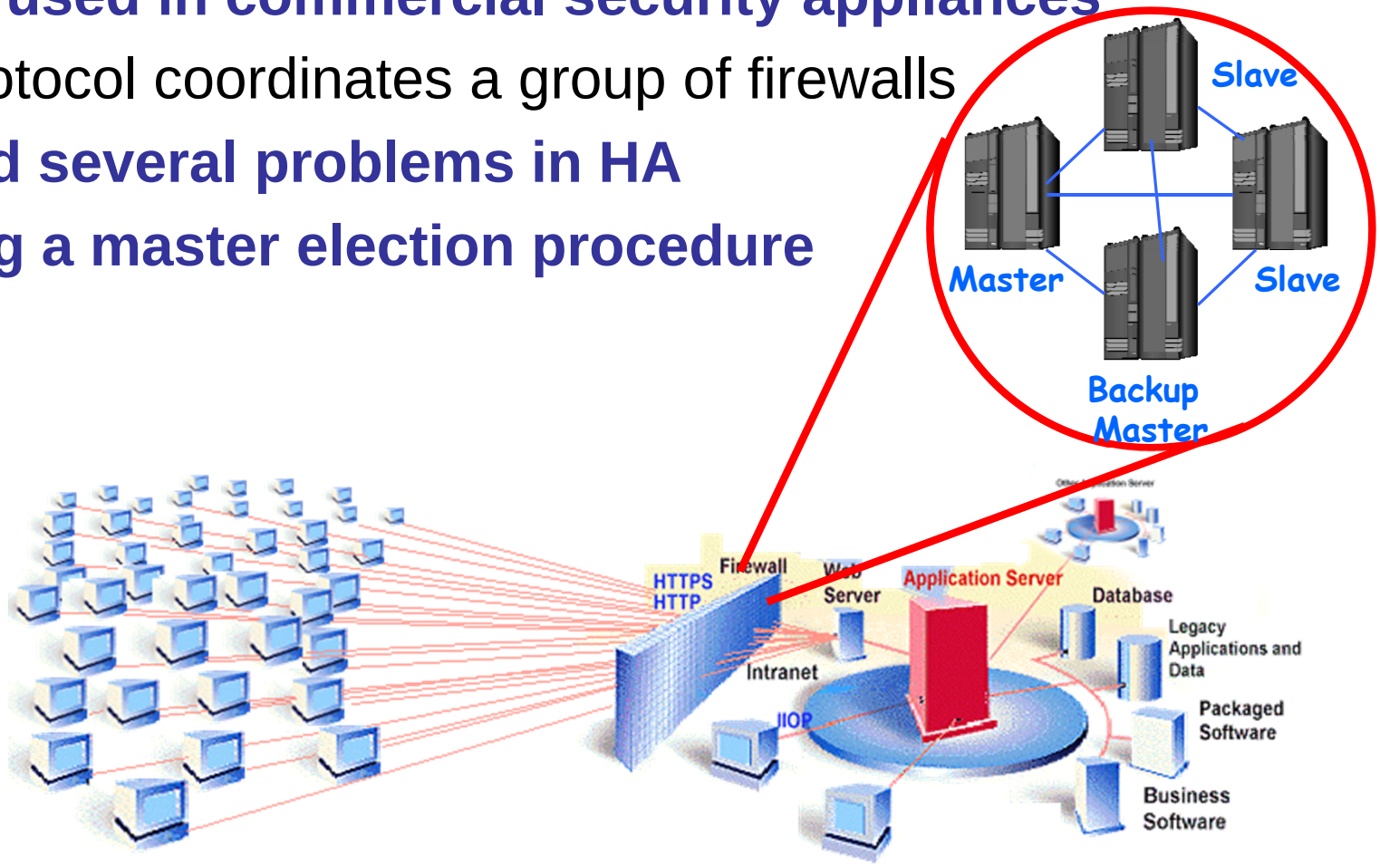
Sun microsystems

NASA Jet Propulsion Laboratory California Institute of Technology

The MathWorks™ Accelerating the pace of engineering and science

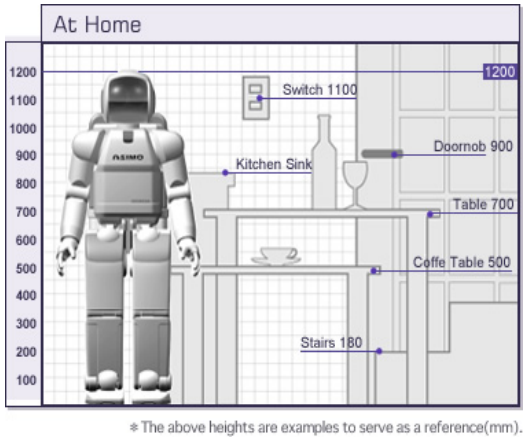
Verification of High-Availability Protocol

- **We develop a formal model of high-availability protocol used in commercial security appliances**
  - HA protocol coordinates a group of firewalls
- **We found several problems in HA regarding a master election procedure**

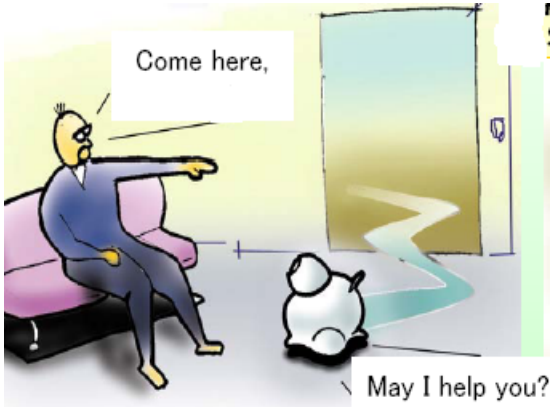


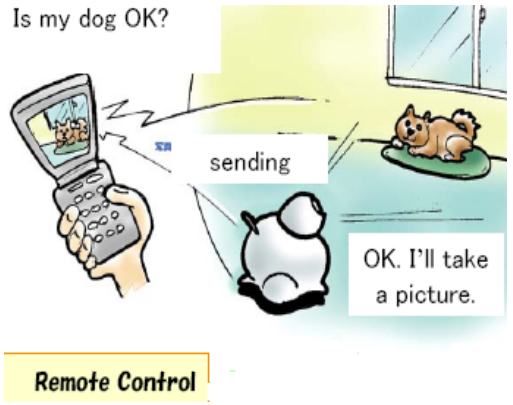
Home Service Robot

- Designed for providing various services to human user
  - Service areas : home security, patient caring, cleaning, etc



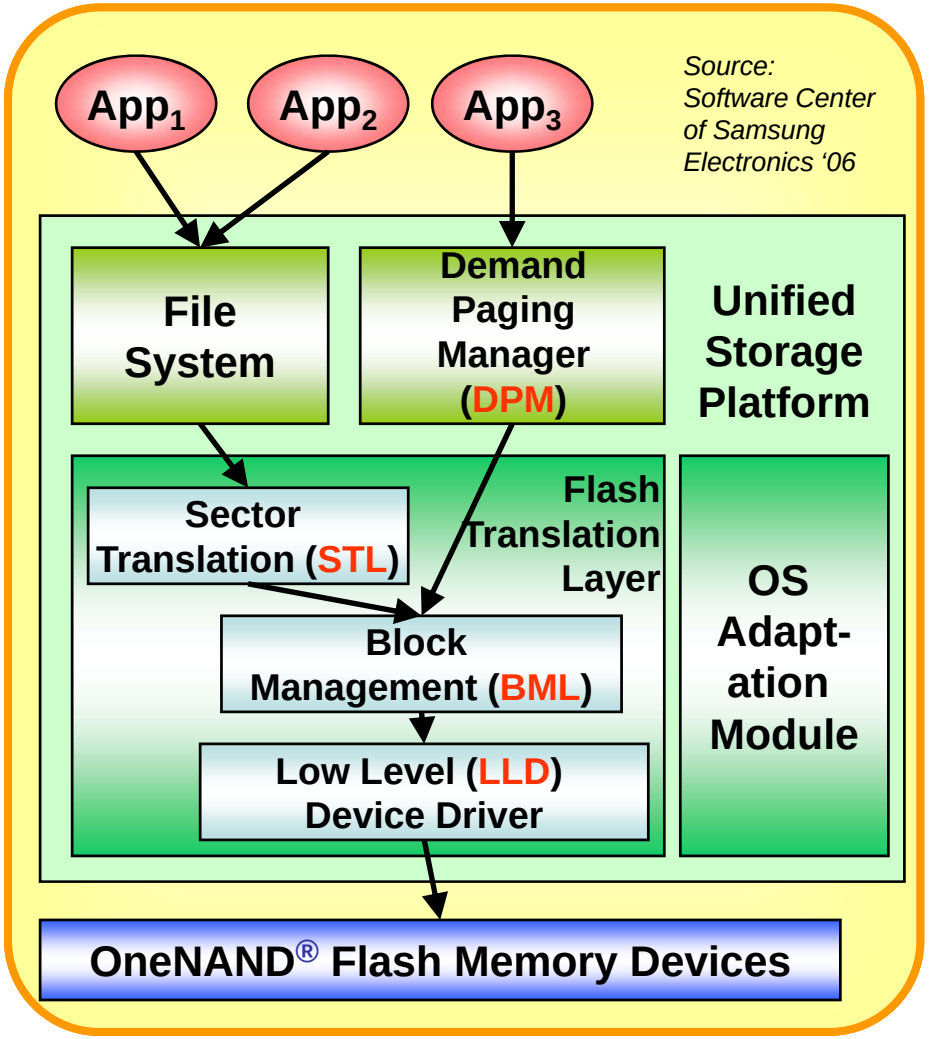
* The above heights are examples to serve as a reference(mm).





OneNAND® Flash Memory Verification

- Each memory cell can be written limited number of times only
- XIP by emulating NOR interface through demand-paging scheme
- Performance enhancement

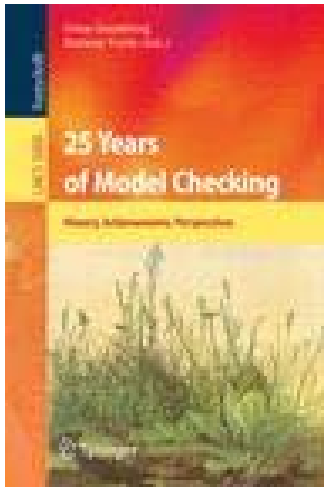


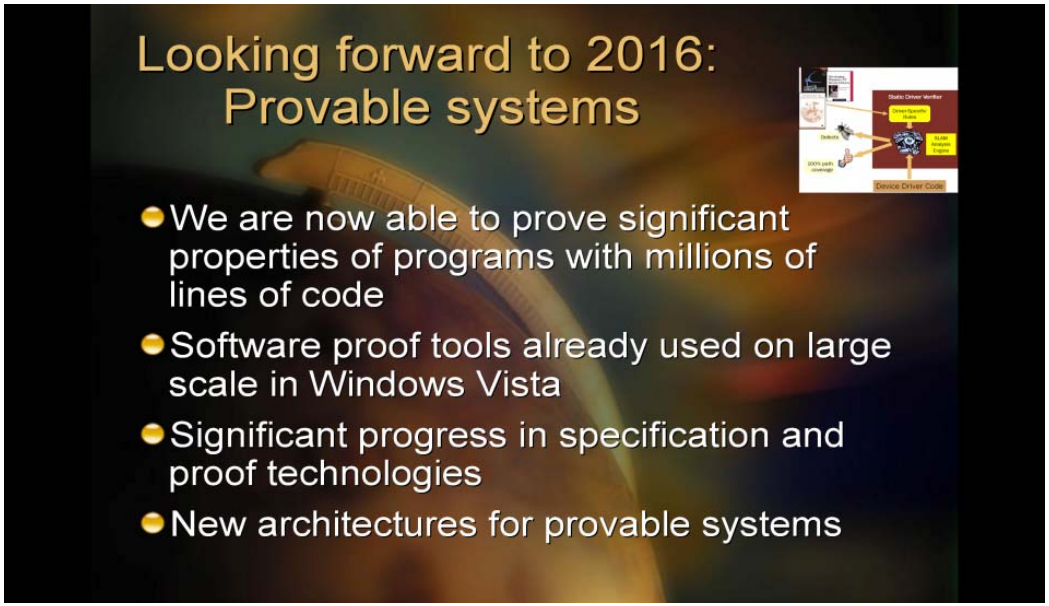
Research Trends toward Quality Systems

- **Academic research on developing embedded systems has reached stable stage**
  - just adding a new function to a target system is not considered as an academic contribution anymore
- **Research focus has moved on to the quality of the systems from the mere functionalities of the systems**
  - Energy efficient design, ez-maintenance, dynamic configuration, etc
- **Software reliability is one of the highly pursued qualities**
  - ASPLOS 2011 Best paper
    - "S2E: a platform for in-vivo multi-path analysis for software systems" @ EPFL
  - OSDI 2008 Best paper
    - "Klee: Unassisted and Automatic Generation of High-Coverage Tests for Complex Systems Programs" @ Stanford
  - NSDI 2007 Best paper
    - "Life, Death, and the Critical Transition: Finding Liveness Bugs in Systems Code" @ U.C. San Diego

Formal Verification as a Foundational and Promising CS Research

- **2007 ACM Turing Awardees**
  - Prof. Edmund Clarke
  - Dr. Joseph Sipfakis
  - Prof. E. Allen Emerson
- **For the contribution of migrating from pure research to industrial reality**
- **One of the four Microsoft Research main areas**





Tool-based Interactive Learning

- **Model checker**
  - Explicit model checker: Spin home page
  - Symbolic model checker: NuSMV home page
- **Software model checker**
  - Bounded model checker for C program:CBMC home page
  - Predicate abstraction for C program: BLAST home page
- **Satisfiability solver**
  - **MiniSAT home page**
- **Satisfiability Module Solver**
  - **Yices home page**
  - **Z3 home page**
- **Concolic testing tools**
  - **CREST home page**
- **Formal proof**
  - **WHY home page**

Class Schedule

- wk1: overview on formal SW analysis techniques
- Wk2-3: conventional testing techniques
- wk4: background on Propositional logic and SAT (Satisfiability) solvers
- wk5: SAT solver heuristic and tool application 1: MiniSAT
- wk6: background on First order logic
- wk7: Satisfiability Modulo Theory (SMT) basic
- wk8: midterm exam
- wk9: advanced application of SMT solvers
- wk10: directed automated rand om testing
- wk11: tool application : CREST
- wk12: basic temporal logic for r equirement property
- Wk13-14: tool application: Spin & NuSMV
- wk15: state space minimization techniques
- wk16: final exam

Administrative Stuff

- **Instructor: Prof. Moonzoo Kim**
- **Class time: Mon/Wed 12:30 -1:45 PM**
- **Office hour: TBD**
- **Grade policy**
  - HW 50%
  - Attendance & quiz 20%
  - Mid exam 15%
  - Final exam 15%
- **TA: Seokhyun Mun (Rm#2438)**
- **Web page: http://pswlab.kaist.ac.kr**

Final Remarks

- **For undergraduate students:**
  - Highly recommend URP studies or independent studies
    - Ex. 이준희 (05학번) got a silver award and macbook air notebook ☺
      - Debugging Linux kernel through model checking to detect concurrency bugs
    - Ex2. Nam Dang wrote down a paper on distributed concolic testing
      - Y.Kim, M.Kim, N.Dang, Scalable Distributed Concolic Testing: a Case Study on a Flash Storage Platform, Verified Software Track @ Intl. Conf. on Theoretical Aspects of Computing (ICTAC), Aug 2010

Final Remarks

- **For graduate students:**
  - Welcome research discussions to apply formal analysis techniques
    - Systematically debugging C programs
    - Concurrency bug detection
    - Model-based testing
    - Prove the correctness of algorithms, etc