# The Agile Hardware Research Project

## Discoveries and Solutions

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PMI Silicon Valley Chapter

CPRIME TCGen

# The Researchers

## Kevin Thompson

- Agile Practice Lead, cPrime Inc.
- Creator of cPrime Agile Curriculum and Consulting standards
- PhD in Physics, Princeton

## Scott Elliott

- Principal Techzecs
- R&D Director, HP
- Founder, Process Consulting HP
- BS,MS and PhD, UC Berkeley and Santa Barbara

## John Carter

- Principal TCGen Inc.
- Cirrus Logic Board Member
- Former Chief Engineer (Bose)
- MS EE, MIT, BS Harvey Mudd

# The Research Project

## Motivations and Key Questions

- What are effective techniques for
  - Agile development of hardware?
  - Concurrent Agile development of hardware and software?
- What are specific “recipes” for the above, using cPrime’s principles for Agile governance
- Capture what “best practices” exist and what gaps exist
- How organizations have effectively implemented such development

# Companies and Methodology

## Nearly Twenty Companies – Responses from

- Amazon
- Applied Materials
- AT&T
- Beats
- Cisco
- Hitachi
- HP
- KLA Tencor
- Tandem
- Teradata

## Methods

- Developed hypothesis on what could lead to agility in HW/Large programs
- Developed interview guide and construct data collection approach
- Constructed interview guide with key questions
- Gathered information via interviews, probing on emerging best practices
- Analyzed data, extracted common characteristics & outstanding practices
- Consolidated findings to create novel process model and recommend agile development organization

# Research Findings

Hardware companies used different Agile techniques

- None had a full Agile process
- Still emerging, and still experimenting, but some successes

Several best practices emerged

- Not slave to identical sprints, but adhere to identical durations
- Overlapping prototyping of circuit boards – not strictly serial
- Planning with ‘sticky notes on a wall’
- Hardware Sprints of longer than SW (typically 2x duration)
- Creative use of Burn down charts – repurposed for Hardware
- Burn down metrics change by sprint
- Ranking of features by value

# Key Differences
# Hardware Versus Software

- Flexibility is inherently less
  - Can't do an update over the web for physical product
- Cost of change is higher for hardware
- Architectural work is more front-loaded for hardware.
- Availability of standard components constrains hardware design more than software design
- In software development, variation in type of work done over time is small.
  - In hardware development, because of the realization of a physical product, the type of work done changes substantially over time
- Hardware development cost rises towards end of work, while software costs are flat over time
  - Hardware sprints towards end have significant test costs

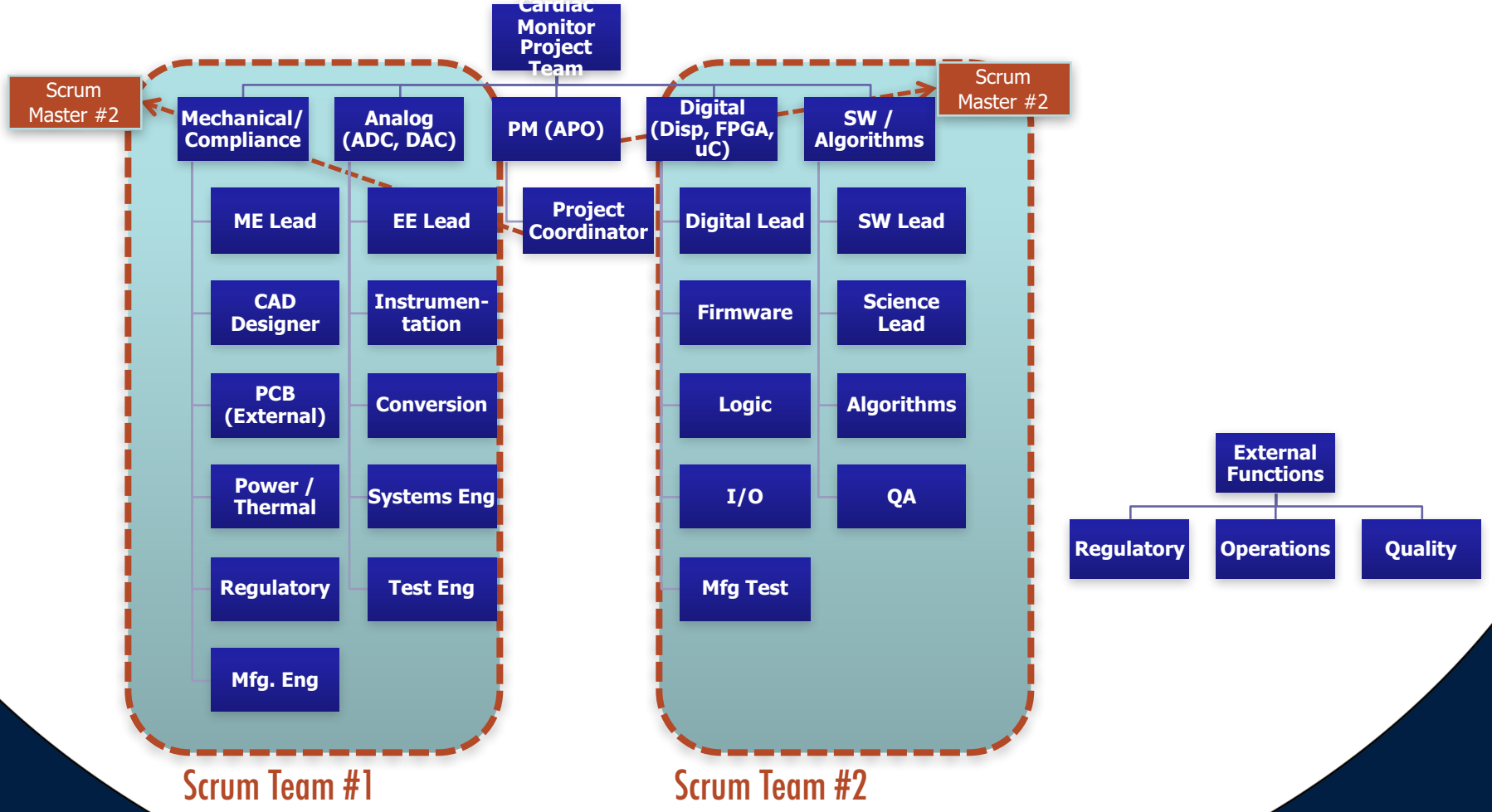
# Key Similarities between Hardware and Software Development

- The total work of product development can be divided into a large number of small and testable deliverables
  - True in Software and Hardware
- Work can be partitioned over sprints, sprints can be estimated, progress can measured, and learning can be integrated
  - Planning poker, Burn down charts, and Retrospectives common to both
- Self-contained, self-organized work teams can be created for even the largest projects
  - Creation of small, self sufficient, cross functional teams with Scrum Masters common to both
- Important distinction:
  - Software: Aggregation of deliverables yields usable features over time
  - Hardware: Aggregation of deliverables yields usable product at the end of development

# Recommended Scrum Process for Hardware Development

1. Story Types: “Hard” vs “Soft”
2. Sprint Length
    1. Recommend 2-8 weeks, based on duration of design/build/test cycle time
    2. Keep standard length across development
3. Release Planning
4. Variation in Sprint Focus during Release Cycle
    1. Beginning – Requirements, Architecture, Silicon Selection
    2. Middle – Repeating sprints of design/build/test
    3. End – Emphasis on Scale – Build/test

# Example Scrum Organization for Hardware Development



# Mechanical Team

| Mechanical Team | | Team Member | Primary Skills |
|---|---|---|---|
| **Product Owner** | Anthony | Anthony | Mech. Engineering Lead and Team PO |
| **Scrum Master** | Caroline | Alex | CAD Designer |
| | | Mahesh | CAD Designer |
| | | Chun | Power & Thermal Engineer |
| | | Brenda | Regulatory & Compliance |
| | | Todd | Manufacturing Engineer |

The Mechanical Team focuses on product packaging and compliance.

# Analog Team

| Analog Team | | Team Member | Primary Skills |
|---|---|---|---|
| **Product Owner** | Franklin | Franklin | Electrical Engineering Lead and Team PO |
| **Scrum Master** | Caroline | Yuri | Instrumentation Engineer |
| The Analog Team handles Sensors, Analog-to-Digital and Digital-to-Analog conversion. | | Krish | Instrumentation Engineer |
| | | Sheldon | Conversion Engineer |
| | | Erica | Conversion Engineer |
| | | Dwight | Systems Engineer |
| | | Yani | Test Engineer |

# Digital Team

| Digital Team | | Team Member | Primary Skills |
|---|---|---|---|
| **Product Owner** | Heinrich | Heinrich | Digital Lead and Team PO |
| **Scrum Master** | Fred | Chuck | Firmware Engineer |
| | | Asha | Firmware Engineer |
| | | Heidi | Firmware Engineer |
| | | Jing | Digital Logic/Glue Logic |
| | | Neeraj | IO - Input/Output (Bus) |
| | | Melissa | Manufacturing Test |

The Digital Team is responsible for the Display, FPGA, instrument control, network communications, and printed circuit development.

# Software Team

| Software Team | | Team Member | Primary Skills |
|---|---|---|---|
| **Product Owner** | Jerry | Jerry | Software Lead and Team PO |
| **Scrum Master** | Fred | Mike | Lead Scientist |
| The Software Team develops algorithms and implements them in software. | | Steve | Instrument SW Engineer |
| | | Padma | Instrument SW Engineer |
| | | Kelly | Algorithms SW Engineer |
| | | Gabe | Algorithms SW Engineer |
| | | Tatiana | QA |
| | | Chris | QA |

# Story Types: Content

User vs Technical

- User Story: Short narrative description of a user experience. Usually written by Product Owners.
- Technical Story: Short description of deliverable that is not user-facing. Usually written by Team Members

- Expect higher ratio of Technical Stories to User Stories in hardware than in software

# User Story

| Title | Buyer views statistics for transactions with Vendors | | | | Rank | 3 |
|---|---|---|---|---|---|---|
| ID | 22 | | Estimate | 8 | Total Task Est. | 13 |

Narrative

As a Buyer, I can view my statistics about my transactions with Vendors, so that I can understand how my history looks to Vendors.

When I click on a buyer-statistics link, I see my statistics. (This link is on the home page, under account information.)

Prototype / UI References: Landing Page: Attached (landingPage.html)
External Documents:
Company Style Guide for UI: http://wiki/UI/UIStyleGuide.doc
Statistics to be computed: http://wiki/apps/buyerstats.doc

Acceptance Criteria

- When the user clicks on the link, the application should display the statistics.
- User can create fictitious buyers and suppliers for use in testing.
- When the user submits or responds to RFPs, report shows updated statistics that reflect the user's activities.

# Technical Story

| Title | 16-bit Digital-to-Analog Converter Motherboard Integration | | | | Rank | 9 |
|---|---|---|---|---|---|---|
| ID | 25 | | Estimate | 8 | Total Task Est. | 60 |

Narrative

Design into the motherboard a Digital-to-Analog converter (DAC), in order to provide the high-level analog voltage required to drive the analog display. Assume that the digital drive presented at the input of the DAC module is of sufficient amplitude to activate the unit properly, but not so large as to damage the input gates. Since no DAC has been chosen for this purpose yet, select an appropriate one for incorporation into the motherboard design.

Acceptance Criteria

- 16-bit output with +/- 0.5 bit nonlinearity
- Single supply operation: 2.7 to 5.5V
- The maximum current to drive the unit is 500mA.
- The maximum clock rate is 3.4 MBit/sec.
- The output will be a time-varying analog signal varying from 0V to 5V at steps of 7.5 μV, with a maximum output impedance of 1 Ohm.
- Device meets the other requirements of the I2S serial bus

# Story Types: Boundaries

Stories in Scrum have “Hard” boundaries—they should not cross a Sprint boundary

Some hardware deliverables may not be able to be completed within a Sprint

- One-thousand-hour accelerated life tests
- Design & sampling of a new specialized System on a Chip (SOC)

Solutions

- Allow these to be “Soft” Stories that can cross a Sprint boundary
- Do this only when unavoidable

# Sprint Length for Hardware

Usual Scrum advice is 2—4 weeks for Sprint length in Software

Slower pace of hardware development may require Sprints up to eight weeks in length

- When implementing Agile, start with shorter sprint lengths
  - Discover whether length is appropriate
- Lengthen if necessary to discover optimum length
- Select and use optimum length for all Sprints and all future products

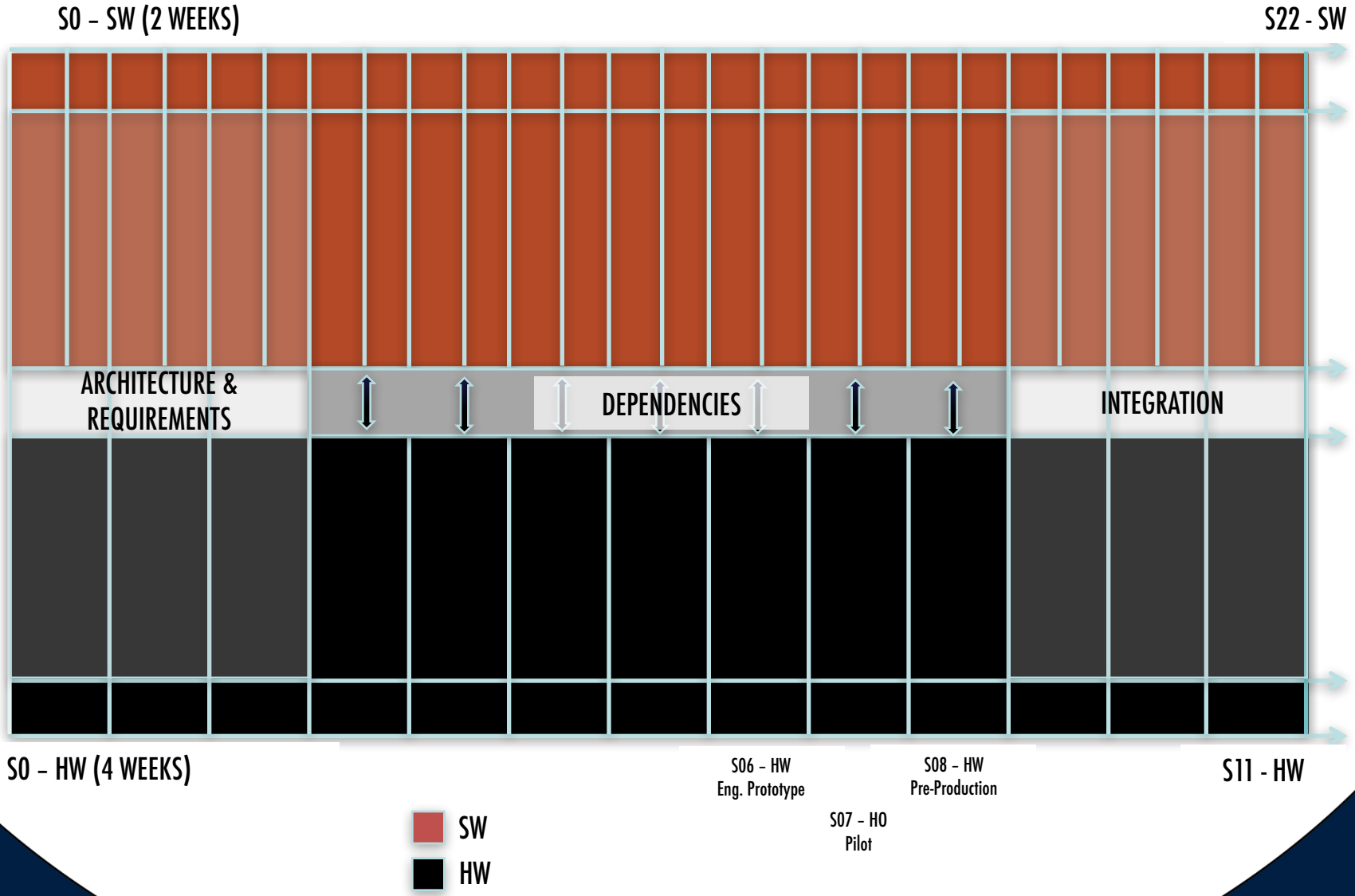
# Release Planning

Release Planning is often useful in software development, but is optional

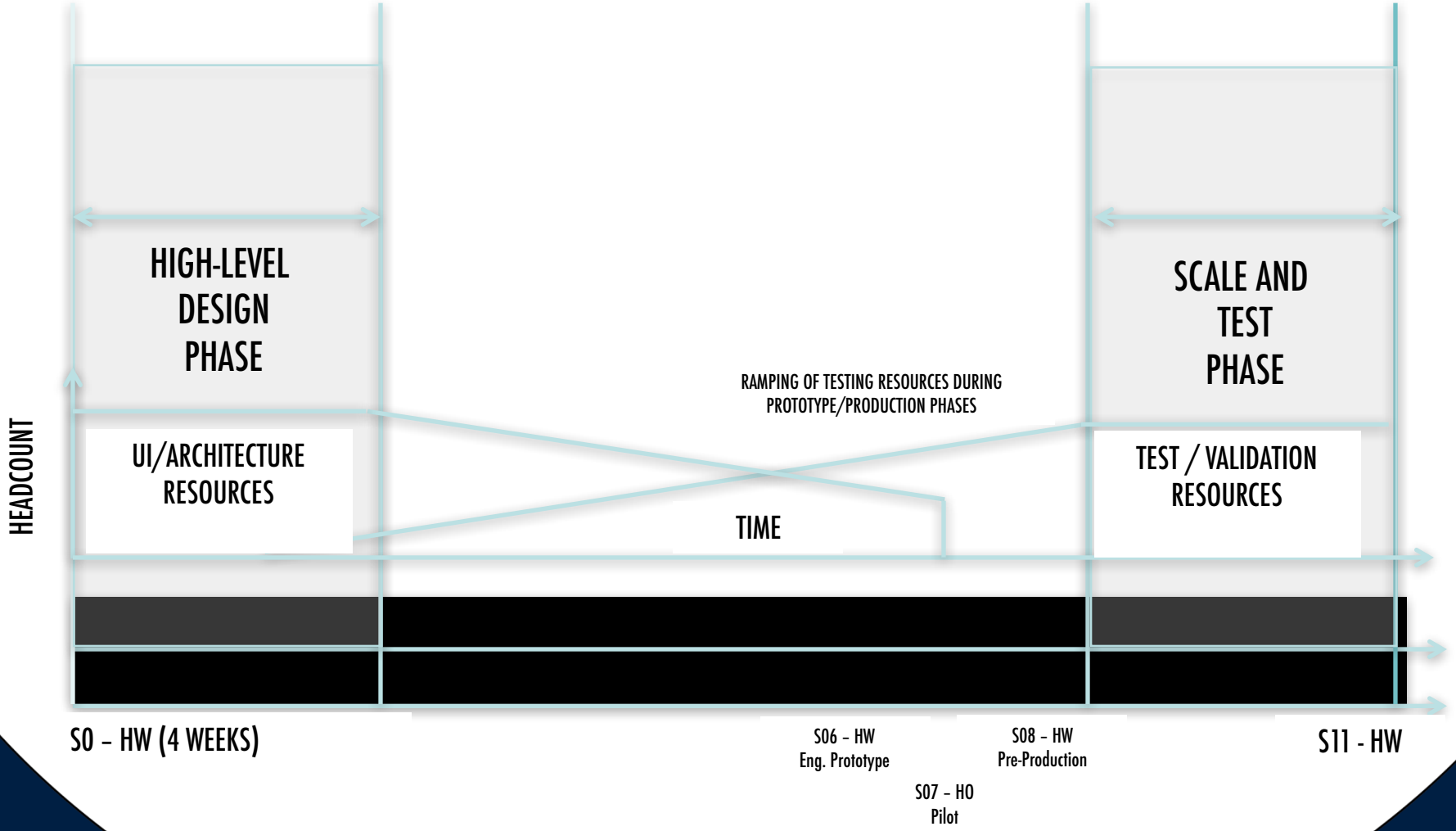
Release Planning is essential for hardware development

- Higher cost of change implies need to plan complete product development to some degree (more than a Sprint)

# Variation in Focus over Release Cycle



# Variation in Skills Over Release Cycle



# Conclusions

1. Hardware development can be done in an Agile way
2. Scrum is well-suited for hardware development
3. Hardware may require longer Sprints, more Release Planning, and a shift in types of Stories relative to software

Download our white paper, “Agile Processes for Hardware Development,” from www.cprime.com

# Discussion

**Questions & Comments**

# Appendix - Outline

1. Researchers
2. Motivation and key questions we are trying to address
3. Companies and methodology
4. Findings
5. Recommendations
6. How to implement what we recommend (next steps) - aligned with 'Learning Organization' theme

# Appendix – Interview Guide

**Background**

- Describe your role and the products/solutions you deliver.

**Establishing Requirements & Planning Estimates**

- How are requirements developed and what do they look like?
- How do they go from requirements (the what) to task definitions (the actions)?
- What methods do you use to estimate the work?
- What does a plan look like? (e.g., Gantt chart, Sprint Backlog, something else)?

**Managing Changes**

- How do you accommodate changes in requirements & scope during development?
- How do you update estimates as the project changes?
- Who makes the decision to change scope?

**Future Wishes**

- What changes do you plan to make in the future to make your process more agile?