

# Crusoe™ Power Management

## Cutting x86 Operating Power Through LongRun™

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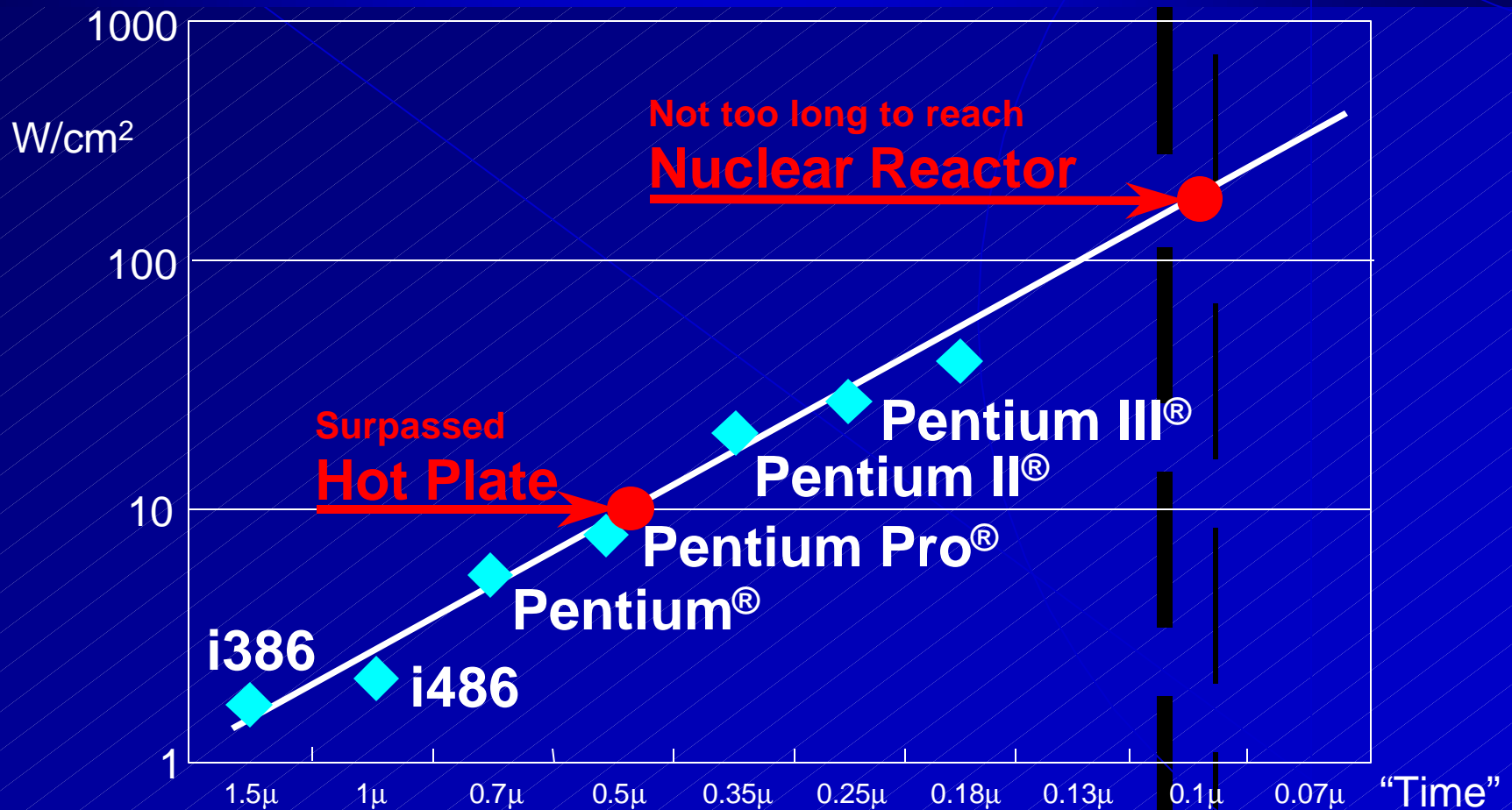


# Overview

- ◆ Key Challenges for Mobile Computing
  - ◆ “Portability” (weight) and “Ease of Use” (battery life)
    - Power consumption is the key limiting factor
- ◆ Solution - Crusoe Processor
  - ◆ Full compatibility with traditional x86 power management model
  - ◆ Significantly lower power
- ◆ LongRun
  - ◆ Transmeta’s new invention to drive breakthrough power savings
    - Adaptive Power Control (performance on demand)
    - Advanced Thermal Control (thermal budget expansion)

# Power Density

## The Fundamental Problem



Source: Fred Pollack, Intel. New Microprocessor Challenges in the Coming Generations of CMOS Technologies, Micro32

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# The Solution ... Increase Efficiency

## Crusoe - The Smart Microprocessor

$$P_{power} = C_{capacitance} \times V_{oltage}^2 \times F_{requency}$$

- ◆ Transmeta Innovation - Code Morphing Software
- ◆ Effect - Replace Millions of Logic Transistors with Software
  - ◆ ... and transistors translate into capacitance
- ◆ Benefit - Significantly Reduces Power Consumption of x86 Power States

# Power Comparison

## Substantial Power Reduction, Delivered by Crusoe

	Conventional Mobile x86 Solution			Crusoe TM5400 Integrated North Bridge		
	Processor	North Bridge	Total	LongRun		
	650 / 500 MHz 1.6 / 1.35 V	3.3 V	650 / 500 MHz 1.6 / 1.35 V	633 ↔ 300 MHz 1.6 ↔ 1.2 V		
Normal (C0)	14.0 / 8.0	2.0	16.0 / 10.0	6.5 ↔ 1.5		Watts
AutoHALT (C1)	1.7 / 1.1	2.0	3.7 / 3.1	0.9 ↔ 0.3		Watts
Quick Start (C2)	1.3 / 0.8	2.0	3.3 / 2.8	0.6 ↔ 0.2		Watts
Deep Sleep (C3)	0.5 / 0.3	~1.0	1.5 / 1.3	0.05 ↔ 0.05		Watts

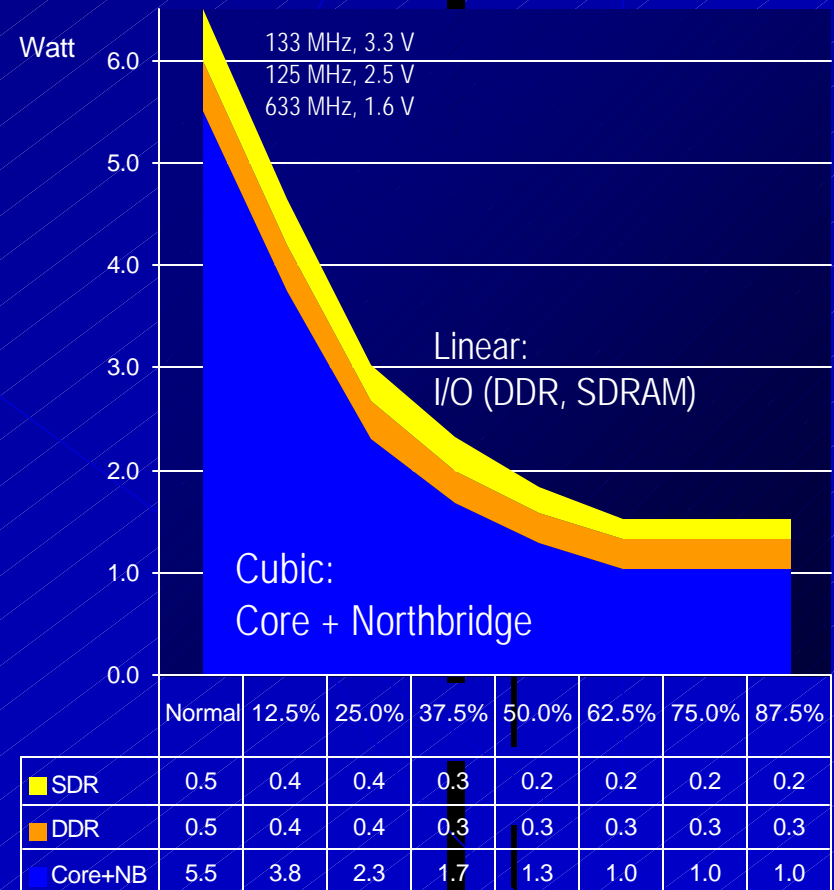
- ◆ Crusoe plays Soft-DVD at the same power that conventional mobile x86 processors use in Deep Sleep (C3)!

# LongRun Adaptive Power Control

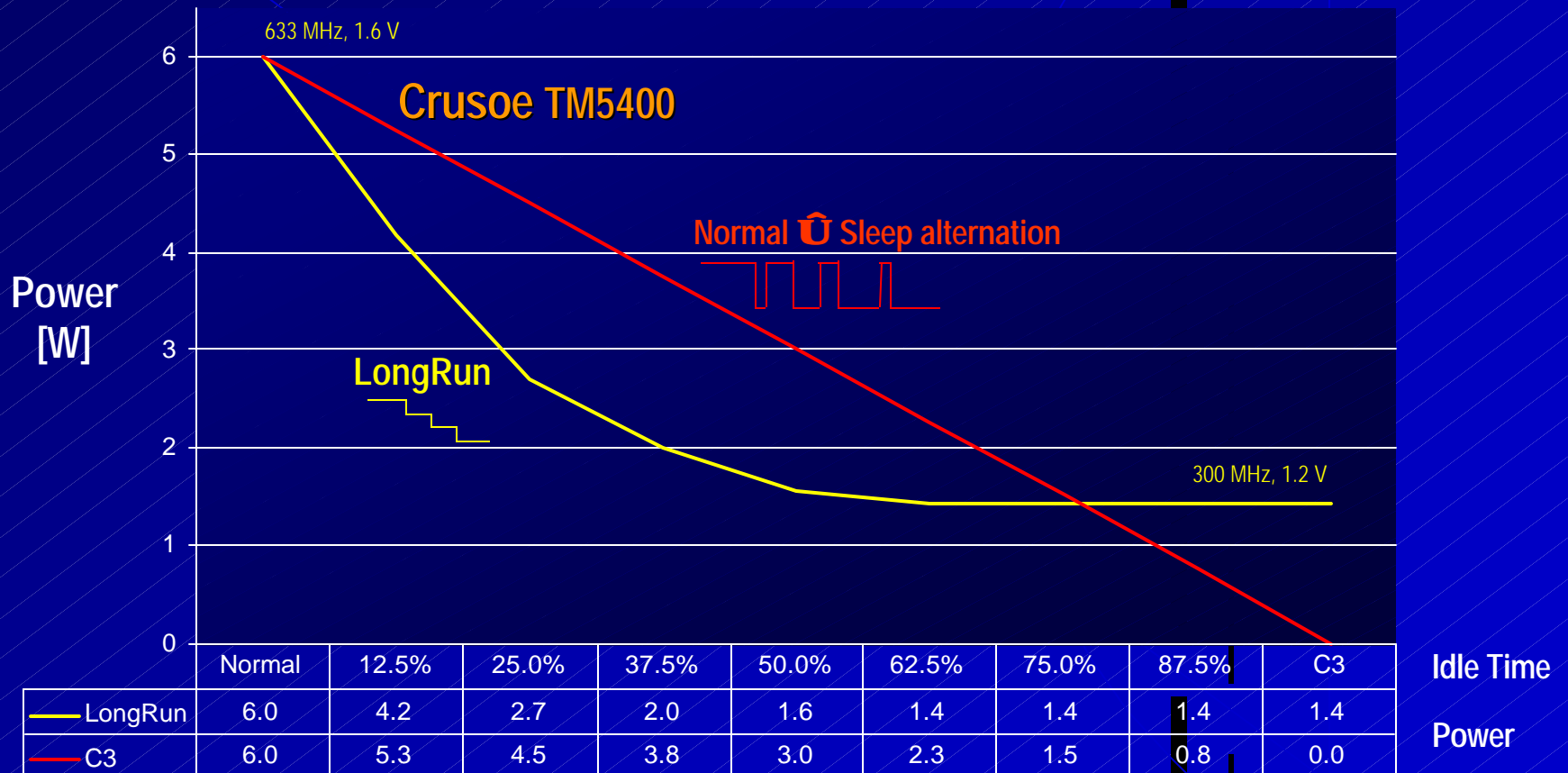
## Maximize Battery Life With Performance on Demand

$$Power = c \times v^2 \times f$$

- ◆ Dynamically adapt both frequency and voltage to performance demands
- ◆ Mechanisms in CPU
  - Fully programmable
- ◆ Policies in CMS
  - ◆ Adapt  $f$  to demand
  - ◆ Reduce  $v$  proportionally
  - Cubic power savings!



# LongRun Adaptive Power Control vs. Traditional Power Management



## Notes

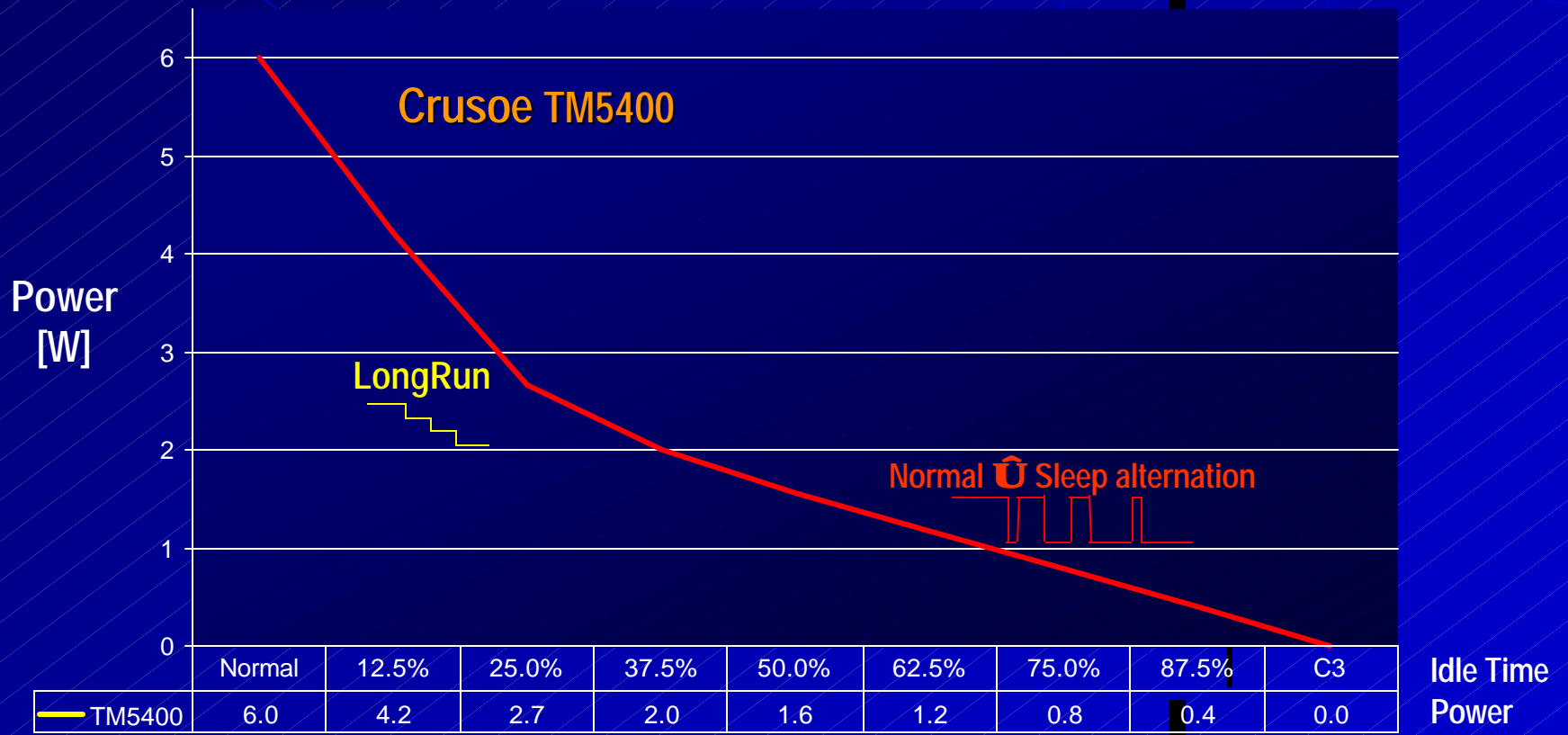
- <sup>1</sup> Power numbers include Northbridge
- <sup>2</sup> DDR-only configuration





# LongRun Adaptive Power Control

## Crusoe Power Profile



### Notes

- <sup>1</sup> Power numbers include Northbridge
- <sup>2</sup> DDR-only configuration

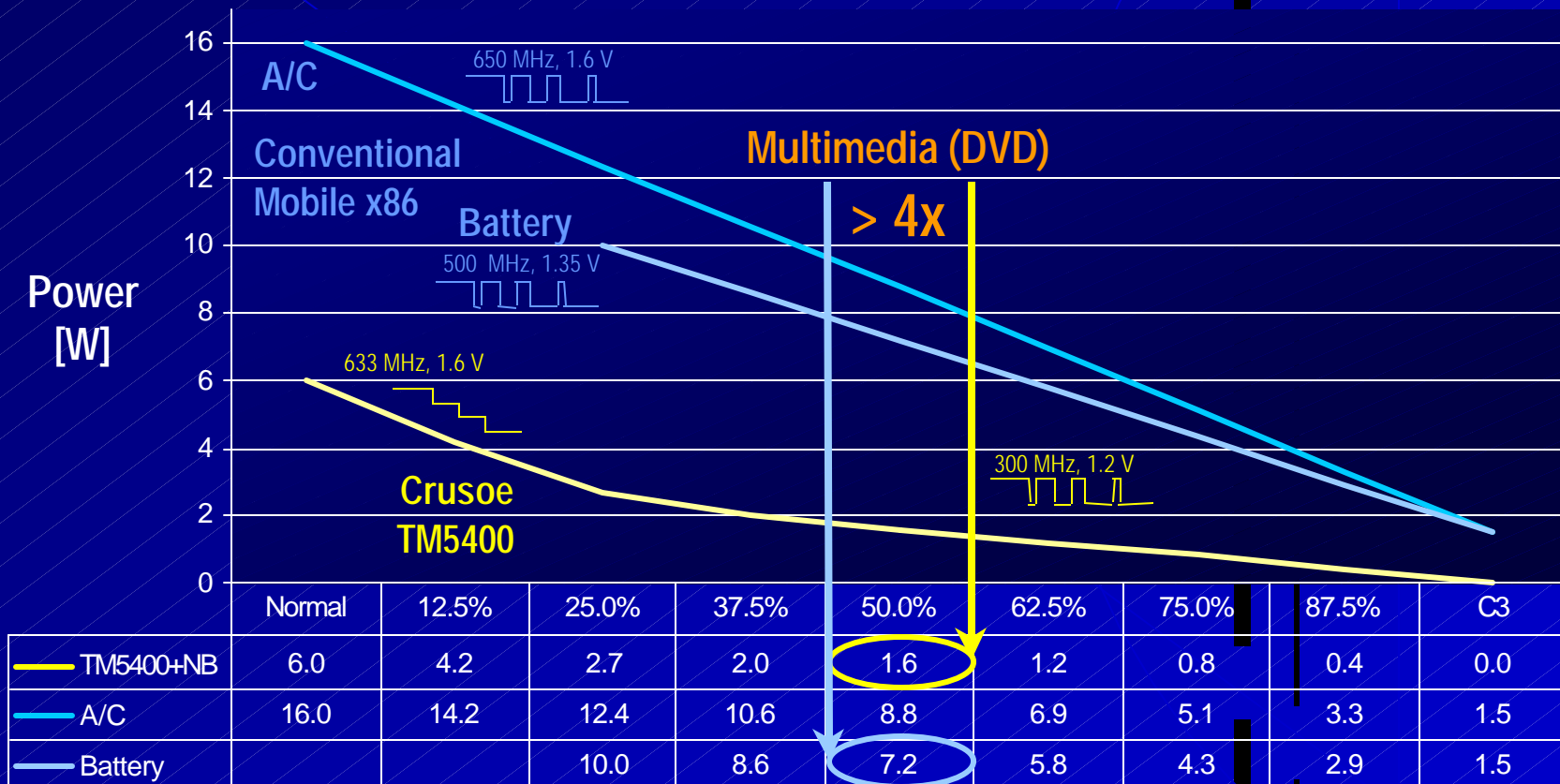
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# The LongRun Effect

## Power Profiles



### Notes

- 1 Power numbers include Northbridge
- 2 DDR-only configuration

# System Architecture

## Standard Applications

No changes required



Closed loop

## Standard Operating System

No changes required

Closed loop

## Standard BIOS

No changes required

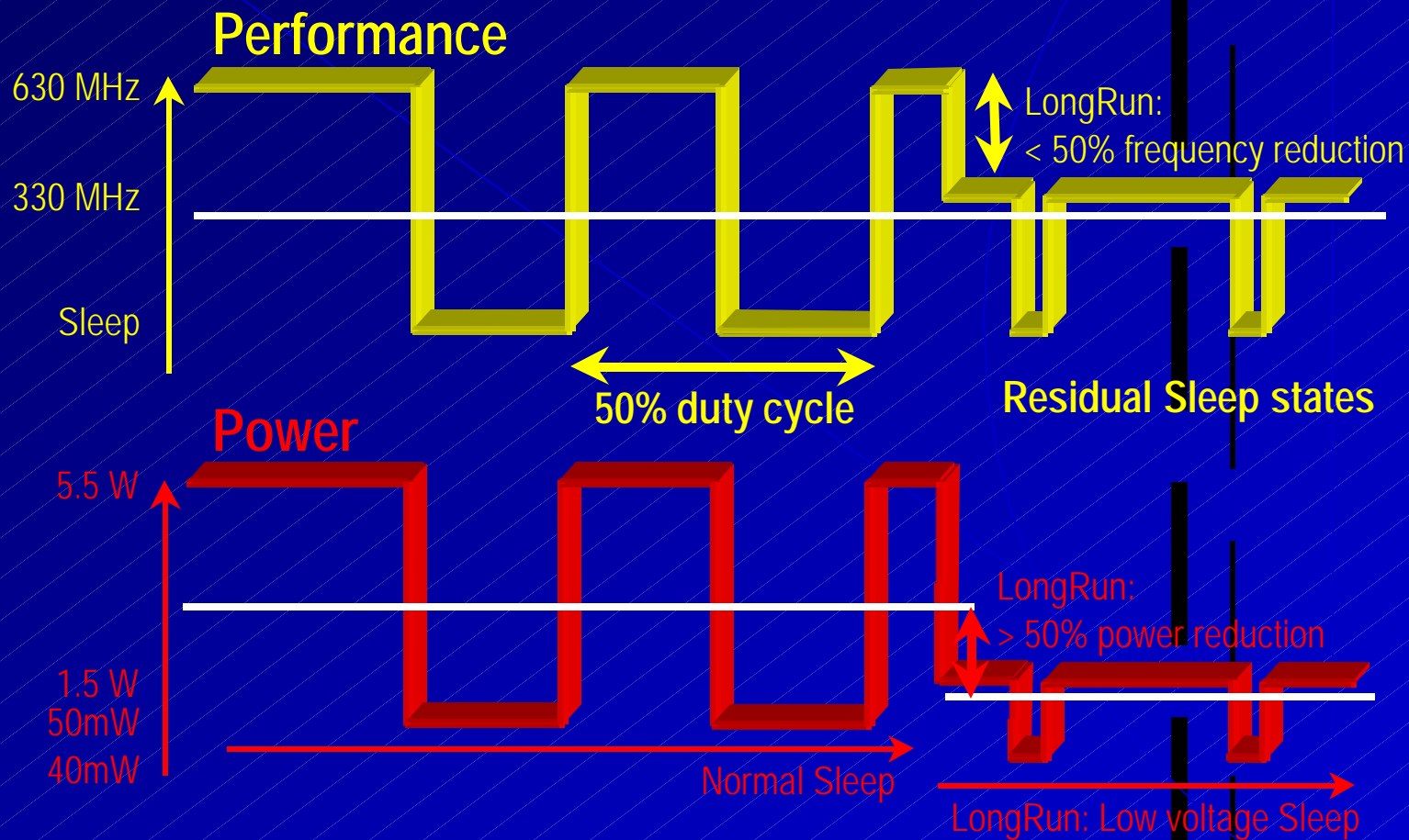
Closed loop

## Crusoe TM5400 processor featuring Transmeta LongRun technology

Code Morphing software monitors system activity and dynamically adapts LongRun performance levels

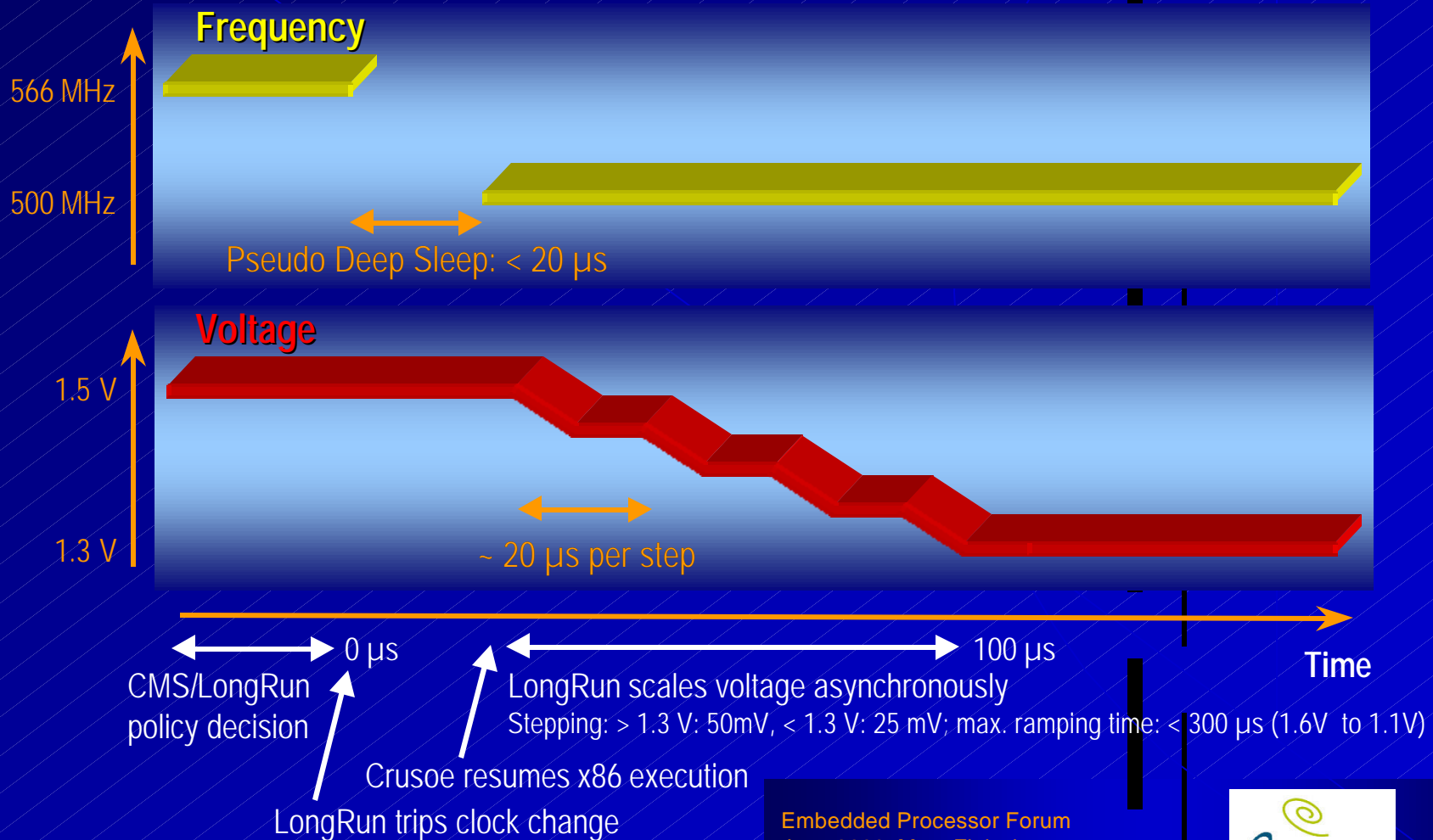
# Performance on Demand

Duty Cycle  $\Leftrightarrow$  Effective Performance Level



# Transition Dynamics

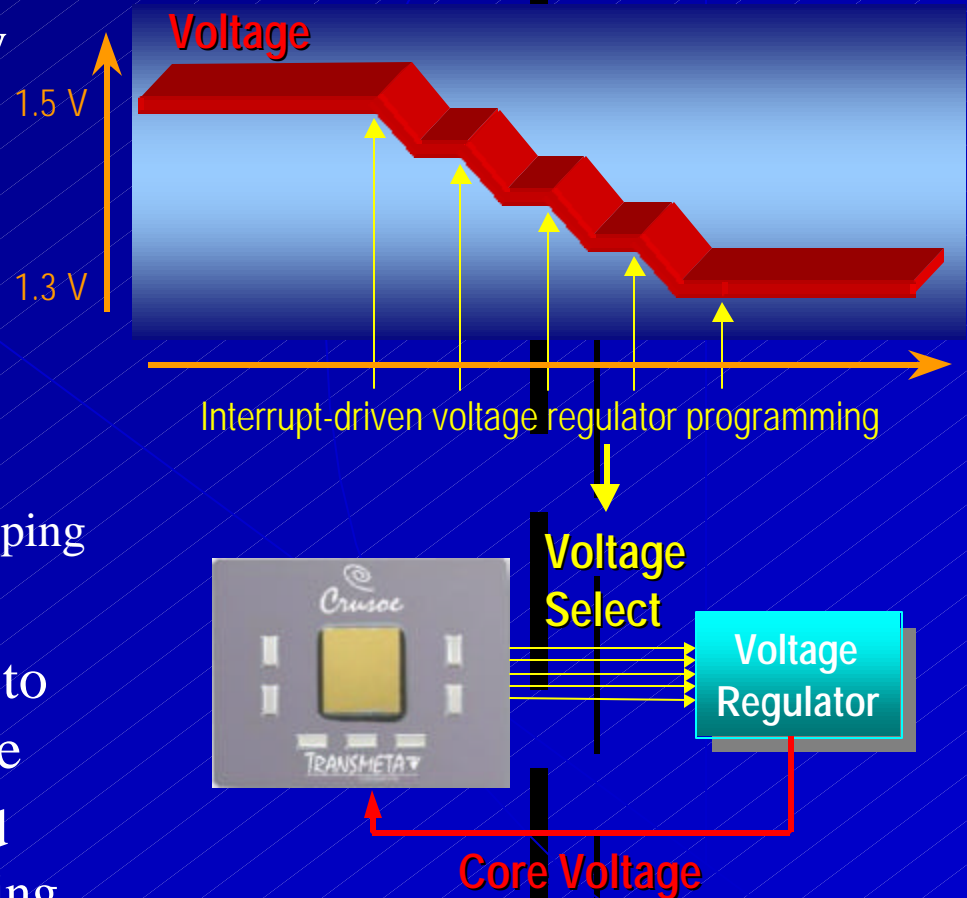
## Fast Frequency/Voltage Scaling



# Transition Details

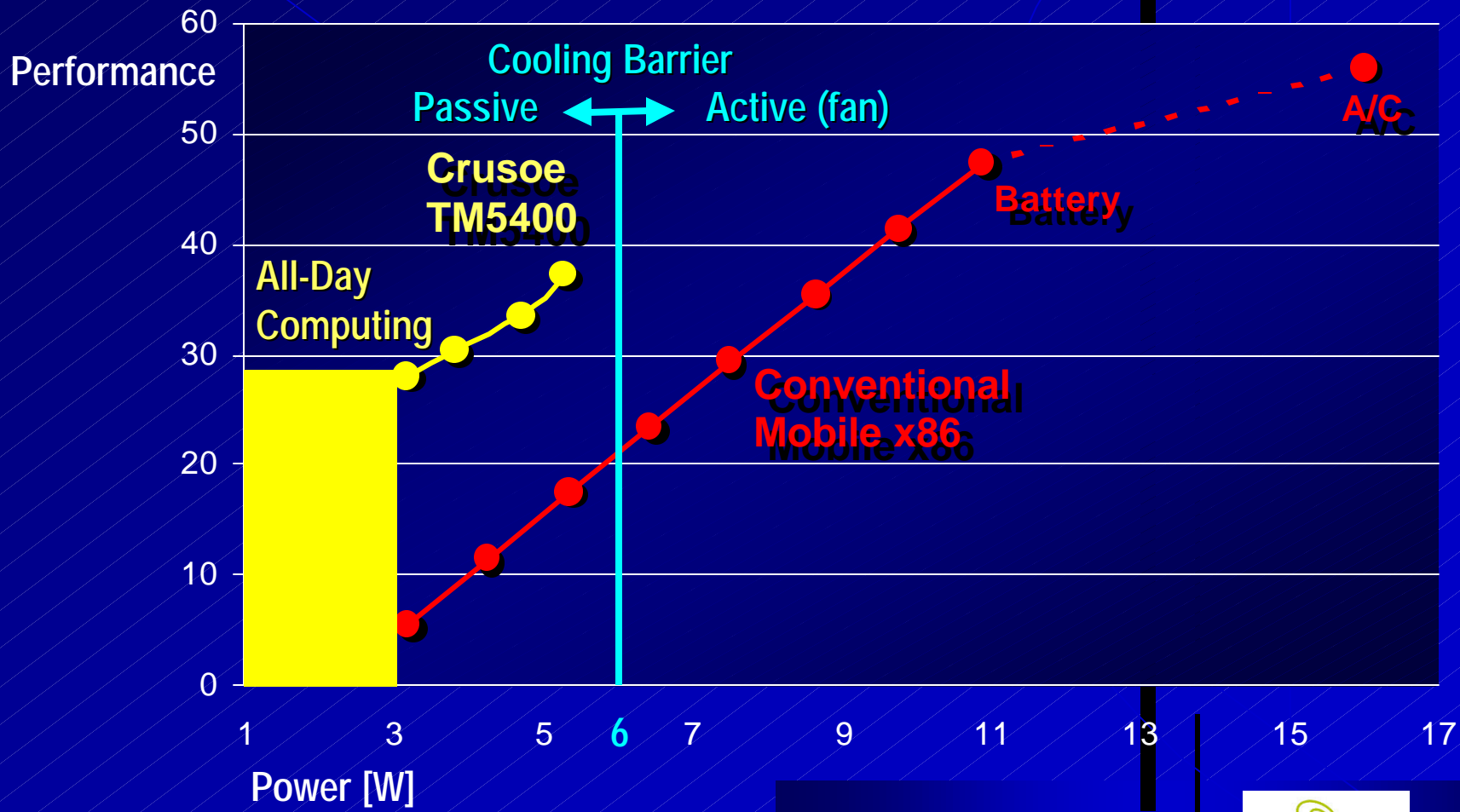
## Voltage Scaling

- ◆ TM5400 Core Voltage is Fully Under Software Control
  - ◆ Code Morphing Software directly controls voltage regulator pins (via internal processor register)
  - ◆ OEM configurable
    - ◆ CPU output pin/voltage mapping
    - ◆ Voltage settling interval
- ◆ Software Schedules Interrupts to Asynchronously Ramp Voltage
  - ◆ Allows sustained x86 forward progress during voltage ramping



# Energy Efficiency

## Superior Performance in Small Form Factors



# The LongRun Advantage

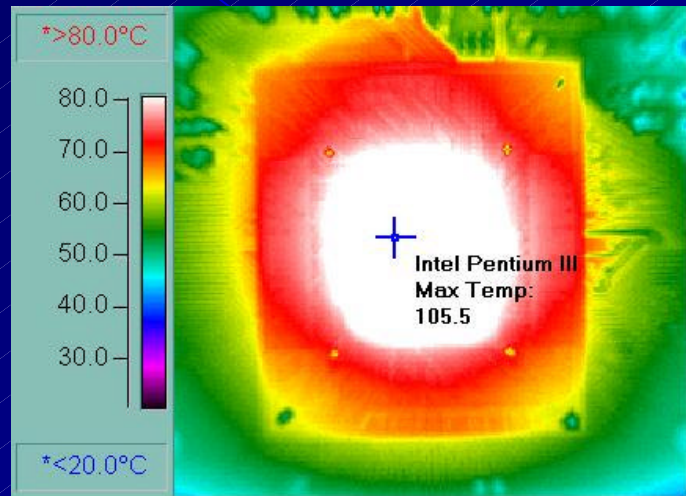
## DVD Playback - Performance on Demand





# The LongRun Advantage

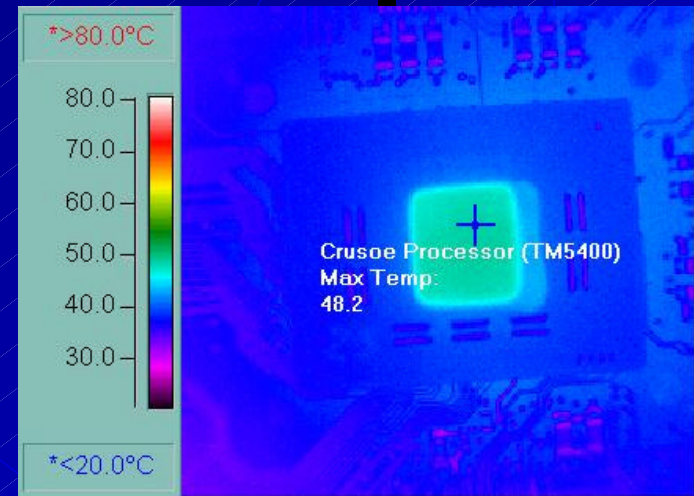
## DVD Playback - Thermal Comparison



Conventional Mobile x86 Processor

**105.5° C      221.9° F**

Active thermal solution required  
(Fan or overload protection)



Crusoe TM5400 Processor with LongRun

**48.2° C      118.8° F**

Passive thermal solution  
(No fan or overload protection)

# Summary

- ◆ Crusoe Supports the x86 Power Management Model with Significantly Reduced Power Consumption
  - ◆ Sleep: 4× (C1) - 30× (C3) power savings
- ◆ Crusoe Leverages Code Morphing Software to Drive Breakthrough Power Management - LongRun
  - ◆ Normal: 2× - 10× power savings
- ◆ Crusoe Leverages LongRun to Expand the Thermal Budget
- ◆ Crusoe's Breakthrough Low-Power Technology Portfolio
  - ◆ Allows a whole new class of battery-powered devices
  - ◆ The full PC and Internet experience - Anywhere and Anytime