# Crusoe Processor Products and Technology
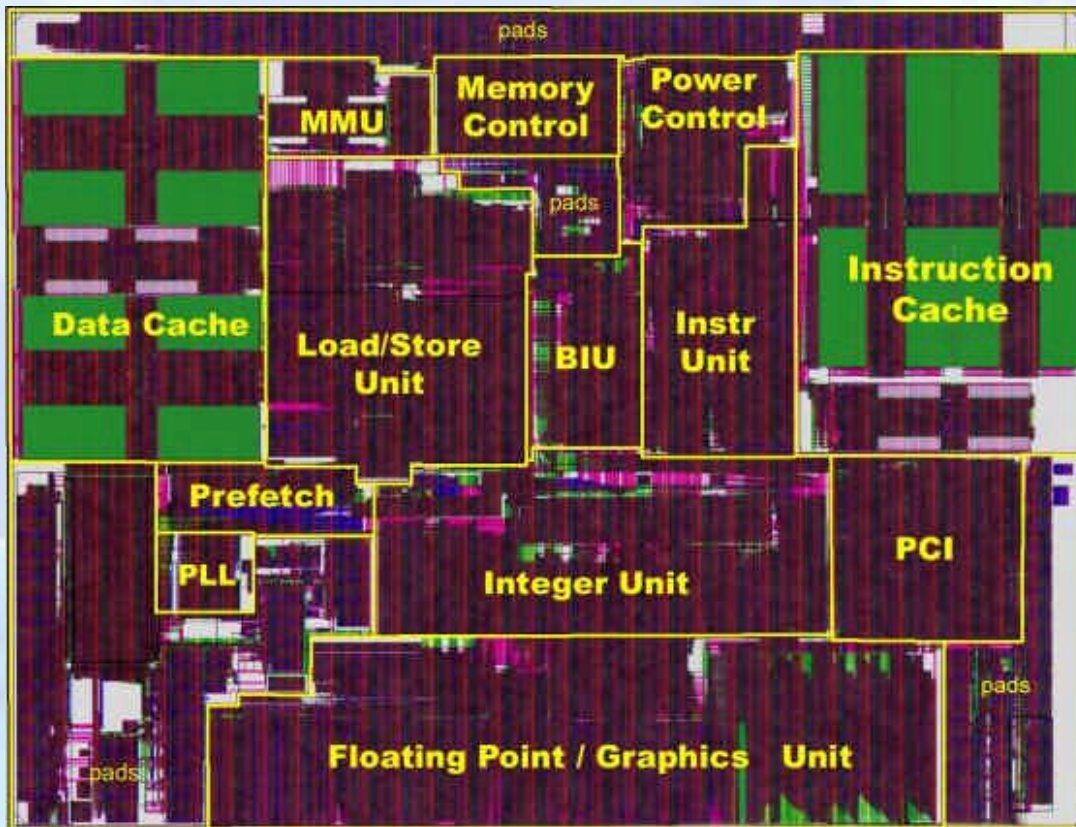
## Doug Laird
## VP Product Development

## January 19th 2000

# Agenda

- **The Crusoe processor family**
- **The technology behind Crusoe**
- **VLIW & Code Morphing software**
- **LongRun power management**
- **The engineering team**
- **Mobile benchmarks**

# TM3120 for Mobile Internet Devices
## (With Mobile Linux O/S)



|  | TM3120 |
|---|---|
| Frequency Range | 333-400 MHz |
| L1 Cache | 96KB |
| L2Cache |  |
| Main Memory | SDRAM |
| Upgrade memory |  |
| North Bridge | Integrated |
| Package | 474 BGA |
|  |  |
| Fab Partner | IBM |
| Process Technology | .22u |
| Die Size | 77mm |
|  |  |
| Sample | Now |
| Production | Now |

# TM5400 for Ultra-Light PCs
## (With Microsoft O/S)
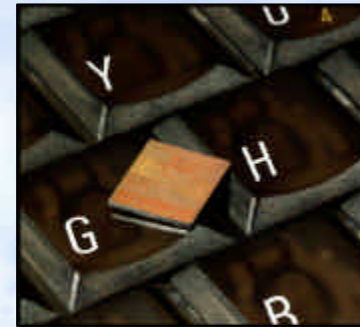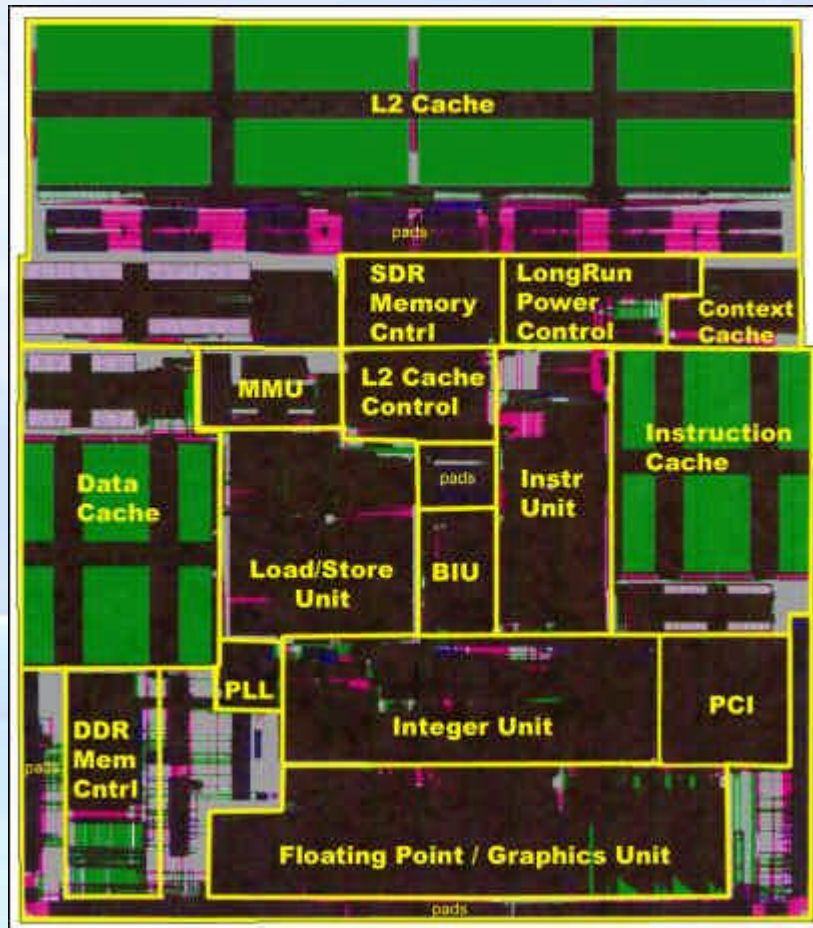


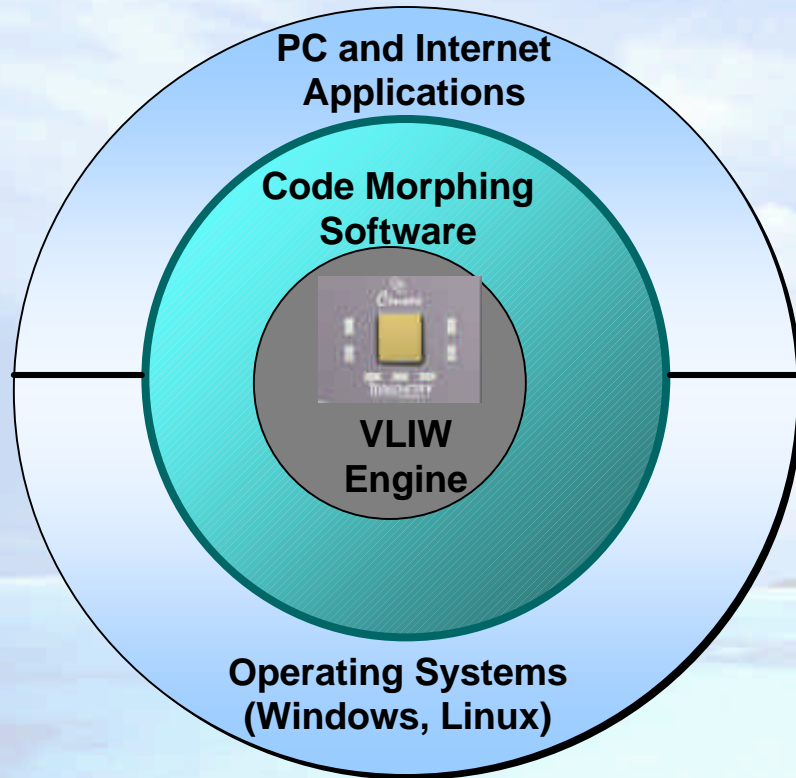|  | TM5400 |
|---|---|
| Frequency Range | 500-700 MHz |
| L1 Cache | 128K |
| L2Cache | 256K |
| Main Memory | DDR-SDRAM |
| Upgrade memory | SDRAM |
| North Bridge | Integrated |
| Package | 474 BGA |
|  |  |
| Fab Partner | IBM |
| Process Technology | .18u |
| Die Size | 73mm |
|  |  |
| Sample | Now |
| Production | Mid 2000 |

# Crusoe Processor
# Hardware System Diagram

**VLIW processor interfacing with PC standard components**

◆ **SDRAM and DDR-SDRAM memory**

◆ **PCI standard I/O devices and controllers**

◆ **Improved system architecture for better performance & lower power**
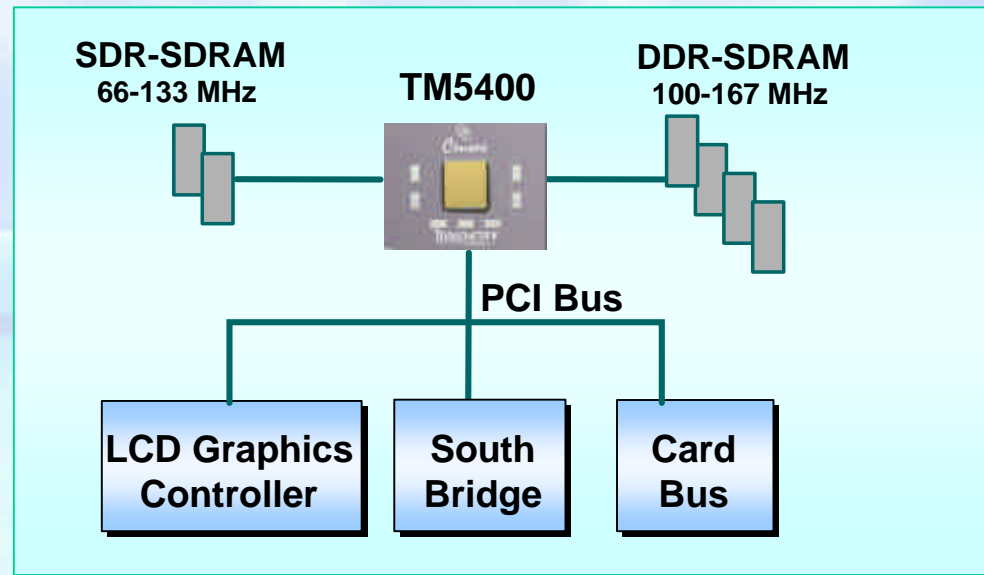
# The Smart
# Microprocessor Architecture

**PC and Internet Applications**

**Code Morphing Software**

**VLIW Engine**

**Operating Systems (Windows, Linux)**

- ◆ **Compatible with any x86 App & OS**

- ◆ **Code Morphing software**
  - ◆ **"Morphs" x86 to VLIW**

- ◆ **High Speed, Low Power VLIW Engine**

- ◆ **VLIW + Code Morphing = x86 compatible solution**

# VLIW Processor Architecture
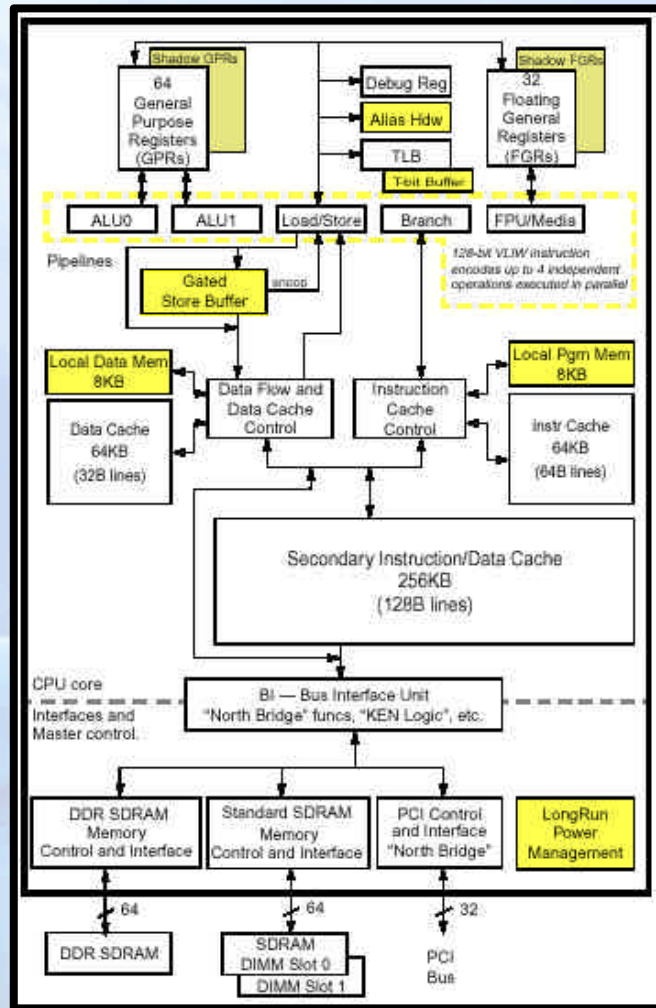


- ◆ **Free from x86 Legacy**
- ◆ **128 bit VLIW processor**
- ◆ **Code morphing hardware facilities**
- ◆ **Integrated North Bridge chipset**

**Simple Fast Low Power Processor**

# Code Morphing Software Overview

**What are the keys to Code Morphing software?**

- **Translates x86 compatible PC applications to VLIW hardware**

# Translation of PC Applications to VLIW
## (x86 Instructions Converted to VLIW)

**x86 Memory**

**Translation Cache**

| 1 | 32 | 64 | 96 | 128 |
|---|---|---|---|---|

| | | | |
|---|---|---|---|
| | VLIW code for block #1 | | |
| | VLIW code for block #2 | | |
| | | | |

**x86 code block #1**

**x86 code block #2**

**addl ...**
**movl ...**
**inc ...**
**je ...**
**...**

**Translate**

**Code Morphing software actions**

- ◆ **No translations found on new x86 code**

- ◆ **Make new translation to VLIW**

# Dynamic Software Execution

**x86 Memory**

| |
|---|
| |
| x86 code block #1 |
| |
| x86 code block #2 |
| |
| addl ... movl ... inc ... je ... ... |

**Translation Cache**

| | VLIW code for block #1 | |
|---|---|---|
| | VLIW code for block #2 | |
| add ... brcc #eq... | ld ... | inc ... ... | .. |
| | | |

**Execute** ➡

**Code Morphing software actions**

- ◆ **Translation has been made**
- ◆ **Proceed with execution**
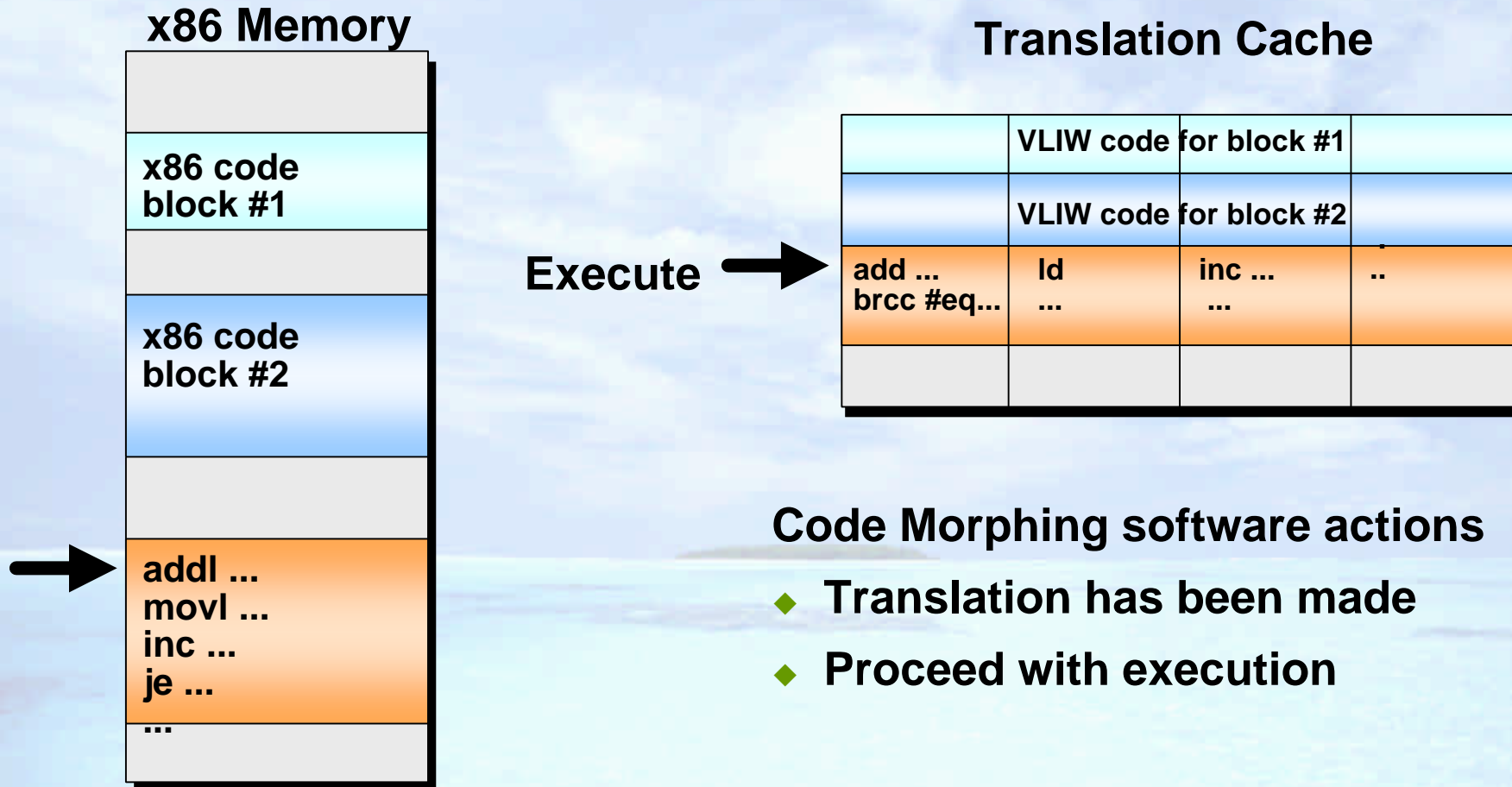
# Dynamic Software Execution (2nd Pass)

**x86 Memory**

| |
|---|
| |
| x86 code block #1 |
| |
| x86 code block #2 |
| |
| x86 code block #3 |
| |

**Translation Cache**

**Execute** →

| | | |
|---|---|---|
| | VLIW code for block #1 | |
| | VLIW code for block #2 | |
| | VLIW code for block #3 | |
| | | |

**Code Morphing software actions**

- **Translation already exists**
- **Execute VLIW code immediately**

# Code Morphing Software Overview

**What are the keys to Code Morphing software?**

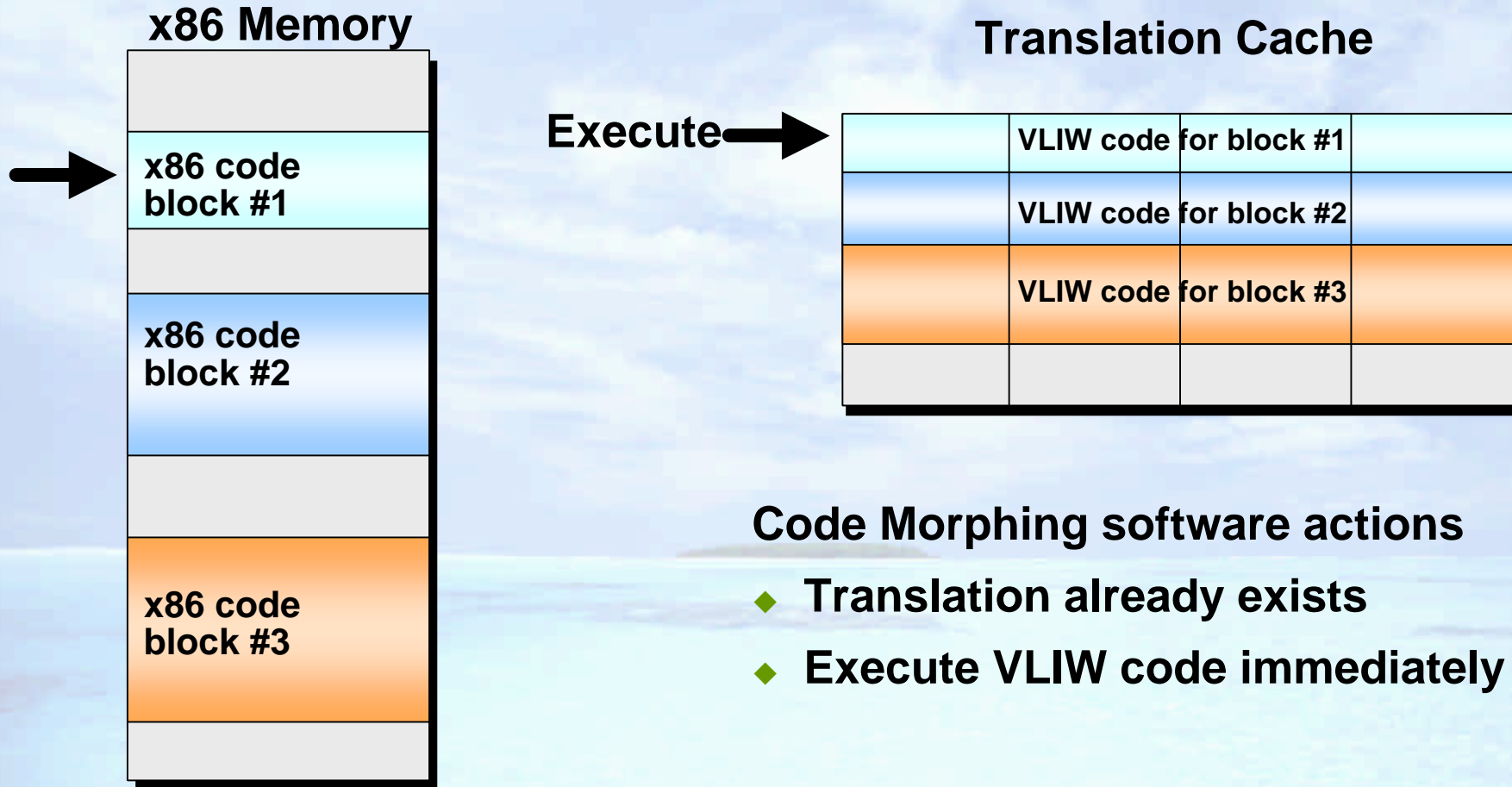- Translates x86 compatible PC applications to VLIW hardware
- **"Learns" and optimizes the application**

# Crusoe Processor Software Optimization

## x86 (IA-32) Instruction Mix

```
        1. movl   %ecx,$0x3
        2. jmp    lbl1
lbl1:
        3. movl   %edx,0x2fc(%ebp)
        4. movl   %eax,0x304(%ebp)
        5. movl   %esi,$0x0
        6. cmpl   %edx,%eax
        7. movl   0x40(%esp,1),$0x0
        8. jle    skip1
        9. movl   %esi,$0x1
skip1:
       10. movl   0x6c(%esp,1),%esi
       11. cmpl   %edx,%eax
       12. movl   %eax,$0x1
       13. jl     skip2
       14. xorl   %eax,%eax
skip2:
       15. movl   %esi,0x308(%ebp)
       16. movl   %edi,0x300(%ebp)
       17. movl   0x7c(%esp,1),%eax
       18. cmpl   %esi,%edi
       19. movl   %eax,$0x0
       20. jnl    exit1
exit2:
```

## "Morphed" (128-bit) VLIW Instructions

```
 1. addi %r39,%ebp,0x2fc
 2. addi %r38,%ebp,0x304
 3. ld %edx,[%r39];       add %r27,%r38,4;      add %r26,%r38,-4
 4. ld %r31,[%r38];       add %r35,0,1;         add %r36,%esp,0x40
 5. ldp %esi,[%r27];      add %r33,%esp,0x6c;   sub.c %null,%edx,%r31
 6. ldp %edi,[%r26];      sel #le %r32,0,%r35;
 7. stam 0,[%r36];        sel #l %r24,%r35,0;   add %r25,%esp,0x7c
 8. stam %r32,[%r33];     add %ecx,0,3;         sub.c %null,%esi,%edi
 9. st %r24,[%r25];       or %eax,0,0;          brcc #lt,<exit2>
10. br <exit1>
```

**A Smart Processor analyzes the programs you run**

- Optimization begins as soon as programs are launched
- Code MorphingTM detects the top running blocks
- Uses techniques beyond out of order engine
- Benefits
  - Good Performance
  - Low Power (reduced number of executions)

# Code Morphing Software Overview

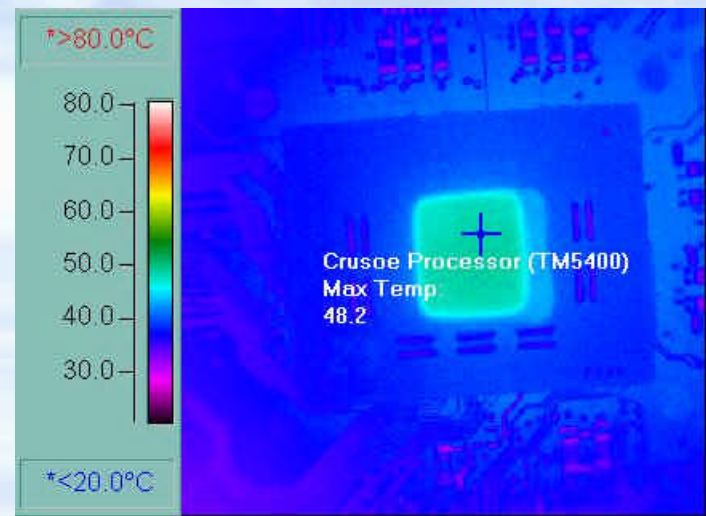**What are the keys to Code Morphing software?**

- Translates x86 compatible PC applications to VLIW hardware

- "Learns" and optimizes the application

- **Produces measurable benefits to Transmeta & users**

# Processor Thermal Comparison
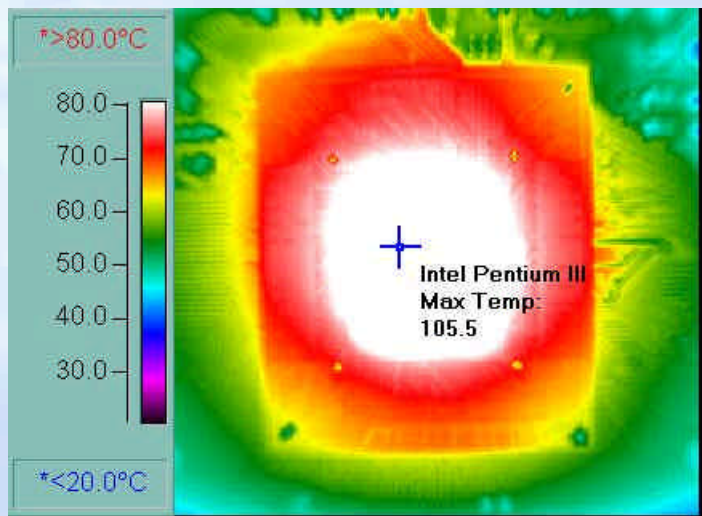


**Pentium III**
**Playing DVD**

105.5º C
221.9º F



**Crusoe Processor**
**Playing DVD**

48.2º C
118.8º F

# Code Morphing Software Overview

**What are the keys to Code Morphing software?**

◆ Translates x86 compatible PC applications to VLIW hardware

◆ "Learns" and optimizes the application

◆ Produces measurable benefits to Transmeta & users

◆ **Provides a platform for future extensions (features)**

# LongRun Technology

## A New Invention for
## Power Management

**"Maximizing Battery Life While Optimizing Performance"**

# LongRun Technology in Operation

- **Crusoe processor starts off at 700MHz**

- **Code Morphing software detects user activity**

- **The software dynamically adjusts MHz and voltage to the most efficient power level**

**Crusoe Processor AC/DC Modes**

| MHz | Voltage |
|-----|---------|
| 700 | 1.65 |
| 667 | 1.65 |
| 633 | 1.60 |
| 600 | 1.60 |
| | |
| 566 | 1.55 |
| 533 | 1.55 |
| 500 | 1.50 |
| 466 | 1.50 |
| 433 | 1.45 |
| 400 | 1.40 |
| | |
| 366 | 1.35 |
| 333 | 1.30 |
| 300 | 1.25 |
| 266 | 1.20 |
| 233 | 1.15 |
| 200 | 1.10 |

# LongRun Technology Demonstration

| MHz | Voltage | % Full Power |
|-----|---------|--------------|
| 700 | 1.65 | 100% |
| 400 | 1.4 | 41% |
| 333 | 1.2 | 25% |

Power = C x $V^2$ x F = 400MHz/700MHz * $1.4V^2$/$1.65V^2$ = 41%

- Crusoe processor starts off at 700MHz

- DVD movie requires between 333 and 400MHz

- Power is reduced to 25 or 41% of full power

- The result is extended DVD playtime

# Mobile Benchmarks

◆ **Today's benchmarks address performance and battery life separately**

◆ **Battery life benchmark should be improved to represent the mobile user**

◆ **Benchmarks for ultra-light mobiles must respond to market needs**

  ◆ All day mobile PCS

  ◆ Multimedia (3-4+ hour PCS)

◆ **Transmeta is working with the industry benchmarking leaders to implement a new methodology**

# Benchmark Methodology

- **Measure the performance on real applications**
- **Measure the battery life after running the application**
- **Generate a result which combines both properties**
- **Transmeta's proposed methodology**
  - Run the same application on all systems
  - Measure the amount of time that it takes for the application to complete
  - Measure the amount of energy that was consumed in the battery
  - Performance = 1/amount of time to complete the application * energy consumed
- **A better score is achieved**
  - The faster for application completes
  - The more battery life you have after running the application
- **The reference machine for comparison is:**
  - Dell Inspiron 7500 with PIII-500MHz
  - 64MB PC-100 SDRAM
  - 440BX Mobile Chipset

# Mobile Platform Benchmarks
## (Mobile Pentium III vs. Crusoe Processor)

| Windows 98 SE | Pentium III 500 MHz 1.54V | TM5400 266-533 MHz LongRun |
|---|---|---|
| Booting Windows | 10 | 31.2 |
| Windows Desktop Idle | 10 | 62.9 |
| Surfing the Web | 10 | 40.7 |
| Intel Media Benchmark | 10 | 18.3 |
| MP3 playback | 10 | 46.9 |
| DVD playback | 10 | 31.1 |

# Summary

- **Introduction of the TM3120 and the TM5400**
- **Three key features**
  - Small, fast VLIW processor
  - Full x86 compatibility
  - LongRun compatibility
- **Description of the VLIW processor and Code Morphing Software**
- **Great Engineering team**
- **New benchmark methodology**

**We really did re-invent the microprocessor!**