ECE 298: System-on-Chip Description and Modeling Lecture 4

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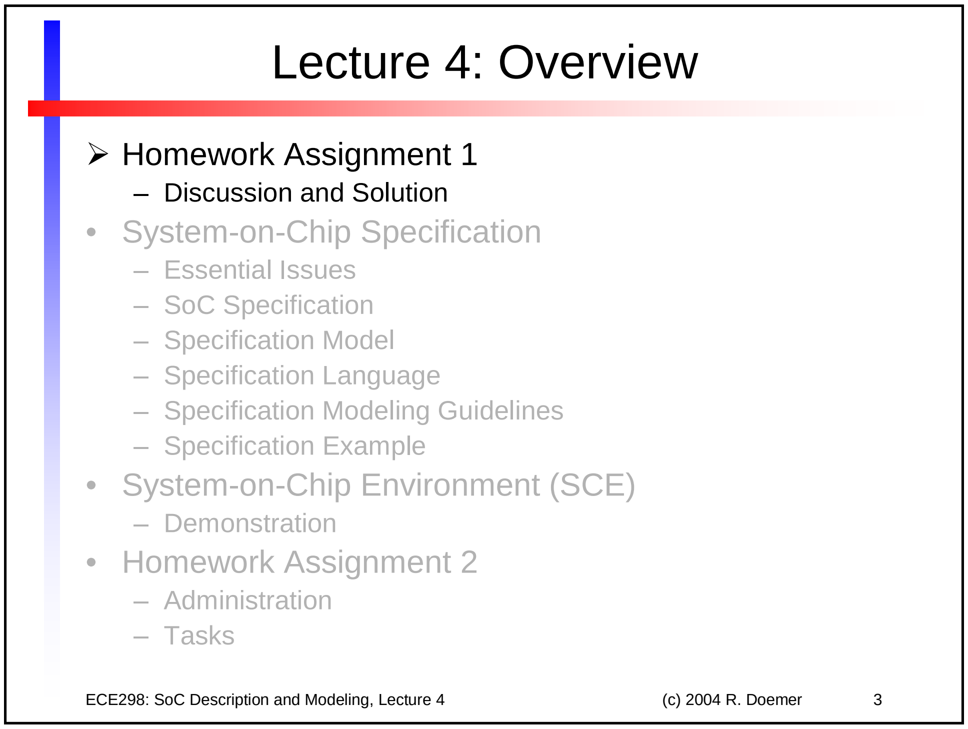
Lecture 4: Overview

- Homework Assignment 1
  - Discussion and Solution
- System-on-Chip Specification
  - Essential Issues
  - SoC Specification
  - Specification Model
  - Specification Language
  - Specification Modeling Guidelines
  - Specification Example
- System-on-Chip Environment (SCE)
  - Demonstration
- Homework Assignment 2
  - Administration
  - Tasks



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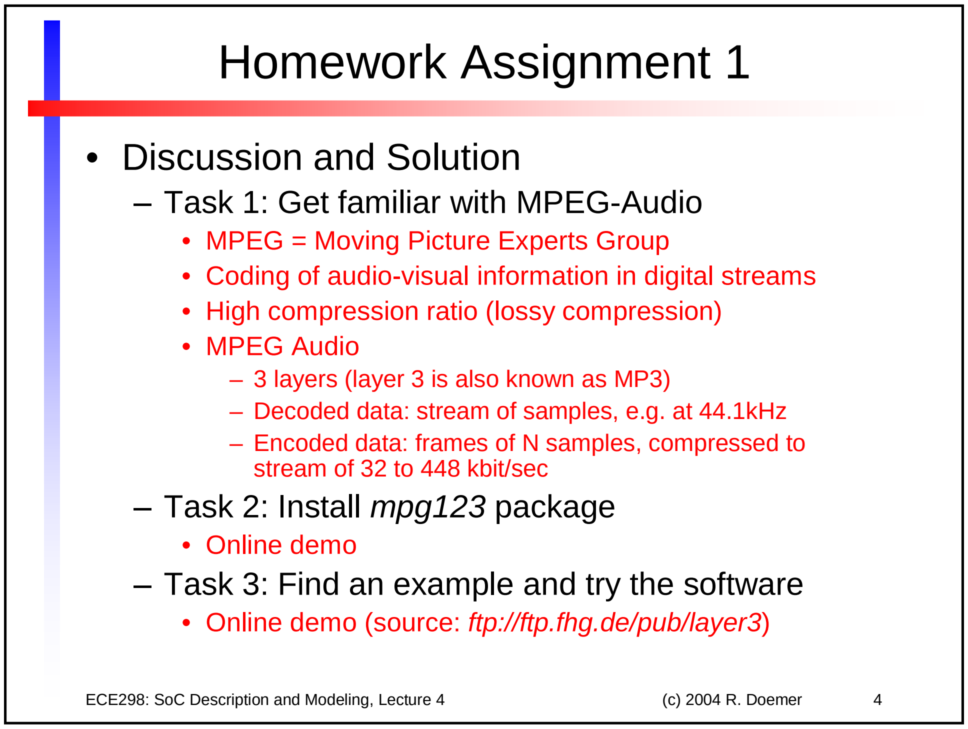

Homework Assignment 1

- Discussion and Solution
  - Task 1: Get familiar with MPEG-Audio
    - MPEG = Moving Picture Experts Group
    - Coding of audio-visual information in digital streams
    - High compression ratio (lossy compression)
    - MPEG Audio
      - 3 layers (layer 3 is also known as MP3)
      - Decoded data: stream of samples, e.g. at 44.1kHz
      - Encoded data: frames of N samples, compressed to stream of 32 to 448 kbit/sec
  - Task 2: Install *mpg123* package
    - Online demo
  - Task 3: Find an example and try the software
    - Online demo (source: *ftp://ftp.fhg.de/pub/layer3*)

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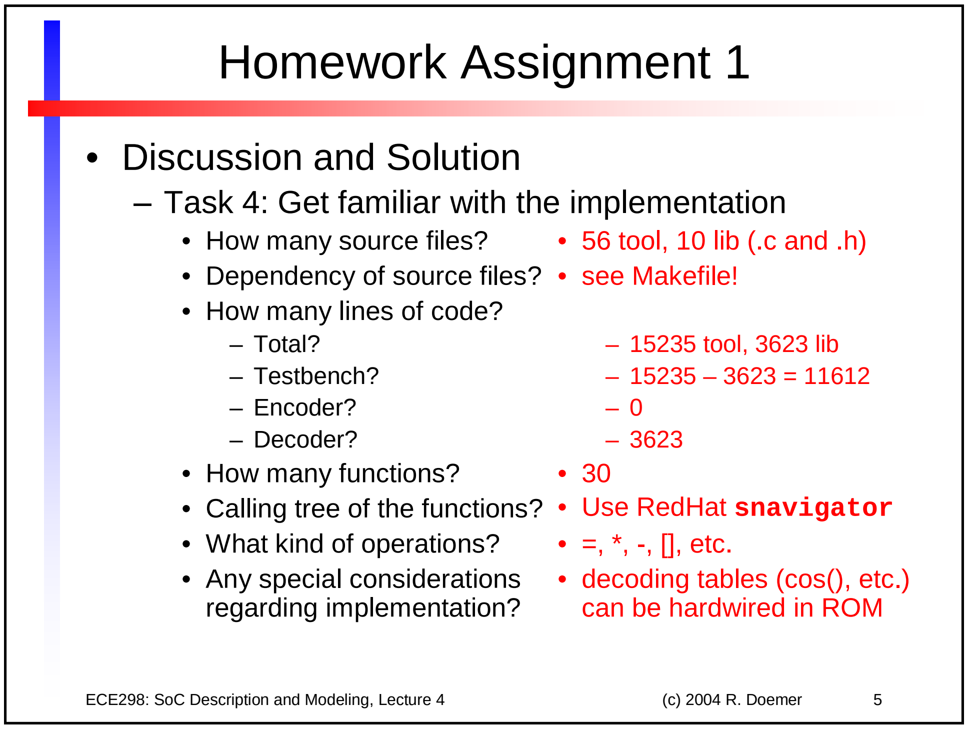

Homework Assignment 1

- Discussion and Solution
  - Task 4: Get familiar with the implementation

• How many source files?	• 56 tool, 10 lib (.c and .h)
• Dependency of source files?	• see Makefile!
• How many lines of code?	
– Total?	– 15235 tool, 3623 lib
– Testbench?	– 15235 – 3623 = 11612
– Encoder?	– 0
– Decoder?	– 3623
• How many functions?	• 30
• Calling tree of the functions?	• Use RedHat **`snavigator`**
• What kind of operations?	• =, *, -, [], etc.
• Any special considerations regarding implementation?	• decoding tables (cos(), etc.) can be hardwired in ROM

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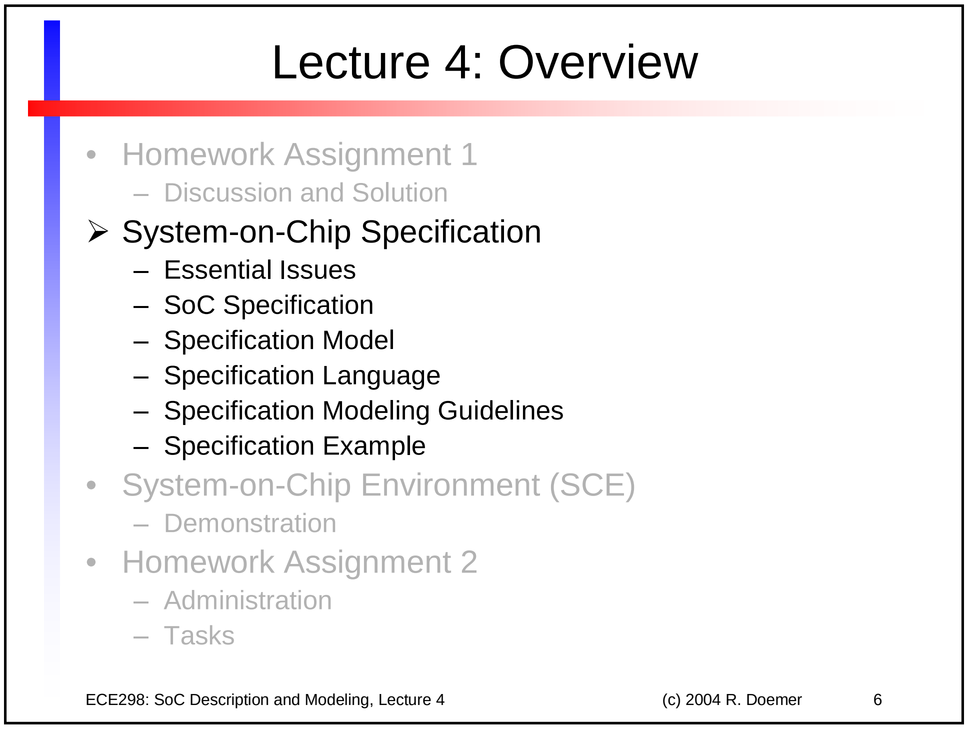

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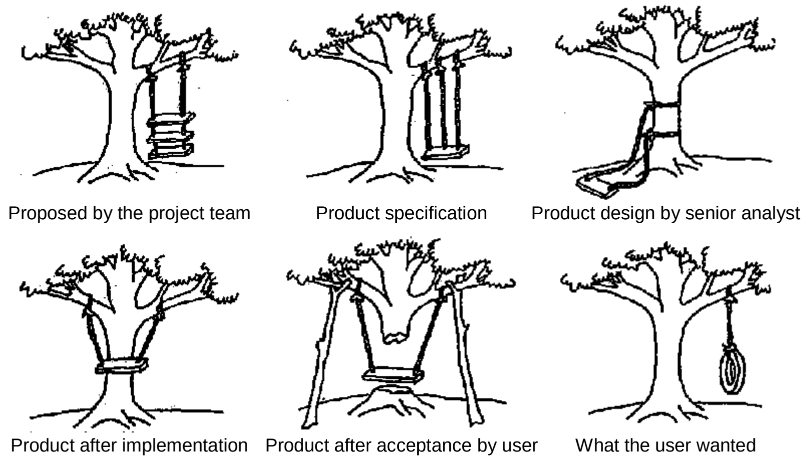
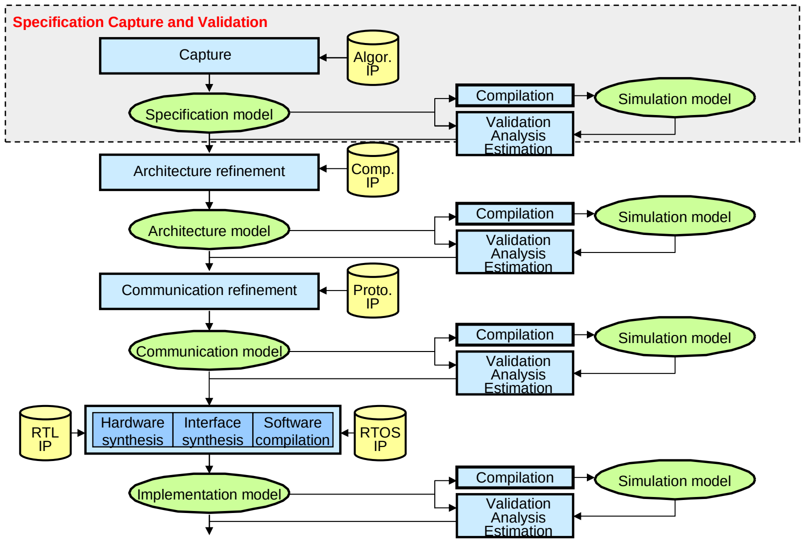
Specification Issues

- An Example ...


Proposed by the project team
Product specification
Product design by senior analyst
Product after implementation
Product after acceptance by user
What the user wanted

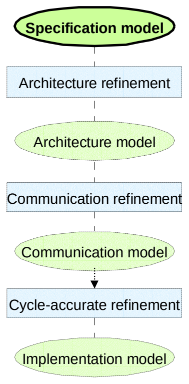
Source: unknown author

SoC Specification



Specification Model

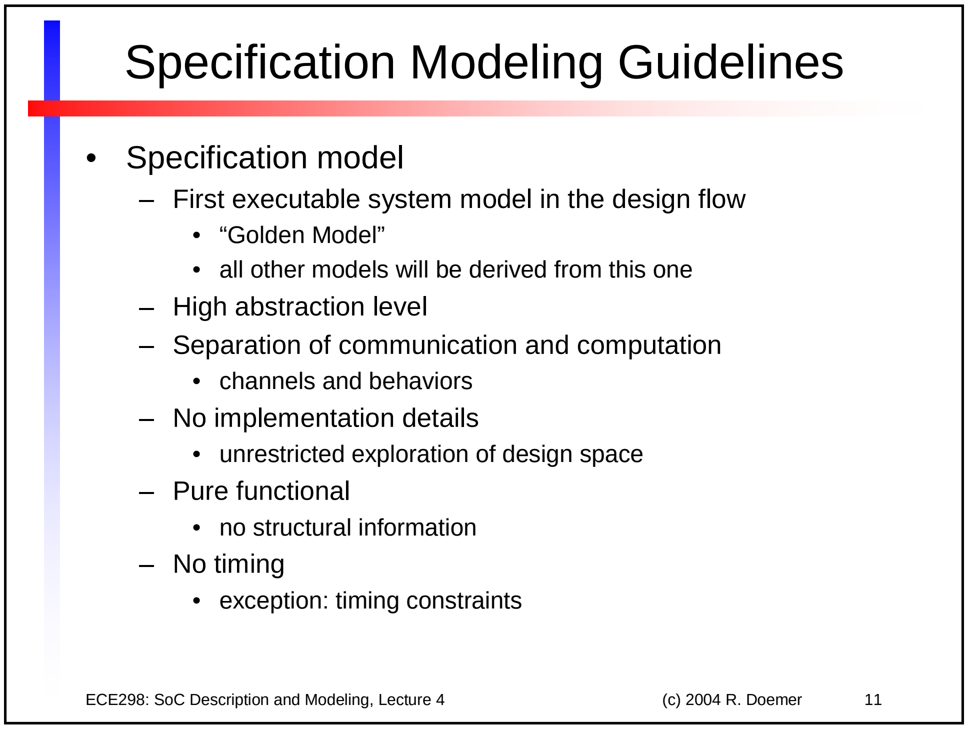
- High-level, abstract model
  - Pure system functionality
  - Algorithmic behavior
  - No implementation details
- No implicit structure / architecture
  - Behavioral hierarchy
- Untimed
  - Executes in zero (logical) time
  - Causal ordering
  - Events only for synchronization



(Source: A. Gerstlauer)

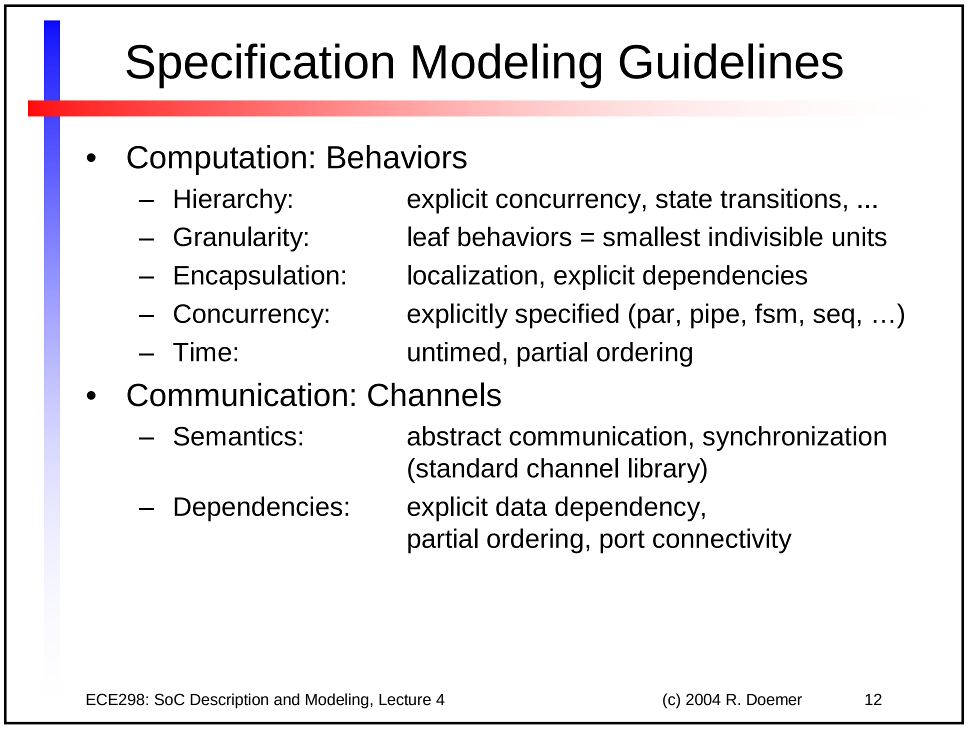
Specification Language

- Specification model
  - PSM model of computation
  - Separation of communication and computation
  - Hierarchical network of behaviors and channels
- SpecC language
  - True superset of ANSI-C
    - ANSI-C plus extensions for HW-design
  - Support of all concepts needed in system design
    - Structural and behavioral hierarchy
    - Concurrency
    - State transitions
    - Communication
    - Synchronization
    - Exception handling
    - Timing
    - RTL



Specification Modeling Guidelines

- Specification model
  - First executable system model in the design flow
    - “Golden Model”
    - all other models will be derived from this one
  - High abstraction level
  - Separation of communication and computation
    - channels and behaviors
  - No implementation details
    - unrestricted exploration of design space
  - Pure functional
    - no structural information
  - No timing
    - exception: timing constraints



Specification Modeling Guidelines

- Computation: Behaviors

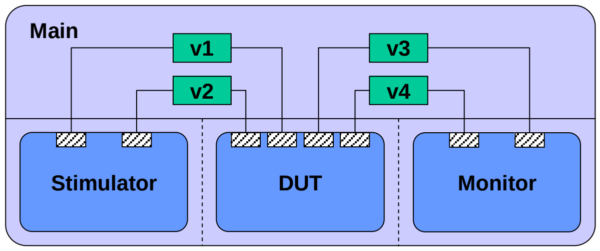
– Hierarchy:	explicit concurrency, state transitions, ...
– Granularity:	leaf behaviors = smallest indivisible units
– Encapsulation:	localization, explicit dependencies
– Concurrency:	explicitly specified (par, pipe, fsm, seq, …)
– Time:	untimed, partial ordering

- Communication: Channels

– Semantics:	abstract communication, synchronization (standard channel library)
– Dependencies:	explicit data dependency, partial ordering, port connectivity

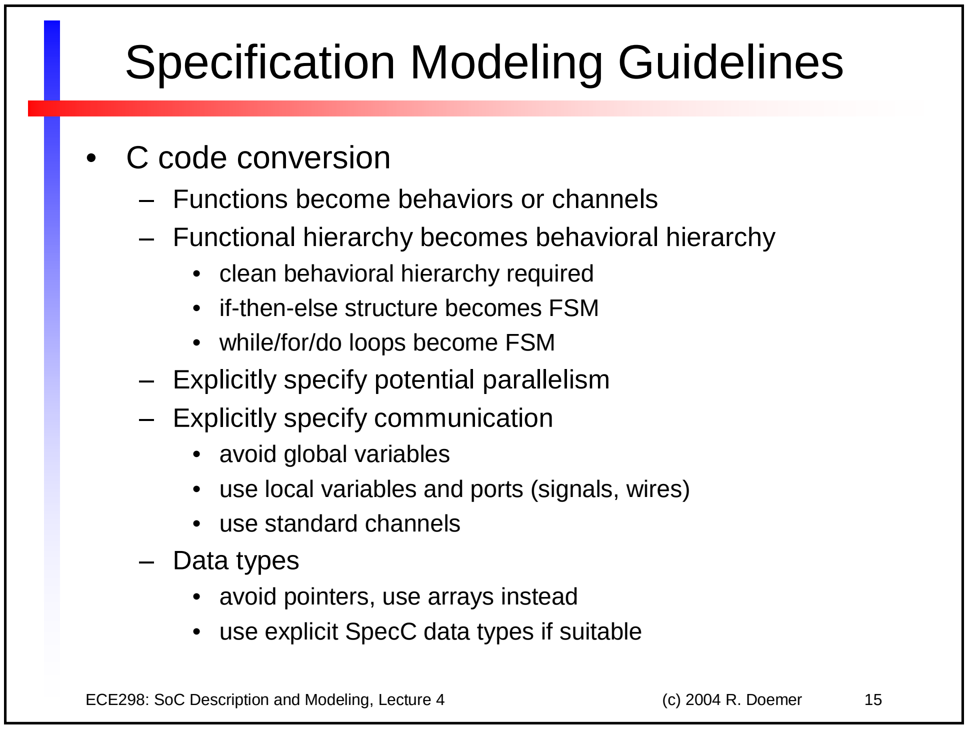
Specification Modeling Guidelines

- Modeling rules
  - Syntax and semantics
    - SpecC language, Version 2.0
  - Test bench (Stimulator, Monitor)
    - no restrictions in syntax and semantics (no synthesis)
  - DUT (Design under test)
    - restricted by syntax and semantic rules (for synthesis!)



Specification Modeling Guidelines

- Example rules for SpecC environment
  - Clean behavioral hierarchy
    - hierarchical behaviors:
      no code other than par, pipe, seq, fsm, try-trap, ... statements
    - leaf behaviors:
      no child behavior calls (basically pure ANSI-C code)
  - Clean communication
    - point-to-point communication via standard channels
    - ports of plain type or interface type, no pointers!
    - port maps to local variables or ports only
- Detailed rules for SpecC Environment
  - CECS Technical Report 03-21:
    "*System-on-Chip Specification Style Guide*"
    by A. Gerstlauer, K. Ramineni, R. Doemer, D. Gajski
  - http://www.ics.uci.edu/~doemer/publications/CECS_TR_03_21.pdf



Specification Modeling Guidelines

- C code conversion
  - Functions become behaviors or channels
  - Functional hierarchy becomes behavioral hierarchy
    - clean behavioral hierarchy required
    - if-then-else structure becomes FSM
    - while/for/do loops become FSM
  - Explicitly specify potential parallelism
  - Explicitly specify communication
    - avoid global variables
    - use local variables and ports (signals, wires)
    - use standard channels
  - Data types
    - avoid pointers, use arrays instead
    - use explicit SpecC data types if suitable

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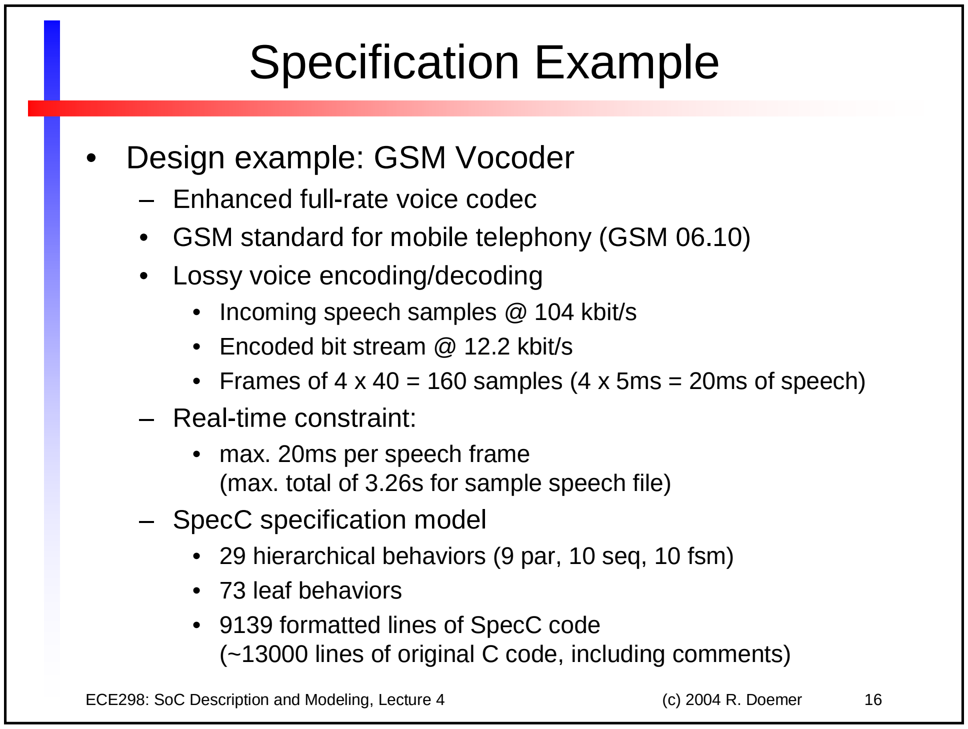

Specification Example

- Design example: GSM Vocoder
  - Enhanced full-rate voice codec
  - GSM standard for mobile telephony (GSM 06.10)
  - Lossy voice encoding/decoding
    - Incoming speech samples @ 104 kbit/s
    - Encoded bit stream @ 12.2 kbit/s
    - Frames of 4 x 40 = 160 samples (4 x 5ms = 20ms of speech)
  - Real-time constraint:
    - max. 20ms per speech frame
      (max. total of 3.26s for sample speech file)
  - SpecC specification model
    - 29 hierarchical behaviors (9 par, 10 seq, 10 fsm)
    - 73 leaf behaviors
    - 9139 formatted lines of SpecC code
      (~13000 lines of original C code, including comments)

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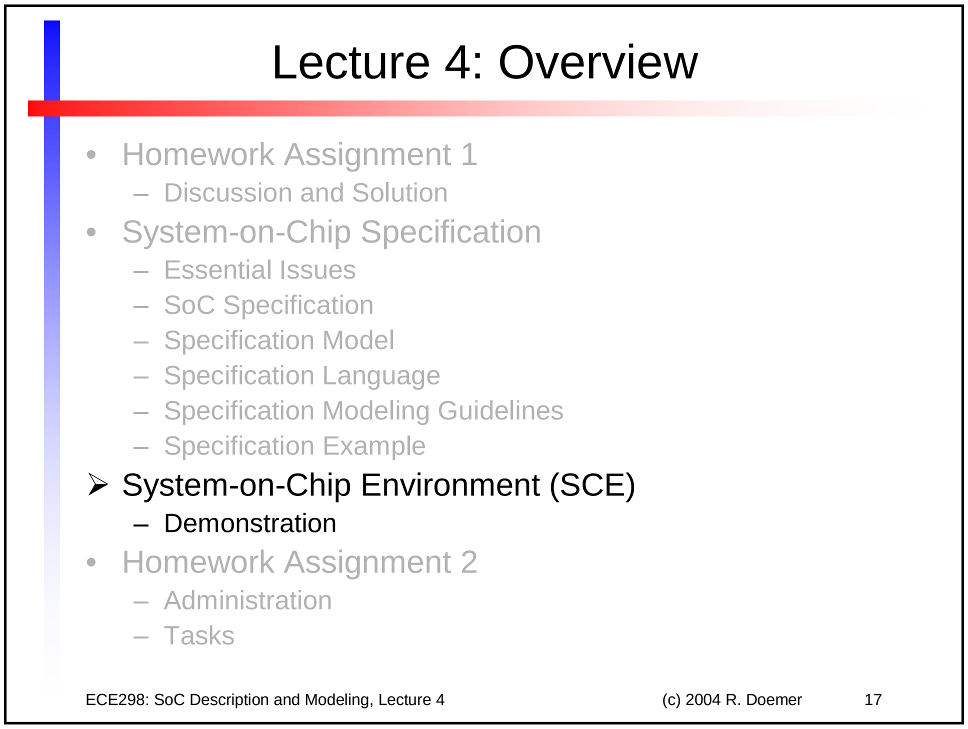

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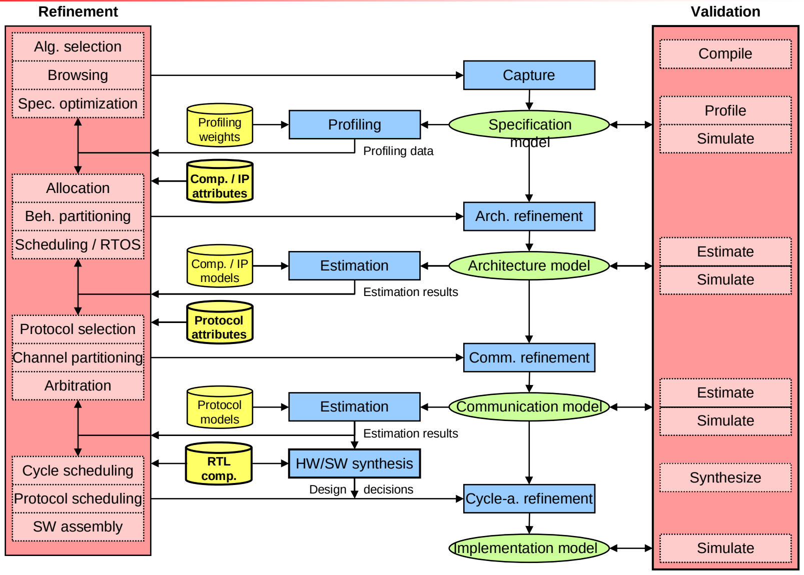
System-on-Chip Environment (SCE)



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System-on-Chip Environment (SCE)

- SCE Components:
  - Graphical frontend (`sce, scchart`)
  - Editor (`sced`)
  - Compiler and simulator (`scc`)
  - Profiling and analysis (`scprof`)
  - Architecture refinement (`scar`)
  - RTOS refinement (`scos`)
  - Communication refinement (`sccr`)
  - RTL refinement (`scrtl`)
  - Software refinement (`sc2c`)
  - Scripting interface (`scsh`)
  - Tools and utilities ...

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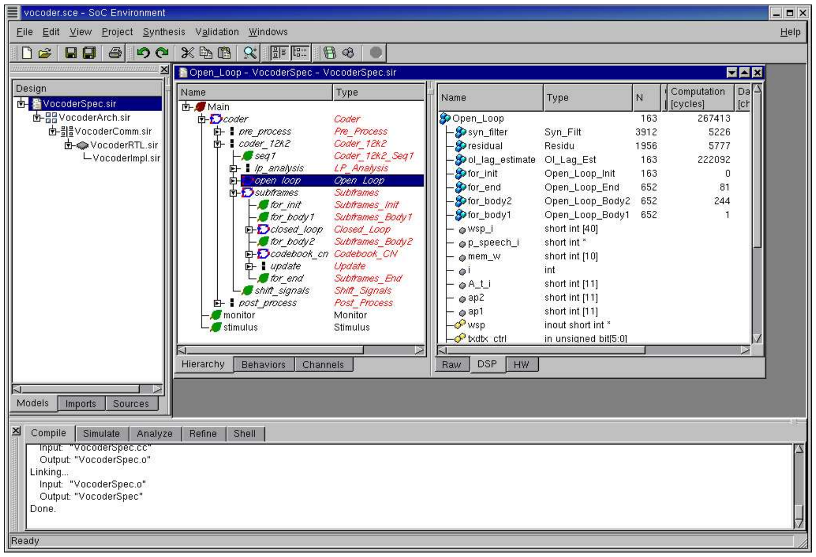
SCE Main Window



Design
- VocoderSpec.sir
  - VocoderArch.sir
    - VocoderComm.sir
      - VocoderRTL.sir
        - VocoderImpl.sir

Name	Type
Main	
coder	Coder
pre_process	Pre_Process
coder_12k2	Coder_12k2
seq1	Coder_12k2_Seq1
lp_analysis	LP_Analysis
open_loop	Open_Loop
subframes	Subframes
for_init	Subframes_Init
for_body1	Subframes_Body1
closed_loop	Closed_Loop
for_body2	Subframes_Body2
codebook_cn	Codebook_CN
update	Update
for_end	Subframes_End
shift_signals	Shift_Signals
post_process	Post_Process
monitor	Monitor
stimulus	Stimulus

Name	Type	N	Computation [cycles]
Open_Loop		163	267413
syn_filter	Syn_Filt	3912	5226
residual	Residu	1956	5777
ol_lag_estimate	Ol_Lag_Est	163	222092
for_init	Open_Loop_Init	163	0
for_end	Open_Loop_End	652	81
for_body2	Open_Loop_Body2	652	244
for_body1	Open_Loop_Body1	652	1
wsp_i	short int [40]		
p_speech_i	short int *		
mem_w	short int [10]		
i	int		
A_t_i	short int [11]		
ap2	short int [11]		
ap1	short int [11]		
wsp	inout short int *		
txdtx_ctrl	in unsigned bit[5:0]		

```
  Input:  "VocoderSpec.cc"
  Output: "VocoderSpec.o"
Linking...
  Input:  "VocoderSpec.o"
  Output: "VocoderSpec"
Done.
```

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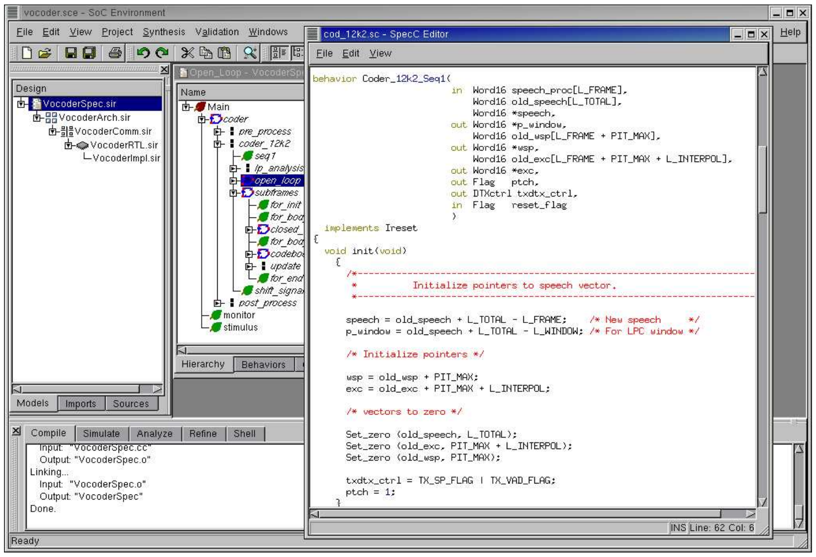
SCE Source Editor



```
  Input: "VocoderSpec.cc"
  Output: "VocoderSpec.o"
Linking...
  Input: "VocoderSpec.o"
  Output: "VocoderSpec"
Done.
```

```
behavior Coder_12k2_Seq1(
                         in  Word16 speech_proc[L_FRAME],
                             Word16 old_speech[L_TOTAL],
                             Word16 *speech,
                         out Word16 *p_window,
                             Word16 old_wsp[L_FRAME + PIT_MAX],
                         out Word16 *wsp,
                             Word16 old_exc[L_FRAME + PIT_MAX + L_INTERPOL],
                         out Word16 *exc,
                         out Flag   ptch,
                         out DTXctrl txdtx_ctrl,
                         in  Flag   reset_flag
                         )
  implements Ireset
{
  void init(void)
   {
    /*------------------------------------------------------------------
     *          Initialize pointers to speech vector.
     *------------------------------------------------------------------

    speech = old_speech + L_TOTAL - L_FRAME;    /* New speech     */
    p_window = old_speech + L_TOTAL - L_WINDOW; /* For LPC window */

    /* Initialize pointers */

    wsp = old_wsp + PIT_MAX;
    exc = old_exc + PIT_MAX + L_INTERPOL;

    /* vectors to zero */

    Set_zero (old_speech, L_TOTAL);
    Set_zero (old_exc, PIT_MAX + L_INTERPOL);
    Set_zero (old_wsp, PIT_MAX);

    txdtx_ctrl = TX_SP_FLAG | TX_VAD_FLAG;
    ptch = 1;
   }
```

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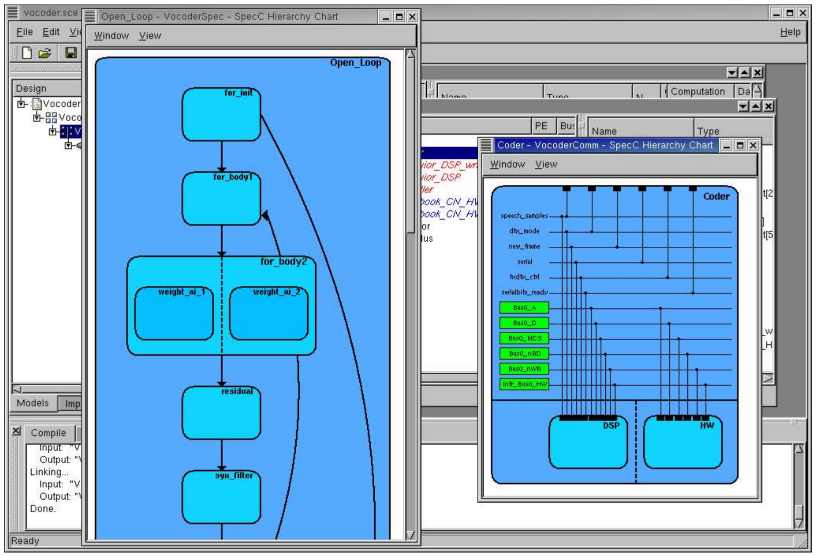
SCE Hierarchy Displays



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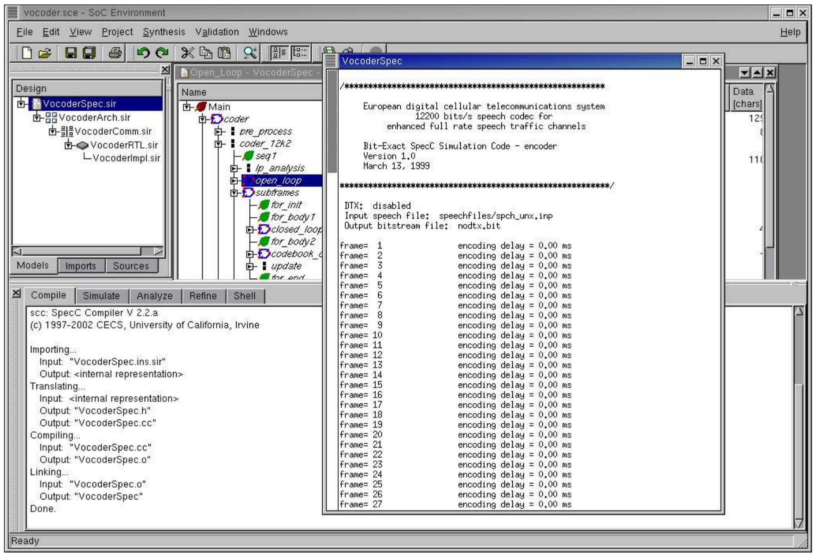
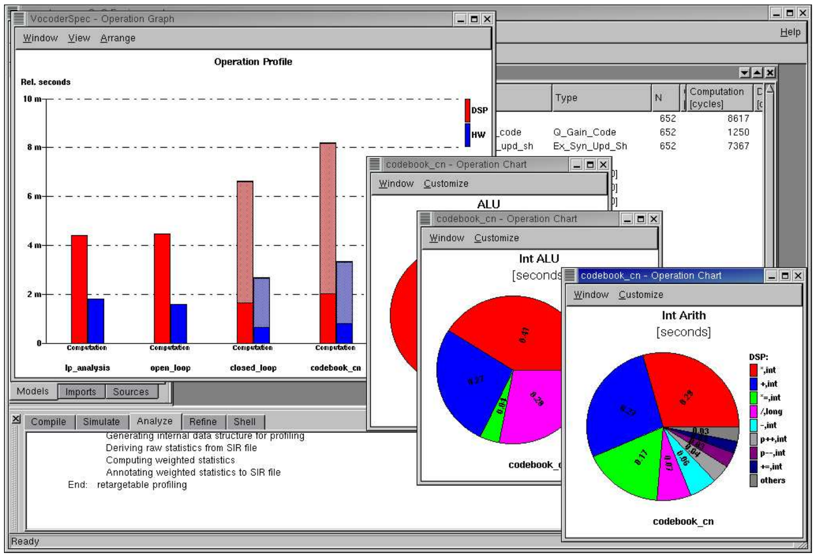
SCE Compiler and Simulator



```
scc: SpecC Compiler V 2.2.a
(c) 1997-2002 CECS, University of California, Irvine

Importing...
  Input:  "VocoderSpec.ins.sir"
  Output: <internal representation>
Translating...
  Input:  <internal representation>
  Output: "VocoderSpec.h"
  Output: "VocoderSpec.cc"
Compiling...
  Input:  "VocoderSpec.cc"
  Output: "VocoderSpec.o"
Linking...
  Input:  "VocoderSpec.o"
  Output: "VocoderSpec"
Done.
```

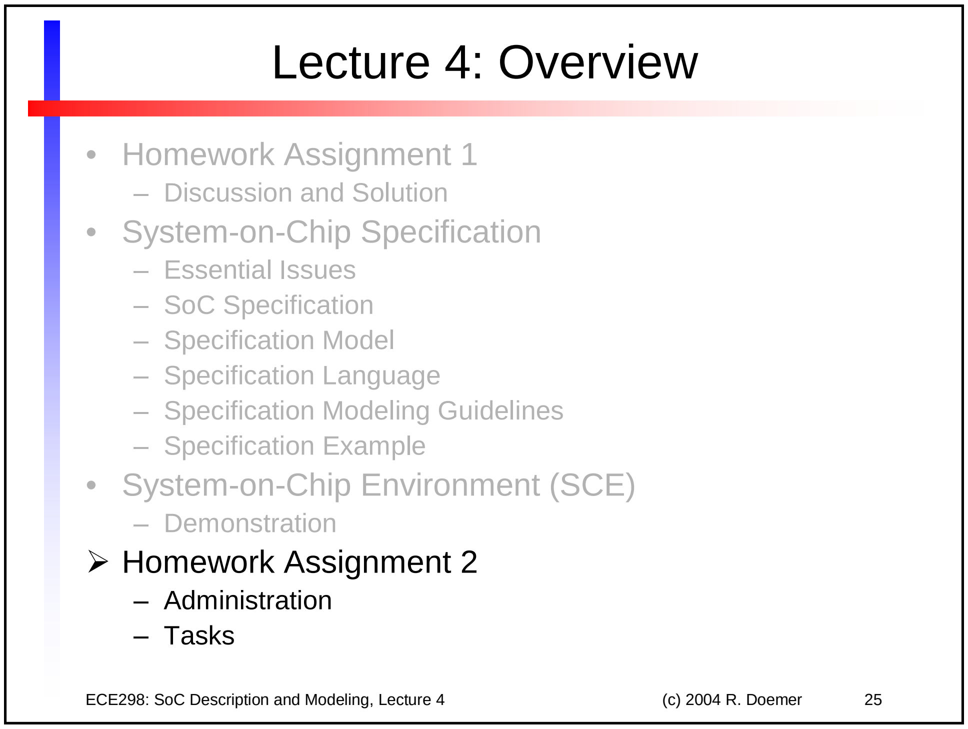
```
/*****************************************************************

    European digital cellular telecommunications system
              12200 bits/s speech codec for
         enhanced full rate speech traffic channels

    Bit-Exact SpecC Simulation Code - encoder
    Version 1.0
    March 13, 1999

*****************************************************************/

 DTX:  disabled
 Input speech file:  speechfiles/spch_unx.inp
 Output bitstream file:  nodtx.bit

frame=  1                encoding delay = 0.00 ms
frame=  2                encoding delay = 0.00 ms
frame=  3                encoding delay = 0.00 ms
frame=  4                encoding delay = 0.00 ms
frame=  5                encoding delay = 0.00 ms
frame=  6                encoding delay = 0.00 ms
frame=  7                encoding delay = 0.00 ms
frame=  8                encoding delay = 0.00 ms
frame=  9                encoding delay = 0.00 ms
frame= 10                encoding delay = 0.00 ms
frame= 11                encoding delay = 0.00 ms
frame= 12                encoding delay = 0.00 ms
frame= 13                encoding delay = 0.00 ms
frame= 14                encoding delay = 0.00 ms
frame= 15                encoding delay = 0.00 ms
frame= 16                encoding delay = 0.00 ms
frame= 17                encoding delay = 0.00 ms
frame= 18                encoding delay = 0.00 ms
frame= 19                encoding delay = 0.00 ms
frame= 20                encoding delay = 0.00 ms
frame= 21                encoding delay = 0.00 ms
frame= 22                encoding delay = 0.00 ms
frame= 23                encoding delay = 0.00 ms
frame= 24                encoding delay = 0.00 ms
frame= 25                encoding delay = 0.00 ms
frame= 26                encoding delay = 0.00 ms
frame= 27                encoding delay = 0.00 ms
```

SCE Profiling and Analysis



	Type	N	Computation [cycles]
		652	8617
_code	Q_Gain_Code	652	1250
_upd_sh	Ex_Syn_Upd_Sh	652	7367

```
            Generating internal data structure for profiling
            Deriving raw statistics from SIR file
            Computing weighted statistics
            Annotating weighted statistics to SIR file
     End:   retargetable profiling
```



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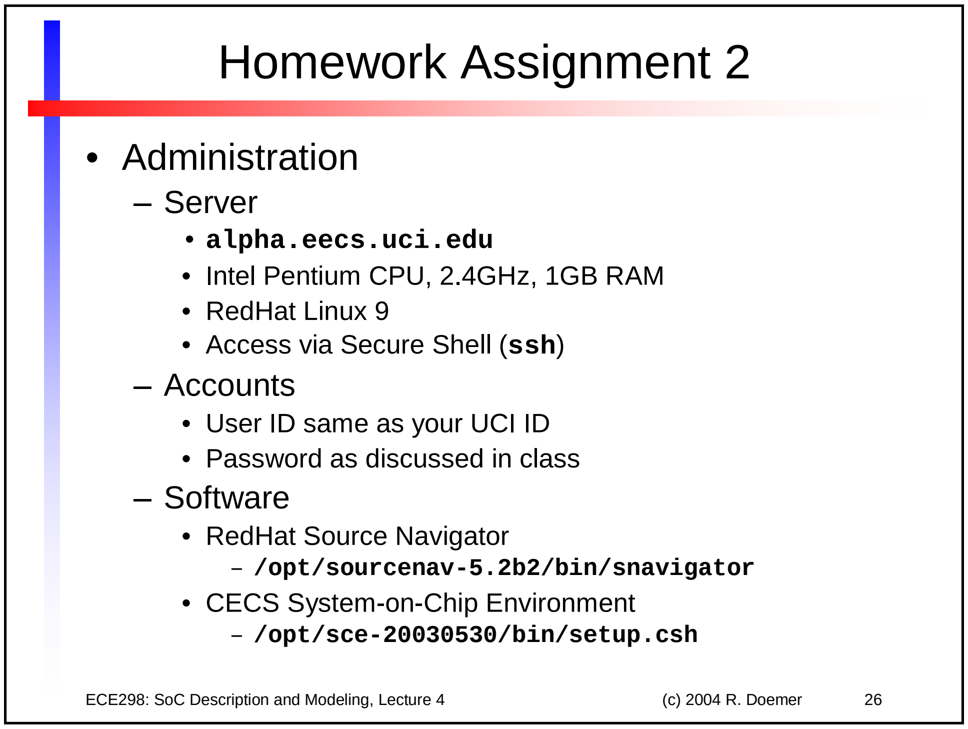

Homework Assignment 2

- Administration
  - Server
    - **`alpha.eecs.uci.edu`**
    - Intel Pentium CPU, 2.4GHz, 1GB RAM
    - RedHat Linux 9
    - Access via Secure Shell (**`ssh`**)
  - Accounts
    - User ID same as your UCI ID
    - Password as discussed in class
  - Software
    - RedHat Source Navigator
      - **`/opt/sourcenav-5.2b2/bin/snavigator`**
    - CECS System-on-Chip Environment
      - **`/opt/sce-20030530/bin/setup.csh`**

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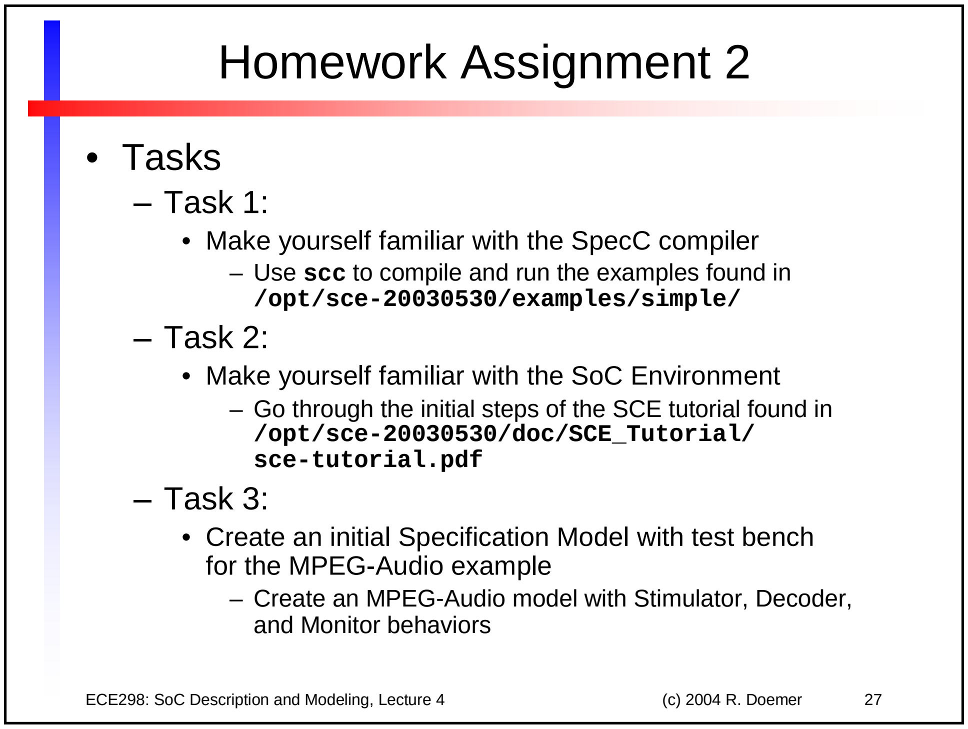

Homework Assignment 2

- Tasks
  - Task 1:
    - Make yourself familiar with the SpecC compiler
      - Use **`scc`** to compile and run the examples found in **`/opt/sce-20030530/examples/simple/`**
  - Task 2:
    - Make yourself familiar with the SoC Environment
      - Go through the initial steps of the SCE tutorial found in **`/opt/sce-20030530/doc/SCE_Tutorial/sce-tutorial.pdf`**
  - Task 3:
    - Create an initial Specification Model with test bench for the MPEG-Audio example
      - Create an MPEG-Audio model with Stimulator, Decoder, and Monitor behaviors

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