Guaranteed Vertical Reuse

C Execution In A UVM Environment

ST ERICSSON

Guaranteed Vertical Reuse

A LITTLE BACKGROUND

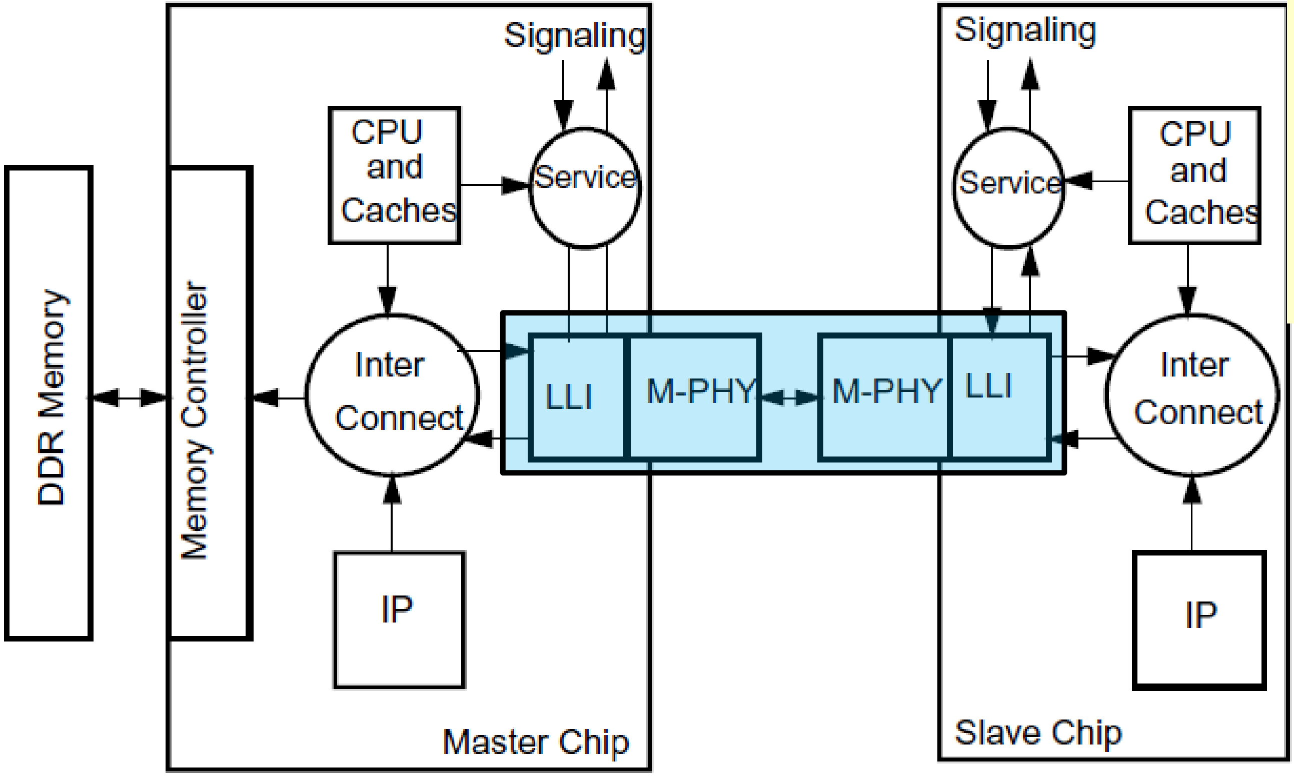
Team Introduction

- IP & Sub system verification team
  - 18 ST-Ericsson employees
  - 2 subcontractors
- Seniority
  - ~ 4 years
- Expertise
  - Subsystem verification with C/TLM platform or with SV/UVM
  - Constrained random verification
  - Formal verification

What If ?

- You could run SW tests in your UVM environment?
- You could get coverage from these SW tests?
- You had the flexibility of implementing your tests in UVM or SW when appropriate?
- You could reuse the same SW across your different verification platforms ?

Our Project Context

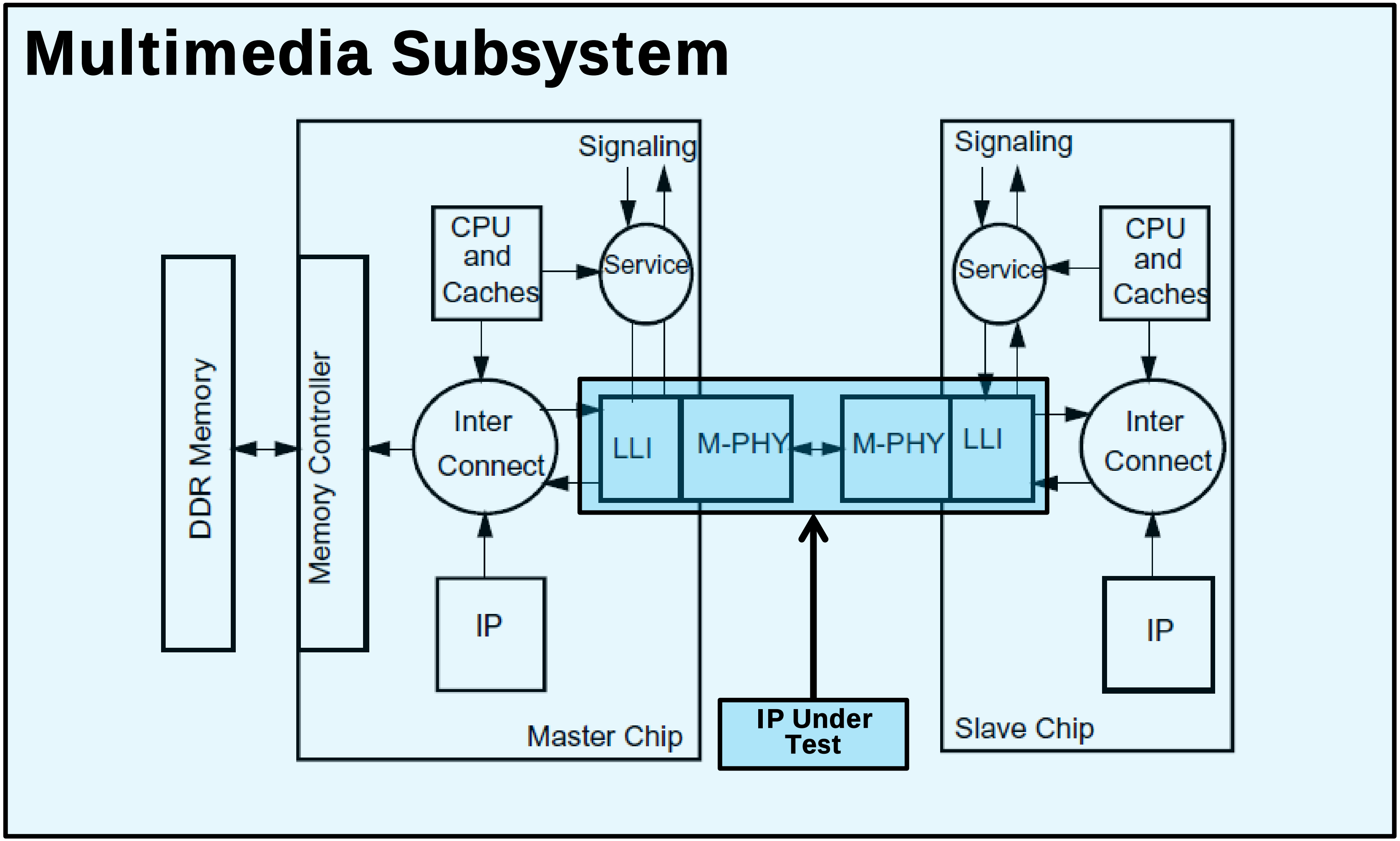


i.e. A companion chip (slave) can share and boot from main memory of an application chip (master)

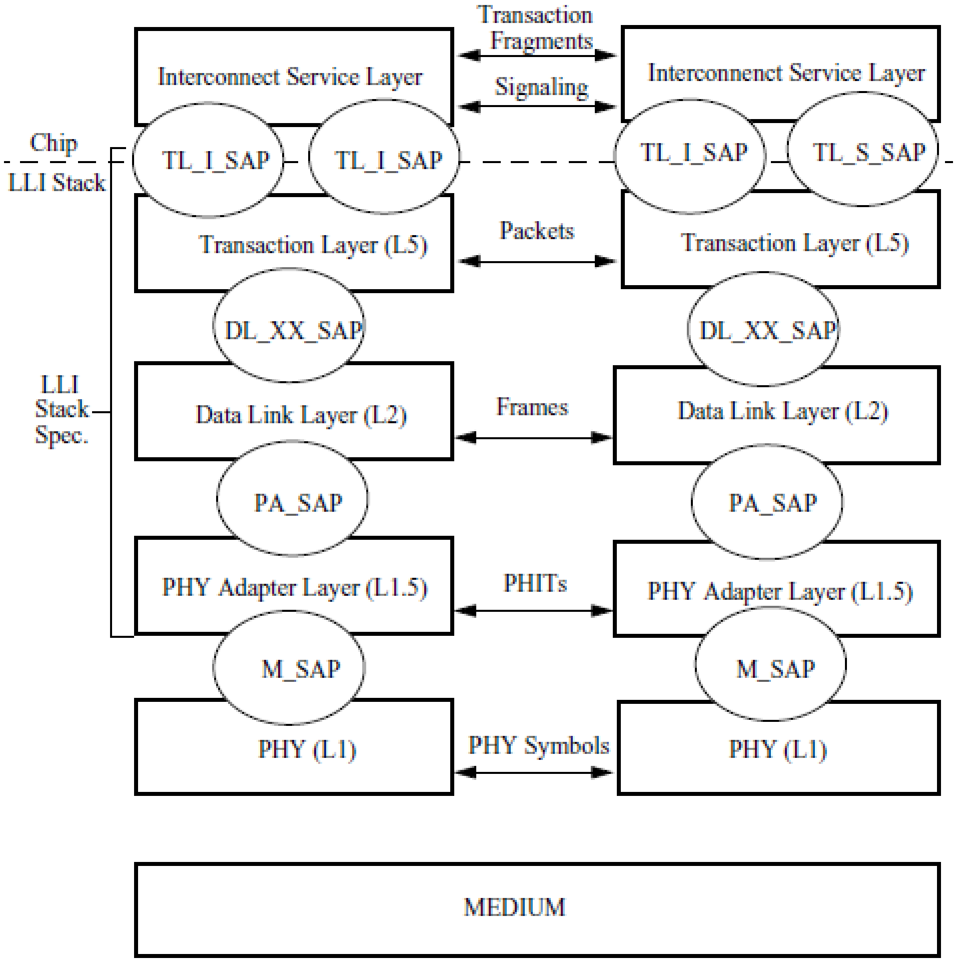
MIPI standard for Low Latency Interface interconnecting 2 chips remotely using memory mapped transactions

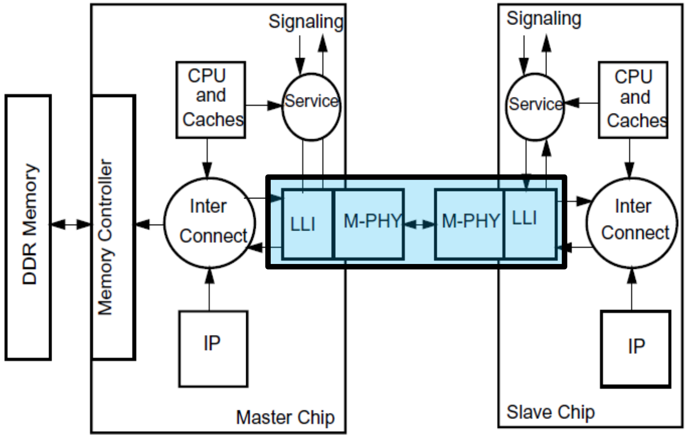
Sponsored By:

Our Project Context



Our Project Context

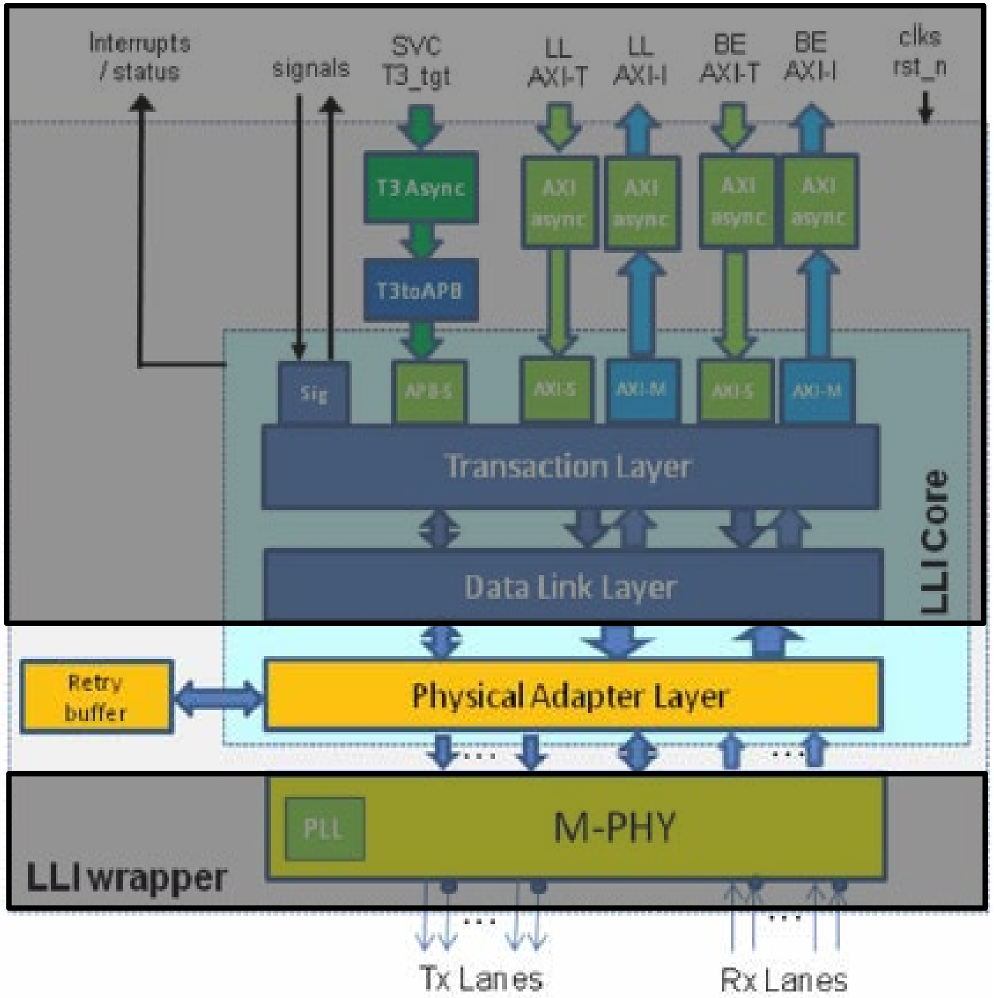




MIPI standard for Low Latency Interface interconnecting 2 chips remotely using memory mapped transactions

Where We Start From?

- Only PA layer extensively verified
  - Constrained random
  - Functional coverage
  - Formal properties



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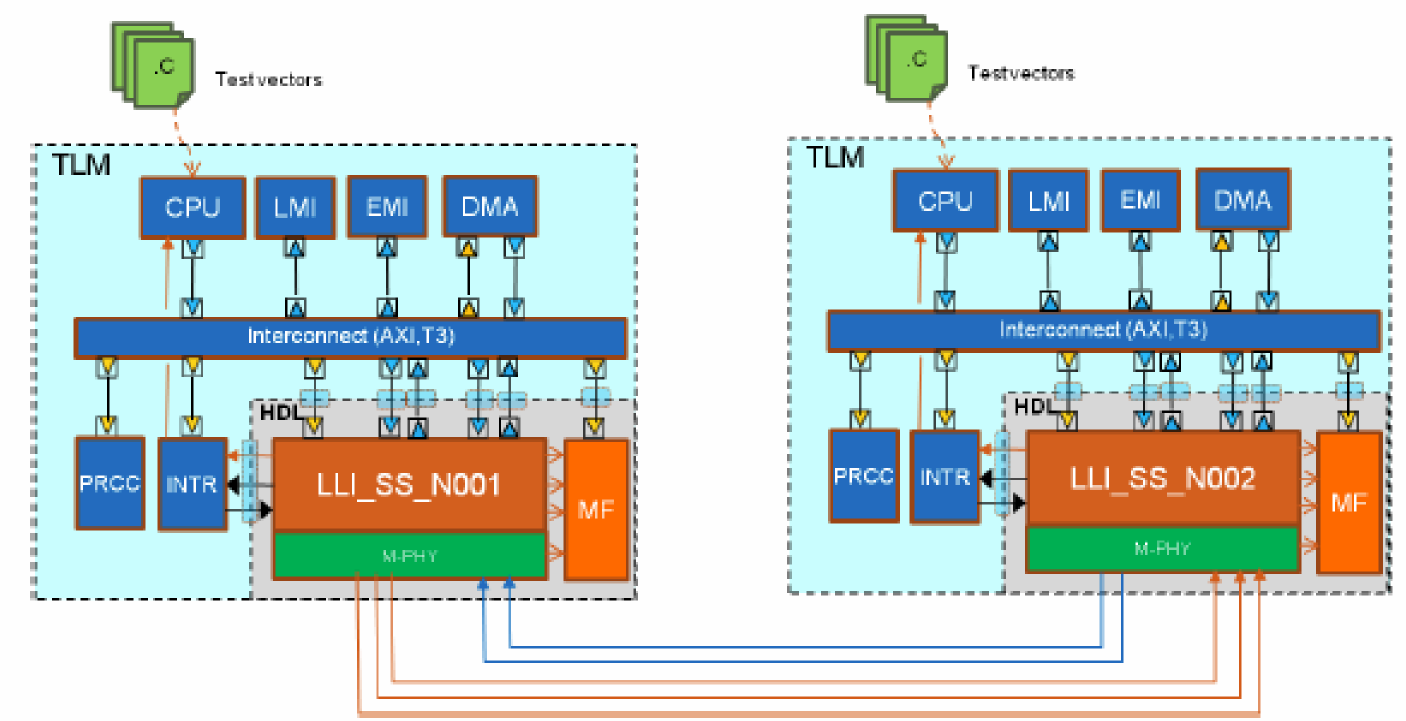
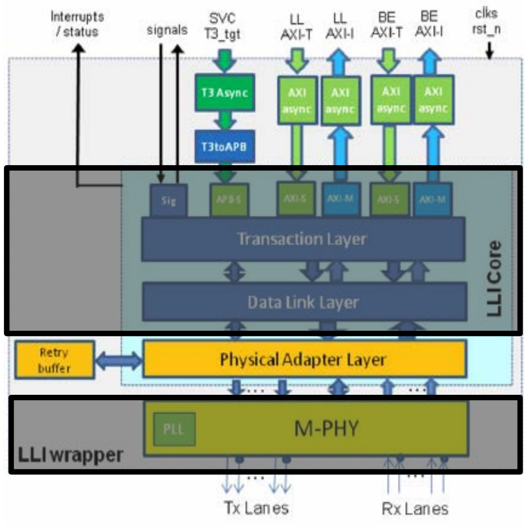
Where We Start From?

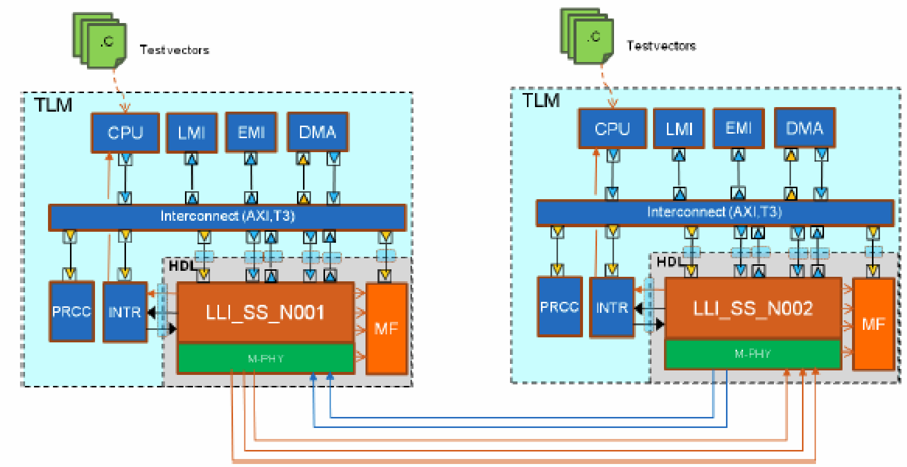
- Full LLI verified with 2 back to back connected DUTs executing C tests
  - SW layer Early validation/Use Cases



Known Limitations

- Constrained Random/Coverage only @ PA layer
- No functional coverage from SW tests
- DUT not verified against a golden model





Addressing Known Limitations

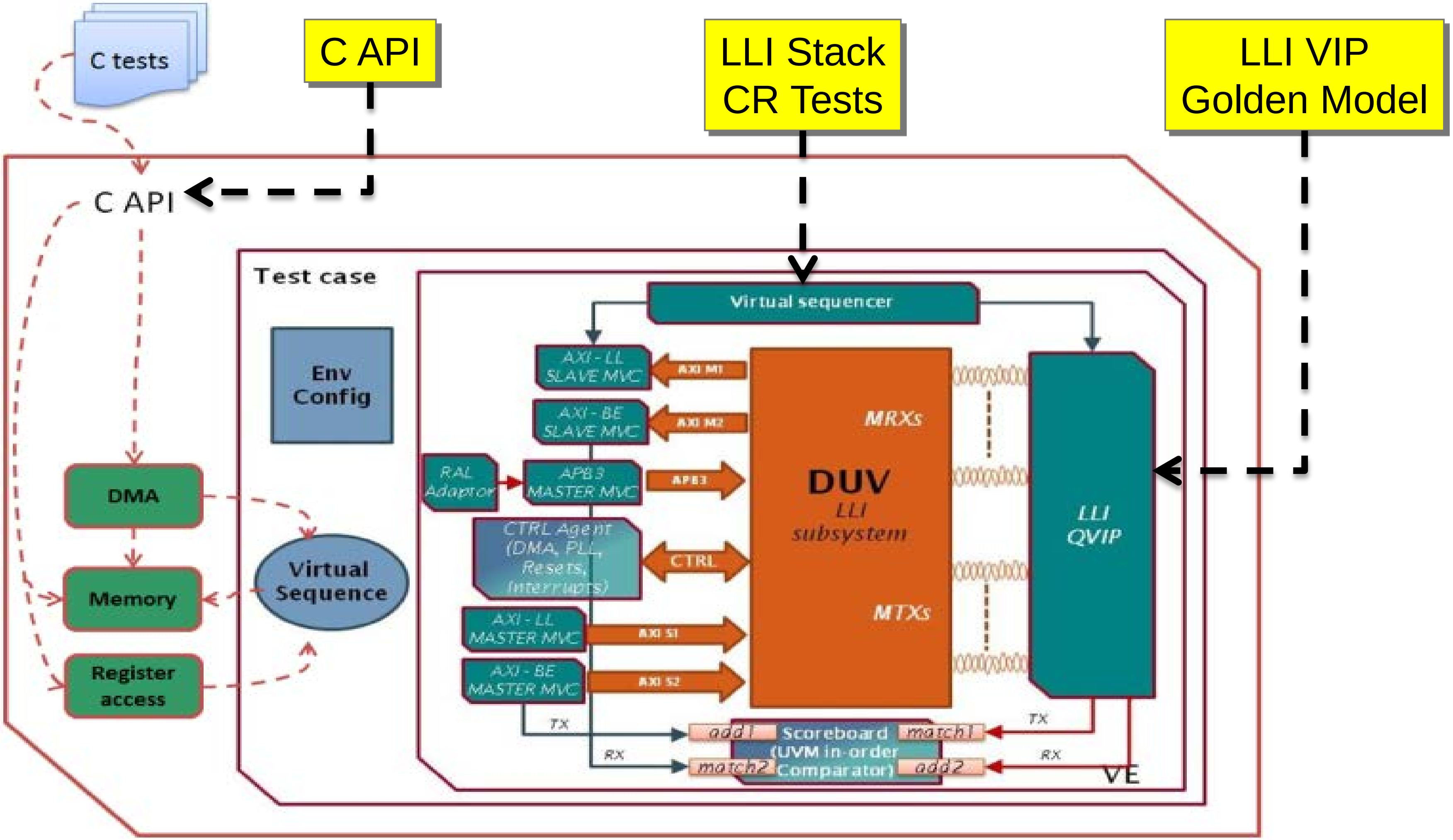
Limitations

- DUT not verified against a golden model
- Random/Coverage only @ PA layer
- No coverage for SW executed

Enhancements

- Use a LLI VIP to verify complete LLI stack
- Develop CR tests with coverage @ all LLI stack layers
- Develop C API to run C code on UVM TB and gather associated functional coverage

Enhanced Verification Environment


C API

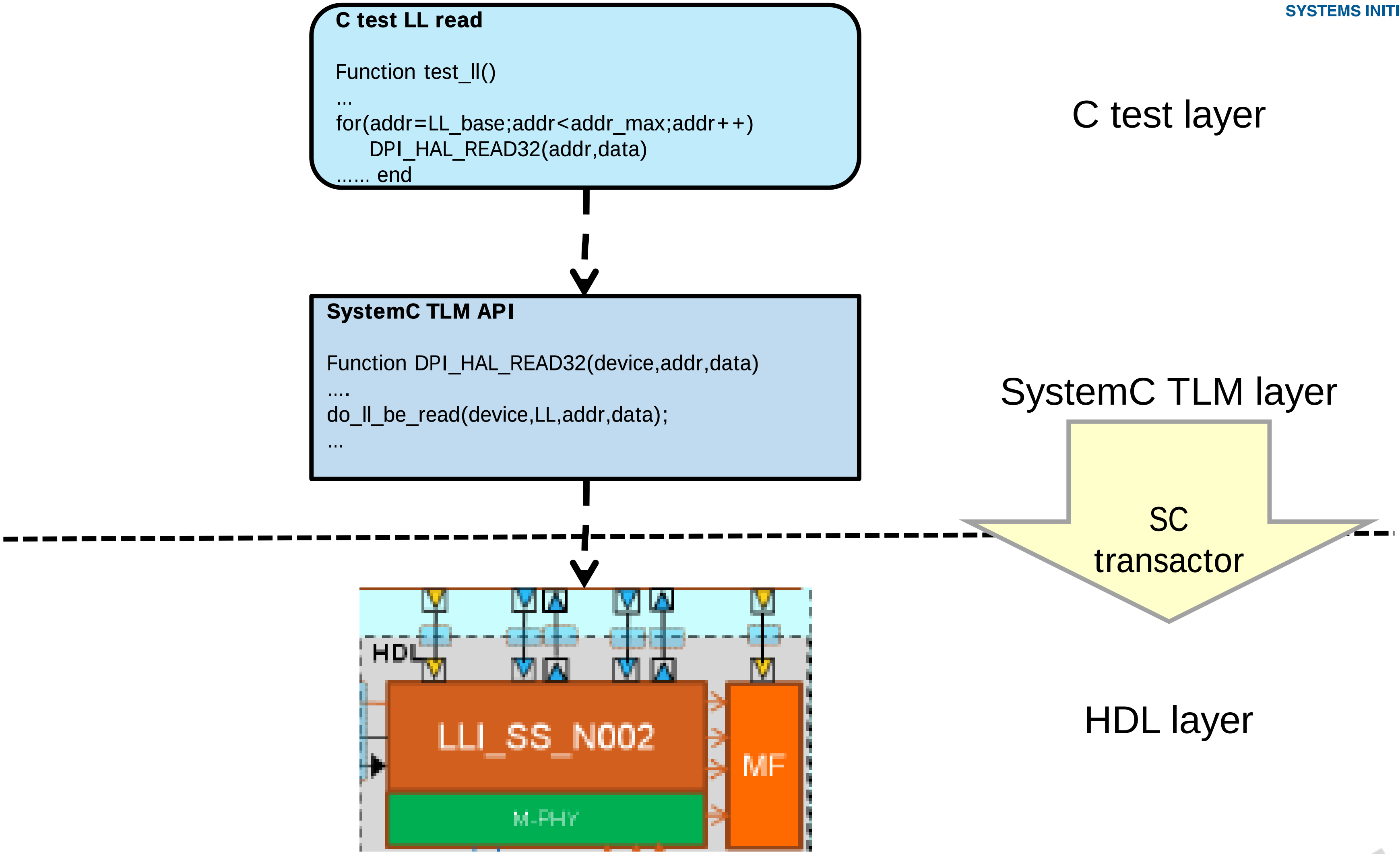
LLI Stack
CR Tests

LLI VIP
Golden Model

Guaranteed Vertical Reuse

C API IMPLEMENTATION FOR SYSTEM VERILOG

Where We Start From?



C test LL read

```
Function test_ll()
...
for(addr=LL_base;addr<addr_max;addr++)
     DPI_HAL_READ32(addr,data)
...... end
```

C test layer

SystemC TLM API

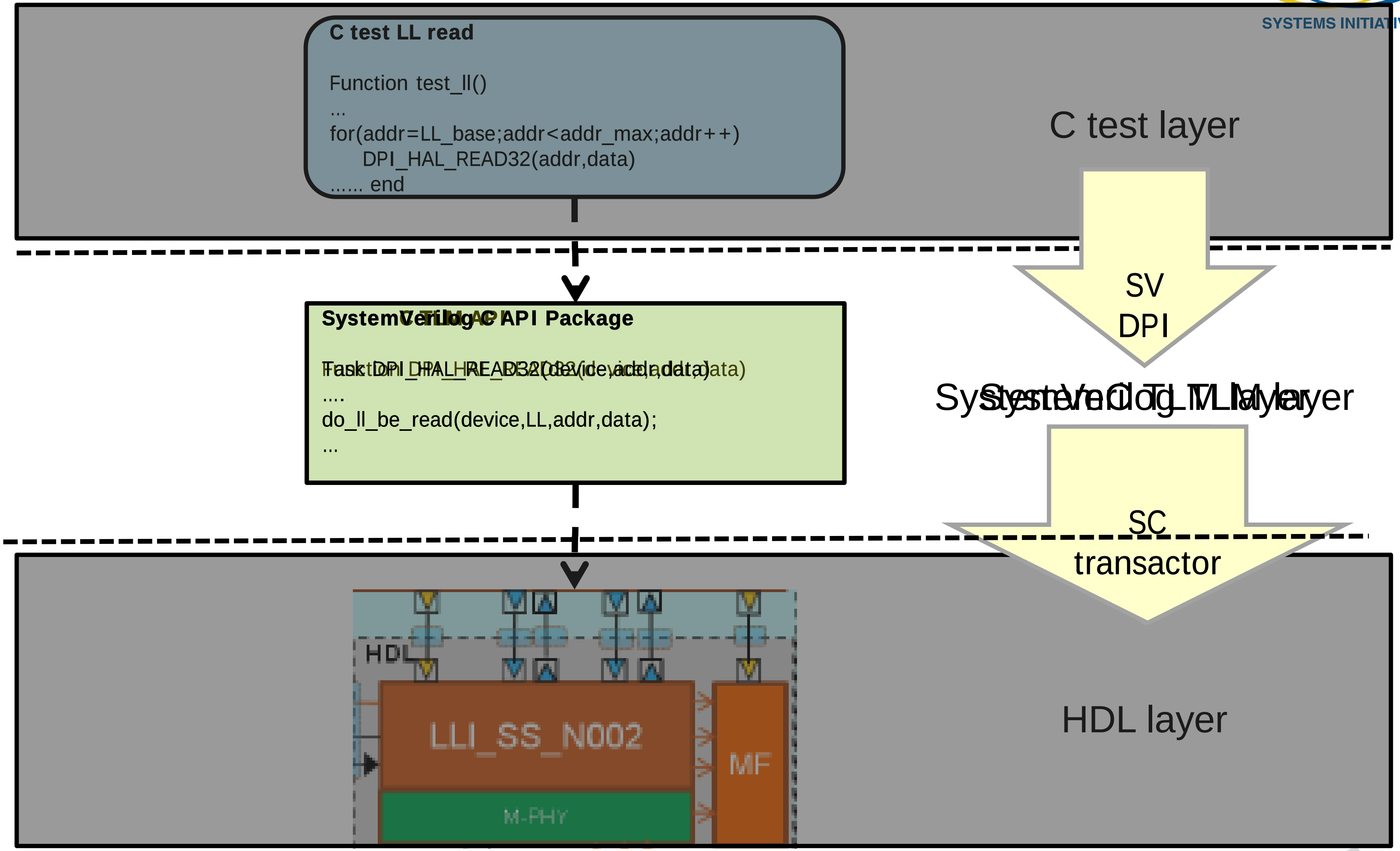
```
Function DPI_HAL_READ32(device,addr,data)
....
do_ll_be_read(device,LL,addr,data);
...
```

SystemC TLM layer

SC transactor

HDL layer

What Need To Be Implemented



C test LL read

```
Function test_ll()
...
for(addr=LL_base;addr<addr_max;addr++)
     DPI_HAL_READ32(addr,data)
...... end
```

C test layer

SV
DPI

SystemVerilog API Package

C TLM API

```
Task DPI_HAL_READ32(device,addr,data)
Function DPI_HAL_READ32(device,addr,data)
....
do_ll_be_read(device,LL,addr,data);
...
```

SystemVerilog layer

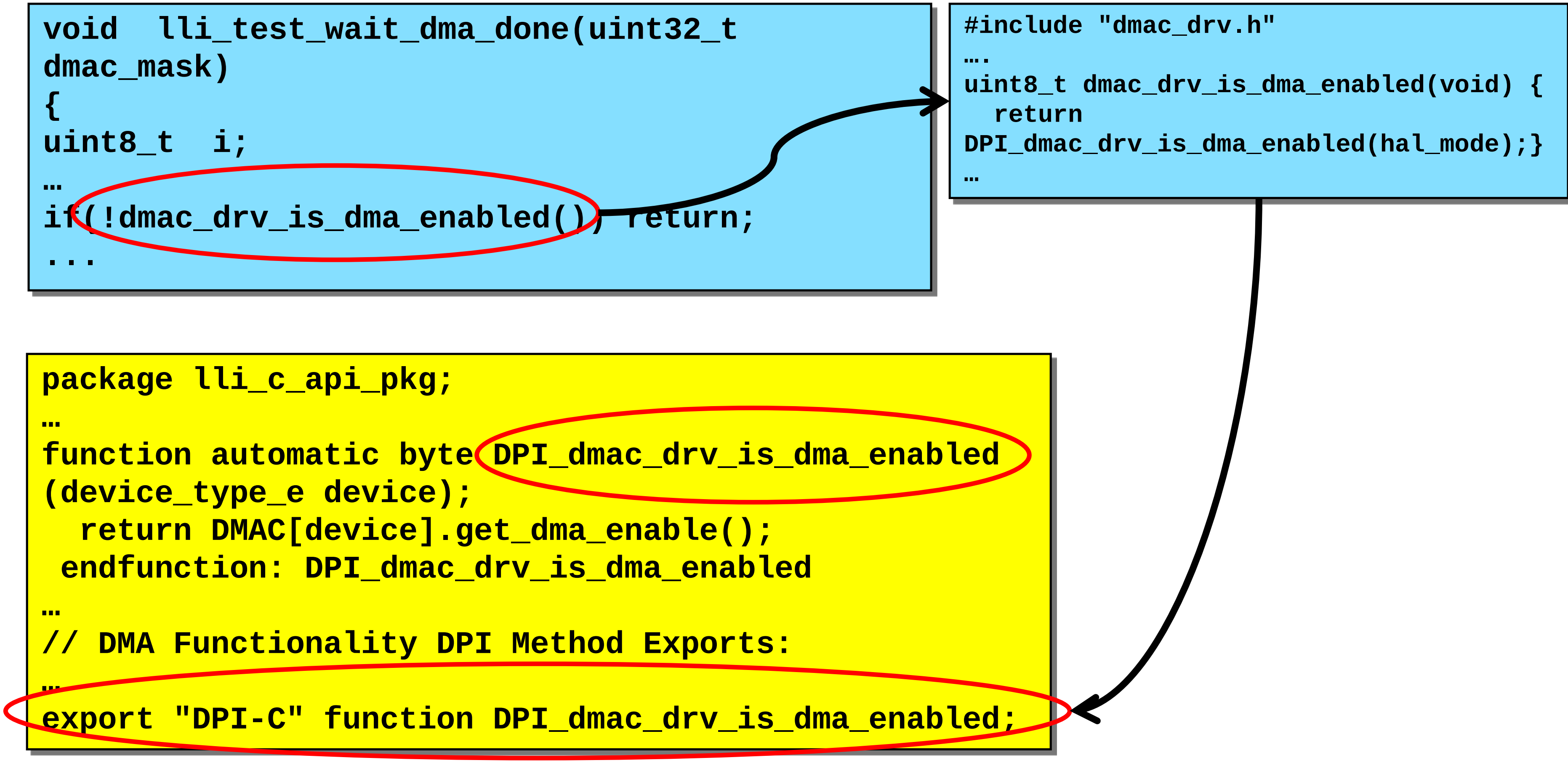
SystemC TLM layer

SC
transactor

HDL layer

SystemVerilog DPI Overview

- Allows C code to call SV tasks



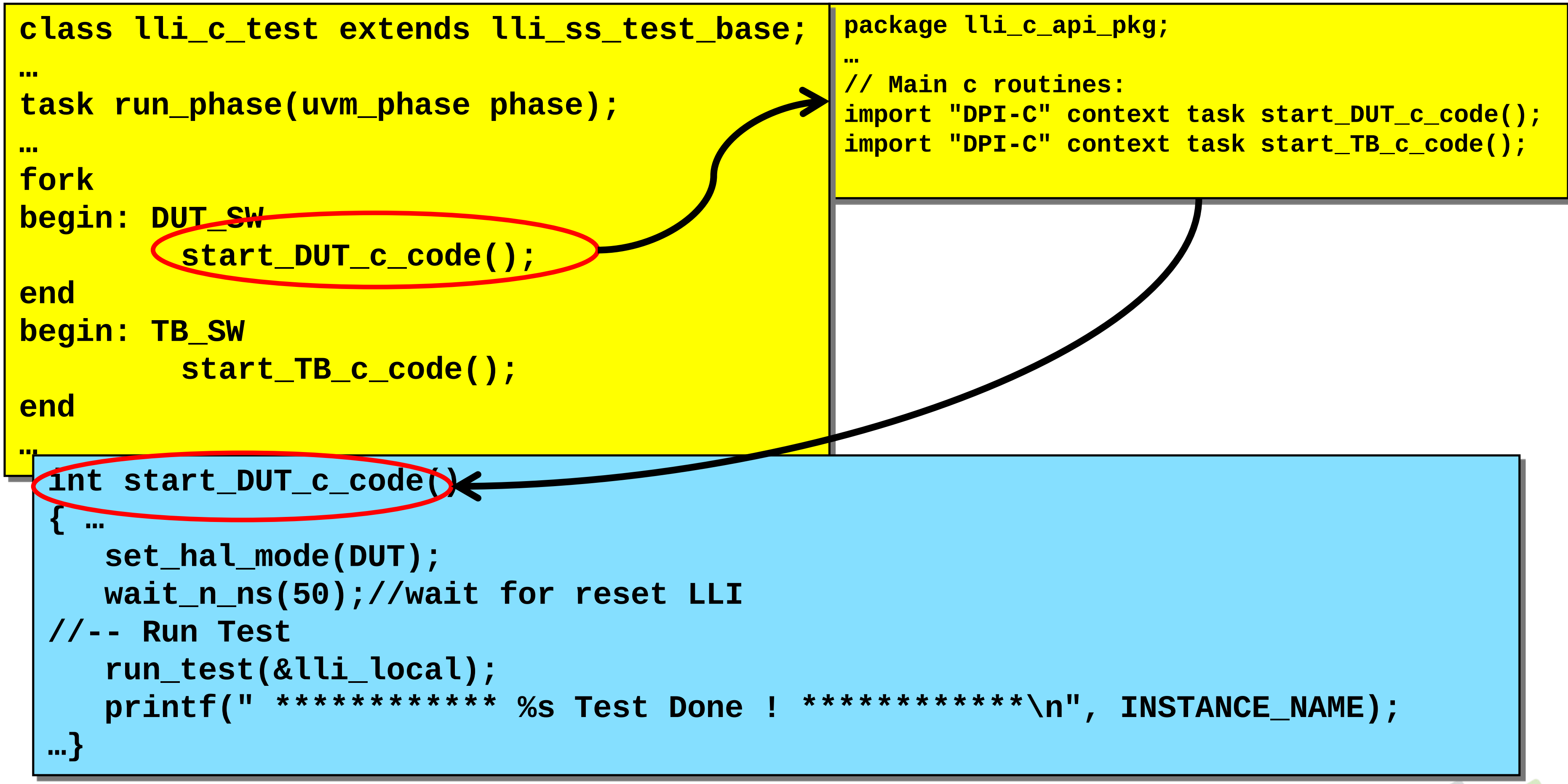
```
void  lli_test_wait_dma_done(uint32_t
dmac_mask)
{
uint8_t  i;
…
if(!dmac_drv_is_dma_enabled()) return;
...
```

```
#include "dmac_drv.h"
….
uint8_t dmac_drv_is_dma_enabled(void) {
  return
DPI_dmac_drv_is_dma_enabled(hal_mode);}
…
```

```
package lli_c_api_pkg;
…
function automatic byte DPI_dmac_drv_is_dma_enabled
(device_type_e device);
  return DMAC[device].get_dma_enable();
 endfunction: DPI_dmac_drv_is_dma_enabled
…
// DMA Functionality DPI Method Exports:
…
export "DPI-C" function DPI_dmac_drv_is_dma_enabled;
```

SystemVerilog DPI Overview

- Allows SV code to call C functions

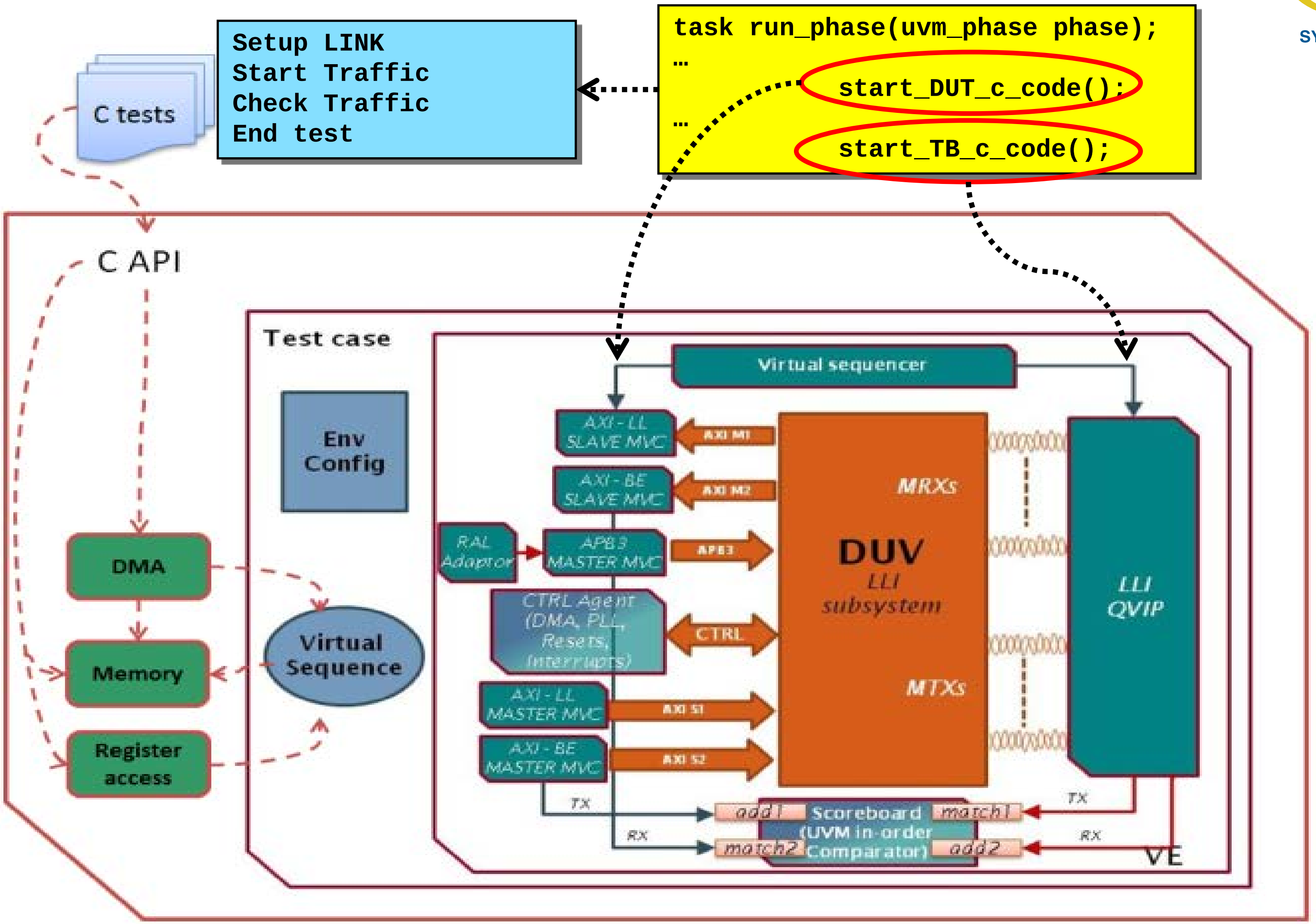


```
class lli_c_test extends lli_ss_test_base;
…
task run_phase(uvm_phase phase);
…
fork
begin: DUT_SW
         start_DUT_c_code();
end
begin: TB_SW
         start_TB_c_code();
end
…
```

```
package lli_c_api_pkg;
…
// Main c routines:
import "DPI-C" context task start_DUT_c_code();
import "DPI-C" context task start_TB_c_code();
```

```
int start_DUT_c_code()
{ …
   set_hal_mode(DUT);
   wait_n_ns(50);//wait for reset LLI
//-- Run Test
   run_test(&lli_local);
   printf(" ************ %s Test Done ! ************\n", INSTANCE_NAME);
…}
```

C Test Execution Example



```
Setup LINK
Start Traffic
Check Traffic
End test
```

```
task run_phase(uvm_phase phase);
…
        start_DUT_c_code();
…
        start_TB_c_code();
```

C Test Execution Example

C API calls on DUT side

- Setup Link
  - Configure DUT via APB3 VIP to R/W DUT registers
- Start traffic
  - Initiate LLI data traffic on LLI IF through DMA request via AXI3 VIPs sequences

C API calls on TB side

- Setup Link
  - Configure VIP via its configuration API
- Start Traffic
  - Initiatie LLI data traffic directly on VIP LLI IF via LLI VIP sequences

C API Implementation Details

- Setup Link implementation

```
task automatic DPI_HAL_READ32(input device_type_e device, input int address, output int
data);
…
// AXI Address range:
else if((address >= `LLI_LL_BASE_ADDRESS) && (address <= `LLI_LL_BASE_ADDRESS +
`LLI_MEM_RANGE))
          do_ll_be_read(device, LL, 32, address, data);
else if((address >= `LLI_BE_BASE_ADDRESS) && (address <= `LLI_BE_BASE_ADDRESS +
`LLI_MEM_RANGE))
          do_ll_be_read(device, BE, 32, address, data);
else//anything else is configuration access
begin
          if(device == DUT)
                    apb_read(device, address[15:0], data);
          else
          begin//TB configuration
          wait_n_us(10);
          if((address >= `LLI_SVC_BASE_ADDRESS) && (address <= (`LLI_SVC_BASE_ADDRESS +
`LLI_SVC_RANGE)))
          begin
…
                    lli_cfg.get_config_capability_space(address[15:0], data);
…
end
endtask: DPI_HAL_READ32
```

C API Implementation Details

- Start Traffic implementation

```
task automatic DPI_HAL_READ32(input device_type_e device, input int address, output int
data);
…
// AXI Address range:
else if((address >= `LLI_LL_BASE_ADDRESS) && (address <= `LLI_LL_BASE_ADDRESS +
`LLI_MEM_RANGE))
          do_ll_be_read(device, LL, 32, address, data);
else if((address >= `LLI_BE_BASE_ADDRESS) && (address <= `LLI_BE_BASE_ADDRESS +
`LLI_MEM_RANGE))
          do_ll_be_read(device, BE, 32, address, data);
else//anything else is configuration access
begin
          if(device == DUT)
                    apb_read(device, address[15:0], data);
          else
          begin//TB configuration
          wait_n_us(10);
          if((address >= `LLI_SVC_BASE_ADDRESS) && (address <= (`LLI_SVC_BASE_ADDRESS +
`LLI_SVC_RANGE)))
          begin
…
                    lli_cfg.get_config_capability_space(address[15:0], data);
…
end
endtask: DPI_HAL_READ32
```

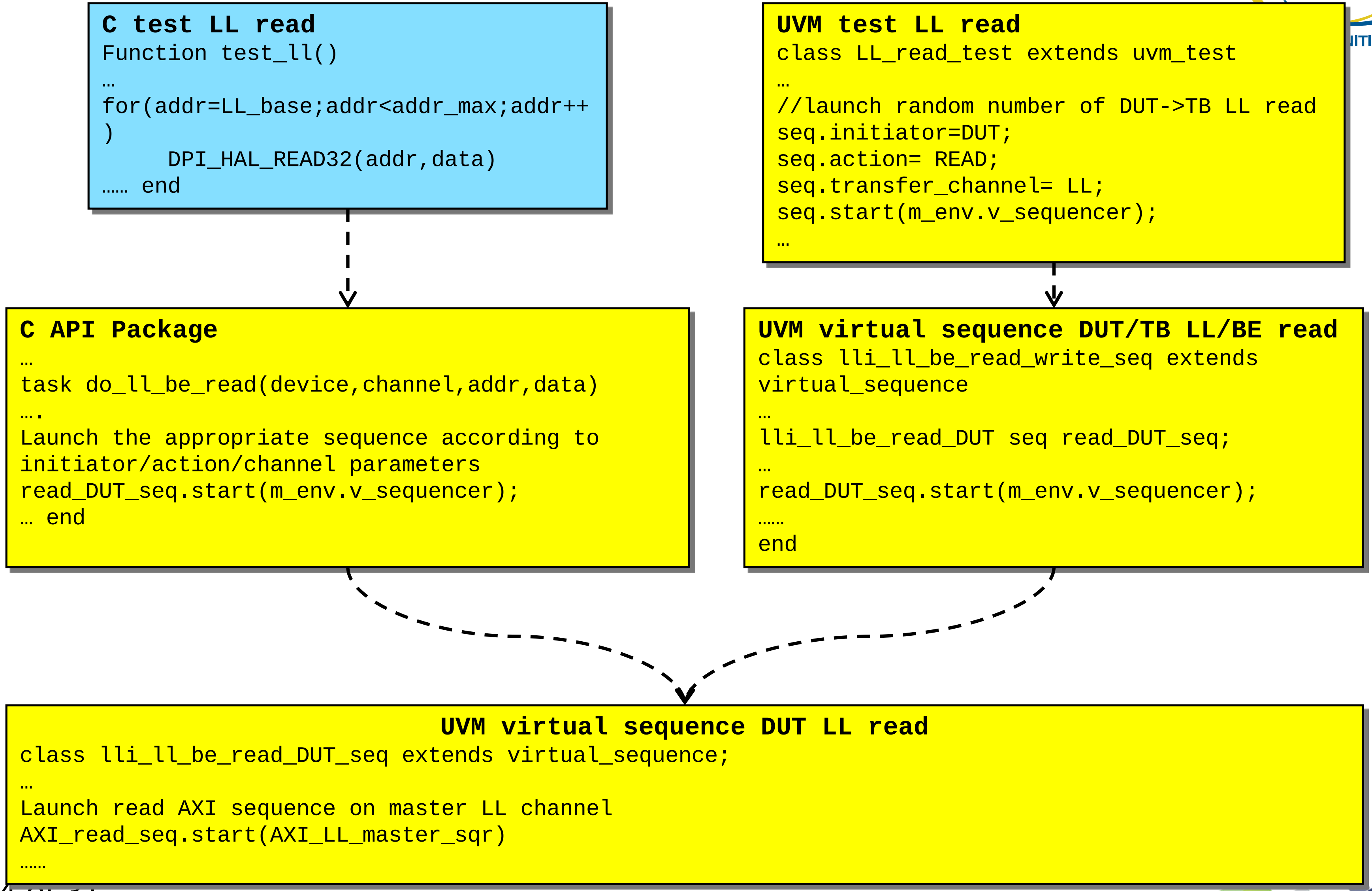
Learn More on C API details

- you can go visit https://verificationacademy.com/cookbook/CBasedStimulus
  - Tool-agnostic explanation/code example of C based stimulus testbench

Guaranteed Vertical Reuse

RESULTS & LESSON LEARNS

Reuse Across C/UVM Tests



C test LL read

```
Function test_ll()
…
for(addr=LL_base;addr<addr_max;addr++
)
     DPI_HAL_READ32(addr,data)
…… end
```

UVM test LL read

```
class LL_read_test extends uvm_test
…
//launch random number of DUT->TB LL read
seq.initiator=DUT;
seq.action= READ;
seq.transfer_channel= LL;
seq.start(m_env.v_sequencer);
…
```

C API Package

```
…
task do_ll_be_read(device,channel,addr,data)
….
Launch the appropriate sequence according to
initiator/action/channel parameters
read_DUT_seq.start(m_env.v_sequencer);
… end
```

UVM virtual sequence DUT/TB LL/BE read

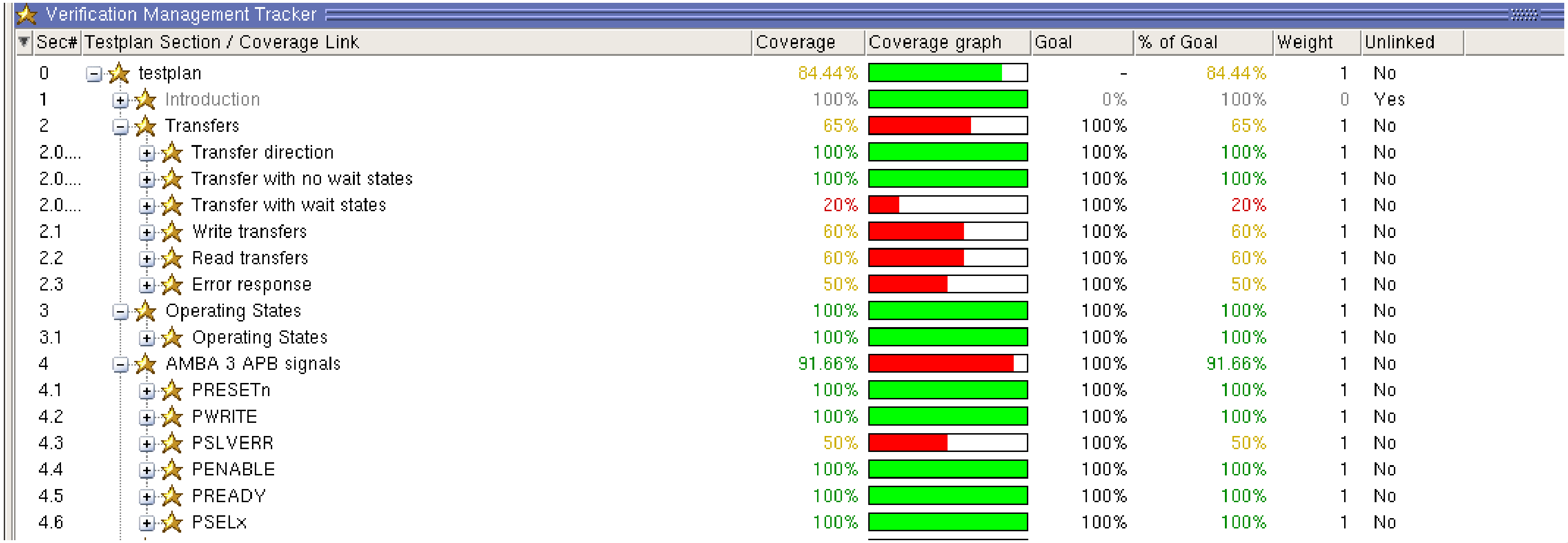
```
class lli_ll_be_read_write_seq extends
virtual_sequence
…
lli_ll_be_read_DUT seq read_DUT_seq;
…
read_DUT_seq.start(m_env.v_sequencer);
……
end
```

UVM virtual sequence DUT LL read

```
class lli_ll_be_read_DUT_seq extends virtual_sequence;
…
Launch read AXI sequence on master LL channel
AXI_read_seq.start(AXI_LL_master_sqr)
……
```

C Tests Functional Coverage

- Reuse existing C tests to reach coverage closure
  - Functional coverage gathered on C test run
- After C test coverage analysis, verifier may choose to
  - add C tests or SV ones to reach coverage goal
  - Remove C test if not contributing to coverage



Verification Management Tracker

Sec#	Testplan Section / Coverage Link	Coverage	Coverage graph	Goal	% of Goal	Weight	Unlinked
0	testplan	84.44%	🟩	-	84.44%	1	No
1	Introduction	100%	🟩	0%	100%	0	Yes
2	Transfers	65%	🟥	100%	65%	1	No
2.0....	Transfer direction	100%	🟩	100%	100%	1	No
2.0....	Transfer with no wait states	100%	🟩	100%	100%	1	No
2.0....	Transfer with wait states	20%	🟥	100%	20%	1	No
2.1	Write transfers	60%	🟥	100%	60%	1	No
2.2	Read transfers	60%	🟥	100%	60%	1	No
2.3	Error response	50%	🟥	100%	50%	1	No
3	Operating States	100%	🟩	100%	100%	1	No
3.1	Operating States	100%	🟩	100%	100%	1	No
4	AMBA 3 APB signals	91.66%	🟥	100%	91.66%	1	No
4.1	PRESETn	100%	🟩	100%	100%	1	No
4.2	PWRITE	100%	🟩	100%	100%	1	No
4.3	PSLVERR	50%	🟥	100%	50%	1	No
4.4	PENABLE	100%	🟩	100%	100%	1	No
4.5	PREADY	100%	🟩	100%	100%	1	No
4.6	PSELx	100%	🟩	100%	100%	1	No

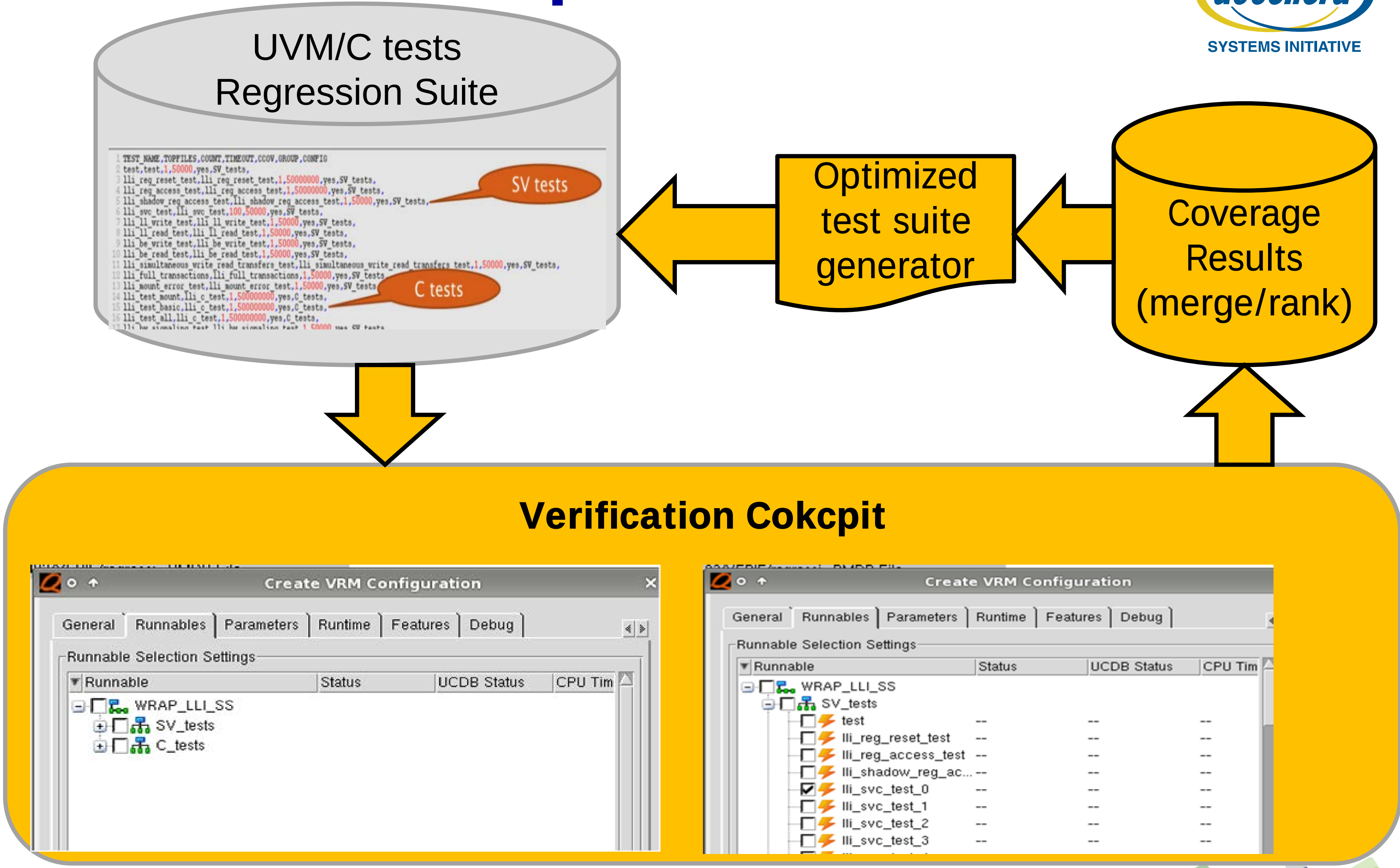
C Tests Verification Cycle & Debug

- C test use cases mainly used at the beginning of the verification cycle
  - Used as smoke tests prior running full regression and implement additional tests
  - Used as a mini regression test after smoke tests passed
- Useful in that verification window to have C debug available together with UVM debug
- C debug achieved with printf but also with C debugger running together with RTL simulator

Verification Cockpit

- Fully automated test/regression run flow
  - Automatically distinguish C test run and SV test run
    - Load SW shared object for both DUT and TB if C test
    - Add appropriate simulator options
  - Automatically collect/merge coverage
- Common SW framework across the company to maximize reuse
  - SW modules separated in groups
    - IPs modules, including IP, drivers, interfaces and tests
    - platform-specific drivers and their interfaces
    - Project-specific elements, including SoC test bench maps and global test runners

Verification Cockpit Overview



```
TEST_NAME,TOPFILES,COUNT,TIMEOUT,CCOV,GROUP,CONFIG
test,test,1,50000,yes,SV_tests,
lli_reg_reset_test,lli_reg_reset_test,1,50000000,yes,SV_tests,
lli_reg_access_test,lli_reg_access_test,1,50000000,yes,SV_tests,
lli_shadow_reg_access_test,lli_shadow_reg_access_test,1,50000,yes,SV_tests,
lli_svc_test,lli_svc_test,100,50000,yes,SV_tests,
lli_ll_write_test,lli_ll_write_test,1,50000,yes,SV_tests,
lli_ll_read_test,lli_ll_read_test,1,50000,yes,SV_tests,
lli_be_write_test,lli_be_write_test,1,50000,yes,SV_tests,
lli_be_read_test,lli_be_read_test,1,50000,yes,SV_tests,
lli_simultaneous_write_read_transfers_test,lli_simultaneous_write_read_transfers_test,1,50000,yes,SV_tests,
lli_full_transactions,lli_full_transactions,1,50000,yes,SV_tests,
lli_mount_error_test,lli_mount_error_test,1,50000,yes,SV_tests,
lli_test_mount,lli_c_test,1,500000000,yes,C_tests,
lli_test_basic,lli_c_test,1,500000000,yes,C_tests,
lli_test_all,lli_c_test,1,500000000,yes,C_tests,
lli_hw_signaling_test,lli_hw_signaling_test,1,50000,yes,SV_tests,
```

Create VRM Configuration

General | Runnables | Parameters | Runtime | Features | Debug

Runnable Selection Settings

Runnable	Status	UCDB Status	CPU Tim
⊟ □ WRAP_LLI_SS			
⊞ □ SV_tests			
⊞ □ C_tests			

Create VRM Configuration

General | Runnables | Parameters | Runtime | Features | Debug

Runnable Selection Settings

Runnable	Status	UCDB Status	CPU Tim
⊟ □ WRAP_LLI_SS			
⊟ □ SV_tests			
□ test	--	--	--
□ lli_reg_reset_test	--	--	--
□ lli_reg_access_test	--	--	--
□ lli_shadow_reg_ac...	--	--	--
☑ lli_svc_test_0	--	--	--
□ lli_svc_test_1	--	--	--
□ lli_svc_test_2	--	--	--
□ lli_svc_test_3	--	--	--

Vertical Reuse

- IP verification level
  - – 10 test cases written in C running the common IP Use Cases within our UVM environment
    - required for SoC integration and SW driver validation
  - – Remaining tests (~50) developed in SV/UVM for exhaustive verification
- SOC verification level
  - – C tests reused with almost no modification
- Software level
  - – LLI driver reused with minimal changes

Conclusion

Achievements

- **Full functional coverage reached with a mix of HW & SW tests**
- **1st LLI driver code developed prior full RTL availability**
  - Created a Mixed hardware/software approach
- **Horizontal but also vertical reuse becomes a reality thanks to this C API**
  - C API Package developed for reuse so we can use it for next projects

Improvements

- **For a full reuse of the C tests/drivers SOC and system developers ask for more**
  - Wait functions replaced with Interrupt routines
  - Reduced LLI driver code size
    - code size too big → didn't fit in the memory

Thank You !

QUESTIONS?

Overview:

This template contains

- Information on formatting your presentation for DVCon
- Information on how much time you have for presenting your paper
- Tips for including code examples and other information
- Providing copies of your presentation

Change this in the master slide to reflect the maximum number of slides in your presentation

DVCon
Presentation Format

- This template is a guideline for your paper presentation
  - You are not required to use this template
  - If you use your own template, please include the DVCon and Accellera logos on each page, as in this template
    - In the View menu, select Master→Slide Master
    - Select the DVCon logo in the top right, and copy it
    - Paste it into your slide master
- Your company logo may appear on the FIRST SLIDE (title slide) **ONLY**

Recommended Fonts

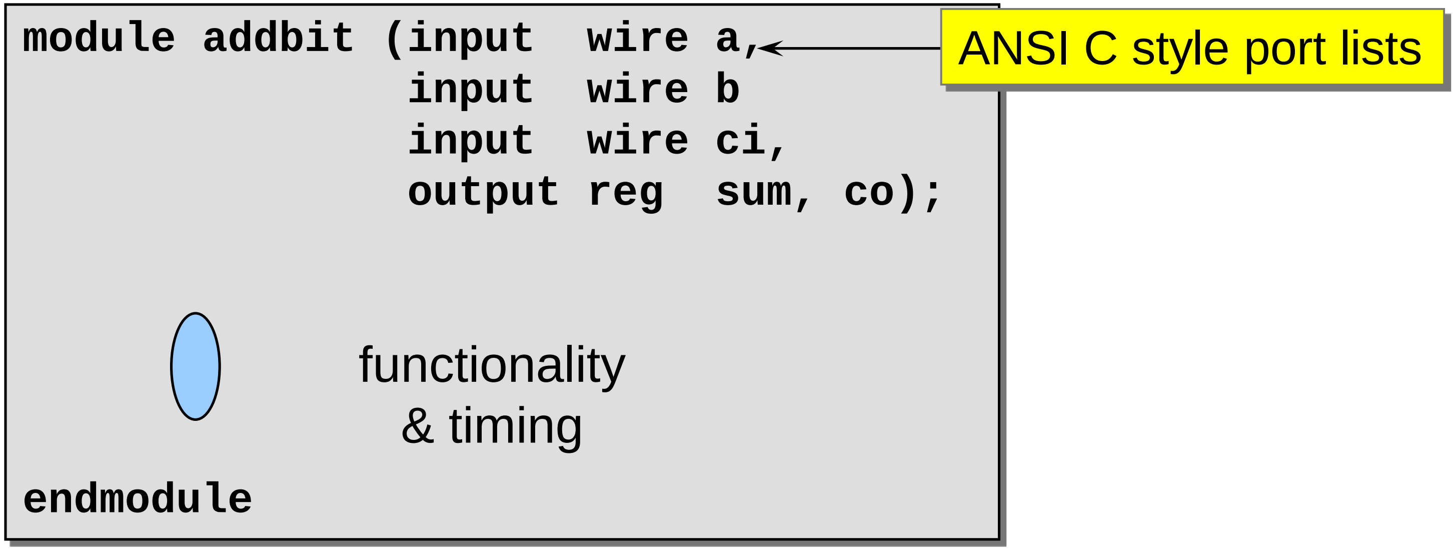
- Use a sans serif font, such as Tahoma, Arial or Helvetica
- Page titles should be in 32 point
- 1st level bullets should be 24 to 28 points
  - 2nd level bullets should also be 24 to 28 points
    - Third and fourth level bullets can use 20 to 24 points

DVCon Presentations

- You may use OpenOffice, LibreOffice, or PowerPoint to create/present your slide presentation. All three programs will be available to you at Conference.
  - An LCD projector will be provided
  - You can connect your own laptop to the projector, or...
  - A computer with OpenOffice, LibreOffice, and PowerPoint will be available
    - **Use a USB drive to load your presentation on to the laptop in your session room**. You are responsible for brining your final presentation with you to your session.

Adding Code and Notes to Your Presentation

- Code examples should use a 16 to 18 point mono spaced font, such a Courier
- You can add note boxes to enrich your presentation and call attention to important points
  - Use 16 to 18 point Arial or Helvetica font for notes



```
module addbit (input  wire a,
               input  wire b
               input  wire ci,
               output reg  sum, co);
```

ANSI C style port lists

functionality
& timing

```
endmodule
```

Paper Presentation Time

- You will have a total of 30 minutes to...
  - Set up and start your presentation
  - Present your paper
  - Answer Questions

No Exceptions!

- We recommend:
  - Arrive early to load and test your presentation before the session begins
  - Allow 20 minutes to present your paper
  - Allow 10 minutes for getting started and then for questions at the end

Additional Tips

Add some clip art to keep your audience's attention (but don't over do it)

- Keep each slide brief
  - Use short phrases, not complete sentences
  - Too many words forces the audience to choose between reading and listening to you
- Limit yourself to just a few bullets per slide
  - Too much information on a slide is distracting
  - Use two or three slides to explain complex ideas
- Use presentation software “builds” to bring up information a little at a time

Hard Copies of Your Presentation Materials

- Your full paper is included in the DVCon Proceedings
- Your presentation slides are *not* included in the Proceedings, but will be in the DVCon archives
  - If you want the audience to have copies of your presentation slides, you can...
    - Provide copies that can be picked up after the session
      - Bring 50 to 75 copies
    - Provide a web site location where copies can be downloaded
  - Tutorial presentations are included with the conference materials
    - Tutorial presenters do not need to provide additional copies

Expert Presentation Tips for New and Advanced Presenters

(with a review of *ALL* of the basics!)

Practice!

- Practice your presentation
- Practice your opening

Starting the Presentation

- 1st - talk slow!
- Nervous speakers have a tendency to speak too fast
- When you first stand up to speak …
- Work the first two slides for a killer introduction
  - Who are you?
  - What are you going to present?
  - What will the audience learn?

Be Confident

- Be Confident
- Don't make apologies!
- Don't share inadequacies!
- Questions during the presentation -
  - Ask audience to hold questions by saying,"Let me hold all questions until the end of the presentation."
  - If the questioner persists, the moderator should step in!

Experienced Presenters

- Where to stand?
  - Podium - if you want
  - To the left of the presentation screen

DON'T STAND BETWEEN THE SCREEN AND THE AUDIENCE!!

DON'T TURN YOUR BACK ON THE AUDIENCE!!

- Where possible, stand to the left of the presentation
  - People are used to reading from left-to-right
  - People will focus from you (the speaker) to the presentation

Setting Up To Present

- Clear your walking area
  - Approaching the screen

Every screen has at least one leg designed to trip the presenter!

- Portable microphone
  - Place it high on the collar
  - Do not place it on a side-collar
  - Do not place it too low
    - Moving your head from side-to-side should not be the volume control
    - The volume will have to be turned u and feedback is inevitable

Under the chin – 2nd button on a shirt

The Conference Support Group

- You should think of the conference attendees as a big support group
- The conference attendees aren't looking to catch mistakes
  - The attendees want to learn from your presentation

Sponsored By:

Learn From Your Audience

- We give as much as we know
  - and then we learn from the audience what we didn't know
- NO MARKETING!!
  - Let the introduction market you
  - Then give a killer technical presentation - that will attract people

Laser Pointers & Use Humor

- Laser pointers
  - Avoid them or learn to control them
  - Do not point them at your audience

- Use Humor!

**If you are having fun ...
your audience is having fun!**

Hands-On Presentation

- People follow your hands - don't be afraid to use them
  - Hands by your side - one of the best resting positions

**It feel awkward
but looks normal**

  - Crossing arms? No!
  - Giving a prayer? No!

- Silence is better than "uh" and "um"
  - Silence gives your audience a chance to think
  - It also gives you a chance to think

Thinking is good!

Common Presentation Mistakes

- Speak to the audience

... not to the screen!

- Walking back and forth in front of the audience

You will be blocking the view for some audience members

- Too many slides
  - the presentation is going long – audience loses interest
- Identify slides you can skip

Type in the new slide number and press `<enter>`

Also, keep extra slide page numbers handy

Summarizing and Sharing

- Abbreviate and repeat the significant points
  - Don't summarize the topics
  - Summarize the guidelines

What should the audience take away from your presentation?

- Repeat questions before answering

Moderators should help remind the presenter to repeat the question

Summary of Important Guidelines

- Before presenting, watch those fluids!
- Speak slow!
- Stand to the left and out of the way
- Give a killer introduction
- <u>NO MARKETING</u>
- If you must use a laser pointer, control it!
- If you run long, be prepared to skip slides
- Summarize important guidelines!
- Repeat all audience questions before answering them