

# Compact Model Council Overview

December 7, 2011

Keith Green (TI), CMC Chair-elect

Josef Watts (IBM), CMC Chair

# Outline

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- **Members, Purpose, Charter, Vision, Strategy**
- CMC Standards History and Works In Progress
- Standardization Process
- Membership Benefits

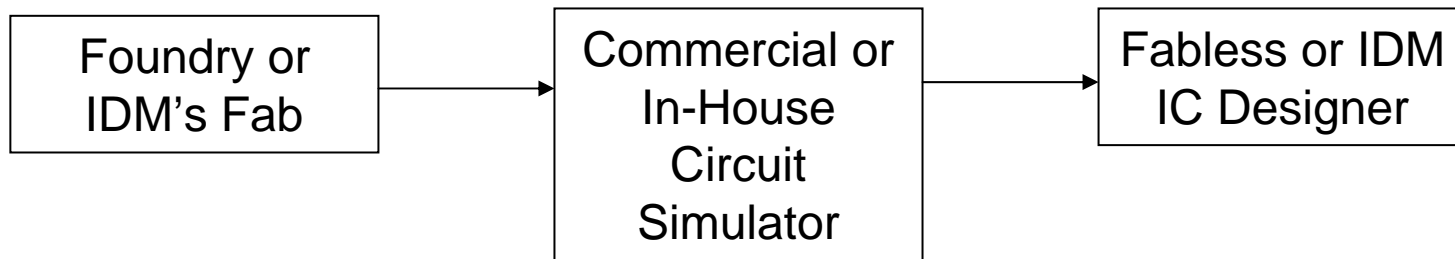
# CMC Members

EDA Vendors, Foundries, IDMs, Fabless, Research Institutions/Consortia

<b>Accelicon</b>	<b>Cypress Semiconductor</b>	<b>Mentor Graphics</b>	<b>STARC</b>
<b>Agilent Technologies</b>	<b>Elpida Memory</b>	<b>ProPlus Design Solutions</b>	<b>ST Microelectronics</b>
<b>AIST</b>	<b>Fujitsu Semiconductor</b>	<b>Qualcomm</b>	<b>Synopsys, Inc.</b>
<b>Analog Devices</b>	<b>GLOBALFOUNDRIES</b>	<b>Renesas Electronics</b>	<b>Texas Instruments Inc.</b>
<b>Ansoft</b>	<b>IBM</b>	<b>Ricoh</b>	<b>Toshiba Corp.</b>
<b>Austria Microsystems</b>	<b>Infineon Technologies</b>	<b>Rohm</b>	<b>Toyota</b>
<b>AWR</b>	<b>Intel</b>	<b>Samsung</b>	<b>TSMC</b>
<b>Broadcom</b>	<b>LEAP</b>	<b>Silvaco</b>	<b>United Microelectronics</b>
<b>Cadence</b>	<b>LSI Corporation</b>	<b>Soitec</b>	
<b>Denso</b>	<b>Magma</b>	<b>Sony</b>	

# History and Purpose

- The CMC was formed in 1996 as a collaboration of foundries, fabless companies, IDMs, and EDA vendors



- Compact models provide the connections.
- Standard compact models enable efficiencies in this process.

# 16 Years Ago in Washington, D.C....

MEETING NAME: Compact Models Workshop [SEMATECH]

MEETING DATE: **December 15, 1995**

LOCATION: Washington Hilton Hotel, **Washington, D.C.**

PURPOSE: Follow-up on standard compact model and interface proposals and test criteria.  
Review test results on BSIM3 and MOS Model 9 and **work on Compact Model Council charter and procedures** for funding and implementation of new models and interfaces.

## EXPECTED RESULTS:

- 1) Review test results of candidate compact models and reach consensus and vote on "draft standard model".
- 2) Develop pathway for type1 and type2 standard interface requirements.
- 3) **Develop framework and charter for the "Compact Model Council"**

# 16 Years Ago in Washington, D.C....

## AGENDA:

7:30 am Registration and Continental Breakfast

8:00 Welcome and Introduction

Reddy Manukonda, SEMATECH

8:15 Standard Models

Britt Brooks, TI

Bhaskar Gadepally, Motorola

Review of MOS9/BSIM3 test results

Note: No enhancements will be presented.

8:30 BSIM3/MOS9 test results

Anacad, Cadence, National,  
Philips, Analog Devices, TI

10:00 Break

10:30 Discussion of test results.

Reddy Manukonda

Reach a consensus for which model we should choose and promote as a "draft standard MOS model. Prepare for voting after lunch

12:00 pm Lunch

# 16 Years Ago in Washington, D.C....

1:00 Voting on "draft standard model"

1:30 API kit evaluations progress

2:00 **Define a "Compact Model Council"**

Asim Husain

Ralph Sokel, Motorola

John Ellis-Monaghan, IBM

Keith Green, TI

Ron Goossens, National

Topics for discussion will include:

- 1) Framework for the "Compact Model Council"
  - a) Membership
  - b) Function
    - i) Revision control (process)
    - ii) Updates, bug fixes, new releases (process)
    - iii) New model submission (process)
    - iv) Standards organization to help promote MOS model
    - v) Funding of the "sustaining" of the model
  - c) How often will the Council meet?
  - d) How will decisions be made?
- 2) Develop a charter for the Council
  - a) Document resolution of issues listed above
  - b) Document the goals/deliverables of the Council
  - c) Determine the "next step" for the Council
- 3) Develop an action item list based on the discussions.

3:00 Break

3:15 Discussion/actions

4:00 Adjourn

Asim Husain

In 1996 the CMC was formed as a committee of the Electronics Information Group and eventually TechAmerica.

# CMC Charter

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To promote the international, nonexclusive standardization of compact model formulations and the model interfaces.

# CMC Vision

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- Standardized compact models for all major technologies so that customer communication and efficiency can be enhanced.
- Standard interfaces so that models can be tested faster and implemented easier.
- Better compact models for the latest technologies, allowing leading edge design development cycles to shorten.

# CMC Strategy

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- Examine, promote and standardize compact modeling efforts based upon business needs.
- Encourage developers to dwell on current and near-term problems that will advance compact modeling.
- Provide industry resources for monitoring/mentoring compact model development.
- Provide a standardization process to the compact model developers.

# Outline

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- Members, Purpose, Charter, Vision, Strategy
- **CMC Standards History and Works In Progress**
- Standardization Process
- Membership Benefits

# Introductions of CMC Model Standards

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- 1996 BSIM3                      CMOS analog/digital design, 0.25um

# Introductions of CMC Model Standards

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- 1996 BSIM3
- 2000 BSIM4                      Short-channel MOSFETs,  $<0.25\mu\text{m}$

# Introductions of CMC Model Standards

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- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI      SOI MOSFETs

# Introductions of CMC Model Standards

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- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI
- 2004 MEXTRAM      BJT's, include SiGe HBT for RF
- 2004 HICUM

# Introductions of CMC Model Standards

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- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI
- 2004 MEXTRAM
- 2004 HICUM
- 2005 R2\_CMC                      Poly & Metal resistors (2 terminal)

# Introductions of CMC Model Standards

- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI
- 2004 MEXTRAM
- 2004 HICUM
- 2005 R2\_CMC
- 2006 PSP

MOSFET model for analog/RF  
especially operating thru  $V_{ds}=0V$

# Introductions of CMC Model Standards

- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI
- 2004 MEXTRAM
- 2004 HICUM
- 2005 R2\_CMC
- 2006 PSP
- 2007 HiSIM\_HV High-Voltage MOSFET such as LDMOS

# Introductions of CMC Model Standards

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- 2004 HICUM
- 2005 R2\_CMC
- 2006 PSP
- 2007 HiSIM\_HV
- 2007 R3\_CMC

Defused Resistor  
(3 terminal)

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- 2004 HICUM
- 2005 R2\_CMC
- 2006 PSP
- 2007 HiSIM\_HV
- 2007 R3\_CMC
- **2008 MOSVAR**                      **MOS Varactor**

# Introductions of CMC Model Standards

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- 2004 MEXTRAM
- 2004 HICUM
- 2005 R2\_CMC
- 2006 PSP
- 2007 HiSIM\_HV
- 2007 R3\_CMC
- 2008 MOSVAR
- 2009 Diode\_CMC      Advanced diode model

# Introductions of CMC Model Standards

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- 2005 R2\_CMC
- 2006 PSP
- 2007 HiSIM\_HV
- 2007 R3\_CMC
- 2008 MOSVAR
- 2009 Diode\_CMC
- 2011 HiSIM2

Additional surface-potential based MOSFET model.

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- 2005 R2\_CMC
- 2006 PSP
- 2007 HiSIM\_HV
- 2007 R3\_CMC
- 2008 MOSVAR
- 2009 Diode\_CMC
- 2011 HiSIM2
- 2012+
  - BSIM6 MOSFET Model
  - BSIM-CMG Multi-Gate MOSFET Model
  - HiSIM-SOI Dynamic-Depletion SOI MOSFET Model
  - ETSOI MOSFET Model

# Active Standards and Subcommittees

## Models

BSIM Bulk MOSFET Models

HiSIM\_HV LDMOS Model

HiSIM2 MOSFET Model

MEXTRAM BJT Model

HiCUM BJT Model

Partially- and Dynamically-Depleted SOI MOSFET Models

Multi-Gate and Extremely-Thin SOI MOSFET Models

Diode Model

GaN HEMT Model

## Interfaces

TMI2 Model Interface

Standard SPICE Language

Reliability (Aging) Simulation

Layout Effect Language

## Operations

Model QA and Release

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# Project Management

- Existing standards projects are reviewed at quarterly Council meetings.
- Subcommittees meet at Council meetings and teleconference between them.
- Ideas for new standards are considered annually:
  - 50% majority need to approve exploration of a new standard.
  - Volunteers from at least four member companies, including a subcommittee chair, are needed.
  - Dues increase may be needed if new standard requires University support.

# CMC Standardization Process at a Glance

## Considerations:

- Is there a need for a (new) standard model?
- Is there potential financial support for a standard model?
- Do models of sufficient quality exist?

## Approaches:

- Standardize existing models, e.g., BSIM4
- Create standards by committee of volunteers, e.g., R3\_CMC, Proximity effect instance parameters

## Operations:

- Competitive selection
- Rigorous testing
- Version Control
- Continuous improvement
- CMC funding for university support

# Four-Phase Standardization Process for an Existing Model

Phase	Description	Typical Duration
I	Define model requirements. Search and review available models	6 months
II	Developer(s) and CMC sponsor(s) fit to common data and report on ability of model(s) to meet requirements.	6 months
III	Additional CMC members test models, using model cards from Phase II and/or own data	6 months
IV	Models readied for release	3 months

Well-defined procedures and criteria are employed to decide when and if a candidate model advances from phase to phase.

# Phase 1 – Requirements

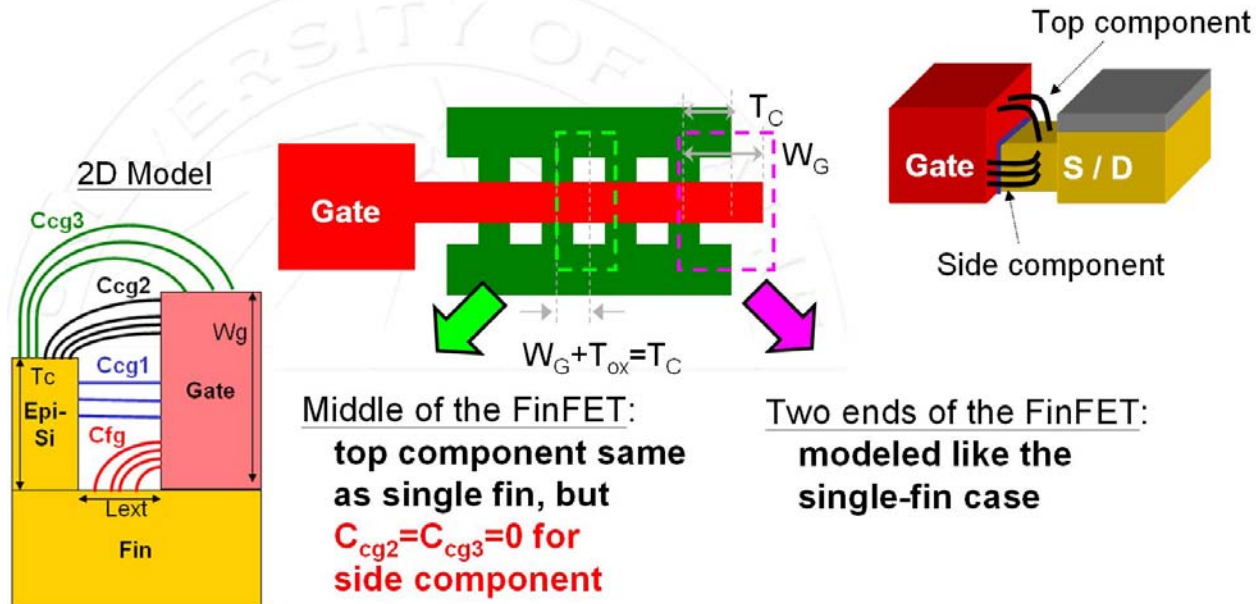
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- Device Structure Definition
- Physical Model Requirements
- Functional Model Requirements
- Supplemental Model Requirements
- Model Acceptance Criteria
- Model Support and Maintenance Requirements

# Phase I – Search and Review of Available Models

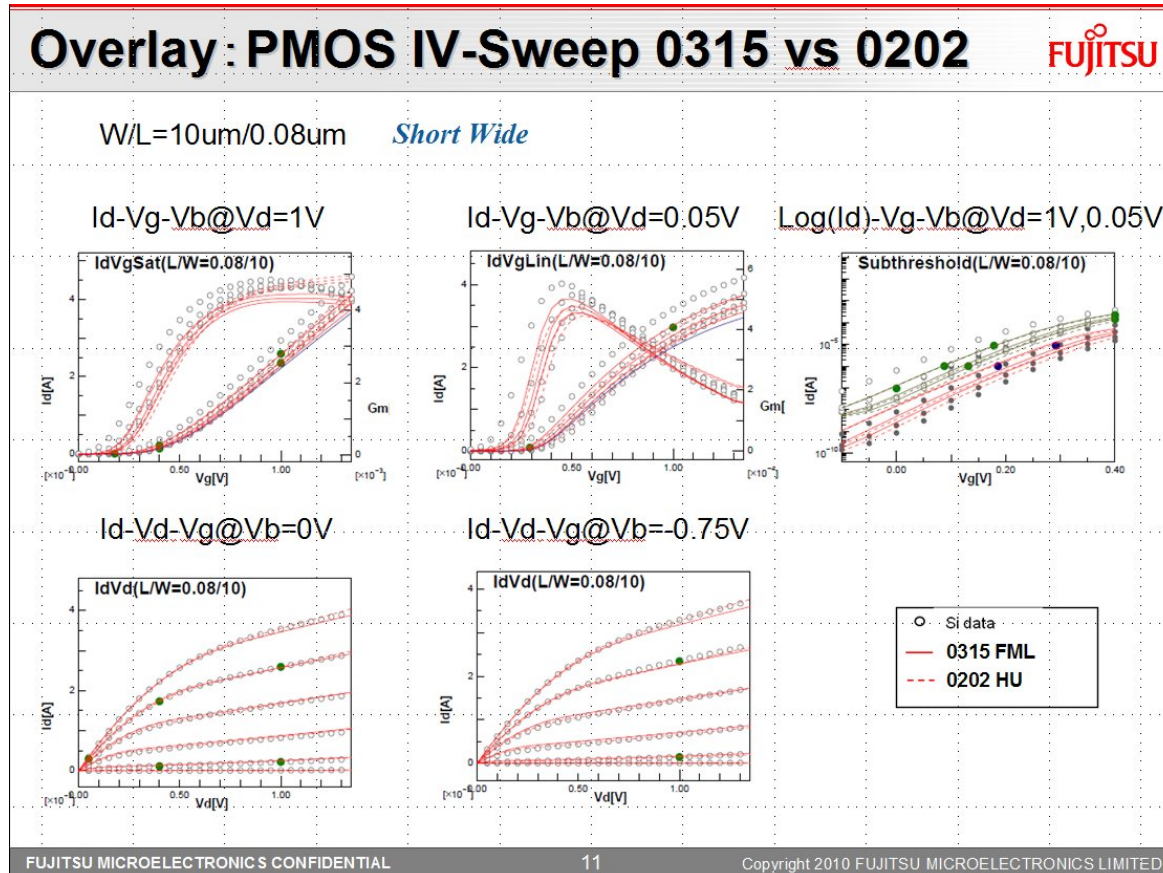
- Model must appear able to meet all requirements within a reasonable time
  - Including support and IP requirements
- Model must attract at least one CMC member as a sponsor

## Extending to the Multi-fin case



# Phase II

- Developer and sponsor fit data and complete physicality tests
- Model must fit the data adequately
- Model must pass physicality tests
- Phase II produces “Frozen code & Model cards”



# Phase III

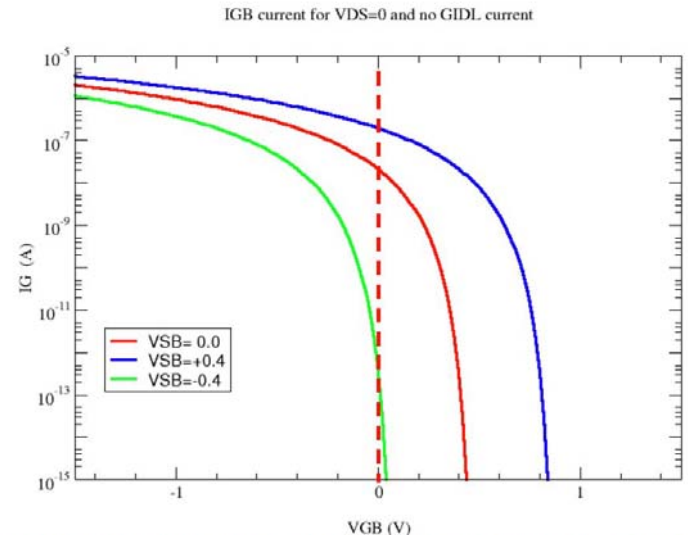
- CMC members test models, using model cards from Phase II and/or own data
- Model must be judged by CMC members to be significant improvement over what is publically available
- Ideally one but sometimes two models
- Models passing Phase III will eventually be CMC standards

## PSP runtime

Comparison of Global CPU time: Bsim4.5, PSP 102.1/Juncap, PSP102.1/Juncap express							
Circuit	Number of transistors	BSIM4.5		PSP 102.1 JUNCAP		PSP 102.1 JUNCAP Express	
		CPU Time (s)	Ratio	CPU time	Ratio	CPU time	Ratio
Comprt	17	3.88	1	6.37	1.641732577	5.04	1.298969072
Fact32	288	4.4	1	6.67	1.515909091	4.7	1.068181818
Irv	10	4.46	1	7.05	1.580717489	5.51	1.235426009
Nand1	44	2.44	1	2.82	1.155737705	2.29	0.93852459
Nand3	132	6.06	1	5.94	0.98019802	5.16	0.851485149
Nor1	44	2.6	1	2.93	1.126923077	2.19	0.842307692
Nor3	132	20.87	1	18.58	0.890273119	15.18	0.727359647
Ring3	66	2.82	1	3.05	1.081560284	2.44	0.865248227
Ring_rc	42	10.31	1	10.18	0.987390883	8.46	0.820562561
Ro19	38	5.65	1	7.98	1.412389381	6.47	1.145132743
Sram	1008	301.02	1	366.42	1.217261312	290.71	0.965749784
Ring	36	12.25	1	15.45	1.26122449	11.19	0.913469388
Average			1		1.237611452		0.972701407

Convention: Green <1.1< Orange <1.3< Red

$I_{gs}=0$   
 $I_{gd}=0$   
 $I_{gate,s}=0$   
 $I_{gate,d}=0$   
 only  $I_{gb}$



should be zero for  $V_{GB}=V_{SB}=0$ ; should only depend on  $V_{GB}$ , not  $V_{SB}$

# Phase IV

- Models readied for release
- Fix problems found in phase II & III
- Model must fully meet requirements
- 2/3 yes vote
- Negative comments resolved (Resolved means)
  - explained to the satisfaction of the commenter
  - Or Fixed
  - Or Set aside by the chairman
- If “substantial” fixing is require a new ballot will be required

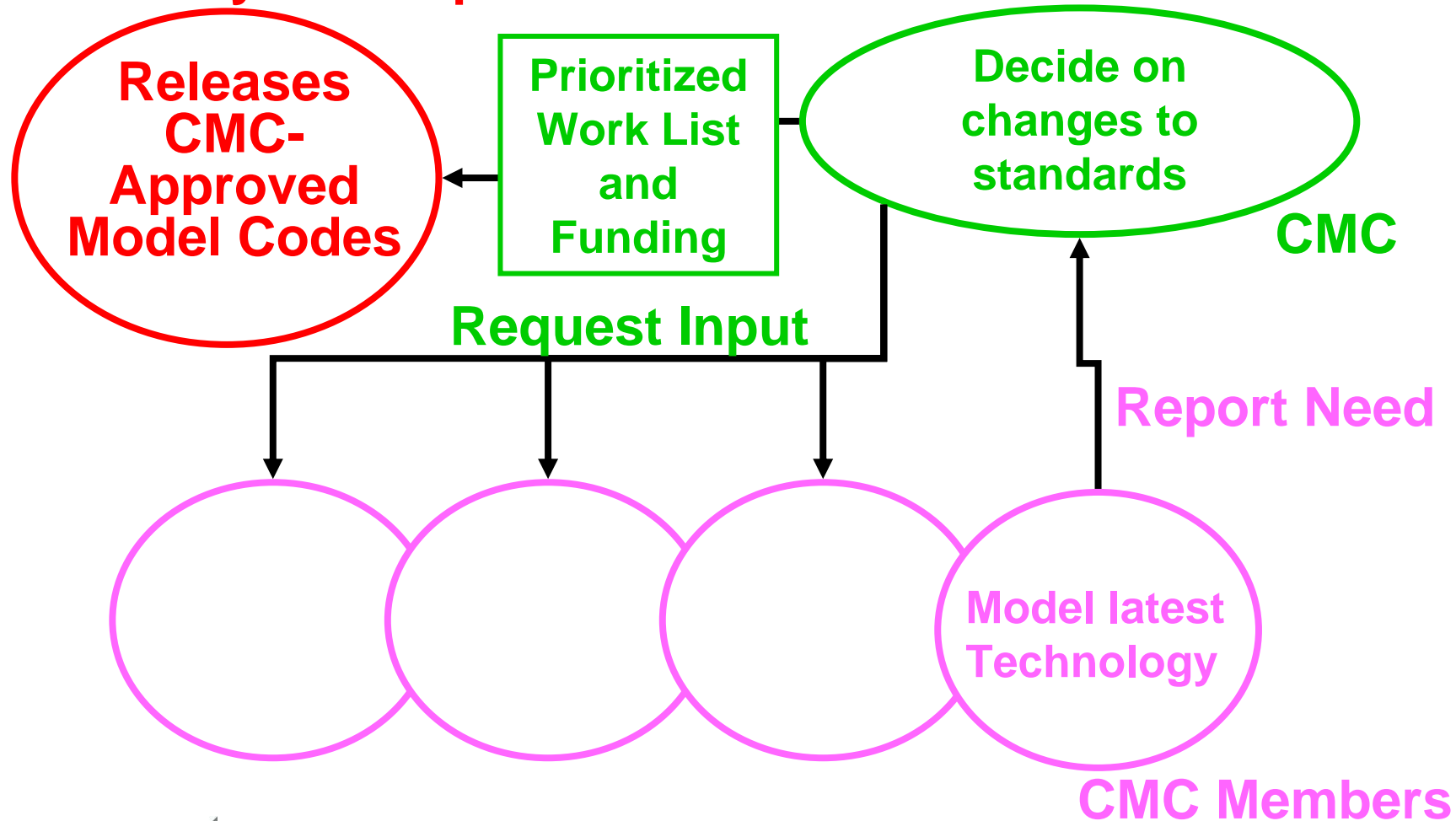
# CMC Models Do Not Remain Static

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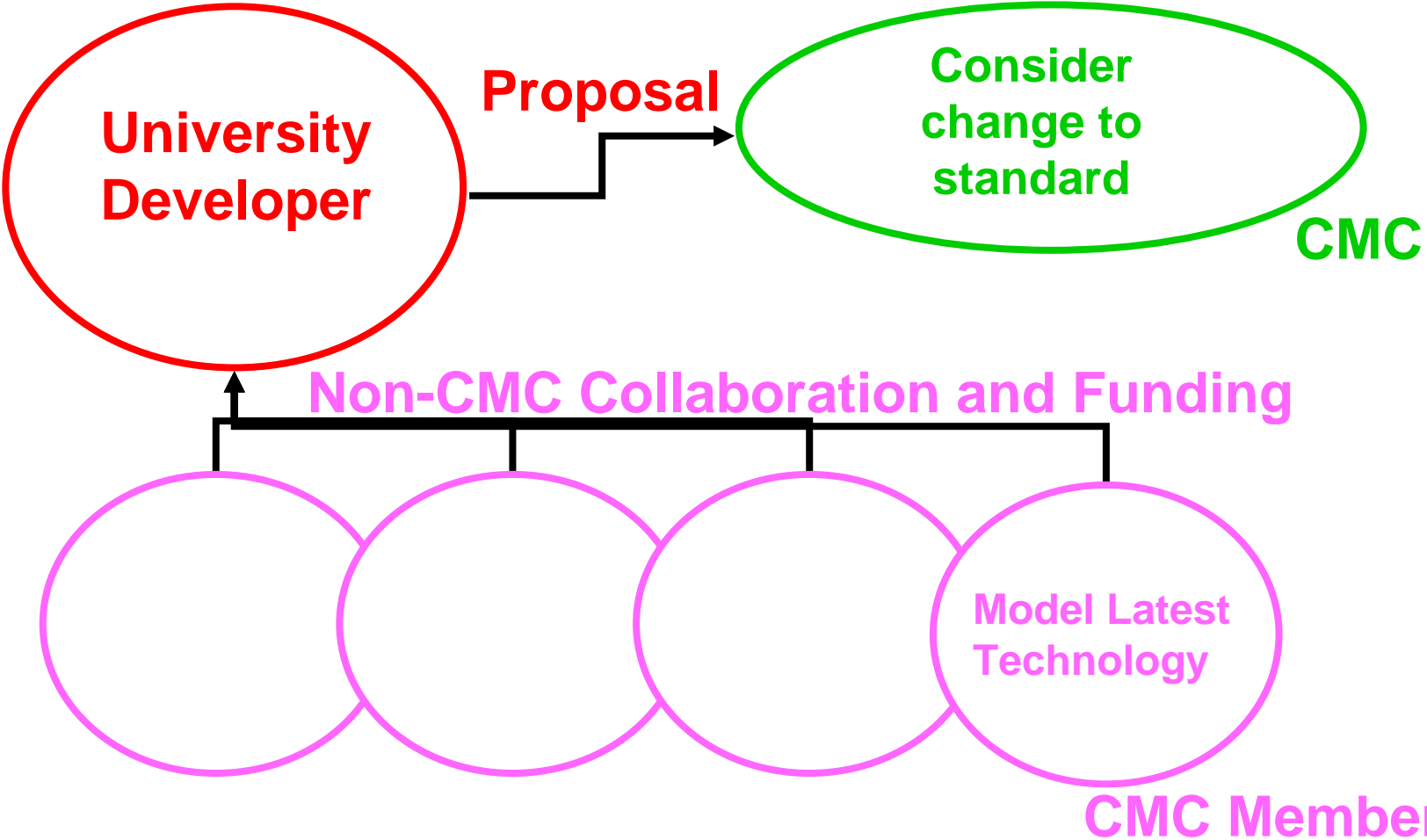
- Most enhancements are requested by members but they can also come from the developer
- CMC decides which enhancements they want to pursue
- CMC members test enhancements before they are released as a standard

# Improvement of Standards is a Collaborative Effort

## University Developer



# University May Become a Focus Center For Additional R&D



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# Member Benefits

- Influence selection and enhancements of standards
- Regular interactions with modeling experts from other companies and universities.
- Full access to CMC website: [www.geia.org/CMC---Council](http://www.geia.org/CMC---Council)
  - Most information produced since 2007 is only available to members.
    - ✓ Quarterly meeting minutes and presentations
    - ✓ Subcommittee activity reports
    - ✓ Some standard model codes
- University-supported standard model codes are available to members and non-members.

The developer grants users a perpetual, irrevocable, worldwide, non-exclusive, royalty-free license with respect to the software. Users are granted the right to modify, copy and redistribute the software and documentation.

# Membership Dues

- Annual renewal
- Majority of revenue goes towards improving standards
- Example Invoice:

## 2011 CMC Participation Fees

Select the models you wish to participate in and have voting rights.

**Regular Member** - \$13,000  
(base fee & one model)

**Additional Models** - \$4,000 each  
(may add up to 2 models)

**Global Member** - \$25,000  
(participates in all models but may designate 0-7 models for determining fund allocation)

BSIM4	_____	_____	\$4,000	_____
BSIMSOI	_____	_____	\$4,000	_____
PSP	_____	_____	\$4,000	_____
HICUM	_____	_____	\$4,000	_____
MEXTRAM	_____	_____	\$4,000	_____
HiSIM_HV	_____	_____	\$4,000	_____
HiSIM2	_____	_____	\$4,000	_____

# Summary

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- The CMC enhances the IC development process
  - Standardizing high-quality device models and simulator interfaces
  - Providing a forum and mechanism to keep these standards current to industry needs
  
- The CMC is a member-driven organization open to any company in the semiconductor business