Compact Model Council Overview

December 7, 2011

Keith Green (TI), CMC Chair-elect
Josef Watts (IBM), CMC Chair

Outline

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

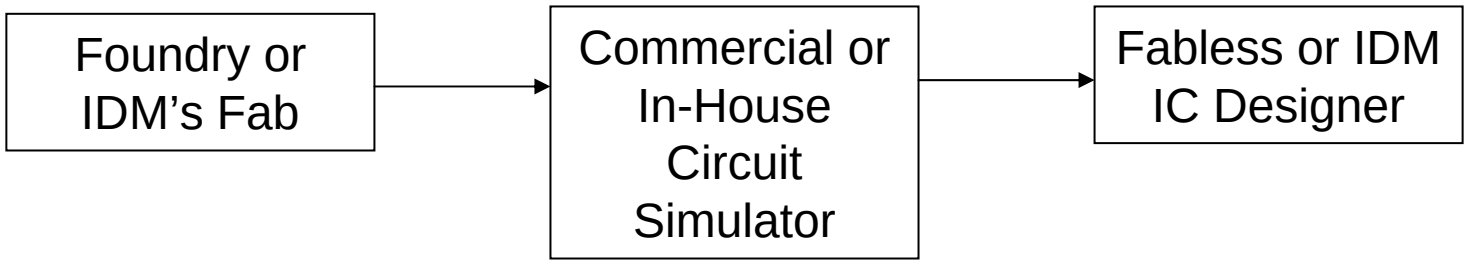
CMC Members

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

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

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"	Asim Husain
1:30	API kit evaluations progress	Ralph Sokel, Motorola John Ellis-Monaghan, IBM
2:00	**Define a "Compact Model Council"**	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.

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

3:00	Break	
3:15	Discussion/actions	Asim Husain
4:00	Adjourn	

Compact Model Council

TechAmerica
WHERE THE FUTURE BEGINS

CMC Charter

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

CMC Vision

- 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

- 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

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

Introductions of CMC Model Standards

- 1996 BSIM3 CMOS analog/digital design, 0.25um

Introductions of CMC Model Standards

- 1996 BSIM3
- 2000 BSIM4 Short-channel MOSFETs, <0.25um

Introductions of CMC Model Standards

- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI SOI MOSFETs

Introductions of CMC Model Standards

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

Introductions of CMC Model Standards

- 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 Vds=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

- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI
- 2004 MEXTRAM
- 2004 HICUM
- 2005 R2_CMC
- 2006 PSP
- 2007 HiSIM_HV
- 2007 R3_CMC — Defused Resistor (3 terminal)

Introductions of CMC Model Standards

- 1996 BSIM3
- 2000 BSIM4
- 2002 BSIMSOI
- 2004 MEXTRAM
- 2004 HICUM
- 2005 R2_CMC
- 2006 PSP
- 2007 HiSIM_HV
- 2007 R3_CMC
- 2008 MOSVAR MOS Varactor

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- 2006 PSP
- 2007 HiSIM_HV
- 2007 R3_CMC
- 2008 MOSVAR
- 2009 Diode_CMC Advanced diode model

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- 2007 HiSIM_HV
- 2007 R3_CMC
- 2008 MOSVAR
- 2009 Diode_CMC
- 2011 HiSIM2

Additional surface-potential based MOSFET model.

Introductions of CMC Model Standards

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- 2006 PSP
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- 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.

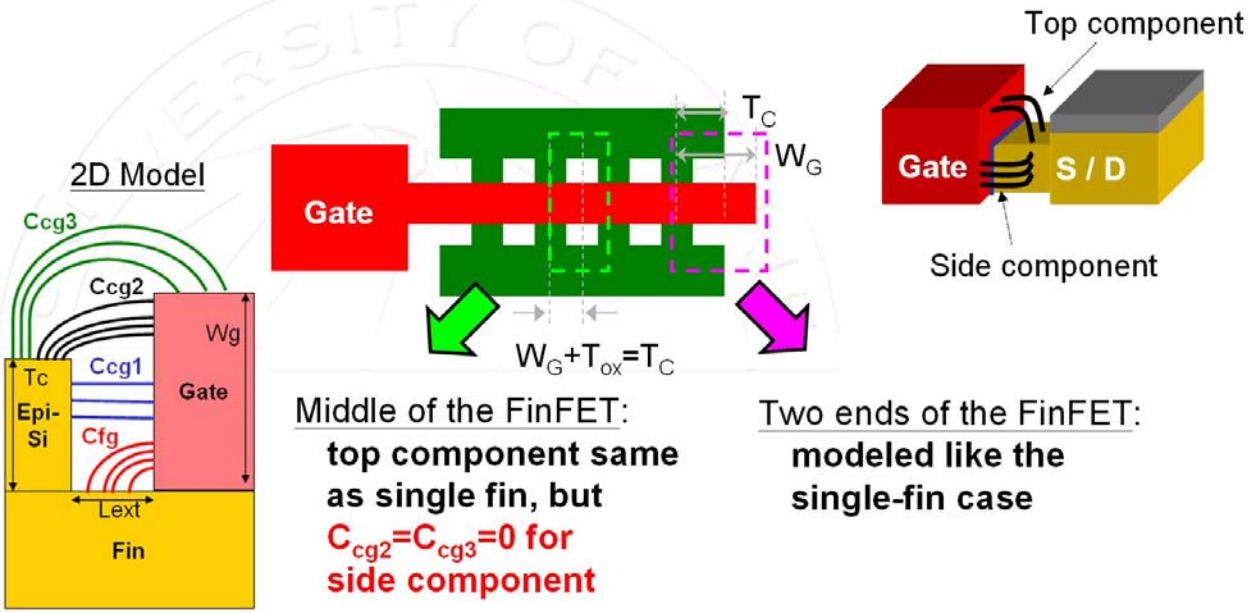
Phase 1 – Requirements

- 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

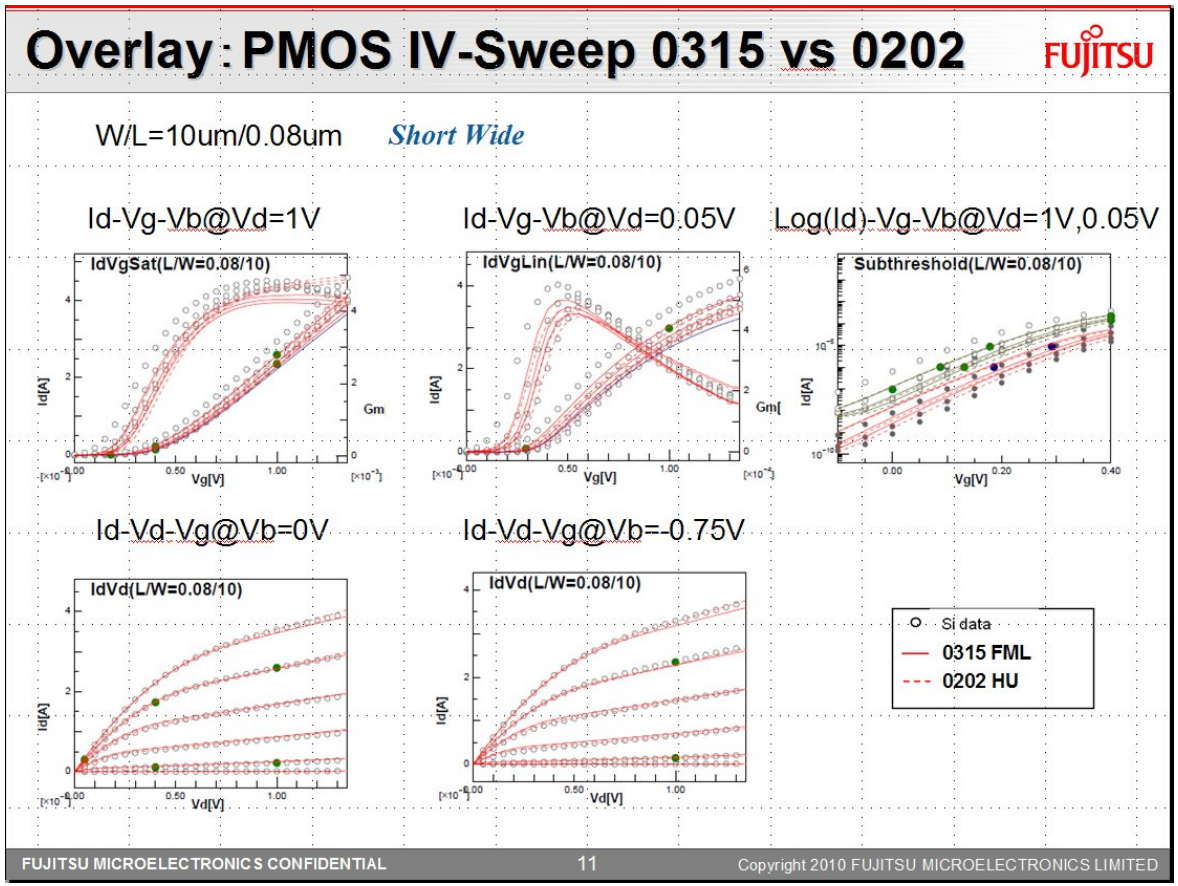


Middle of the FinFET:
top component same as single fin, but $C_{cg2}=C_{cg3}=0$ for side component

Two ends of the FinFET:
modeled like the single-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

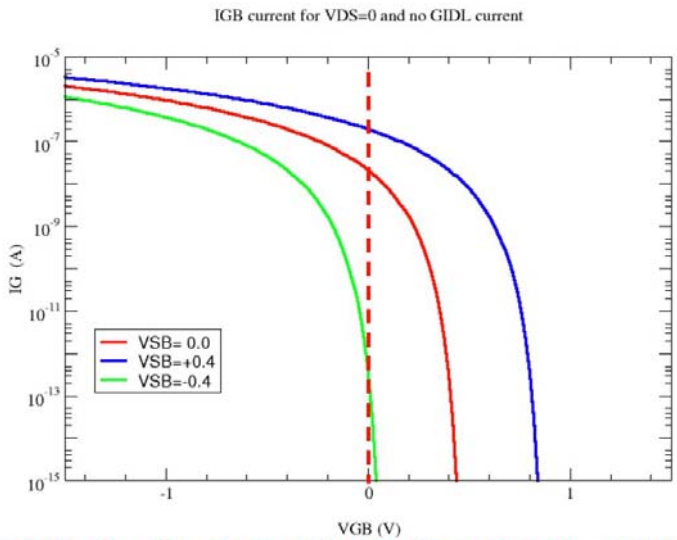
PSP runtime

Comparison of Global CPU time: Bsim4.5, PSP 102.1/Juncap, PSP102.1/Juncap express

Circuit	Number of transistors	BSIM 4.5		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	1.641752577	5.04	1.298969072
Fadd32	288	4.4	1	6.67	1.515909091	4.7	1.068181818
Inv	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	0.727359847
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}

Compact Model Council

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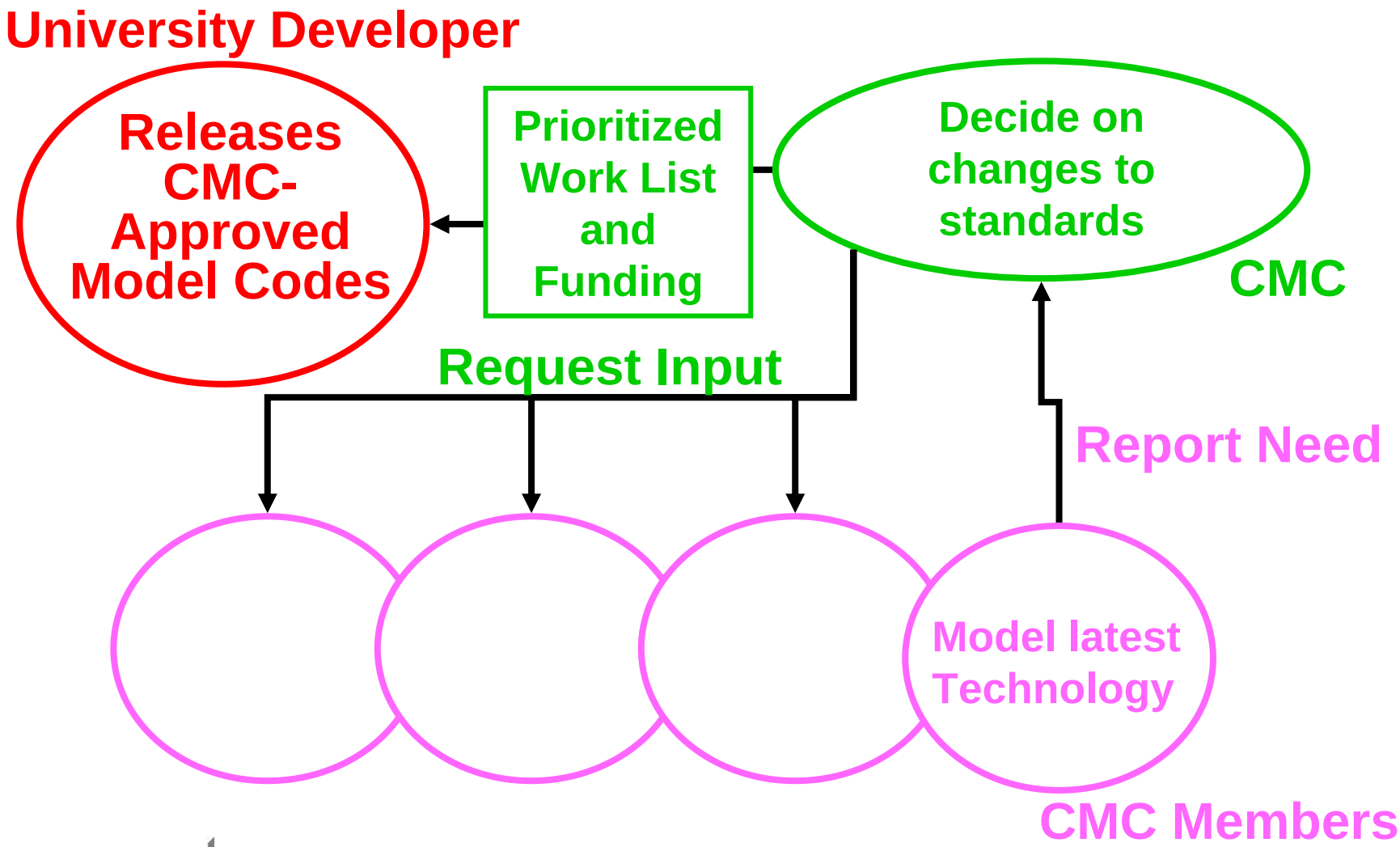
Phase IV

- 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

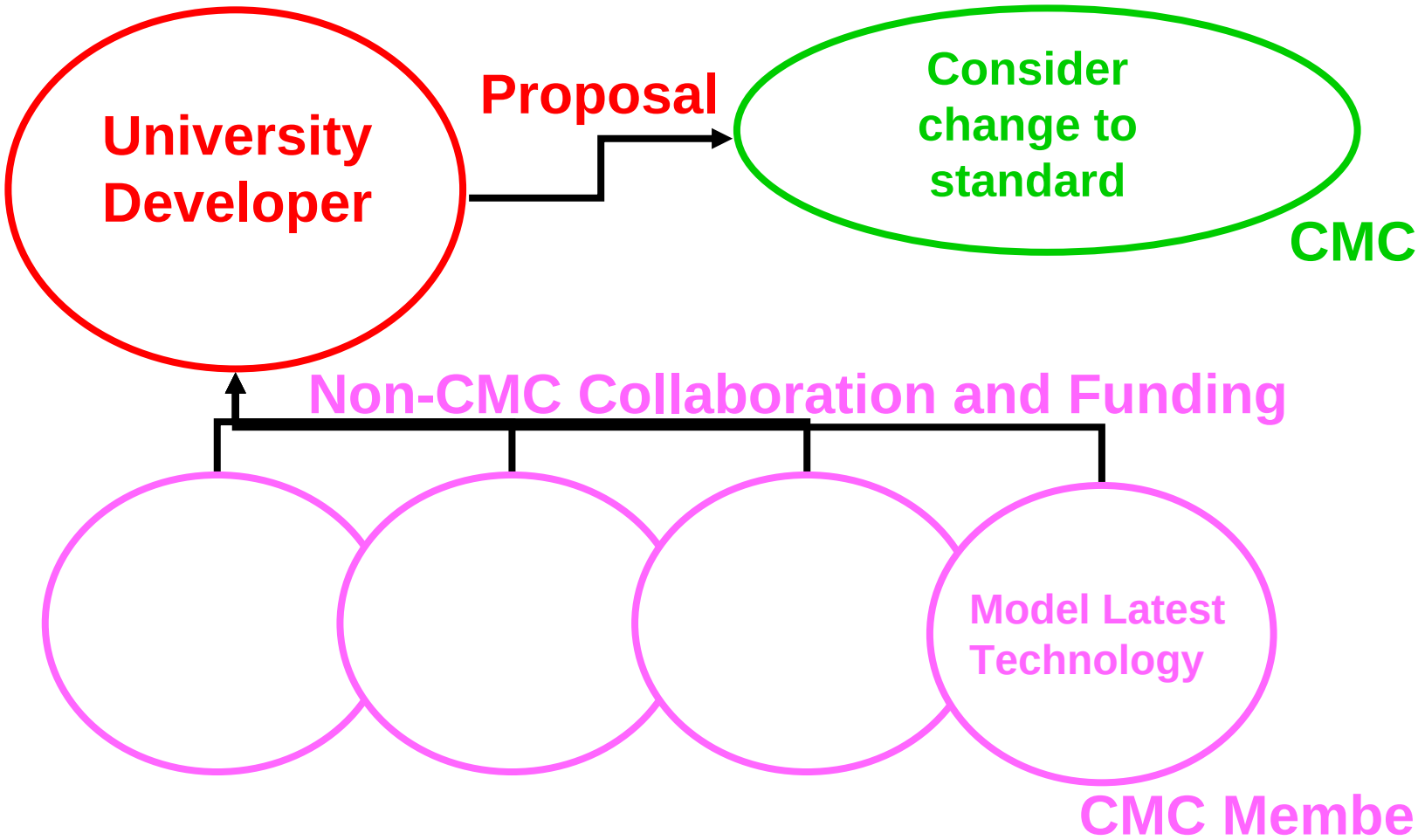
CMC Models Do Not Remain Static

- 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 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
  - 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

- 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