



IBM Systems and Technology Group

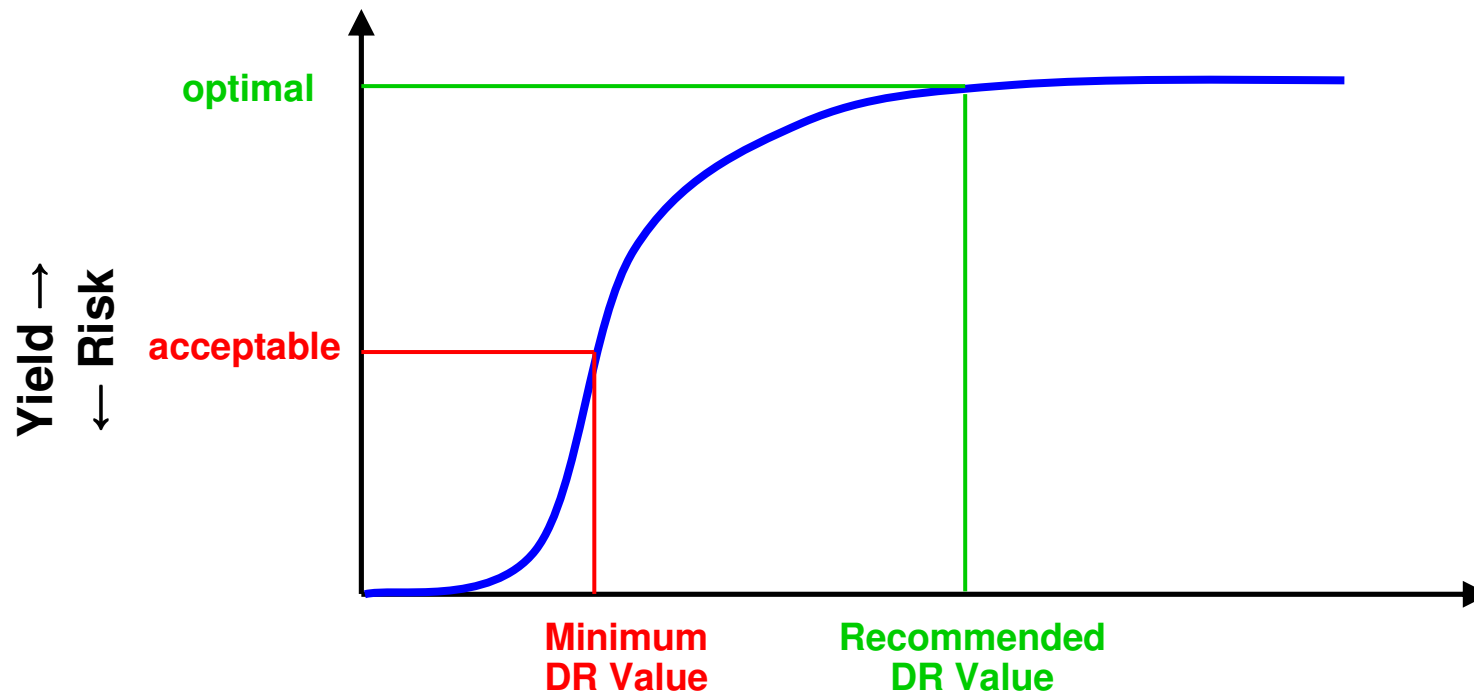
# A Flat Earth for Design and Manufacturing

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# The Olden Days: Rules-Driven DfM

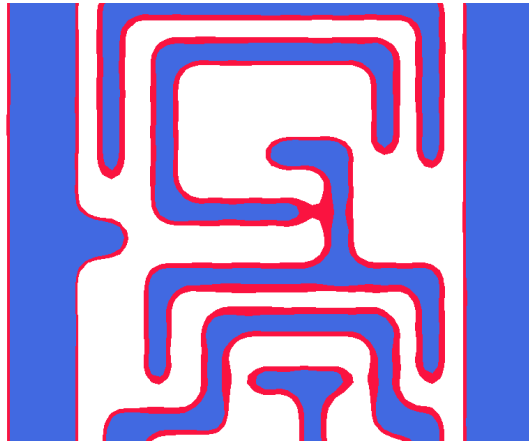


**Design Rule Value (width, space, area, ...)**

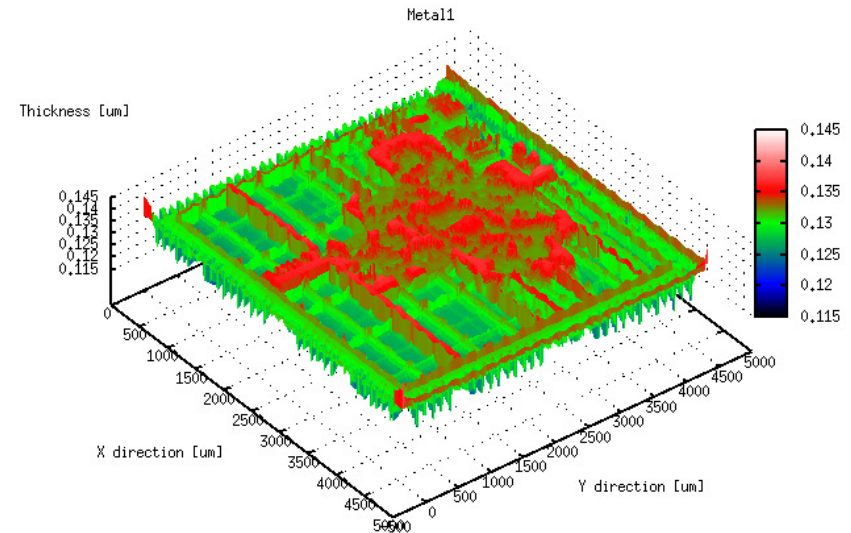
- Exploit the gap between minimum and recommended rule values
- This has worked well for several generations and will continue for 32nm

# Life is Becoming More Difficult: Physical Effects

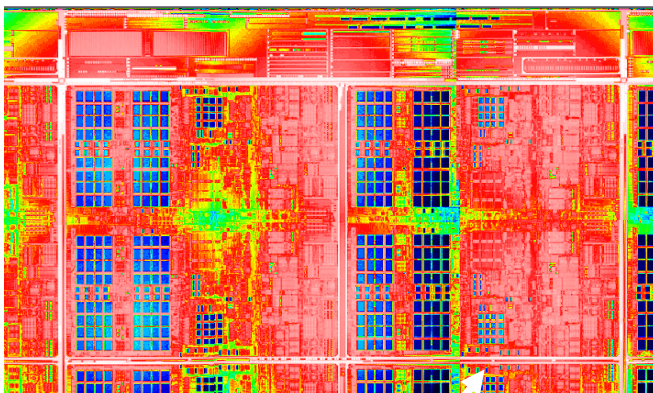
## Lithography



## Chemical-Mechanical Polish

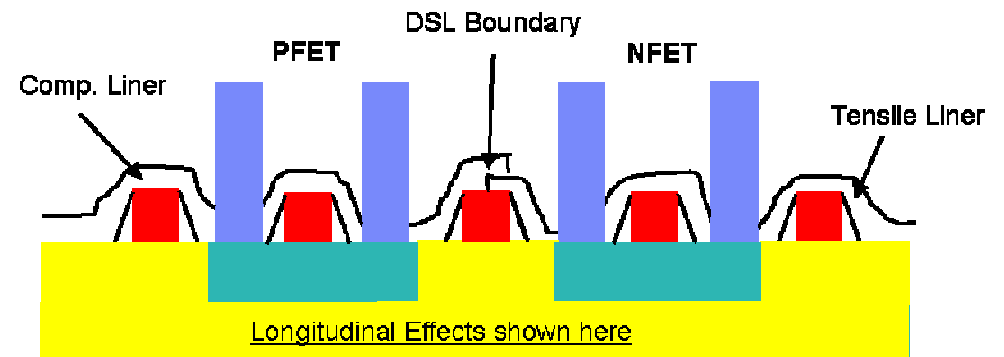


## Rapid Thermal Anneal



~2% reflectance

## Strained Silicon



# Life is Getting Difficult: The Lithographic Picture

Node	90nm	65nm	45nm	32nm	22nm
Year	2003	2005	2007	2009	2011
Pitch	250nm	200nm	140nm	100nm	70nm
$\lambda$	193nm				
NA	.75	.85	1.2	1.35	
% of Scaling	74%	39%	97%	26%	0%
Exit Pupil					
$k_1$	.5	.44	.44	.35	.25
RET	conventional	annular	annular	quadrupole	dipole
	Rigorous Optical Proximity Correction				
	Assist Features				
				Double Patterning & SMO	
Yield vs Pitch					
DfM		Opportunistic DfM		Complex Rules	RDR

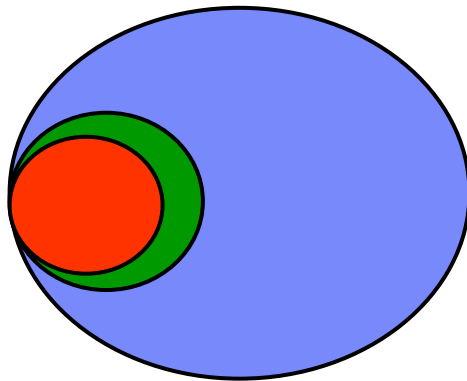
$$\text{Resolution} = k_1 \frac{\lambda}{NA}$$

## Prescriptive Design

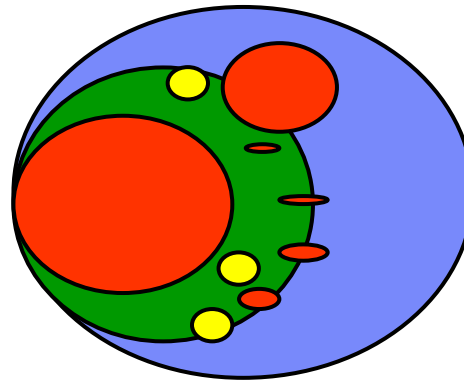
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- Rules have become too complicated
  - and behavior has become non-monotonic
- So instead of *describing* the technology – either through rules or models – let's instead *prescribe* what should be done
  - through restricted design rules (RDRs)
  - through pre-qualified patterns
- We will be able to build only a few things well
  - let's accurately describe the things we can build
  - so that Design sees accurate models of hardware
  - and so that Manufacturing sees an accurate representation of desired electrical behavior

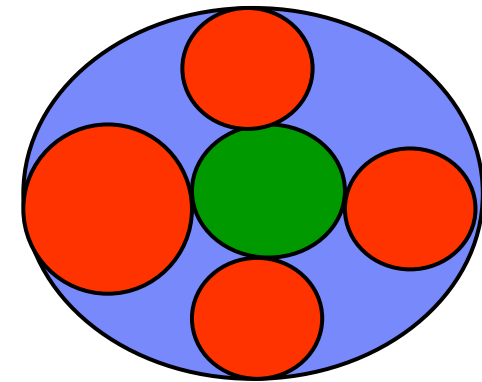
# Moving Past DfM: Design-Rule Taxonomy



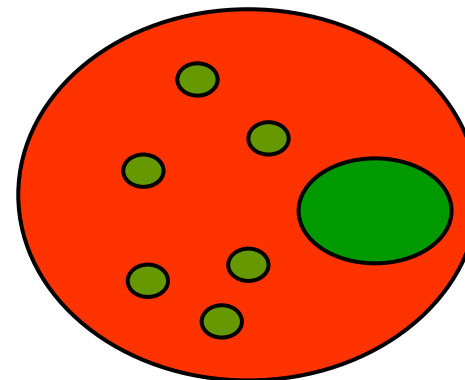
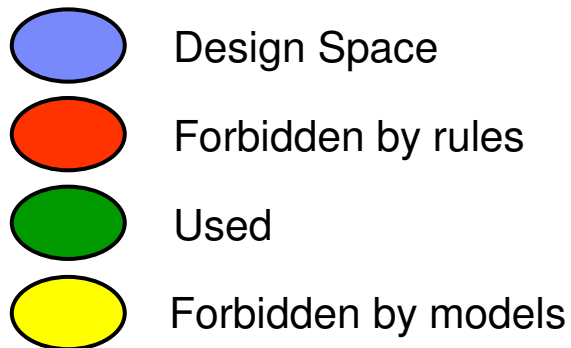
Conventional design rules I



Conventional design rules II

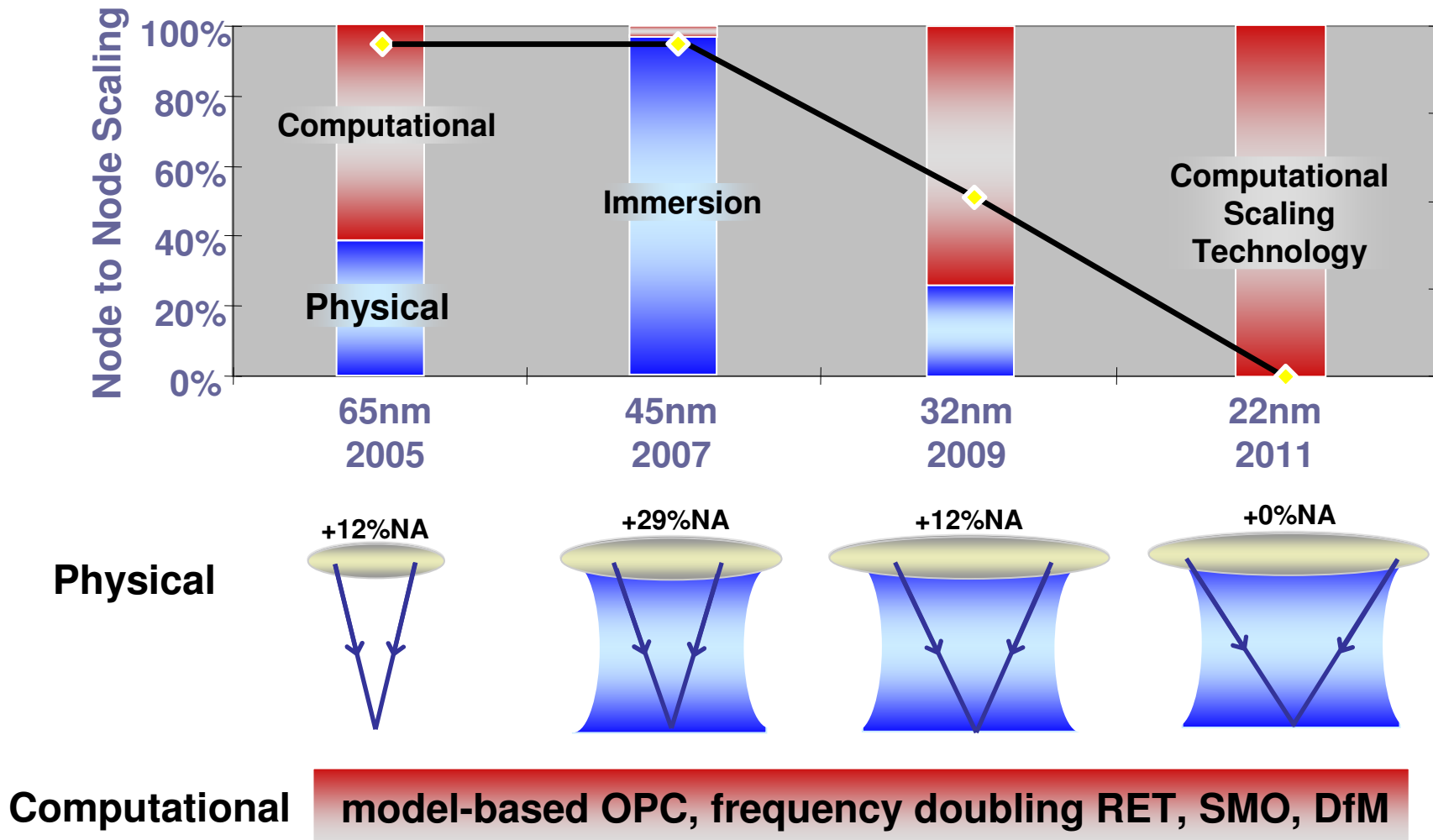


Restricted Design Rules  
(prohibitive)

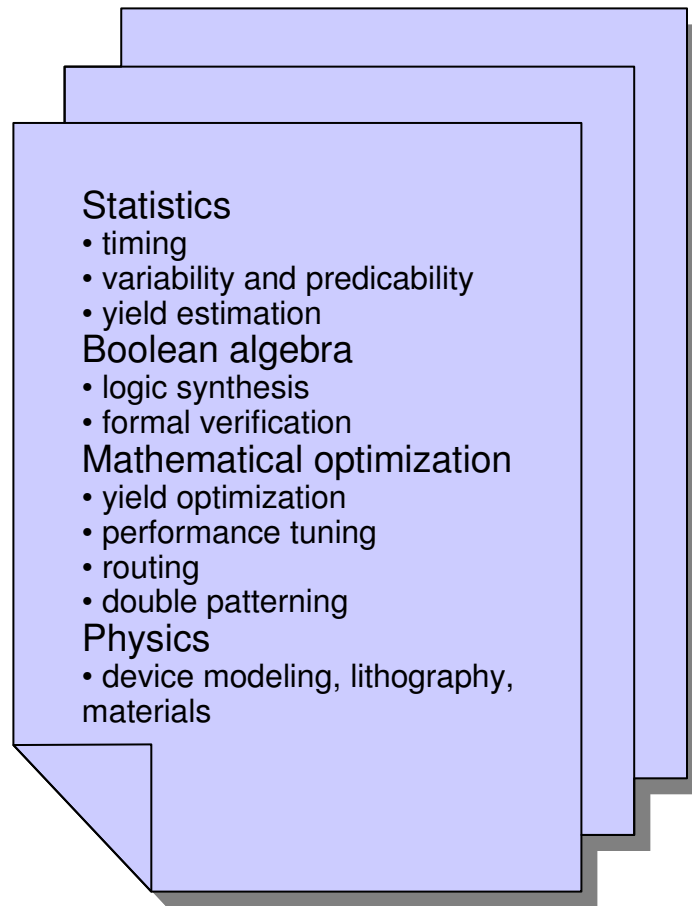


Restrictive Design Rules  
(prescriptive)

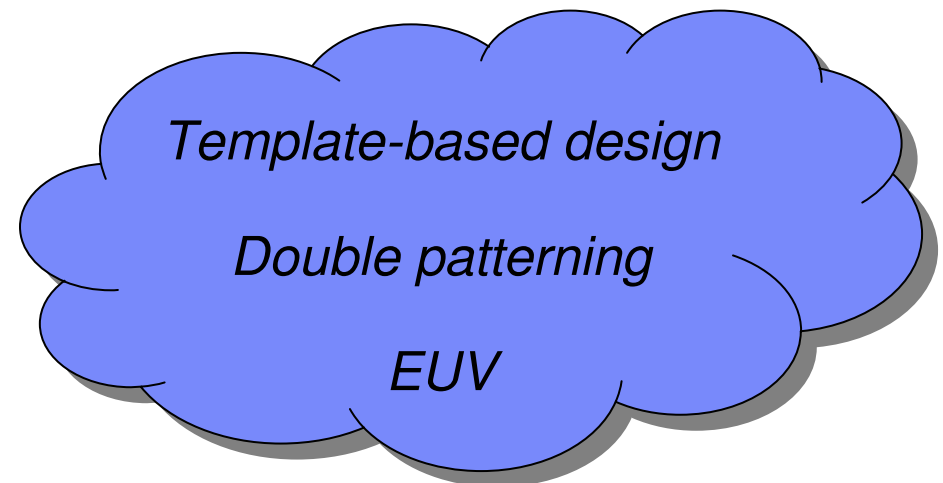
# Computational and Physical Efforts Keep Litho Scaling Alive



# Math, Science ... and Future Challenges



**Our field's tools  
of today...**



**...will have to address  
the challenges of tomorrow**