Evaluation komplexer Systeme und Prozesse durch Modellbildung und Simulation
Workshop 2014 Universität der Bundeswehr München

„The Supply Chain as a Competitive Advantage – The Four Levels of Semiconductor Supply Chain Simulation"

January 20

Hans Ehm, Can Sun

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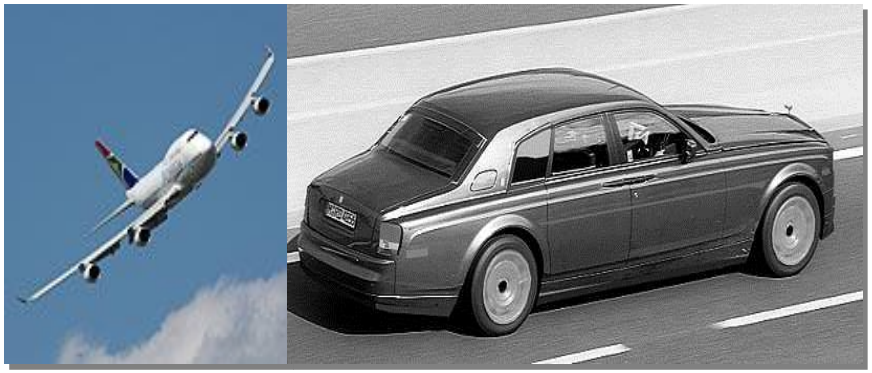
Video

The Semiconductor Environment – an Industry Comparison (… easy to memorize)

Why?



- If the automotive and aircraft industries developed at the same rates as semiconductors in the past 30 year:

- a Rolls Royce would cost $2.75 and get 3 million miles a gallon
- a Boeing 767 would cost $500 and circle the globe in 20 minutes on five gallons of gas.

Jeffrey Rayport, professor at Harvard Business school. Co-author of three leading books on strategy in the network economy. (*e-Commerce*, *Cases in e-Commerce* and *Introduction to e-Commerce*)

Innovation of the First Transistor on Dec 23rd 1947. The Starting Point of the Semiconductor Industry

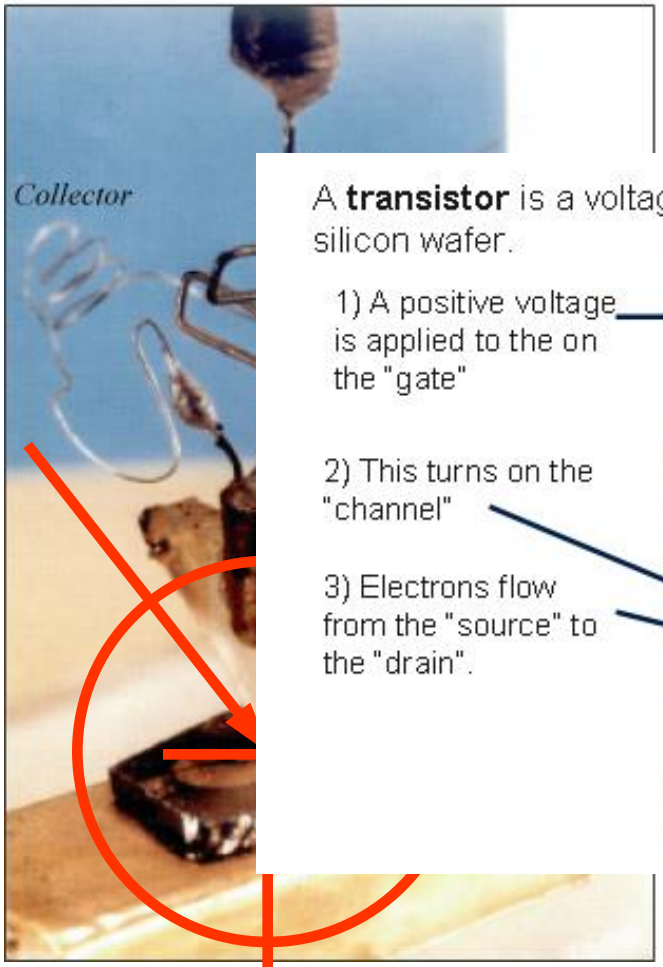
Because

The first point contact transistor

William Shockley, John Bardeen, and Walter Brattain

Bell Laboratories, Murray Hill, New Jersey (1947)

and

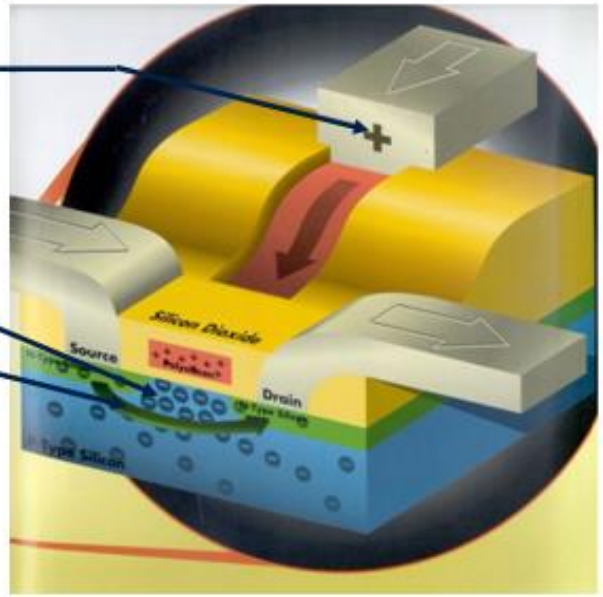


A **transistor** is a voltage controlled switch built on the silicon wafer.

1) A positive voltage is applied to the on the "gate"

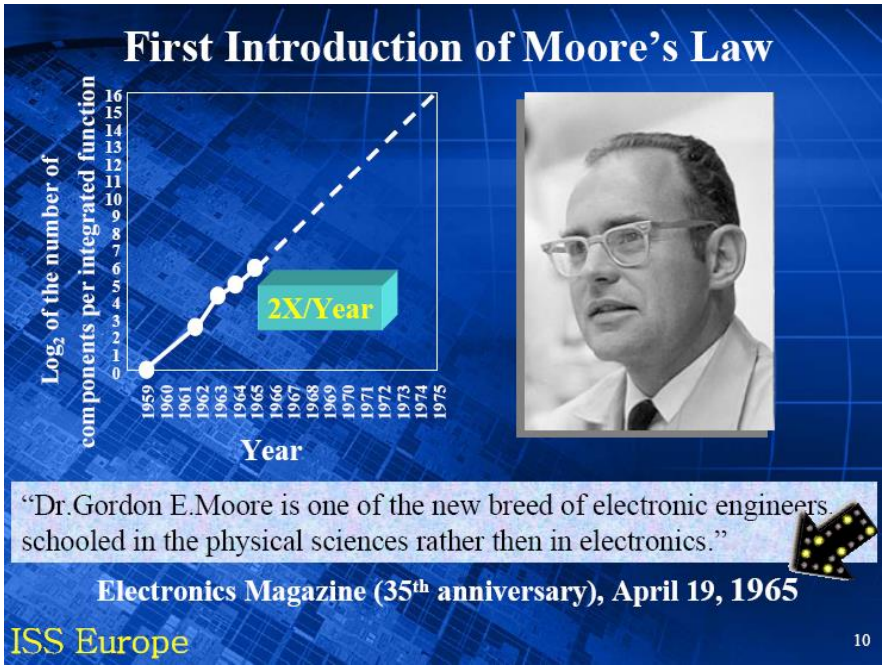
2) This turns on the "channel"

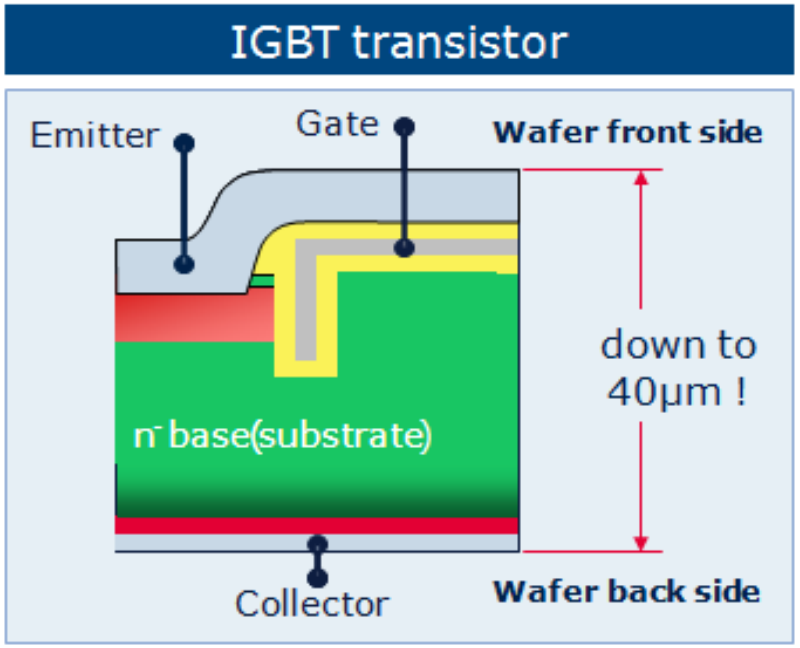
3) Electrons flow from the "source" to the "drain".



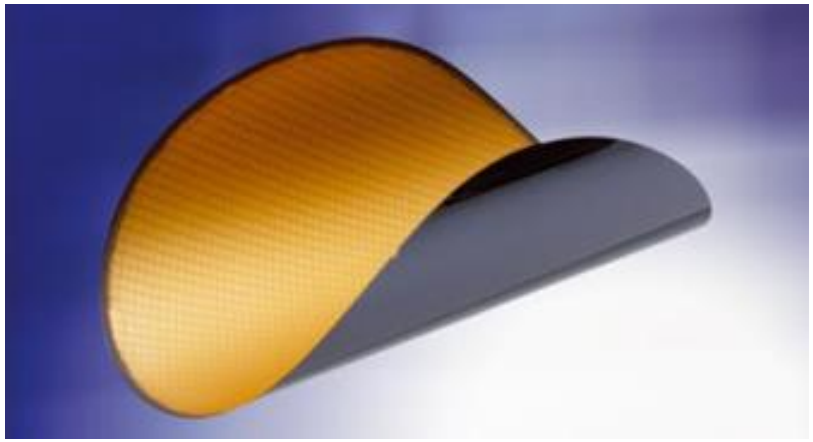
Bell Labs
600 Mountain Ave.
Murray Hill, NY, USA

Because of Moore's Law (the semiconductor law) & Innovations e.g. from Infineon – like ultrathin wafers for low energy loss



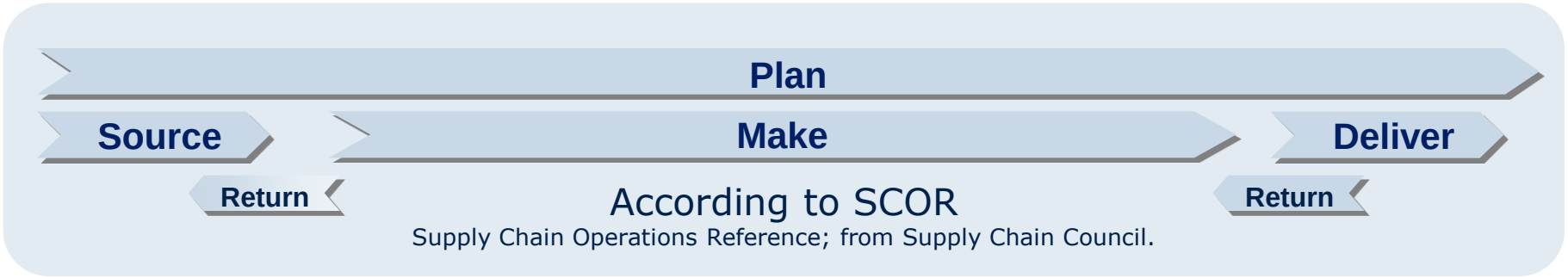


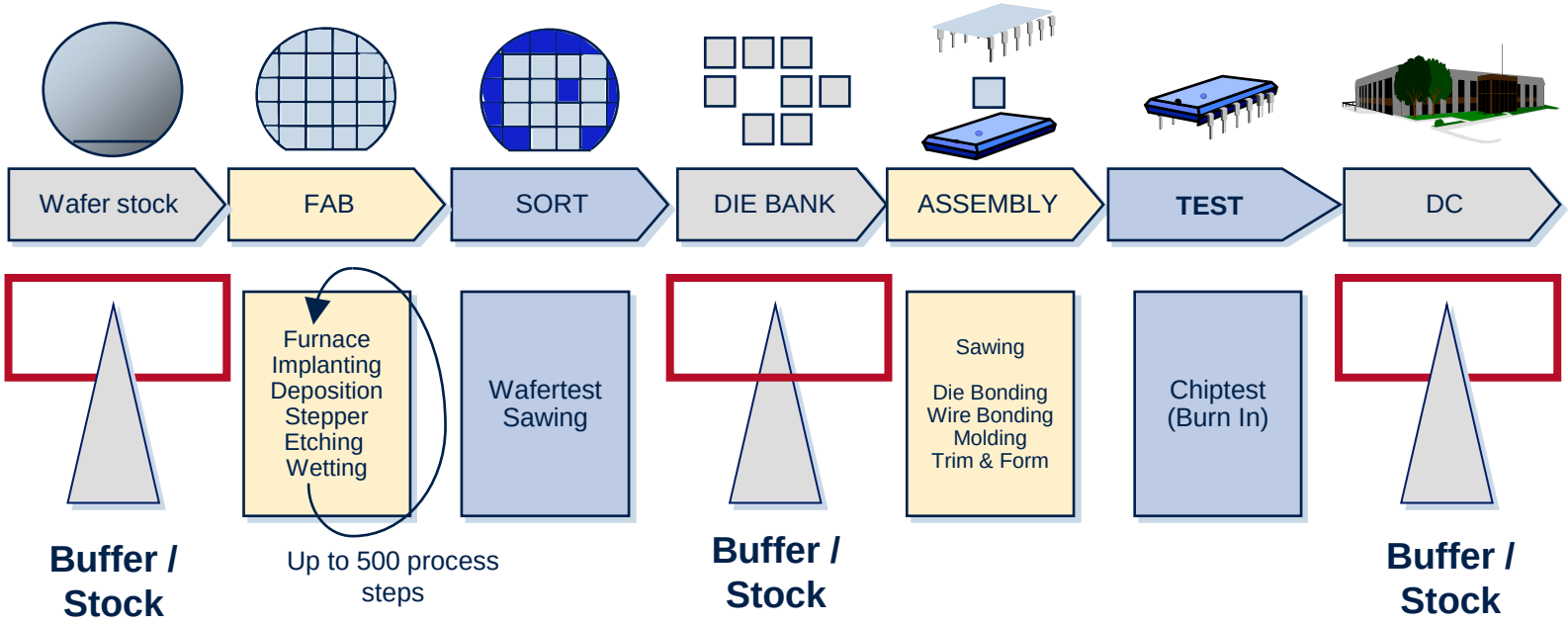
Semiconductor Law in modern words: Every few years you get much more functions for the same CO2 consumption



For internal use only

IFX Supply Chain spans From Supplier's Supplier to Customer's Customer





IFX Supply Chain spans From Supplier's Supplier to Customer's Customer

Plan

Source | Make | Deliver

Return | Return

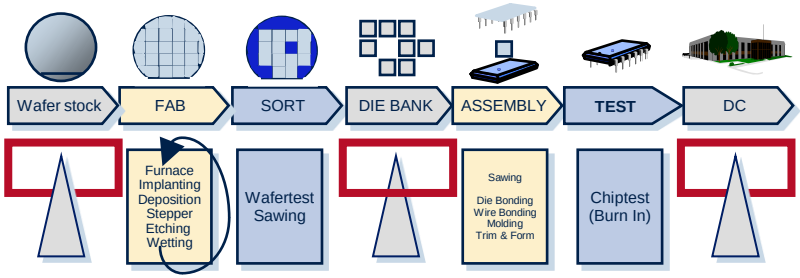
According to SCOR

Supply Chain Operations Reference; from Supply Chain Council.

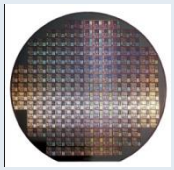
Suppliers

THE LINDE GROUP

siltronic perfect silicon solutions



Foundry Partner



UMC

tsmc

Subcontractors

Amkor Technology

unisem

KYEC The Testing Industry Benchmark

Customers

DELTA

ERICSSON TAKING YOU FORWARD

BOSCH

Continental

gemalto security to be free

LG Life's Good

SAMSUNG

SMA

SIEMENS

FLEXTRONICS

ARROW ELECTRONICS

AVNET

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The Main process acc. To SCOR in the Semiconductor Industry is Make “Produce and Test”. It is Grouped into Front End and Back End Process Separated by a DieBank

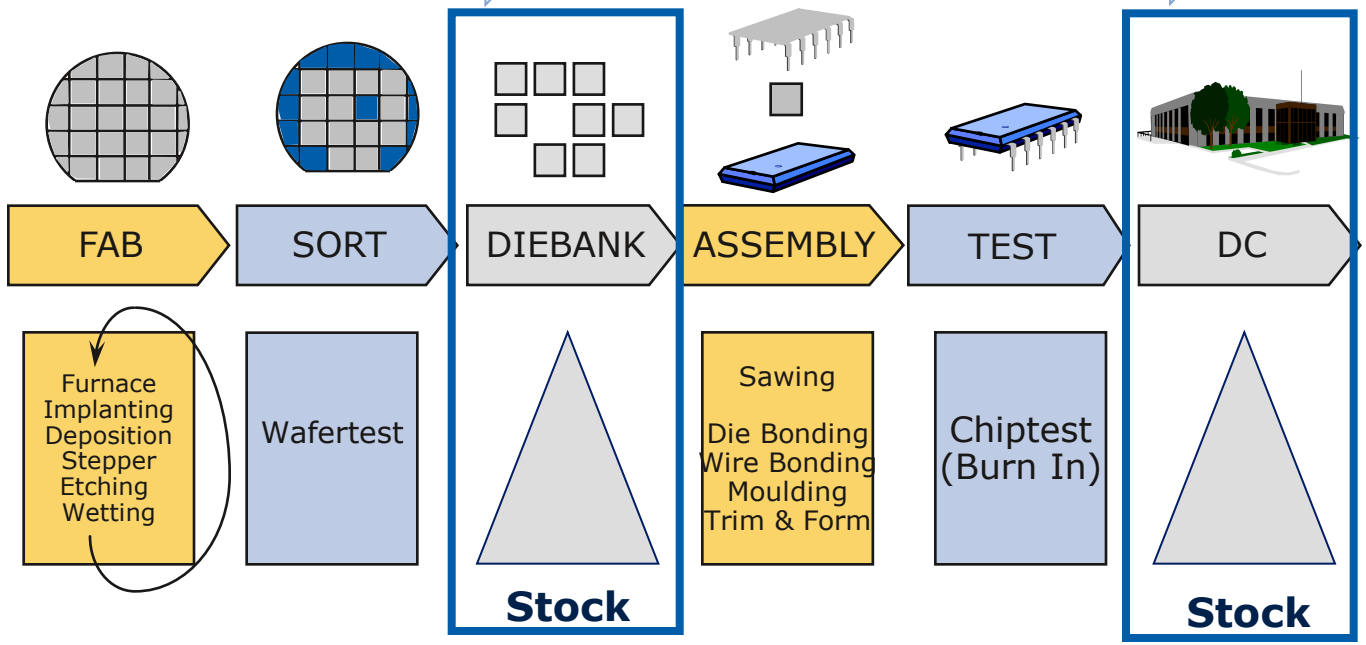
Package

Front End & Back End

Front End (CT 40-100d)

Back End (CT 5-20d)

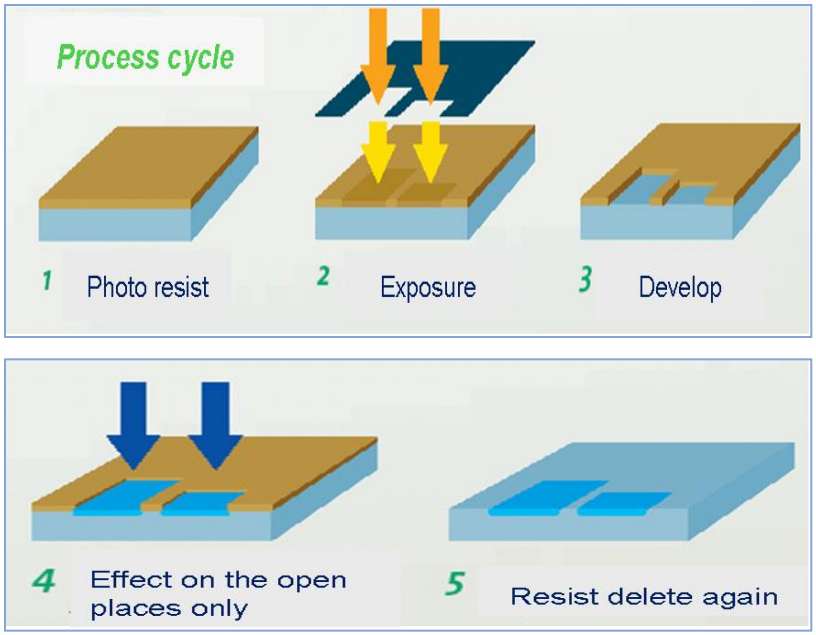
CT:
Cycle Time

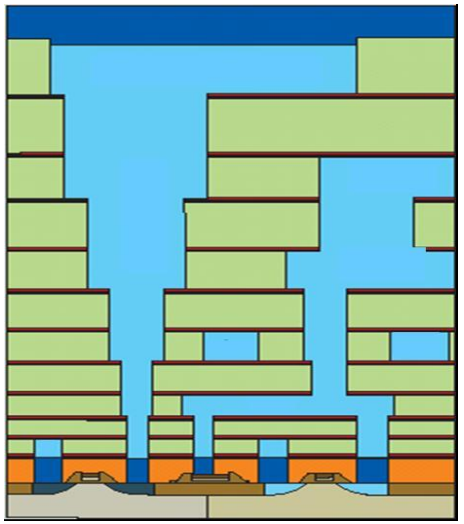


Up to 35 Revolving Lithography Steps per Wafer Transform the Design via Masks to the Wafer …

… generating a three dimensional" landscape on the wafer surface

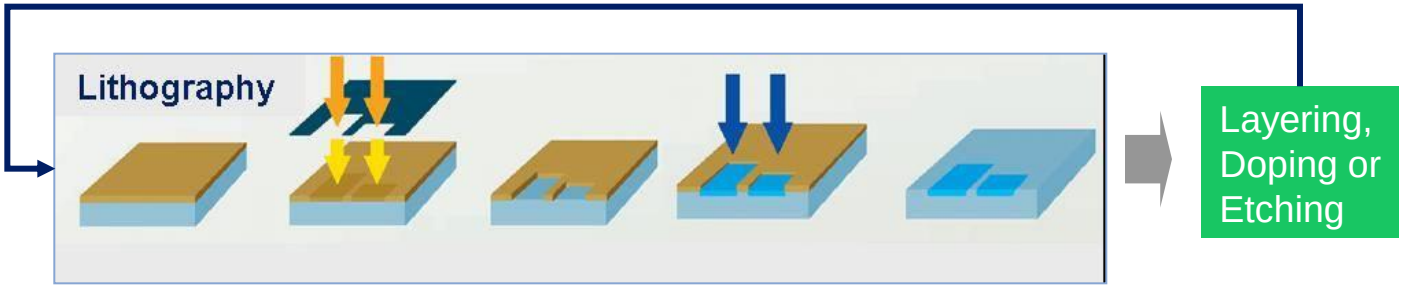
Lithography method: one chip after another is exposed



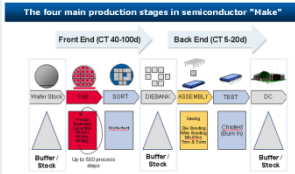


Other processes as etching, doping, layering can change the surface of the wafer permanently on the places that were exposed within lithography.

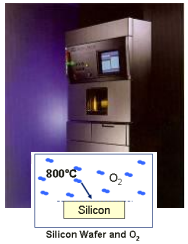
Next exposure step – up to 35 revolving steps



The Frontend SC consisting of 500 process steps+ (many are revolving). It runs at a Flow Factor of 2,5 to 3 times the raw process time (base is 365 days a year 24 hours a day)



FURNACE - Oxid

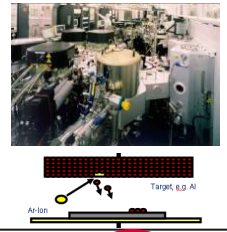


IMPLANT

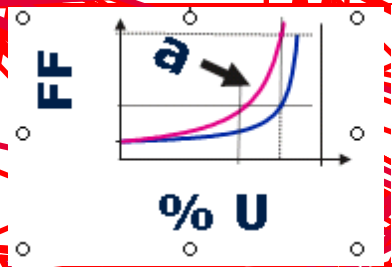
Defect Density

DRY ETCHING

PVD - Sputtering



START



$$FF = \frac{CT}{RPT}$$

- **CT: Cycle Time**
- **RPT: Raw Process Time**

SORT

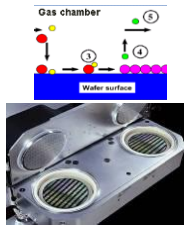
C M P

W E T

METROLOGY *

LITHOGRAPHY

CVD



* one test step after lithography

We learned to master factory complexity by processes, math and IT …

… e.g. flow factor, law of little, 4 partner and operating curve

Flow factor formula

$$FF = \frac{CT}{RPT}$$

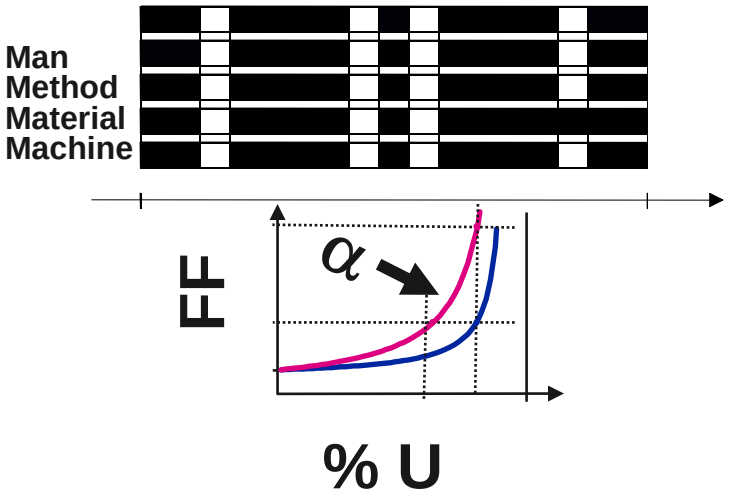
- **CT: Cycle Time**
- **RPT: Raw Process Time**

Law of Little

$$CT = \frac{WIP}{GR}$$

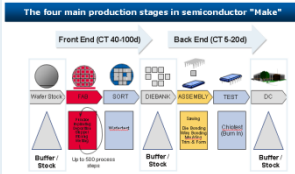
- **WIP: Work in Progress**
- **GR: Going Rate**

4 Partner Method



Operating Curve

In the past it was required to mainly manage internal Frontend SC fast and cost efficient



FURNACE

IMPLANT

Defect Density

ETCHING

PVD

START

SORT

Fab Dresden - GE

C M P

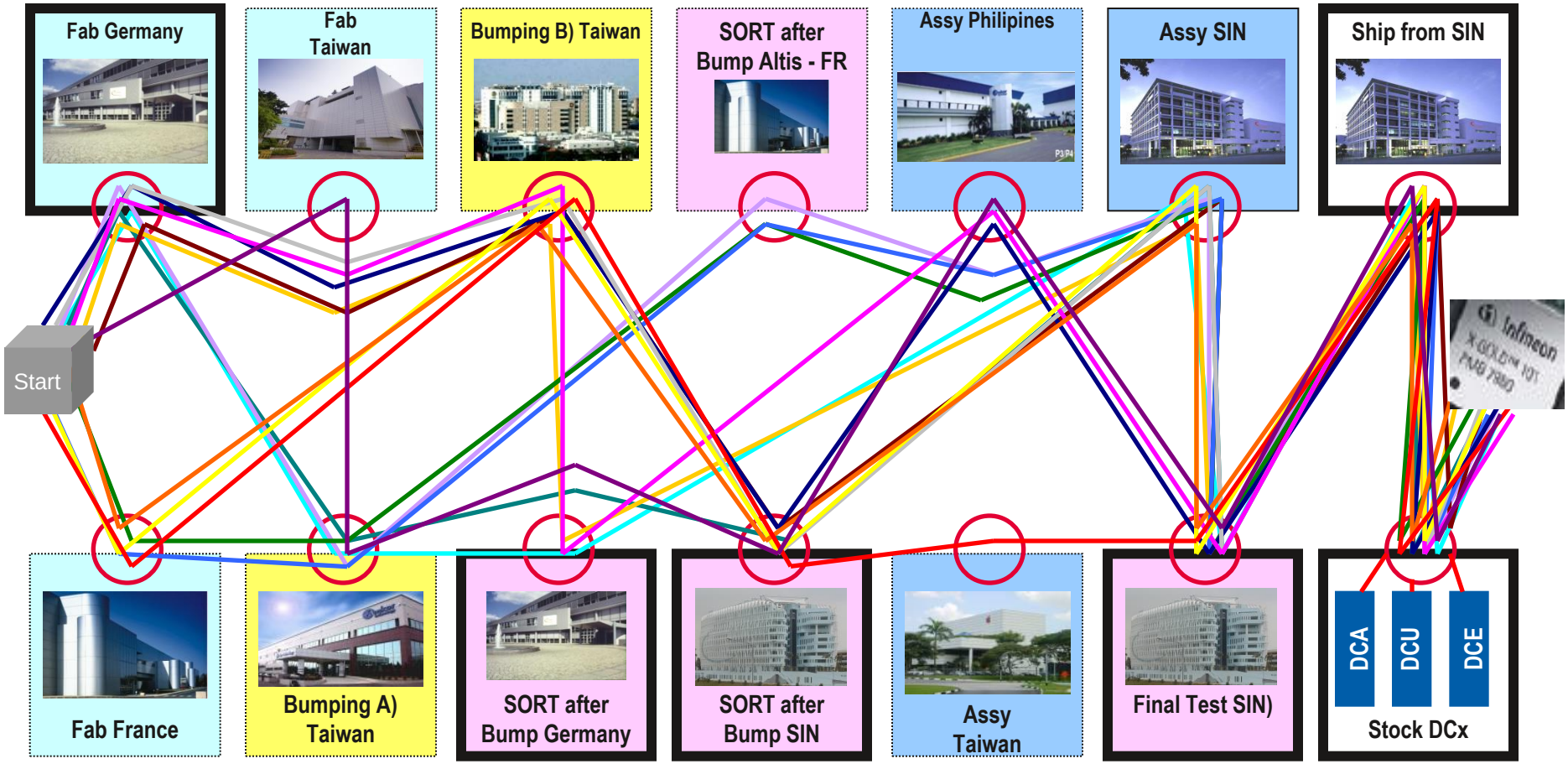
W E T

METROLOGY *

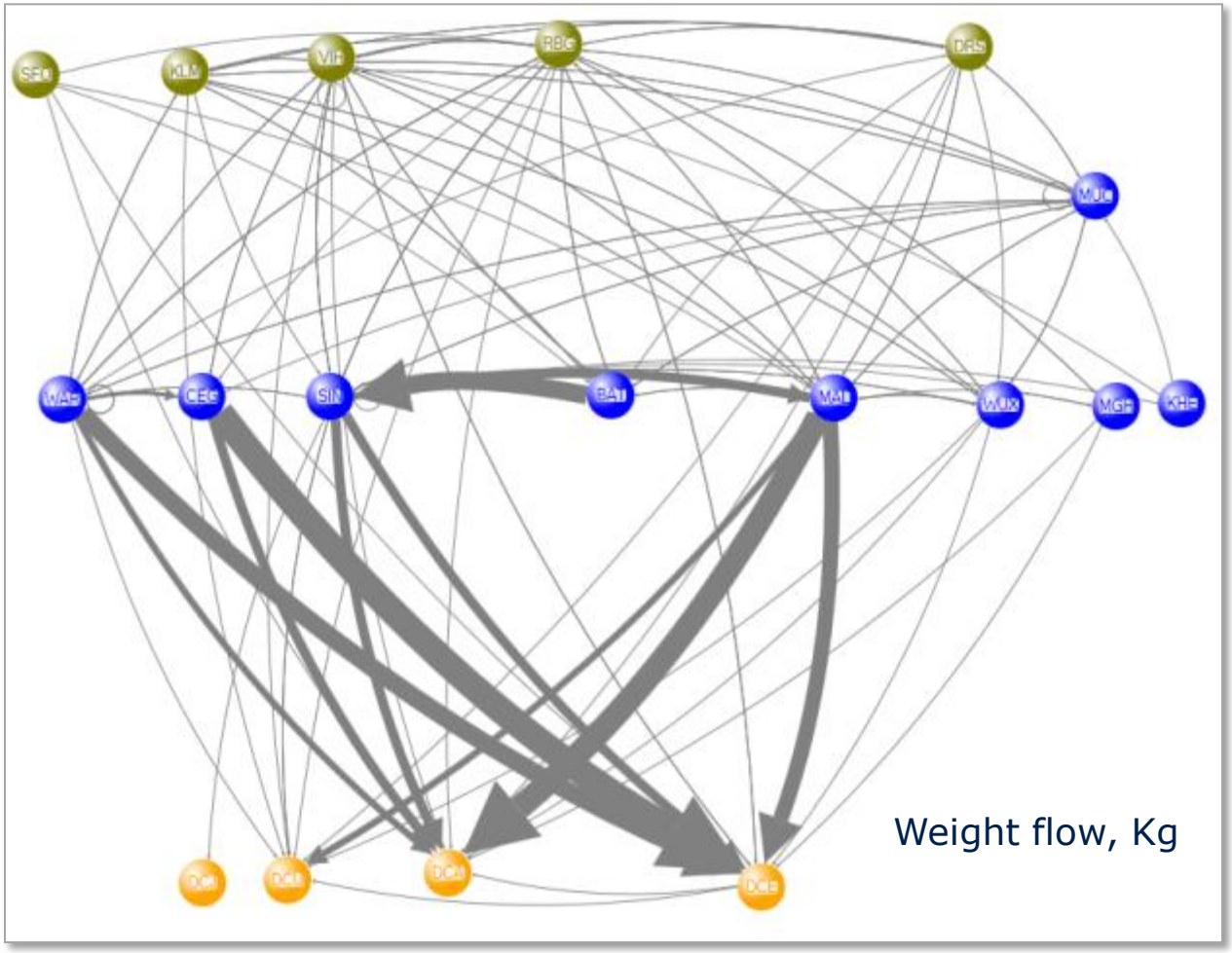
* test step according to lithography

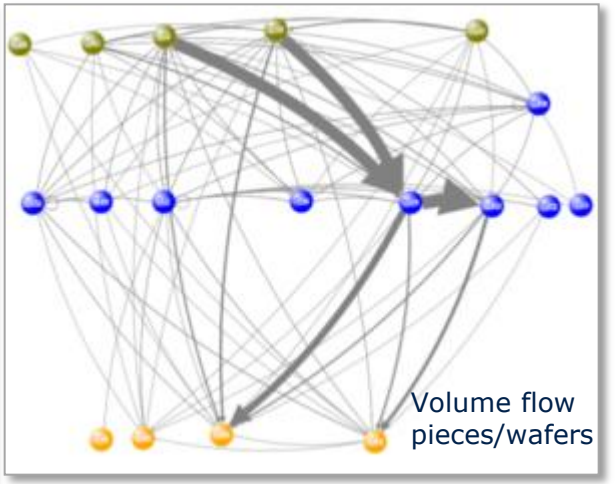
and can benefit from this global production flexibility – Our project: The global SC is our new "Fab"

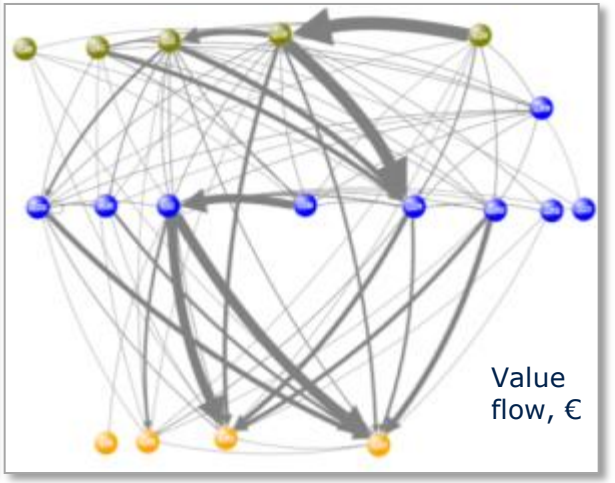
Each new supply chain was a step to win customers via capa increase – example from the qualification flexible mobile phone business



IFX supply chain has more than 140 active routes for material flow *







*) only major routes as used in the monitoring system

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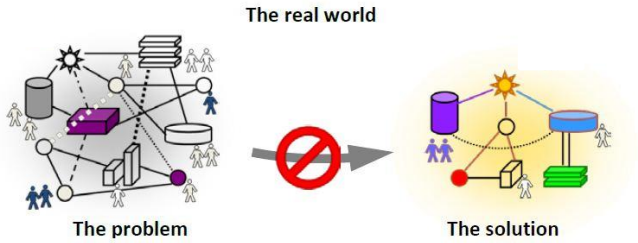
What is Simulation and why we use simulation at Infineon

Simulation is…



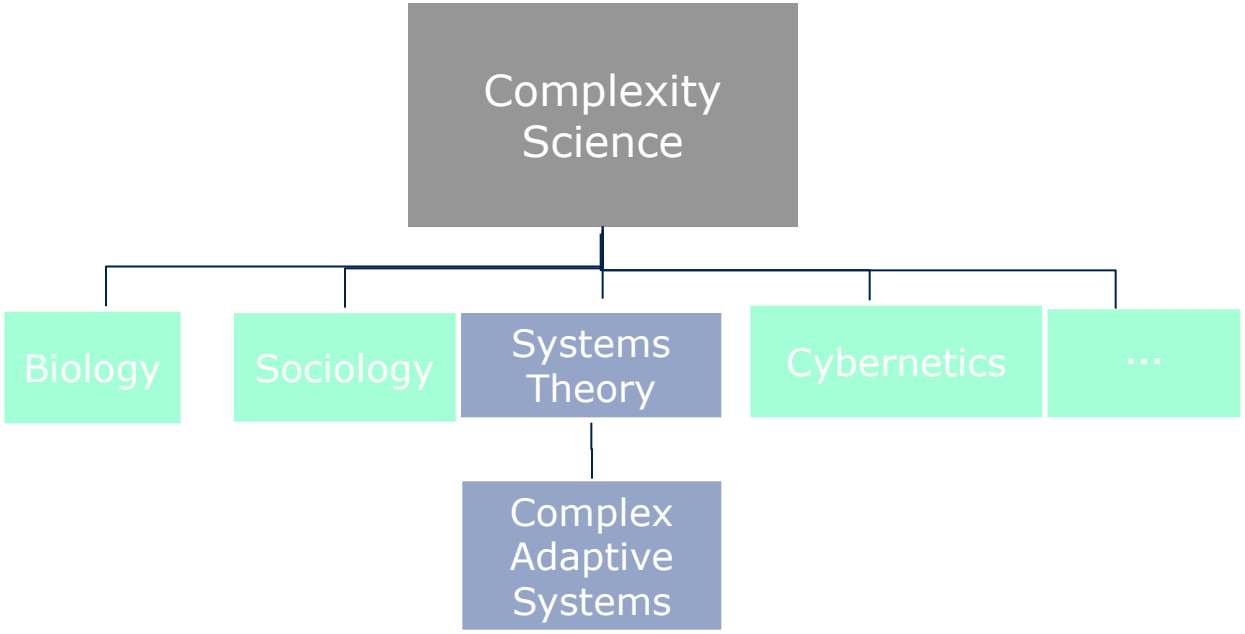
Simulation is an abstract representation of the real world to perform risk-free solution experiments

With Simulation, we want to…

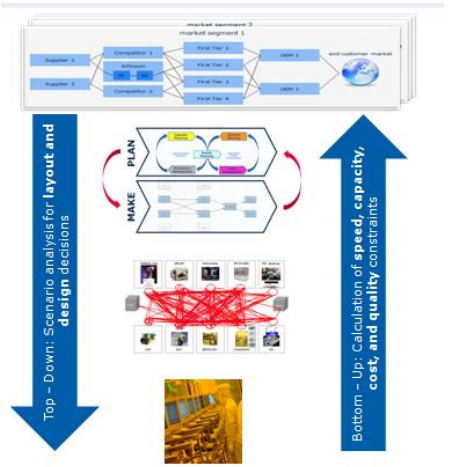
- **Understand complex interactions**
- **Compare ourselves with competitors**
- **Perform what-if analysis**
- **Improve our performance**

Complexity science and Semiconductor Supply Chain Management

→ Supply Chain Complexity combines two disciplines



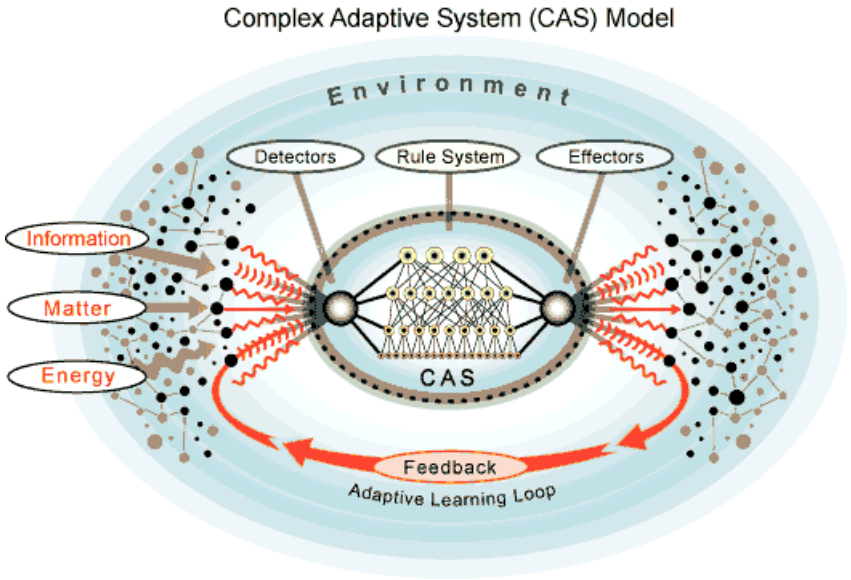
Supply Chain Management

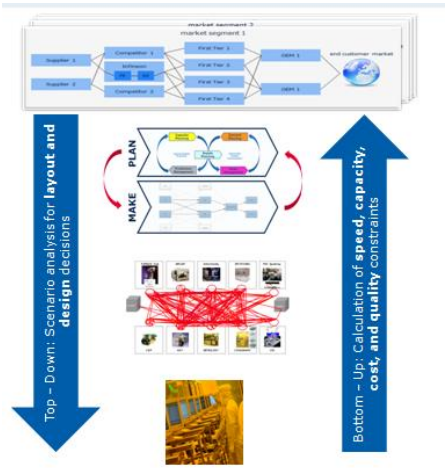


- A test shows that Semiconductor supply chain is a complex adaptive system
- We have to separate value add from non value add complexity in considering the whole system as a complex adaptive system

Consequences for simulation in Complex Adaptive Systems (CAS)

- Definition of CAS:
  - "System that emerges over time into a coherent form, and adapts and organizes itself …" (Holland, 1995).
  - CAS contains multiple interacting agents
  - Agents have detectors, effectors, a rule system, and needs
  - Agents react to signals and behave acc. to conditional actions (if/then)
- Agent based simulation is needed (beyond Dsicrete event simulation), especially on higher levels





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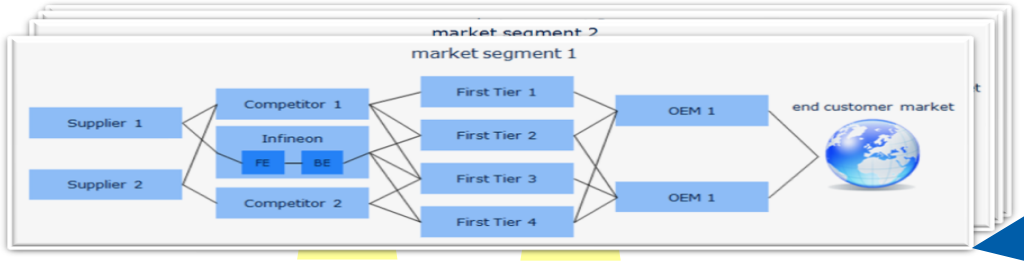
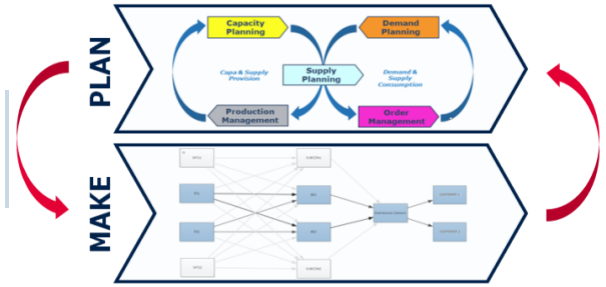
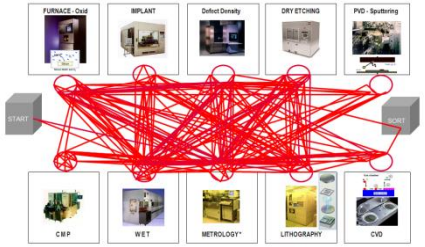
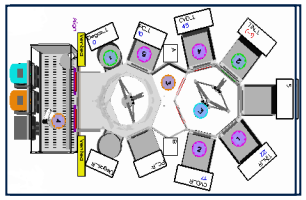
The four levels of Semiconductor supply chain simulations

- Level 4:
  End-To-End SC
- Level 3:
  IFX SC
- Level 2:
  Factory/Single Site
- Level 1:
  Equipment/Workcenter





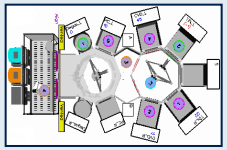




Top – Down: Scenario analysis for **system optimization**

Bottom – Up: Calculation of **speed, capacity, cost, and quality** constraints

Level 1 & 2 simulation
Fab Simulation example Dresden

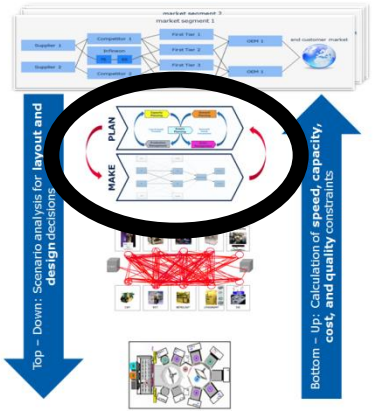


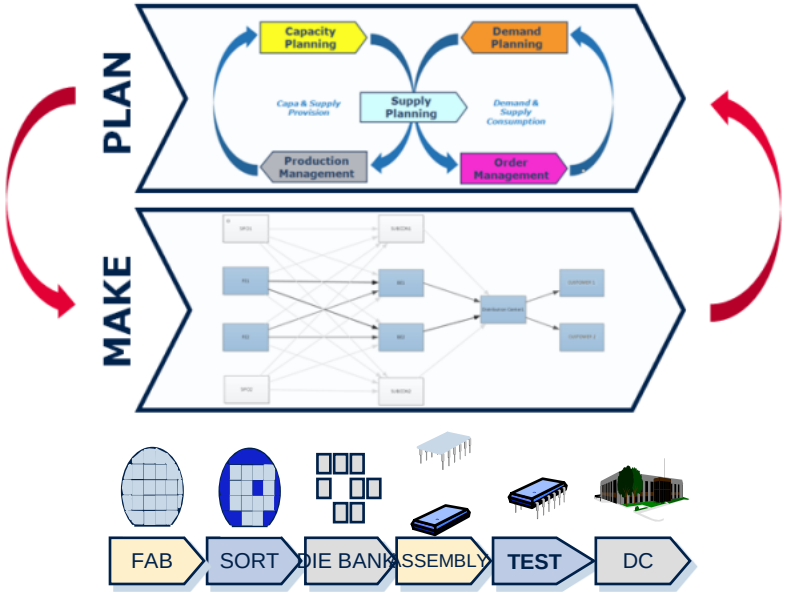
	Operational Simulation	Strategic Simulation
Software	AutoSched AP	AutoSched AP
Initialization	**Transient simulation:** Start with actual line WIP	**Steady-state simulation:** Start with empty fab, warm up with fixed wafer starts

	Ultra Short-Term …	Short-Term Simulation	Long-Term Simulation
Field of application	**Lot scheduling**	**Production control**	**Dynamic capacity planning**
Horizon	**0… ~12 hours**	**1…7 days**	**1… ~15 weeks**
Status (Nov. 2013)	**Productive in pilot areas**	**Productive in pilot areas**	**Productive**

Level 3: IFX Supply Chain Software Anylogic

- The level 3 supply chain simulation models the **Infineon supply chain including all subcons and silicon foundries** in its **full width** but without customers and suppliers.

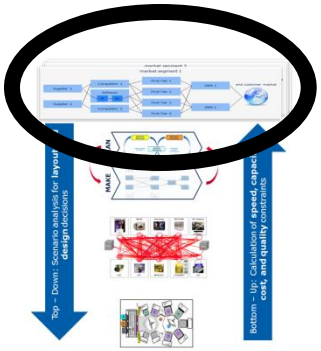


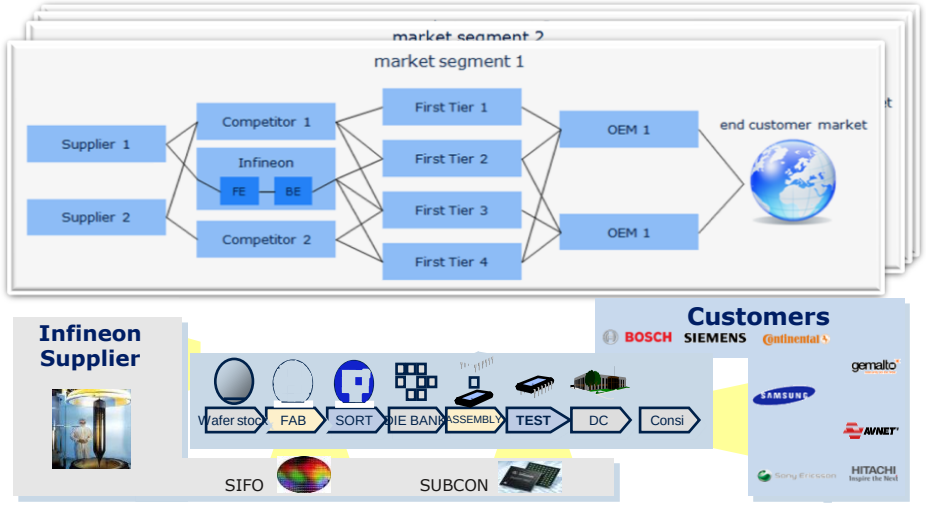


- **Purpose of the model:**
  - **Supports planning process design**
  - **Global SC Model in order to derive targets for level 2**
  - **Test of approaches to improve SC Planning, optimized contingency & buffers**

Level 4: End-to-End Supply Chain Software Anylogic

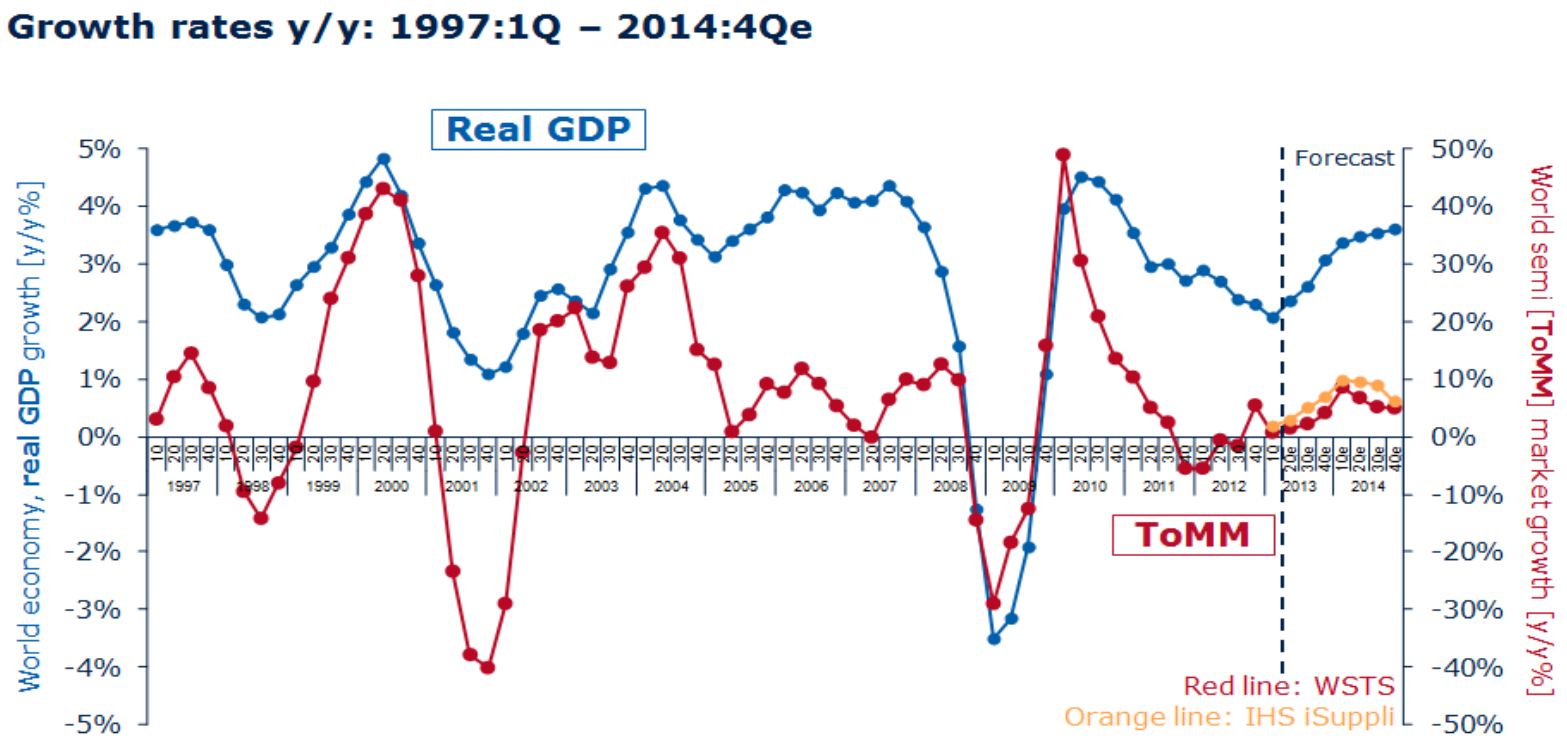
- The level 4 supply chain simulation models the **semiconductor supply chain including all business segments** in its **full length** from the raw material supplier (or even primary production) to the end customer market.

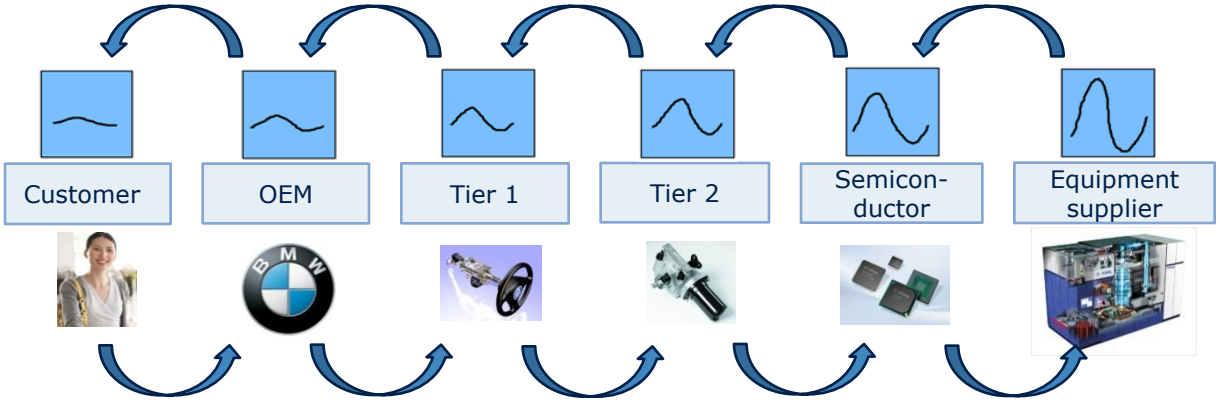




- **Purpose of the model:**
  - **Support supply chain strategy and network design decisions (like Make or buy)**
  - **Enable scenario analysis based on product and market data**
  - **Understand and reduce the bullwhip effect**

Examle Level 4:
The Bullwhip Effect



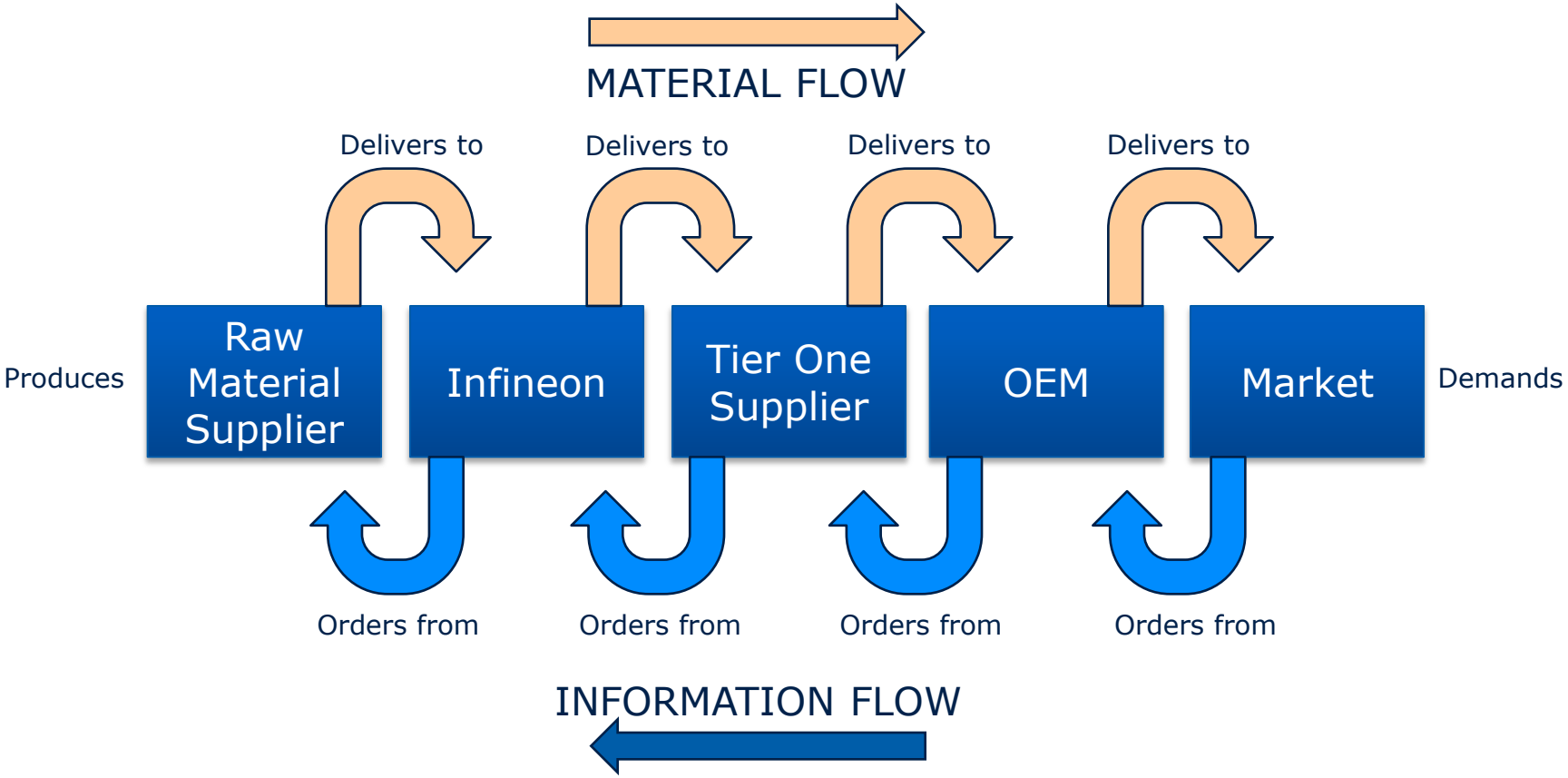


Bullwhip Effect

Overshooting in the value chain

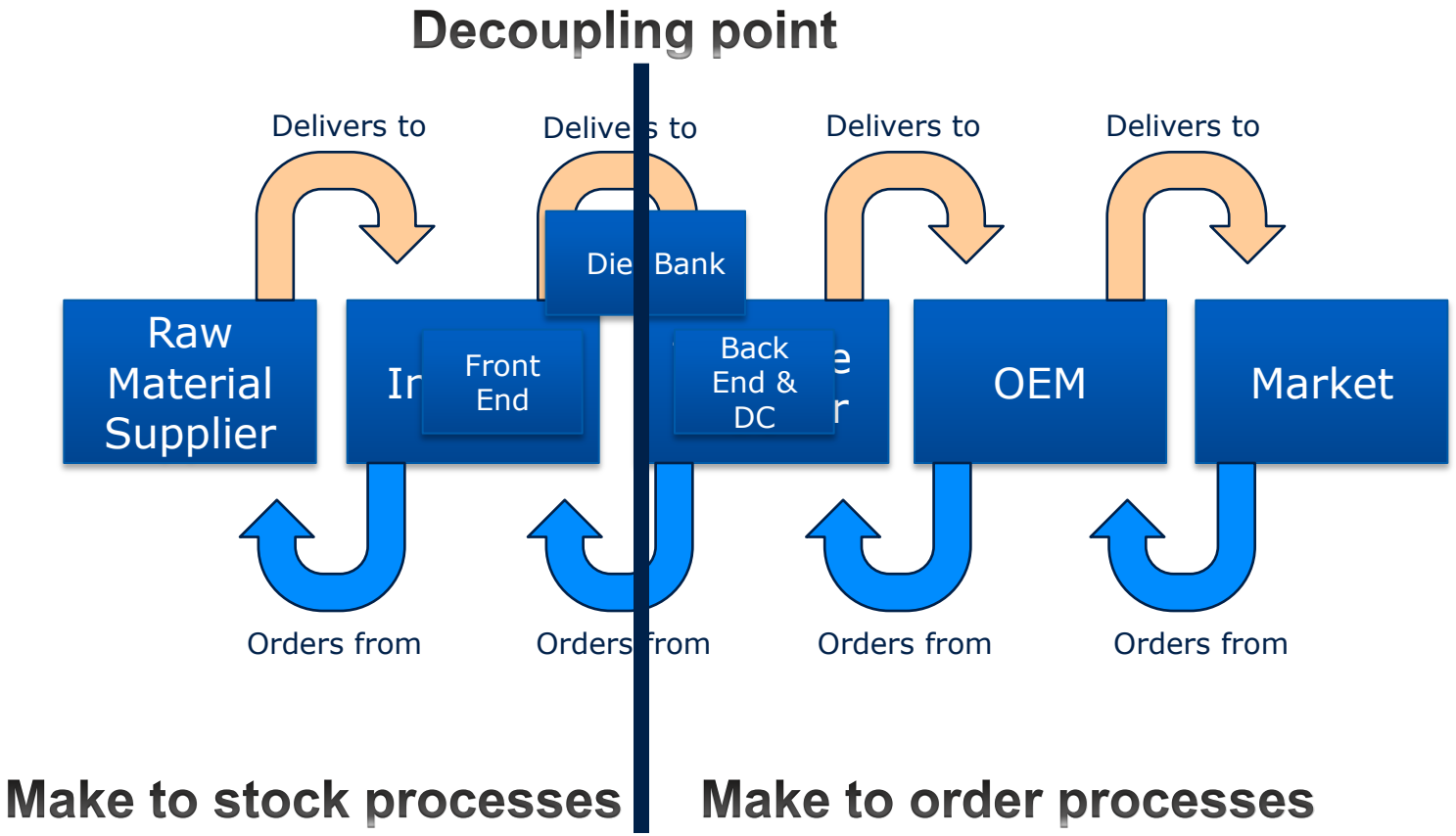
Model description Level 4

- The supply chain model consists of 5 main agents:



Model description Level 4

- The Decoupling point is at the Infineon Die Bank:

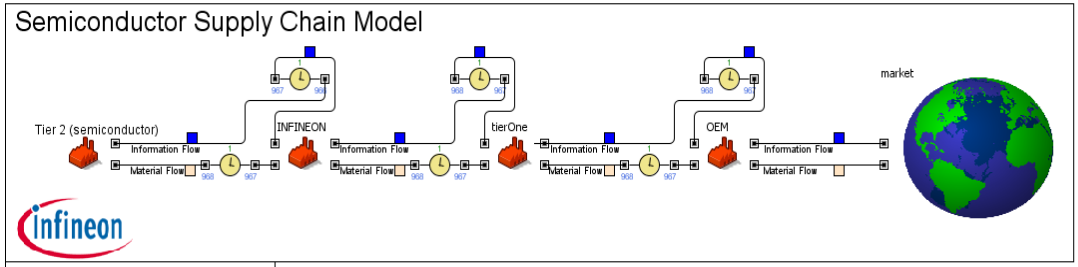


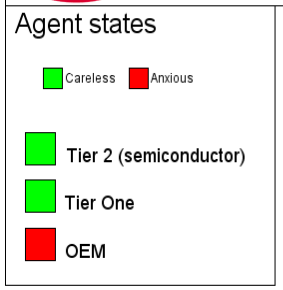
Note: Make to stock process based on an average demand forecast by Semiconductor Planning and control agent and a target stock at semiconductor DC agent.

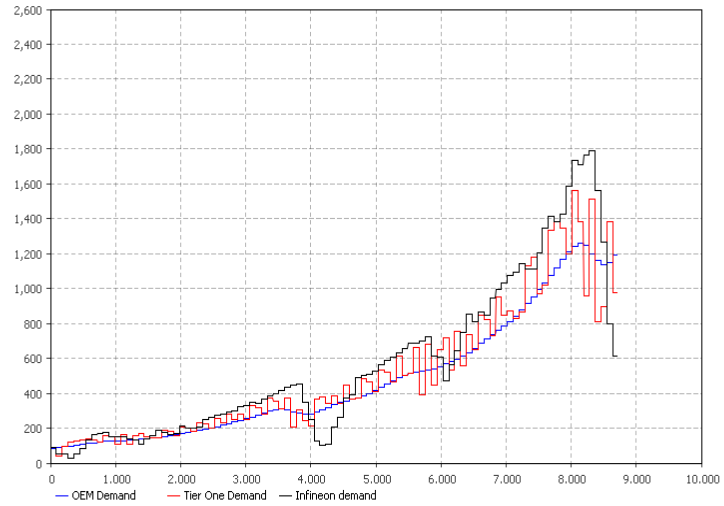
SC Simulation Level 4

Example: The Bullwhip Effect in IFX End-to-End SC

- Demand distortion along the supply chain
- Main root cause lies in the (over-)ordering behavior of the planner
- Agent-based modelling is used to represent the planner's state: 'feeling safe' vs. 'anxious'
- Real demand data is used
- Target: Training, awareness and mindset change







Global Demand

"Instead of *company to company* competition,

We are now in an era of *supply chain to supply chain* competition."

Dr. Hau Lee – Stanford University

Structure of the Simulation Library

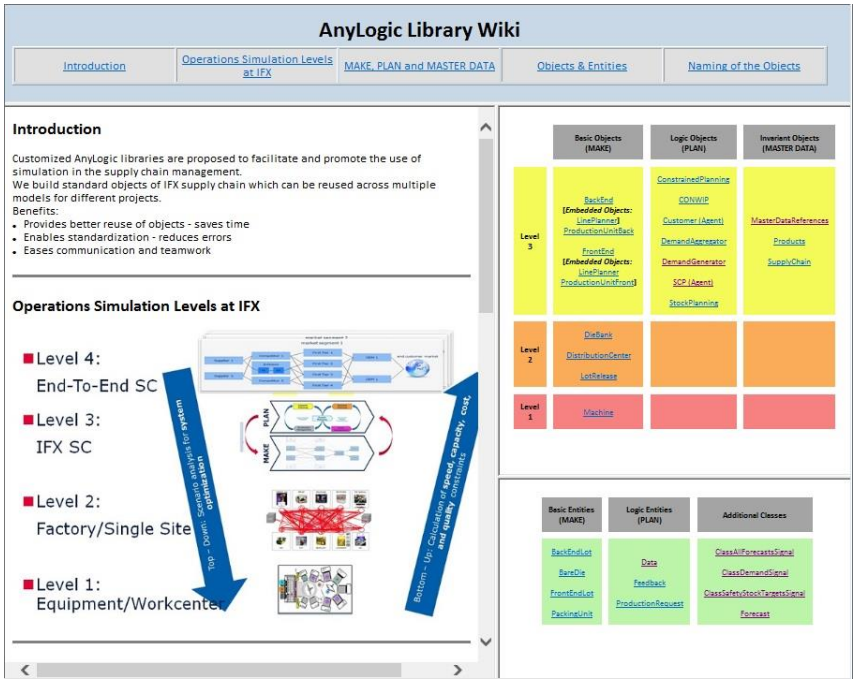
Library matrix

Simulation Level	Make	Plan	Master Data
Level 4: End-To-End SC	-Manufacturer (IFX) -Supplier -Customer End customer -	-IFX SC planning -Demand generator	-Sales product (SP)
Level 3: IFX SC	-Lot -FE/BE site -Die-bank -Distribution center	-Demand/supply Match -Order management -Min/safety stock targets -Demand generator	-Supply Chain -Basic type -Finished product (FP)
Level 2: Production Site	-Lot -Machine -Operator -Automated material handling system (AMHS)	-Dispatching -Scheduling -WIP control -Site preventive maintenance	-EPA/UPS -Basic type -Finished product (FP)
Level 1: Cluster/ Equipment	-Lot -Machine -Operator	-Dispatching -Scheduling -Machine preventive maintenance	-EPA/UPS

Precise & up-to-date documentation is a must for a user-friendly library

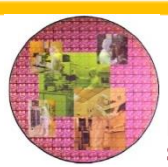
AnyLogic Library Wiki

- Homepage with basic information about AnyLogic & SC Simulation @ IFX
- Object descriptions:
  - "User manuals": all necessary information for users to be able to use the objects in own models (general description, implementation, inputs/outputs)
  - "Modeler pages": further information on the models behind the objects (descriptions of parameters, functions, events, etc.)



Huge Potential for Collaboration with Academia in supply chain complexity and simulation

Prof. Martin Grunow
Prof. Rainer Kolisch
Dr. Jens Brunner
Technische Universität München



Prof. John Fowler
Prof. Oliver Rose
Modeling and Analysis of Semiconductor Manufacturing (MASM)

Prof. Lars Mönch
FernUniversität in Hagen

Research
Fundings
Associations
Education
Academics
aSC³

EDB SINGAPORE
IDA IRELAND
Federal Ministry of Education and Research
PEOPLE

Joe Francis & C. Hunsche
SCOR Supply-Chain Council
Dr.Rolf Winter
ZVEI: Die Elektroindustrie
AKJ Automotive
VDA Verband der Automobilindustrie
ITA
Darius Zand
Prof. K. Schimdt

Michael Hennessy, Prof. Cathal Heavey
University of Limerick
Ollscoil Luimnigh

Chips@School

UNITECH International

Prof. Hau Lee

Prof. Brüggemann-Klein
Technische Universität München

Prof. Zangl
Hochschule für angewandte Wissenschaften FH München

Dr. Gönsch
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Prof.Detlef Urhahne
Jens van Scherpenberg
LMU Ludwig-Maximilians-Universität München

Prof. de-Souza
NUS National University of Singapore

Prof. Kenichi Nakashima
Kanagawa University

Prof. Hoppe
MD.H Mediadesign Hochschule

Prof. Takashi Irohara
Sophia University 上智大学

Fraunhofer IPA
Prof. Bauernhansl

Prof. Koh
SMU Singapore Management University

Fraunhofer IAO
J. Lentes

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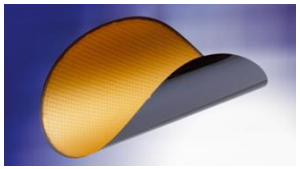
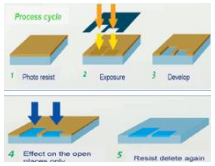
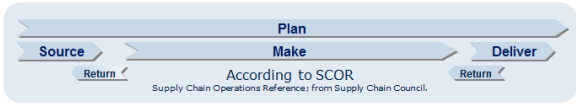
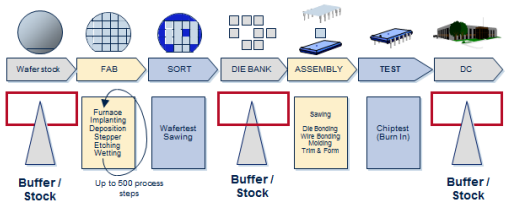
„The Supply Chain as a Competitive Advantage – The Four Levels of Semiconductor Supply Chain Simulation"

- The semiconductor innovation race continues

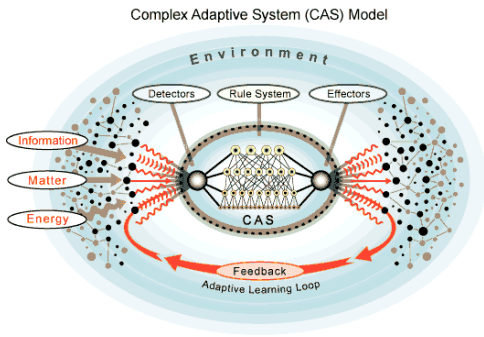


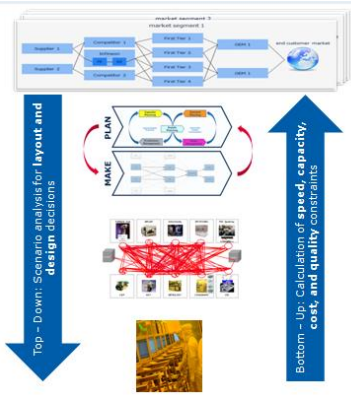






- The global supply chain is our new Fab; We are complex adaptive system where we need to reduce non value add complexity on all four levels; simulation enables understanding, testing solutions and supports implementation





- There is a huge potential when biz from suppliers supplier to customer customer and from industry and academia goes hand in hand & next steps of collaboration became reality

Thank you very much!

Contact: Hans.Ehm@Infineon.com