Implications of Intelligent, Integrated Microsystems for Product Design and Development

IEEE Engineering Management Conference

Monday, August 14, 2000

Disruptive Technologies: MEMS.

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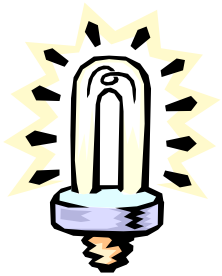
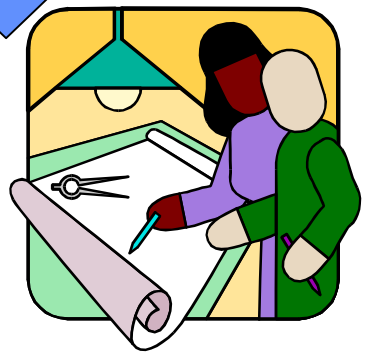
This presentation focuses on the product delivery system



For this discussion we are ignoring:
- marketing and sales
- inbound logistics
- customer service.

Envisioned Product Need



Product Delivery System

Solution

Customer Input

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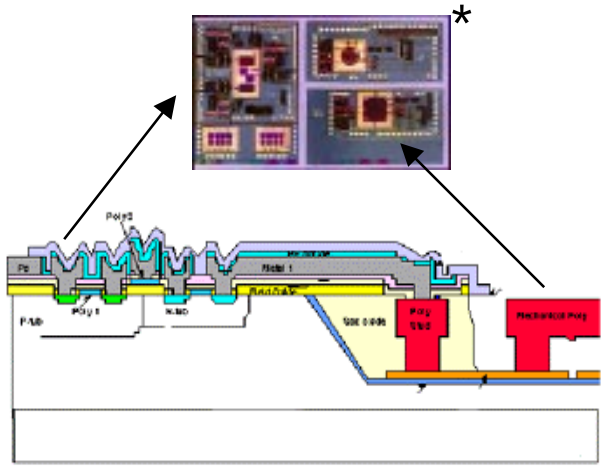
Integrated products are fundamentally different from assembled products

Assembled products:

- are constructed from (largely) independently procured components
- production capacity differs from R&D centers



Integrated products:

- are designed at all once,
- are assembled all at once, thus
- the R&D capability becomes the delivery system
- all parts of the enterprise must have equal say in decision making.

*Inertial sensor designed by UC Berkeley

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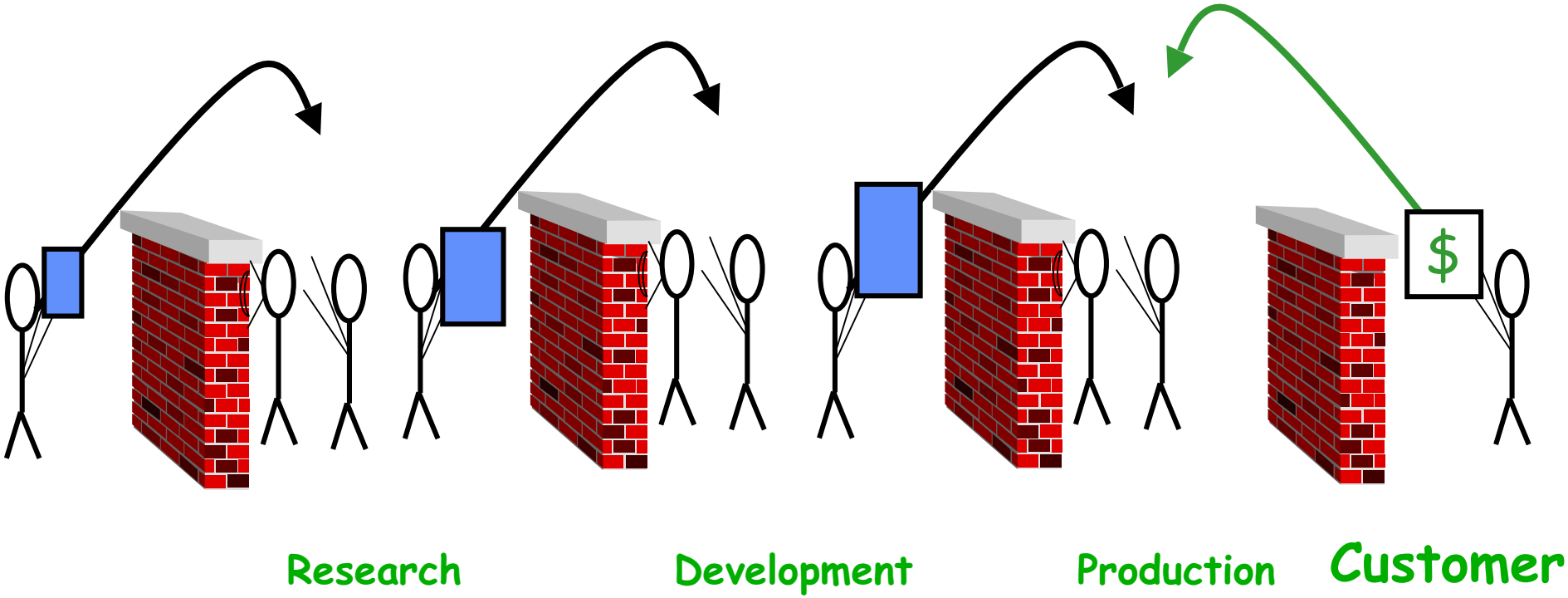
The mid-1970's production enterprise was partitioned into functional elements.



R → D → A

Research Development Application

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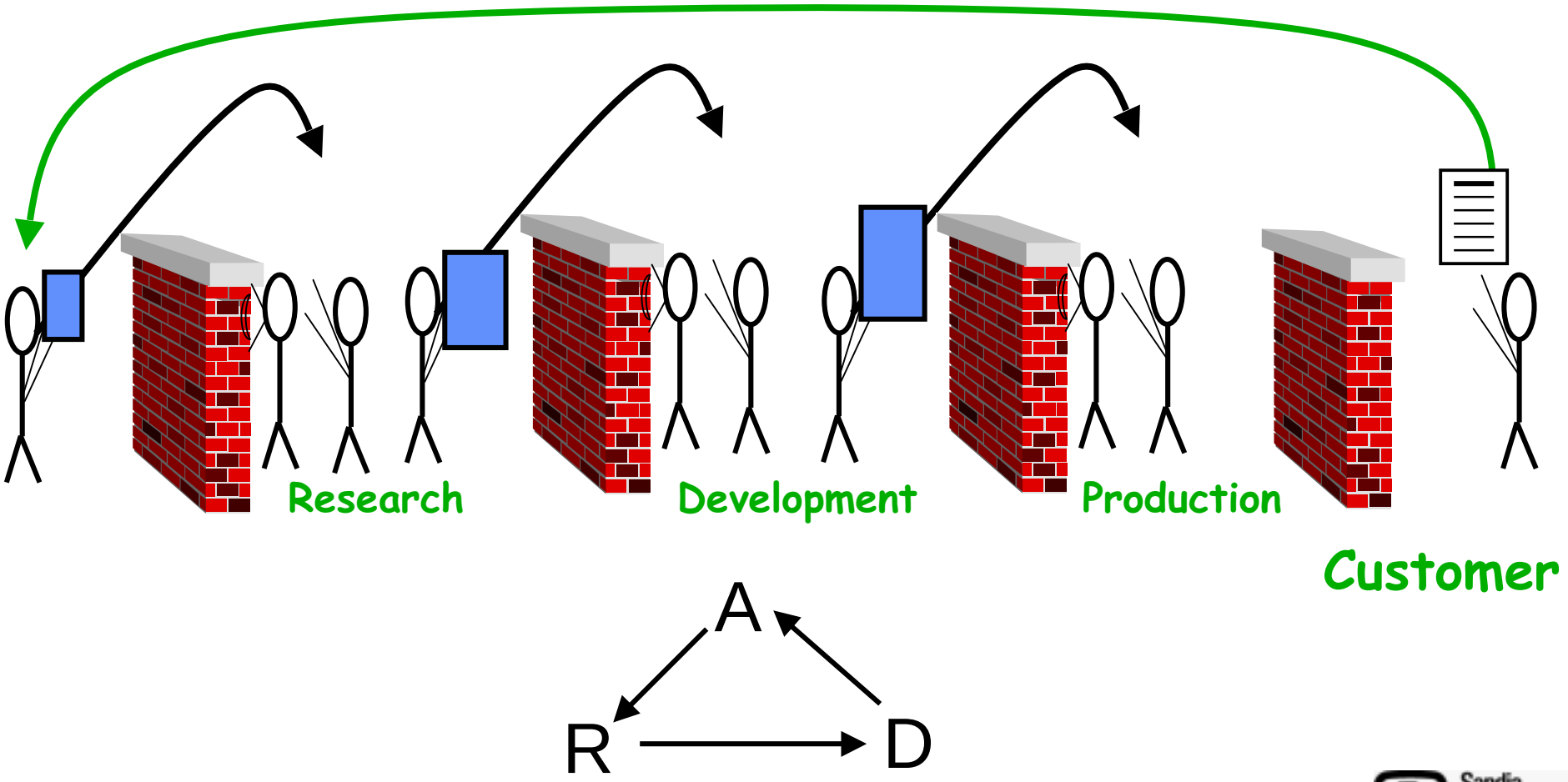
Sustainable enterprises use market feedback to guide R&D activities



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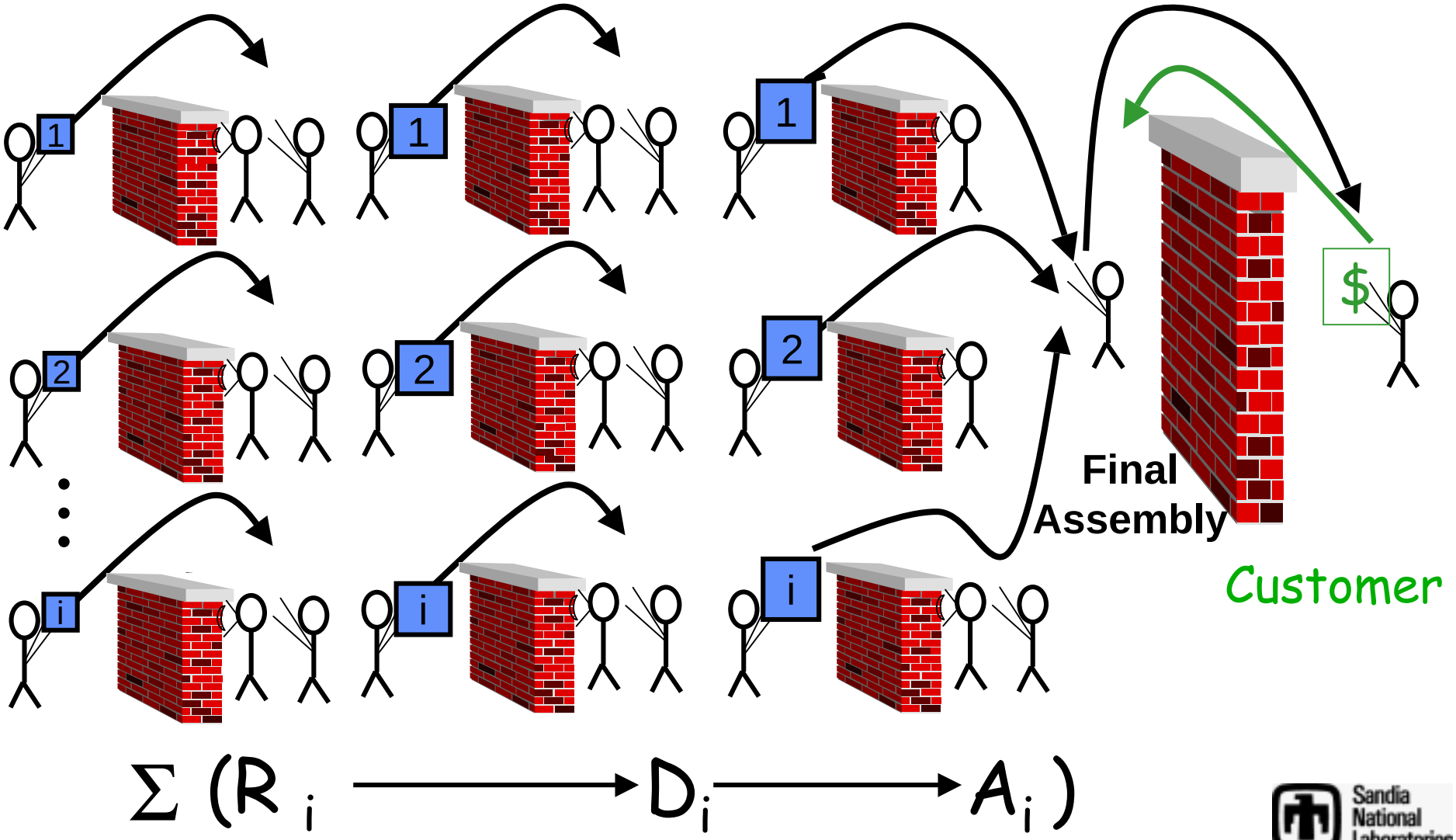
Concurrent engineering expedited production of assembled products



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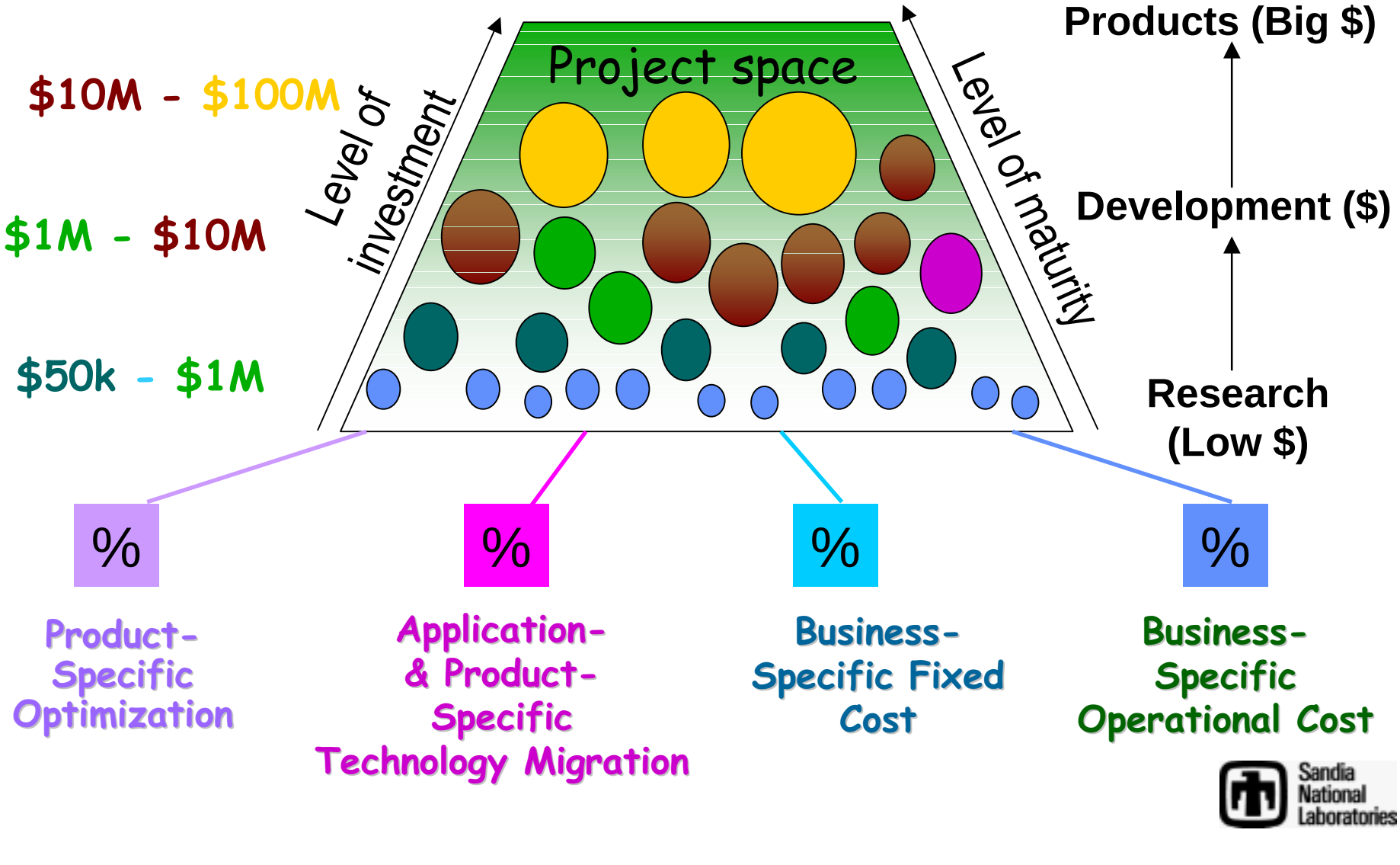
Investment allocations lead to a hierarchical organization "food chain"



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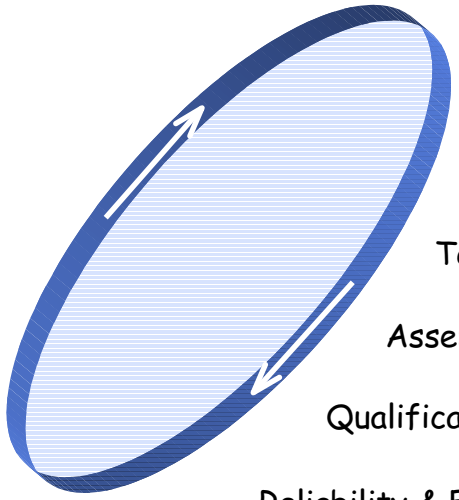
Product-specific supporting infrastructure evolves in a closed cycle



The supporting infrastructure includes:

- Design Tools
- Fabrication Process
- Test Methodologies
- Assembly and Integration
- Qualification Methodology
- Reliability and Failure Analysis.

Infrastructure evolves as technology evolves.

For assembled products, these activities are (essentially) independent for each constituent component

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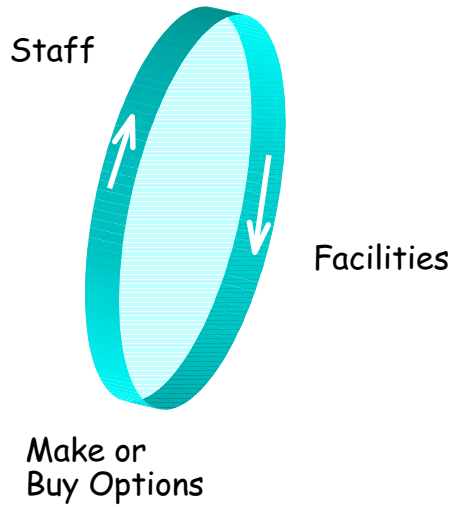
Business-specific fixed costs are coupled in an evolutionary cycle



The business specific costs include

- Staff
- Facilities

The capabilities resident in the staff and facilities determine the trade-offs for *make or buy* decisions:

for components in assembled products,

for design, fabrication, test activities within component manufacturing.

For assembled products, these activities are (essentially) independent for each constituent component

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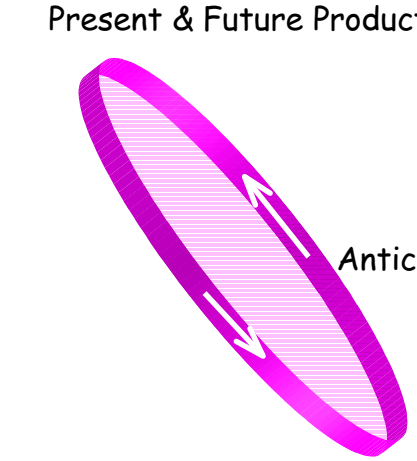
Product migration couples evolutionary and revolutionary research



Product migration is driven by the definition of present and future product specifications:

- Anticipatory product research
- Product development
- Manufacturing optimization
  - unit processes
  - assembly processes

For assembled products, these activities are (essentially) independent for each constituent component

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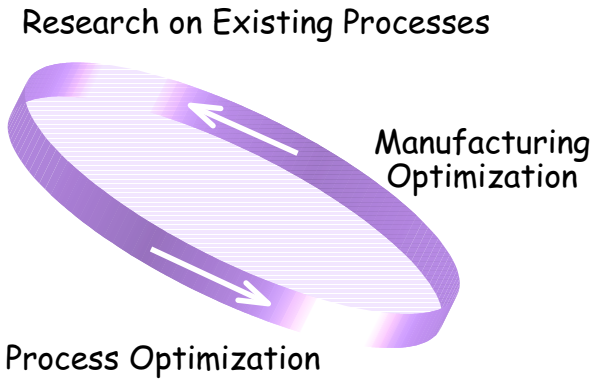
Manufacturing optimization requires process and manufacturing evolution



Product-specific manufacturing optimization involves

- Research on existing unit processes and evolutionary roadmaps
- Manufacturing optimization

For assembled products, these activities are (essentially) independent for each constituent component

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People have an innate ability to confound any proposed analytical hierarchy

With varying degrees of success, traditional organizations that manufacture assembled products propose flattening organizations to:

- Reduce costs to better compete in global market
- Expedite decision making by increased empowerment of more organizational levels
- Better manage information flow

We're here to tell you that integrated products don't give you a choice of functional structure!

Technological imperatives force flatter functional organizations whether you want them or not!

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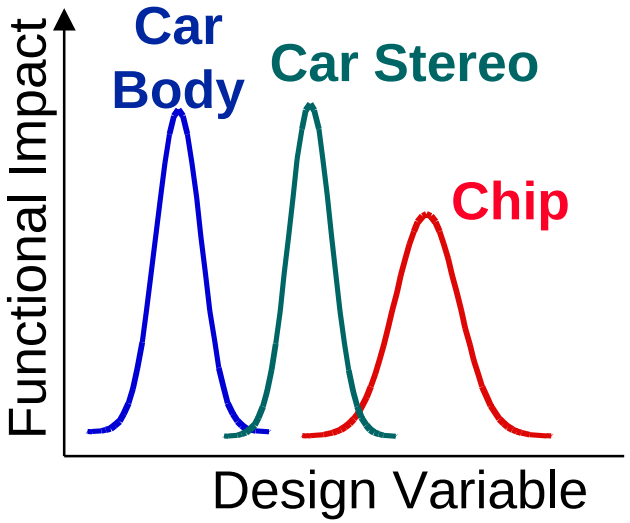
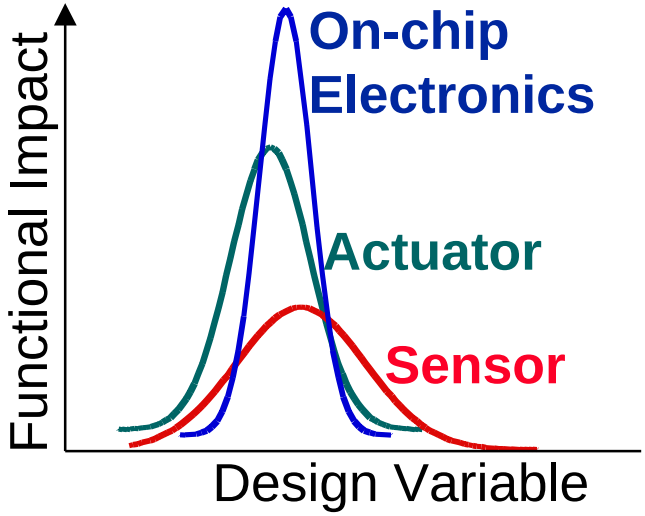
Functional elements interact very strongly in highly integrated products





Assembled product:
Chip overlaps car stereo in several specs: heat tolerance, power supply, bus architecture, etc.
But the car can be designed and assembled with little thought for the chip in the car stereo.
Only the power system and the dashboard or trunk wiring harness matter as far as the chip or the car stereo is concerned.

Integrated microsystem:
Every part must be designed in anticipation of every other part before the entire ensemble is fabricated simultaneously.

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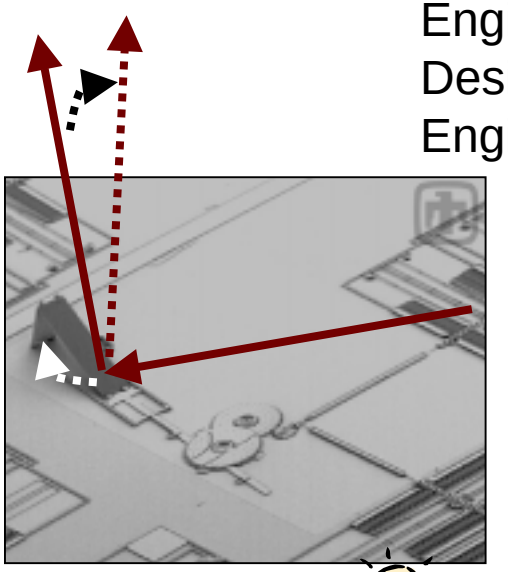
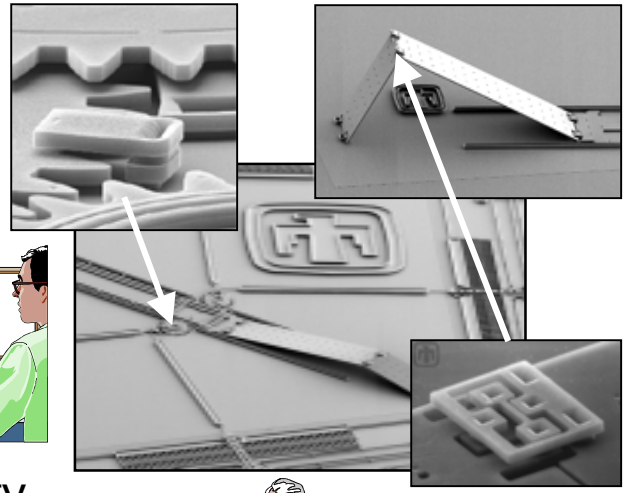
All functional elements must be given equal importance in integrated products.

Component Engineer, Design Engineer

Technology Engineer

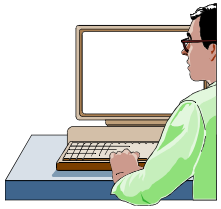




Process Engineer

Application Engineer

Quality Engineer



Material Scientists

Flatter functional organizations will result from the need to satisfy simultaneously *all* the production constraints.

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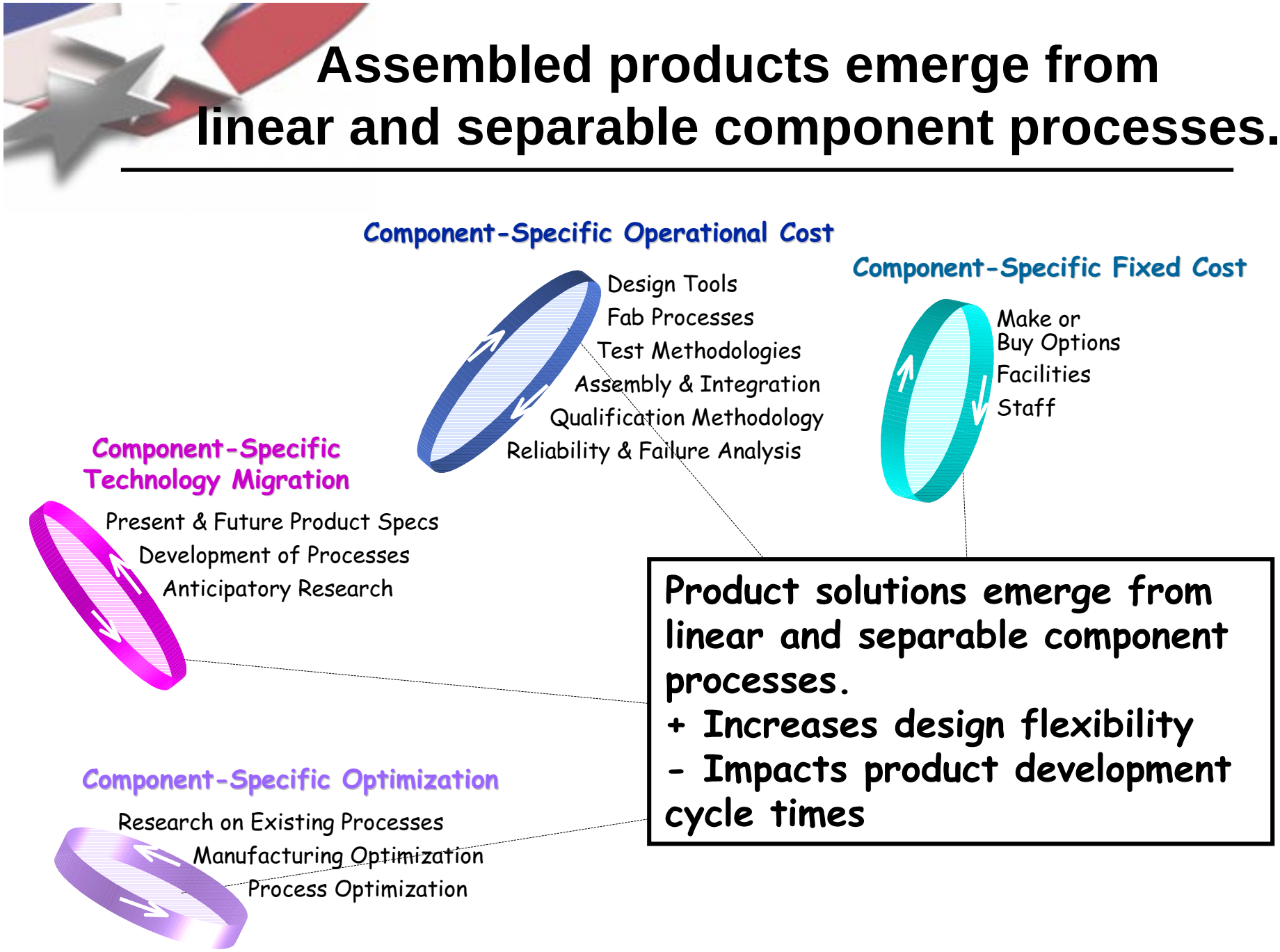
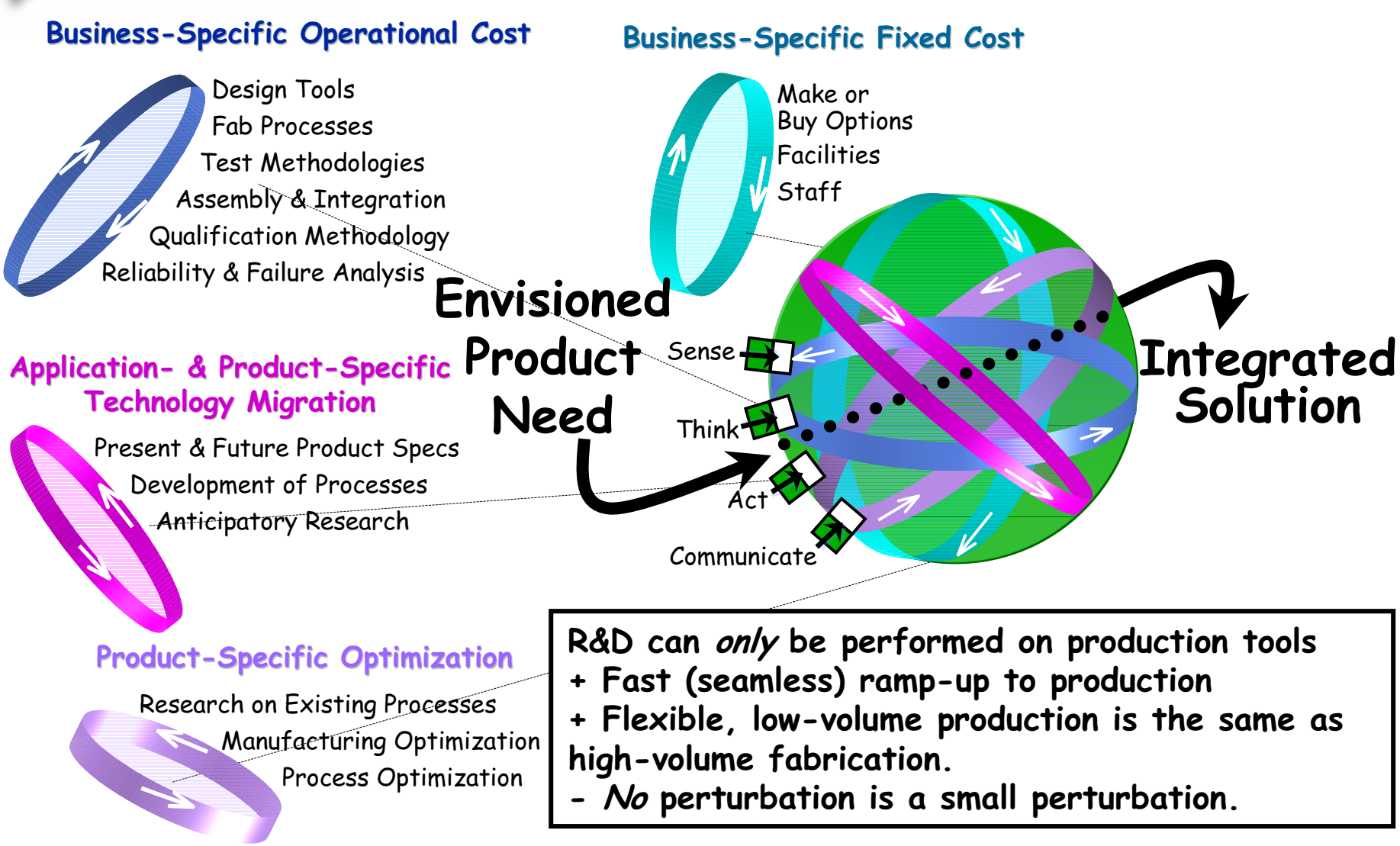
Assembled products emerge from linear and separable component processes.

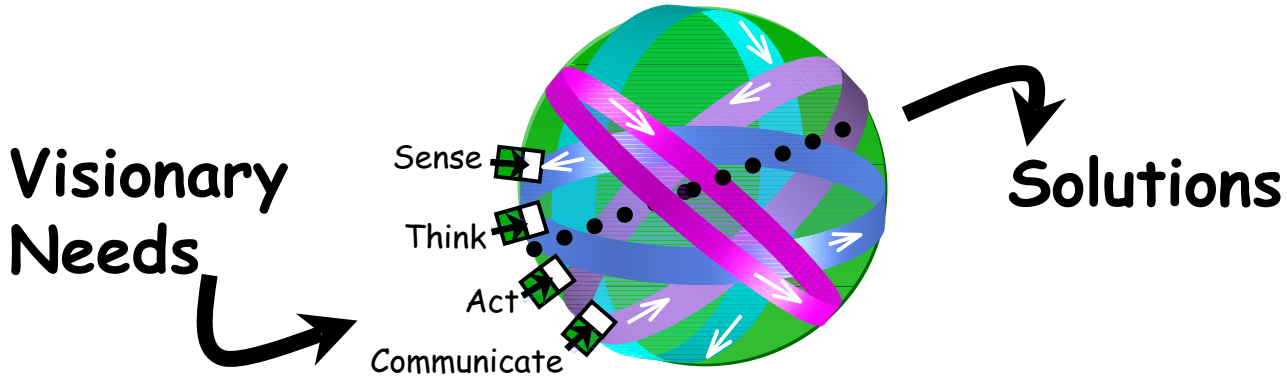


Integrated products couple all the manufacturing functions.



R&D can *only* be performed on production tools
+ Fast (seamless) ramp-up to production
+ Flexible, low-volume production is the same as high-volume fabrication.
- *No* perturbation is a small perturbation.

The manufacturing path for integrated products resembles a chaotic system.



Integrated microsystems couple production activities because the product is manufactured simultaneously.

- If the components interact strongly with each other, then product development evolves from initial conditions
- Make or buy options become restricted to infrastructure issues.
- The desire to maximize reuse of existing capabilities thus constrains evolution of the enterprise from initial capability and products !
- Incremental improvements impact the entire system (**no small changes**)!
- Infrastructure exhibits a **strong dependence on initial conditions** (it is a "chaotic system" in the mathematical sense).

Integrated nature of microsystems production constrains business decisions.

- **Either *make or buy* production infrastructure (design tools, fab equipment, technology, reliability, etc.)**
  - **License technology to:**
    - **expedite market entry**
    - **cost leverage an industry standard**
  - **Develop your own technology**
    - **optimize around a target product or market**
    - **obtain proprietary advantage**
- ***Any* process tweak in integrated production could disrupt all established infrastructure elements, leading to either:**
  - **a divergence of technologies, or**
  - **a limit on product integration.**

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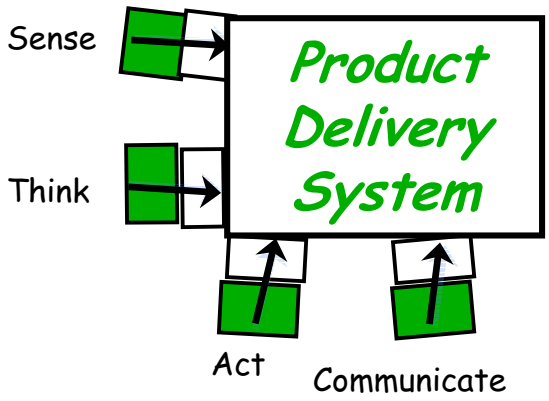
Simultaneous production mandates mutually compatible product functions.



Technology platforms for integrated microsystems can accommodate any or all of the following:

- Sensing
- Thinking (processing information)
- Actuation
- Communication

Each function will require its own optimization strategy for design, production, and test.

Manufacturer must choose where to limit level of integration !

- more integration leads to more design and fabrication complexity
- less integration leads to hybrid products.

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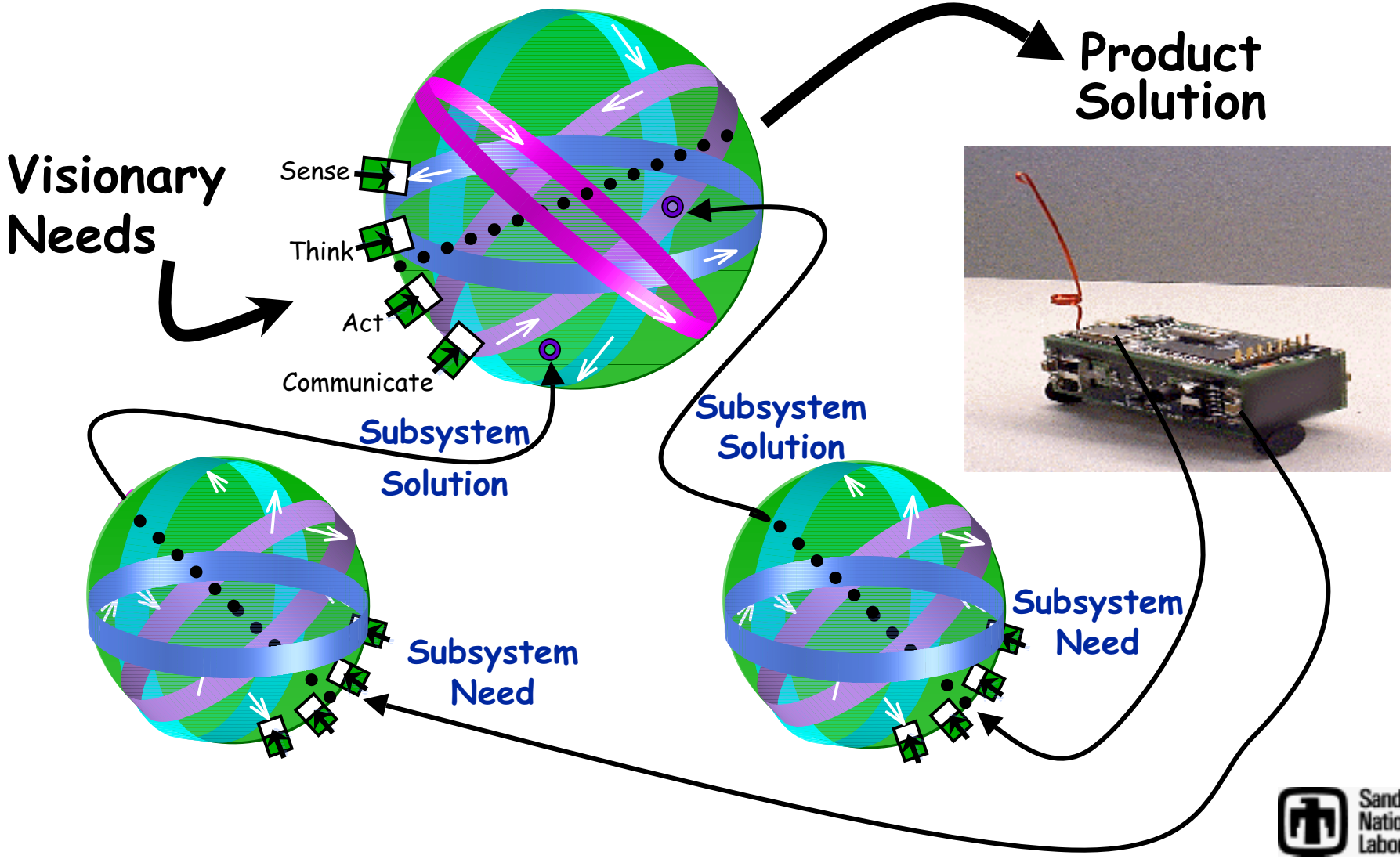
"Mini"system hybrids will trade efficiency for flexibility in assembled products.



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Summary: Integrated microsystems impact product development organizations

- Integrated (simultaneously assembled) products mandate flatter functional organizations
- Integrated products blur previous distinctions between research, development, and production
  - ♈fast ramp up, flexible production
  - – no change is a small change
- Integrated product infrastructures will evolve from first successful products (chaotic model).
- Manufacturers must choose to:
  - "make or buy" infrastructure elements (standardize or customize production).
  - trade "microsystem" efficiency against "mini"systems flexibility in future products.

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