Full Research for Sustainable Industry

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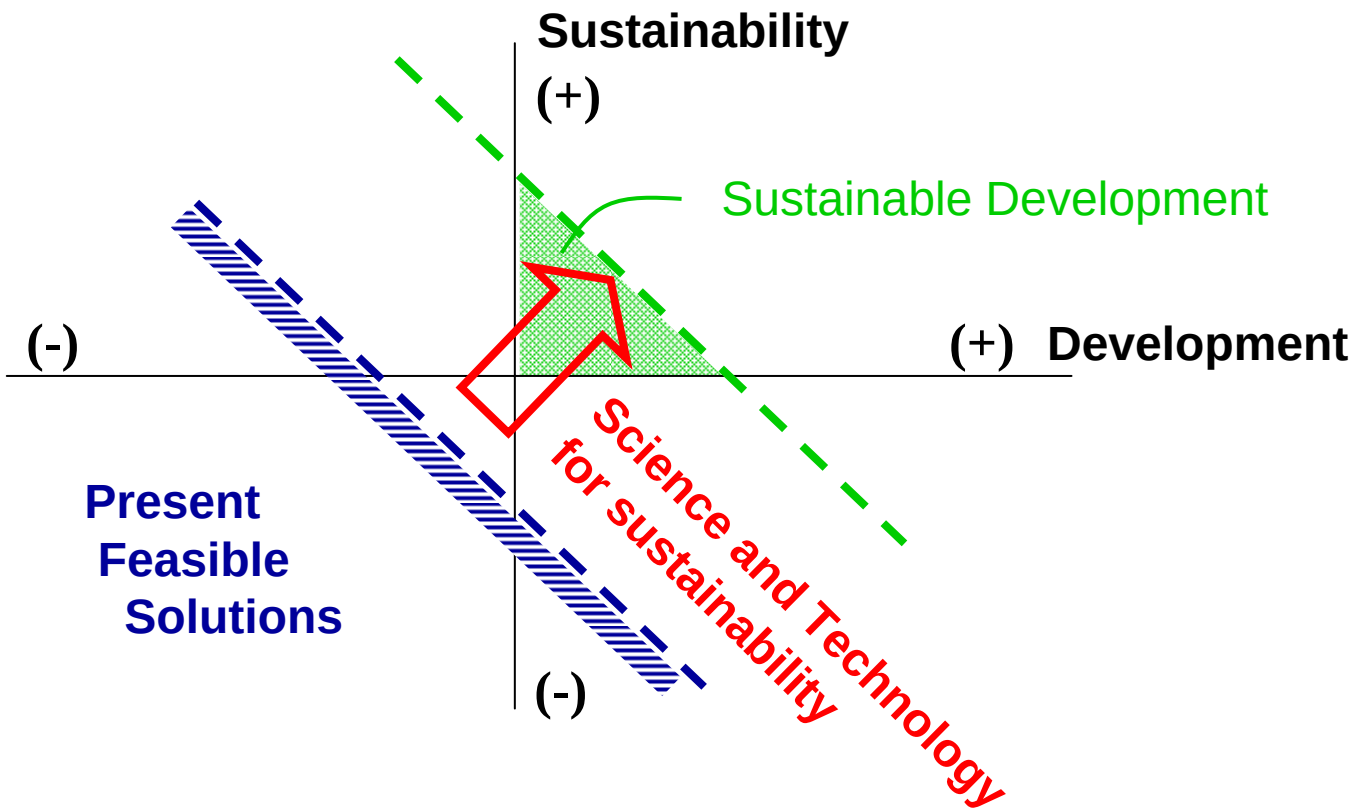
Sustainable Development

1987 Our Common Future by G.Brundtland

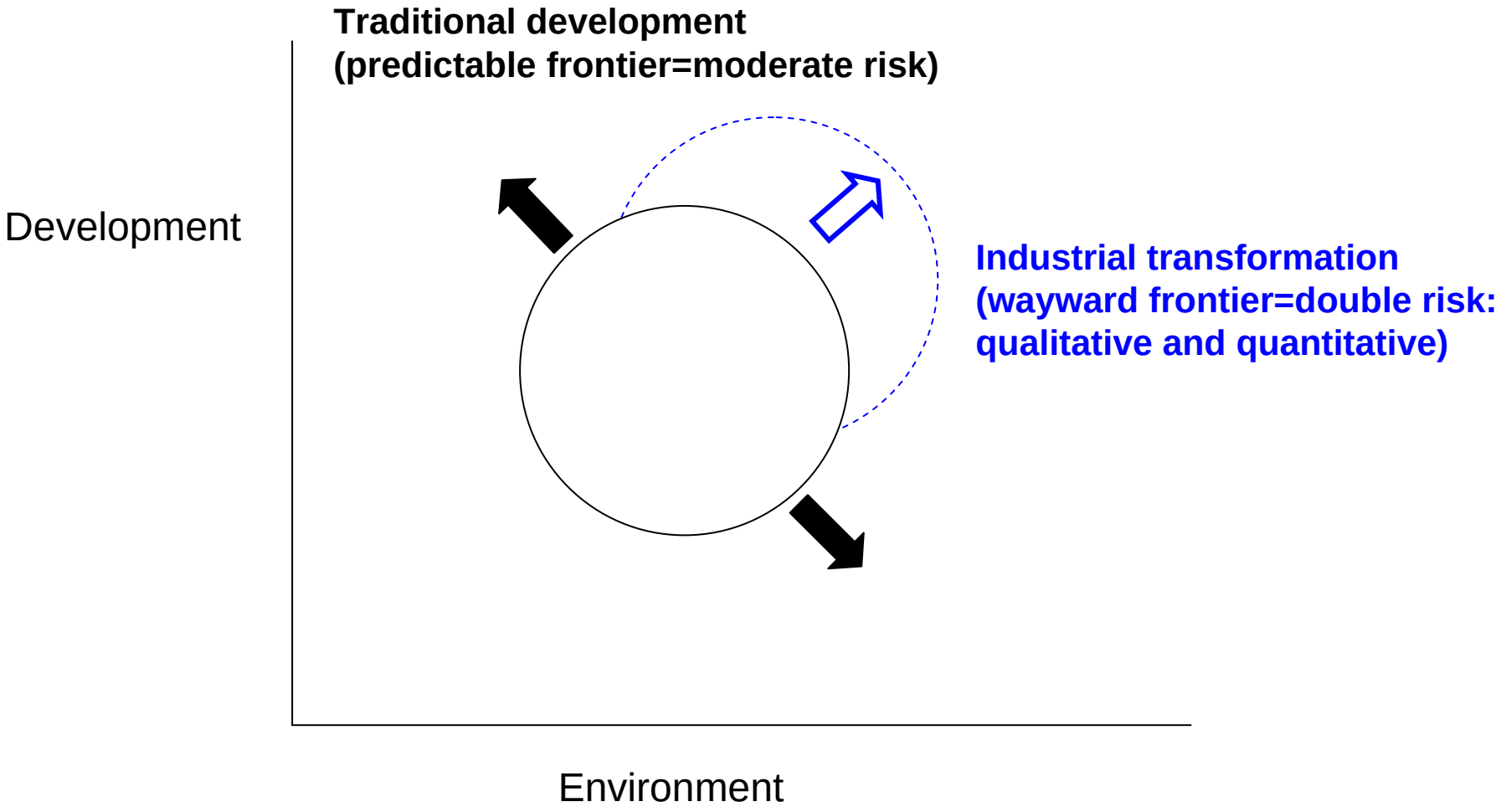
Sustainable Development

= (Sustain the earth) ^ (Develop Less-developed Regions)



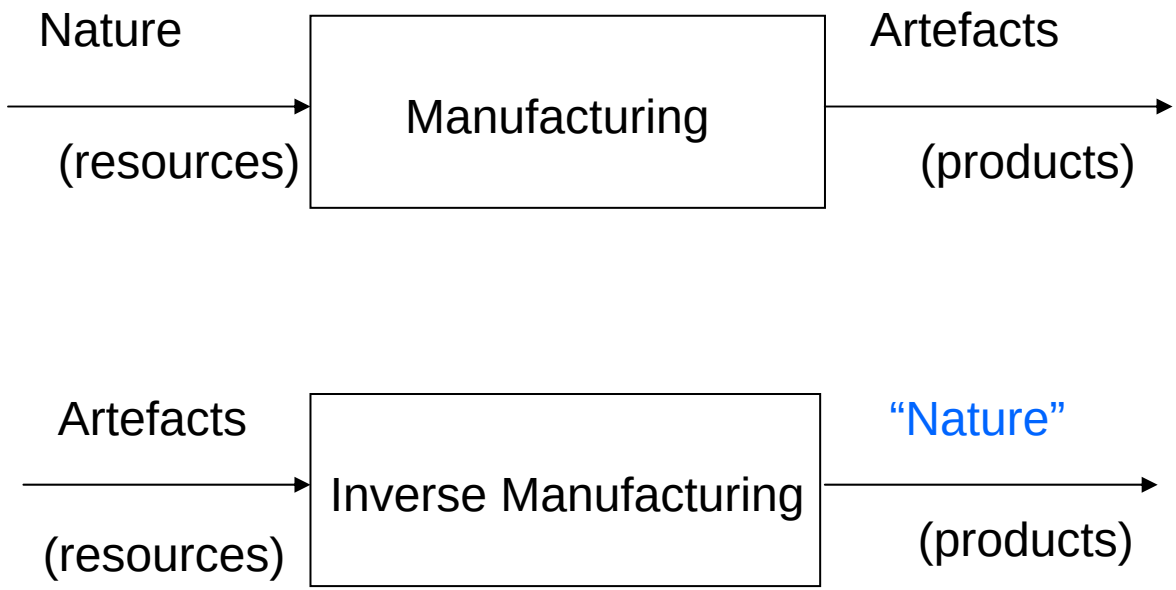
Making a Shift toward Sustainability

"Industrial transformation"



Necessity for Sustainability

Inverse Manufacturing



Remedied nature,
Ecosystem recovered,
Ecosystem services resumed,
Chemical-free agriculture,
Resource by recycle,

Practices of Manufacturing and Inverse Manufacturing

Manufacturing

Mining,
Reclamation,
Construction,
Cultivation and agriculture,
Production of materials,
Production of goods, etc

Inverse Manufacturing

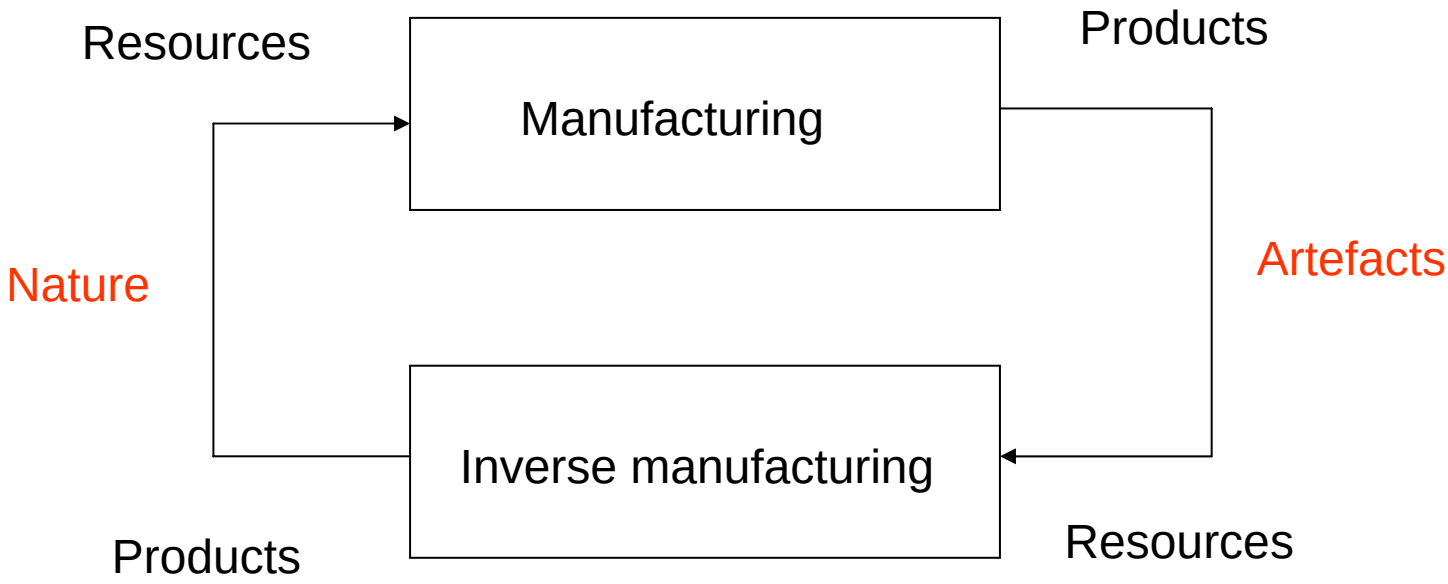
Forestation of desert,
Fish farming,
Recovery of contaminated lands,
Biomass in devastated coast,
Carbon sequestration,
Bio decomposition of plastics,
Waste processing,
Maintenance, etc

For sustainability, it is necessary to;

1. improve efficiency of either manufacturing,
2. keep good balance between both manufacturing, mutually dependent, for optimality, and
3. integrate manufacturing and inverse manufacturing toward a system.

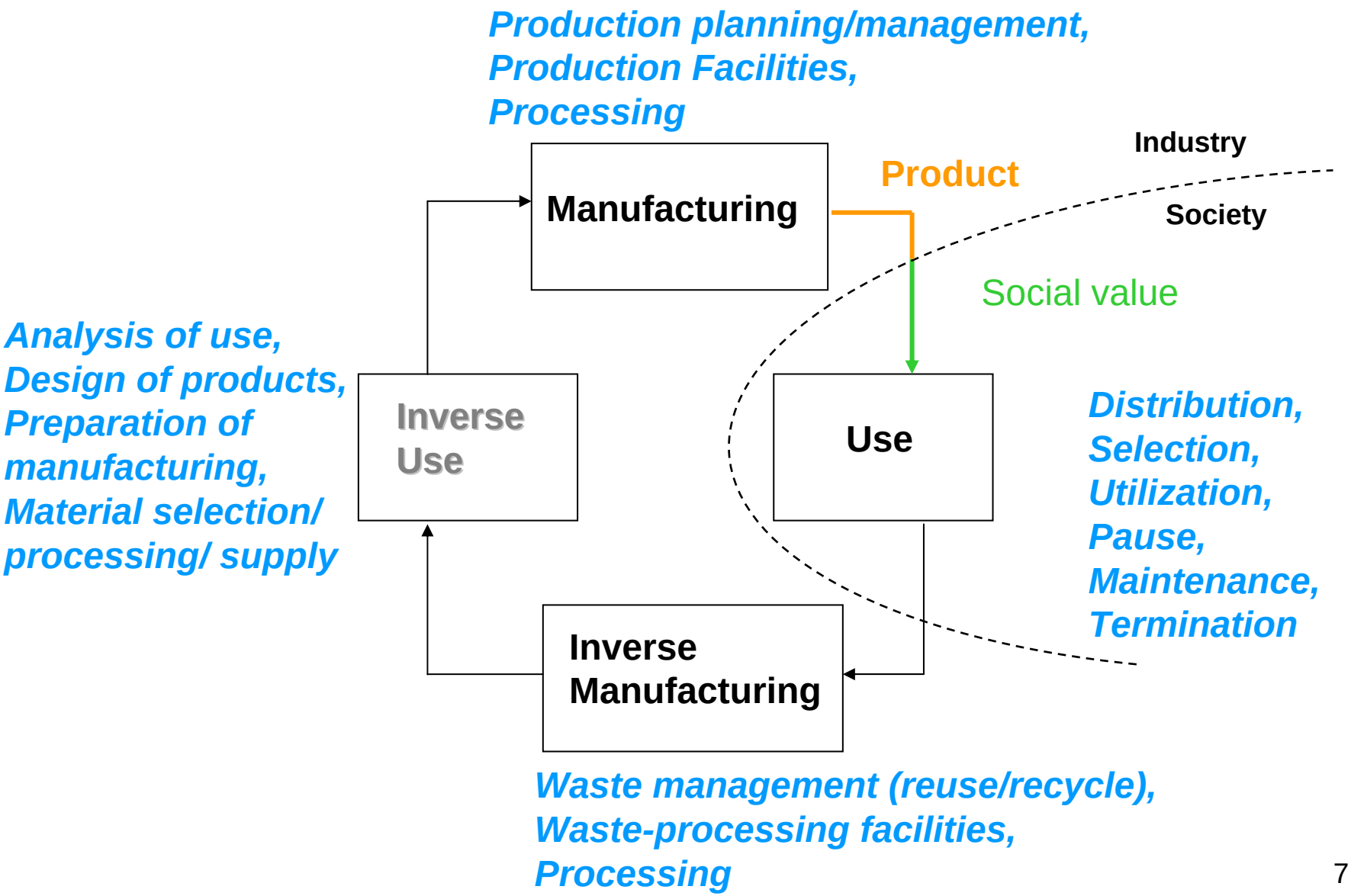
METHODS : 1. STRUCTURE OF HUMAN ACTIONS
2. SUSTAINABILITY METRICS

Integration of both Manufacturing
Closed- Loop Manufacturing



山家譲二、還元工場論、工業技術、１９７５

Elaboration of Actions in Loop (Evolution)



Values of a Product

1. What people value is not a product itself, but its functionality.

2. Functionality of a product is service embedded in the product.

3. Latent functionality appears as service when the product is used.

   (People receive the service someone embedded in the product, when they use the product.)

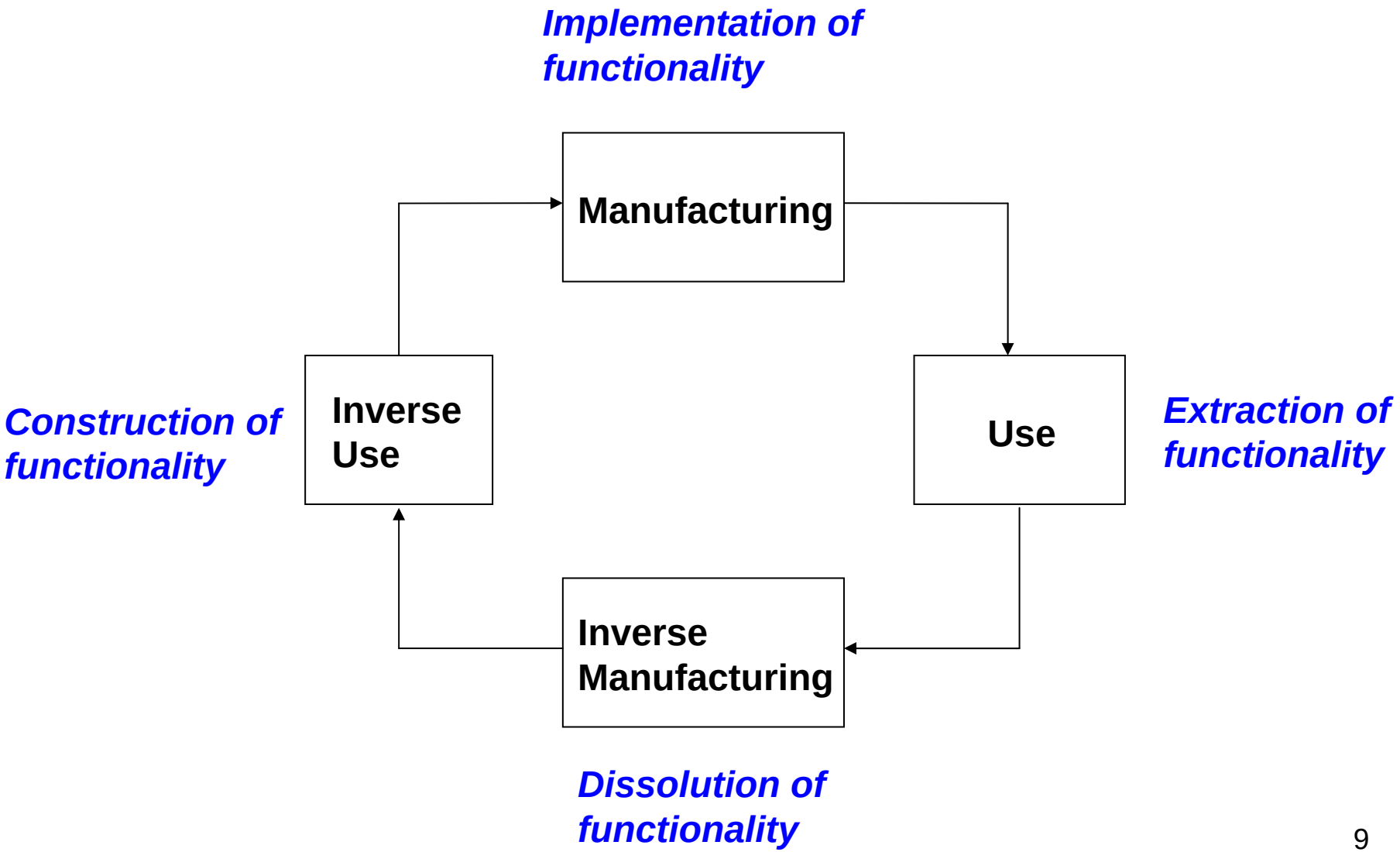
4. Functionality of a product decreases when it is used.

   functionality = Σservice

   (Life of a product terminates when services embedded are exhausted.)

5. Therefore, we can measure the potential value of a product by functionality, that is total amount of service available.

Loop in the aspect of Functionality



Minimal Manufacturing

***DEFINITION*:**

A manufacturing system to produce products of maximal functionality with minimal resource and energy consumption and with minimal waste

***ENABLING TECHNOLOGIES FOR MINIMAL MANUFACTURING* :**

High-density functional materials,
Nano-structures,
Nano-bio materials,
Energy efficient material processing,
Compact processes,
Self-organizing processes,
Localized clean room,
Mobile machine tools,
etc

Maximal Servicing

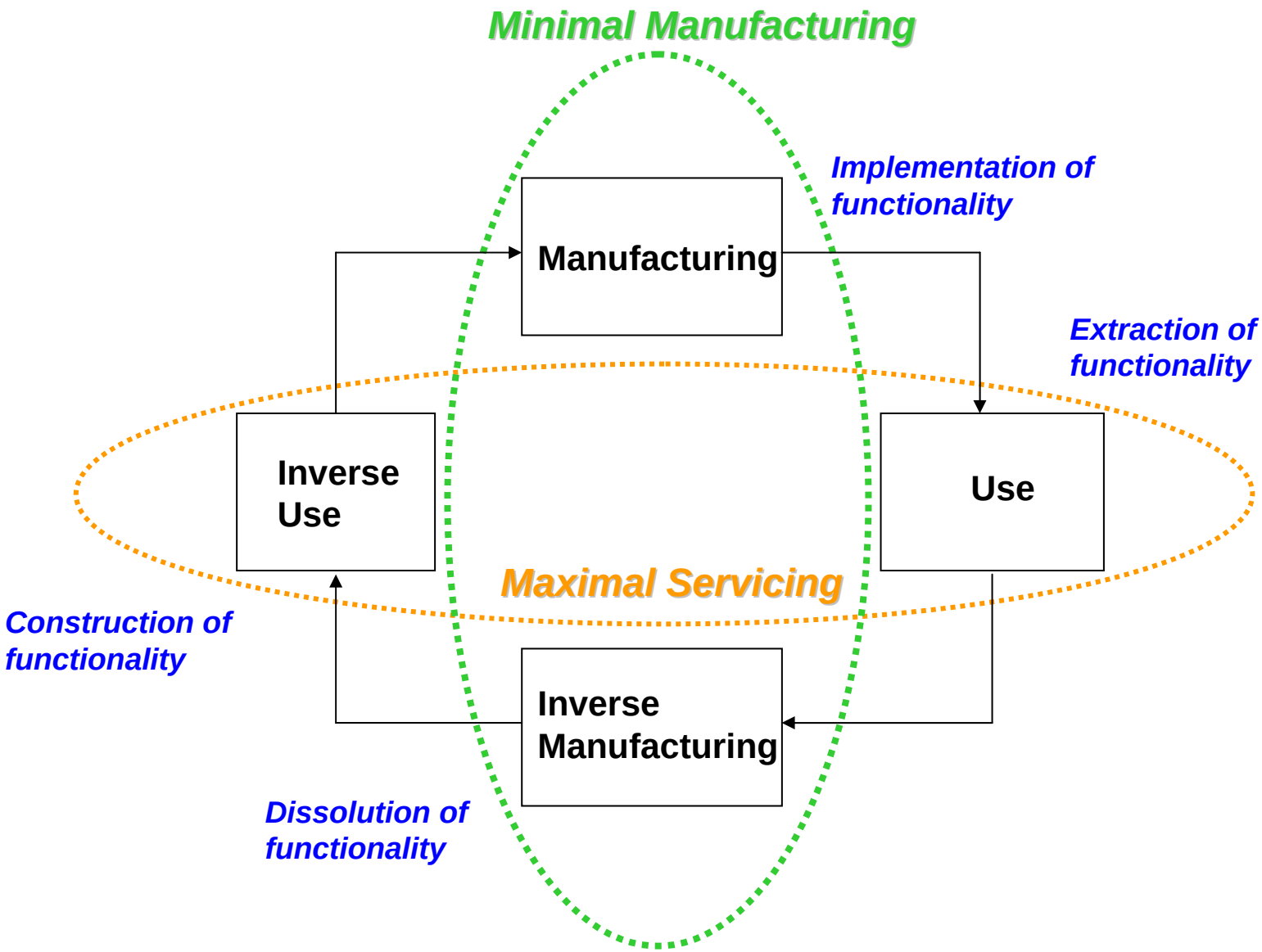
DEFINTION

A service system to do maximal services to people with minimal resource and energy consumption and minimal waste.

ENABLING TECHNOLOGIES FOR MAXIMAL SERVICING

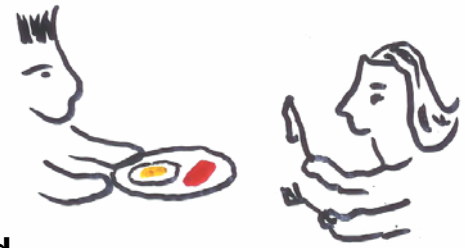
Design of products that efficiently generate services when used,
Low-cost allocation of products that allow people to access easily,
Appropriate social systems to access products such as architect,
Reasonable social rules to get services from products,
Sufficient longevity of products
Automation of maintenance,
Self-repair of products,
Easy collection of wastes,
etc

Minimal Manufacturing and Maximum Servicing for Sustainability

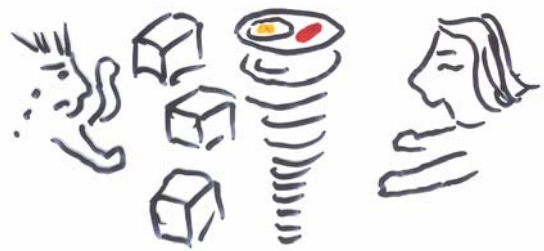


Proliferation and Amplification of Service

1. Fundamentally, service is made by one to someone else (primitive service).
2. Service is countable and unit of service is an independent completion of service. ex. one-hour lecture, cooking ham and egg for someone.
3. We shall measure the amount of service *s* by number of unit of service made by one to someone else.
4. When the service is done within time *u*, the service rate *r* is *s/u* . *
5. Service can be embedded into a specially designed machine. Embedded service is potential. When someone uses the machine, it becomes actual. If the service appears taking time *t*, the service rate is multiplied by *u/t*.
6. Service is available when the machine is used repeatedly, but the number of use is limited that is life of the machine, *n*.
7. A machine, therefore, proliferates the service by the life of machine.
8. When applied *m* machines, the proliferation of service is *n* x *m*. The total service is multiplied by *n* x *m*. It is a stock of service. We call the increase of service rate as amplification. It is *m* x *u/t*.
9. Wealth of a nation is given by total rate of service, instead of GDP.



1 unit



30,000units by three machines

* When it took you half an hour to cook ham and eggs for your wife, you made service 1 unit to her, and service rate is 2 (=1/0.5).

** When you serve your wife using three automatic ham and eggs machines until each machine exhausts its life (*n* = 10,000), then you make service 30,000 units to her. If the machine makes a ham and egg in 6 min., then the service rate is 30 (=3/0.1).

Sustainable Manufacturing

DEFINITION:

A manufacturing system that produces value

TARGETS:

Maximize the total value

Dogma for sustainable manufacturing

1. **Total value is the sum of values natural and artificial.**
2. **Natural value is functionality of space, eco-system and resource.**
3. **Natural services generate when space, ecosystem or resources are used.**
4. **Artificial value is functionality of primitive services, material and product.**
5. **Artificial services generate when primitive services, material or products are operated/used.**

A Strategy for Sustainable Manufacturing

Natural value : Space,
Functionality of eco-system (eco-system services),
Mineral resource, Energy resource, Bio resource

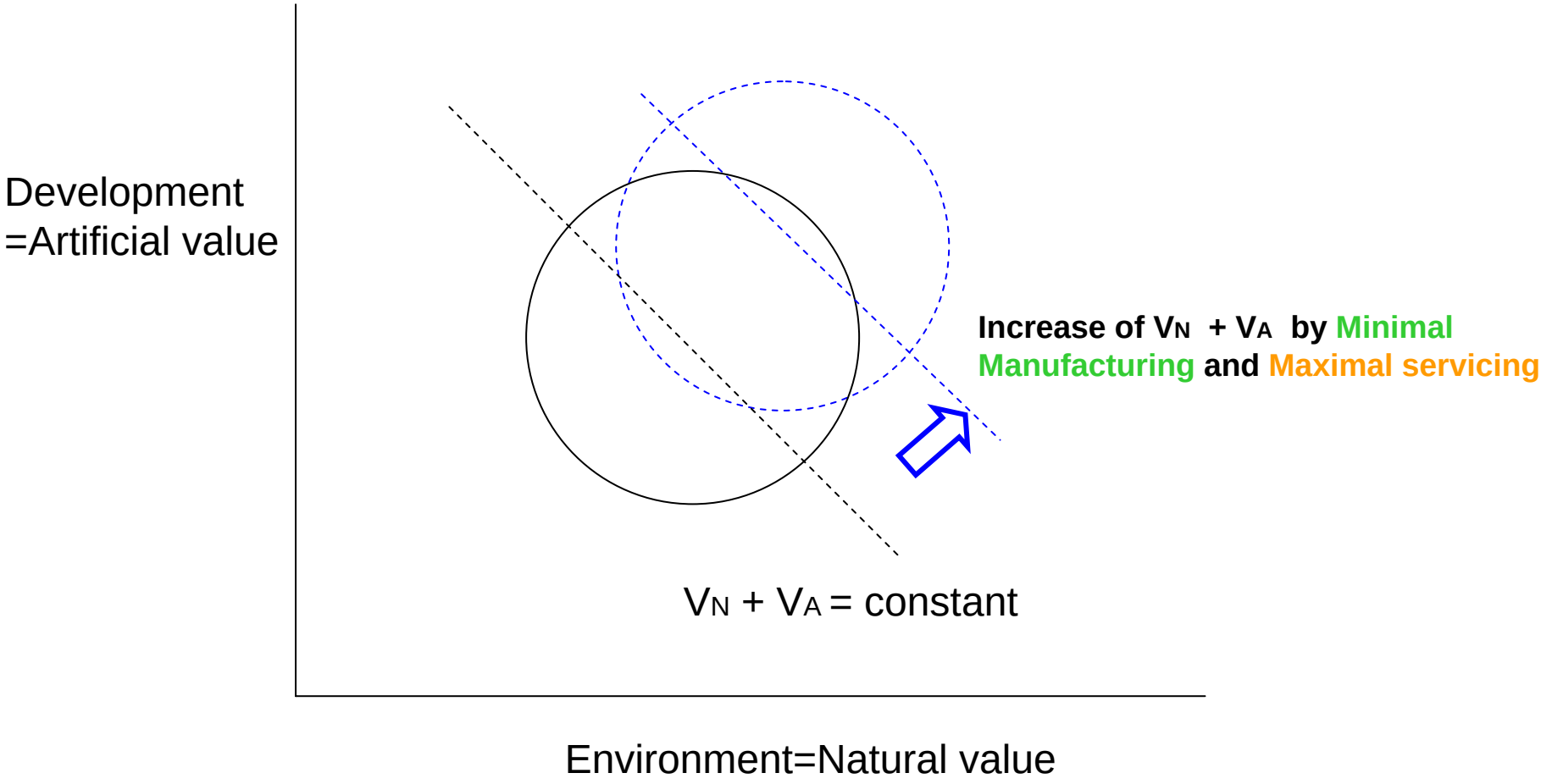
Artificial value : Primitive services potential,
Functionality of material,
Functionality of products

Total Value =(Natural value + Artificial value)

A sustainability paradigm :
Increase the total value by means of
minimal manufacturing* and *maximal servicing

Making a Shift toward Sustainability

"Industrial transformation"



Various Indices of Productivity

Conventional:

$$\text{Productivity} = \frac{\text{Production of Goods}}{\text{Cost (Labour, Materials, Space, Time, etc)}}$$

Global aspect:

$$\text{Global Productivity} = \frac{\text{Global Production of Goods}}{\text{Environmental Burden by Manufacturing}}$$

Each manufacturing aspect:

$$\text{Resource Productivity} = \frac{\text{Production of Goods}}{\text{Consumption of Natural Resources, Emissions}}$$

Sustainability Metrics

in the aspect of minimal manufacturing and maximal servicing

Sustainability Metrics (minimal manufacturing)

$$= \frac{\text{Functionality of product}}{\text{Manufacturing - Inverse manufacturing}}$$

Sustainability Metrics (maximal servicing)

$$= \frac{\text{Service consumed*}}{\text{Manufacturing - Inverse manufacturing}}$$

* Service consumed = content of service in a product x No. of products x rate of use x duration of use

Full Research

Practices of Manufacturing and Inverse Manufacturing

Manufacturing

Mining,
Reclamation,
Construction,
Cultivation and agriculture,
Production of materials,
Production of goods, etc

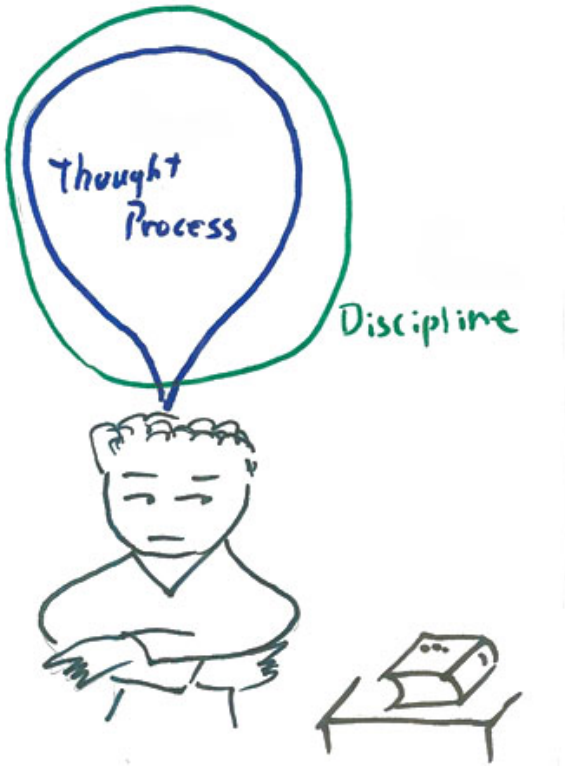
Inverse Manufacturing

Forestation of desert,
Fish farming,
Recovery of contaminated lands,
Biomass in devastated coast,
Carbon sequestration,
Renewable energy,
Bio decomposition of plastics,
Waste processing,
Maintenance,
Simulation of global climate change,
Life cycle assessment, etc

Necessity to integrate disciplines increases as portion of inverse manufacturing increases.

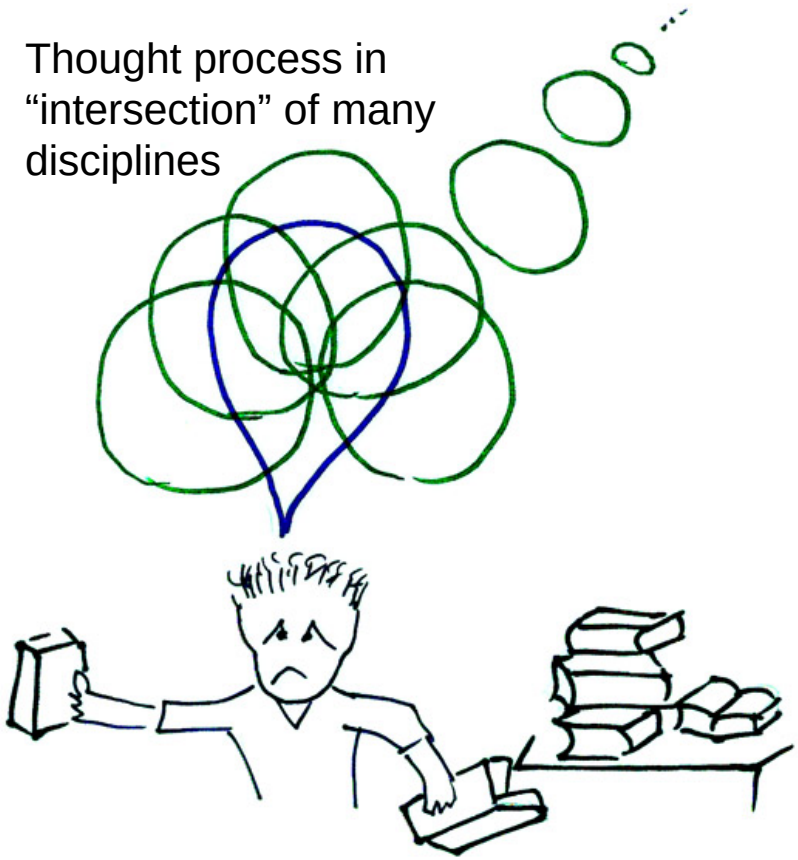
Difficulty of the Discipline- integration

Thought process within their own disciplines



Research within a discipline

Thought process in "intersection" of many disciplines

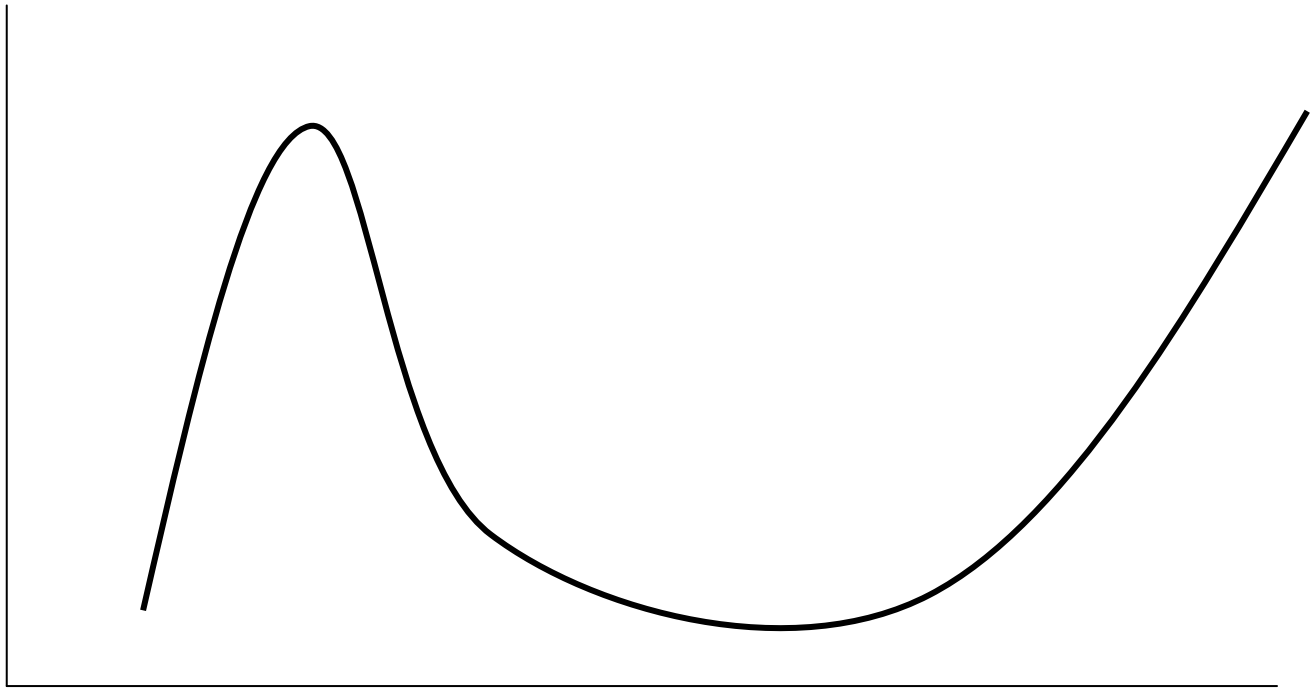


Research independent of disciplines

The more disciplines are involved, the more efforts are required in designing a product.

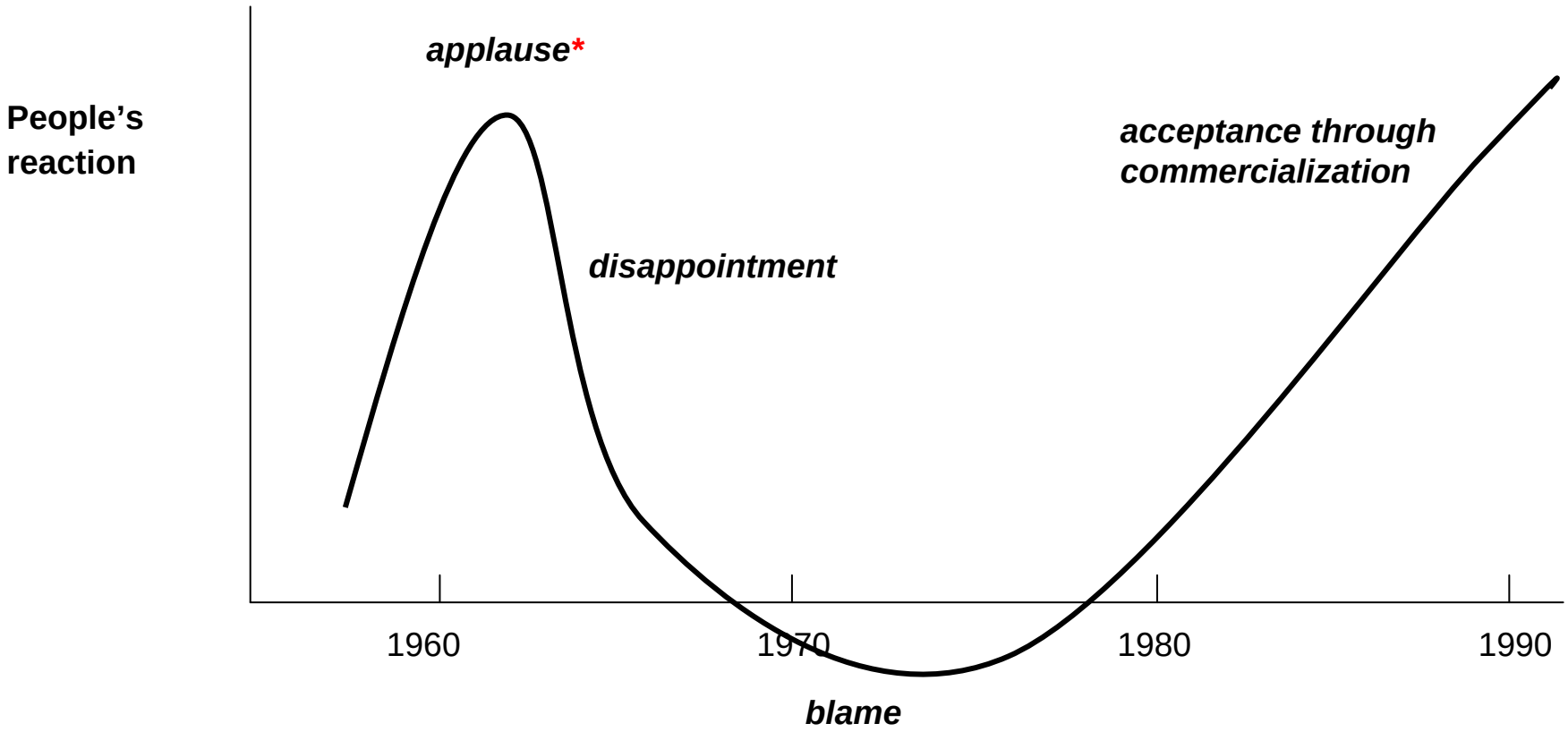
A Typical Process of Innovation

Dreams, Nightmares and Reality



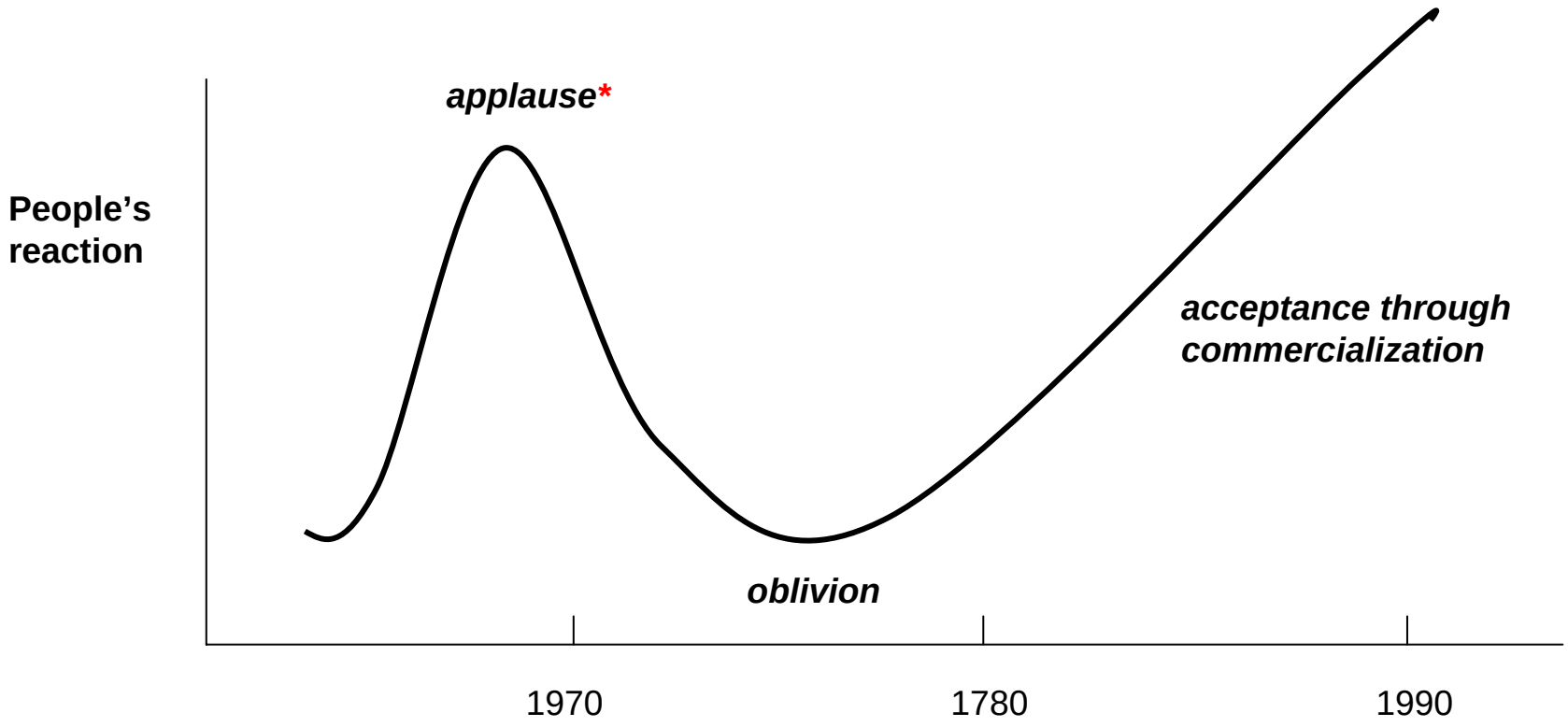
1985 J.Hatvany, H.Yoshikawa

Sutherland's CAD (computer-aided design)



*I.E. Sutherland, "Sketchpad – A man machine graphical communication system" Proc.SJCC,1963,PP329-346

Williamson’s System 24

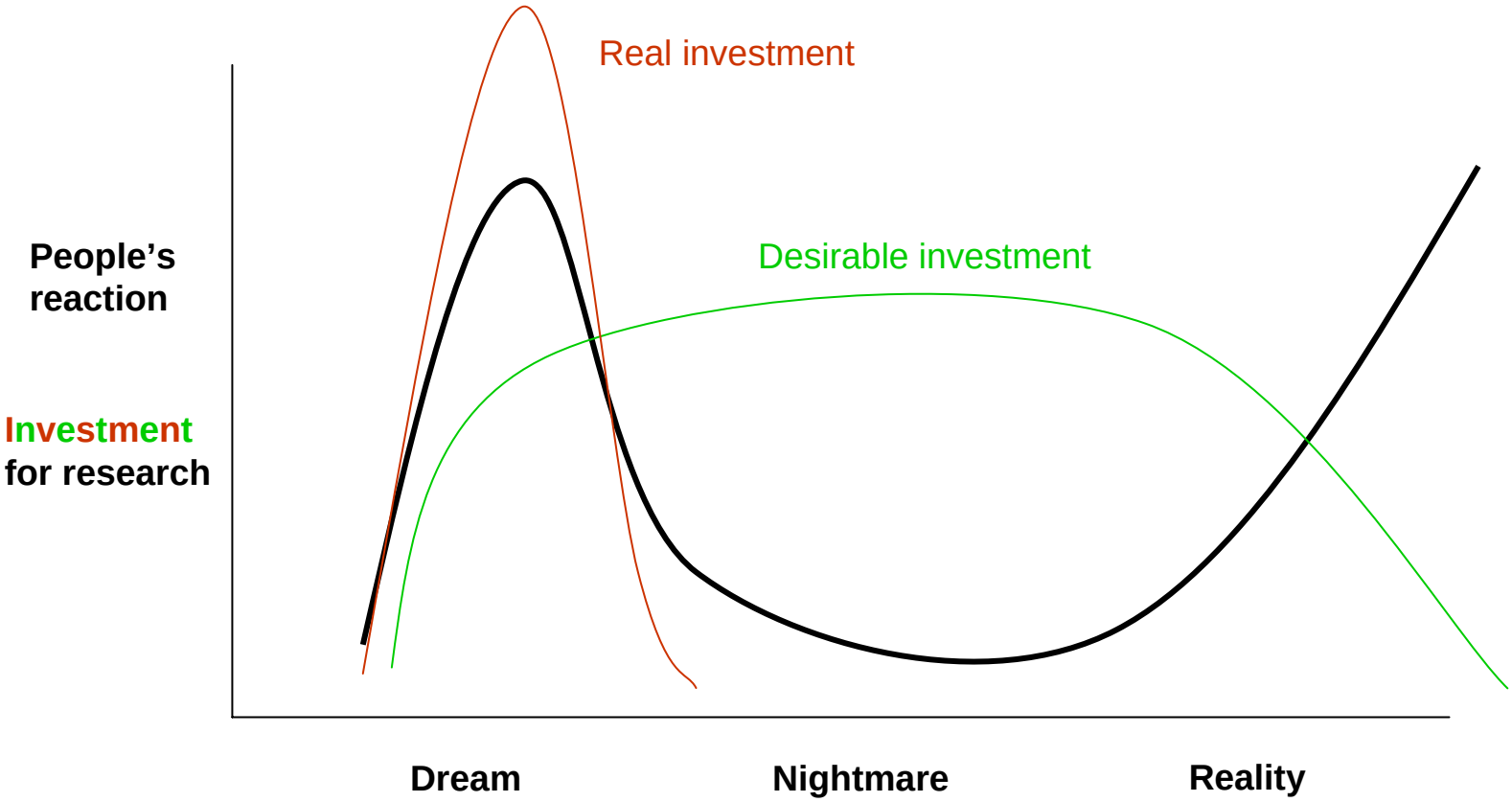


* D.T.N.Williamson, SYSTEM 24 – A new Concept of Manufacture, Proc.MTDR, 1967

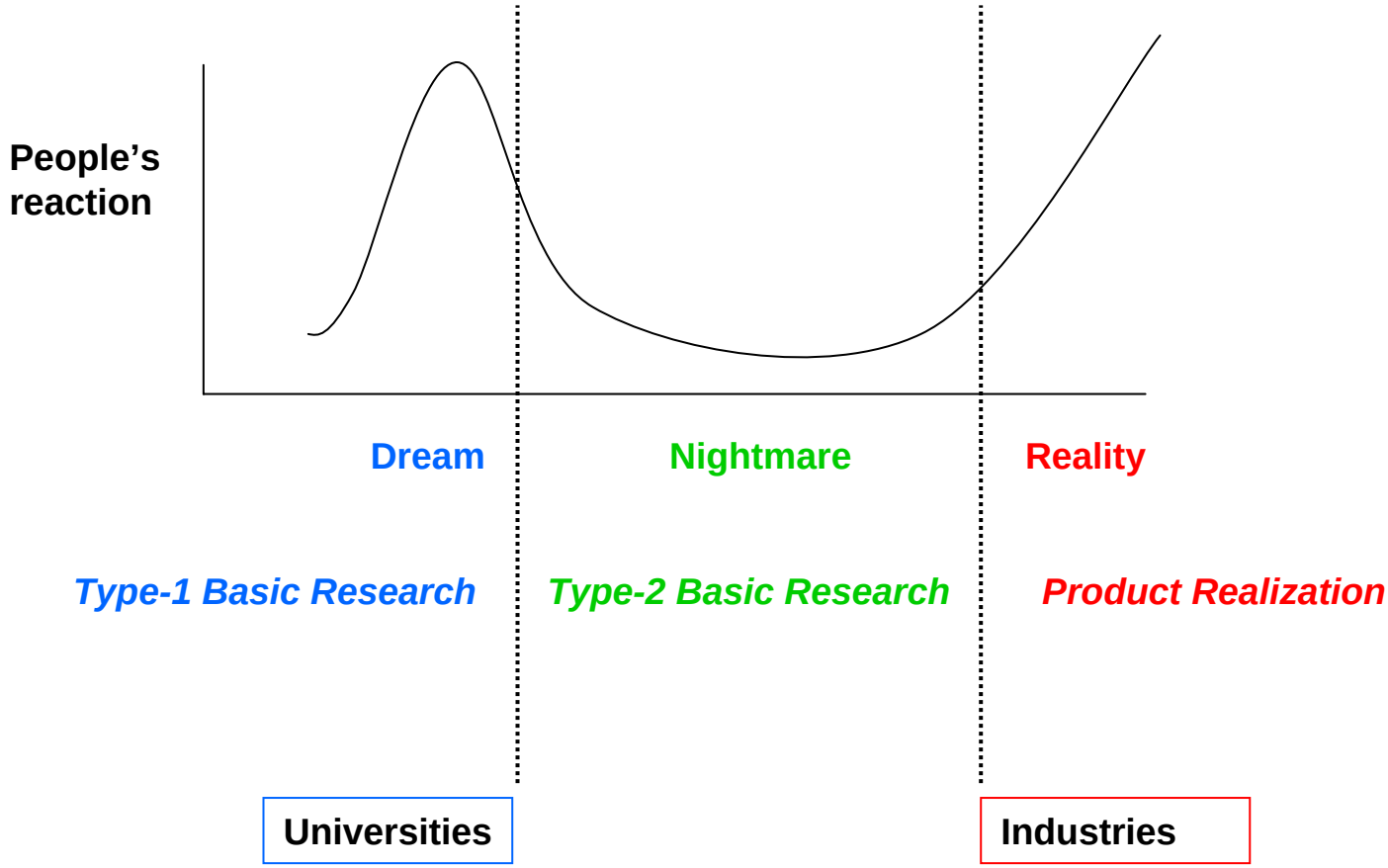
Causes of Nightmare

causes	examples
1. Ambiguity of requirement	Home robots
2. Strictness of requirement	Nuclear power plant
3. Lack of basic science	Computer aided design
4. Insufficient maturity of technology	Industrial robot
5 . Reluctance to accept of society	Organ transplant
6. Resistance of competing firm	Renewable energy
7. Unknown risk of side effect	Genetically modified food
8. Increase of scientific domains involved	Sustainable product

Dreams, Nightmares and Reality



Full Research



Type-2 Basic Research

(1) Type-1 basic research aims at creating new knowledge about facts, but type-2 basic research aims at creating new values* for society.

(2) Type-1 basic research is conducted by an authorized method: “scientific method”, but type-2 basic research has not yet an authorized method.

(3) Type-2 basic research has two missions: creating values for society and establishing a general method of value-creation.

(4) Type-2 basic research is “basic” because of the latter mission of (3) that would contribute to accumulate systematic knowledge for value-creation.

(5) Results of type-2 basic research can not be verified systematically due to lack of general method of research, hence social acceptance is the criterion.

(6) Type-1 basic research is analytical but type-2 basic research is synthetic.

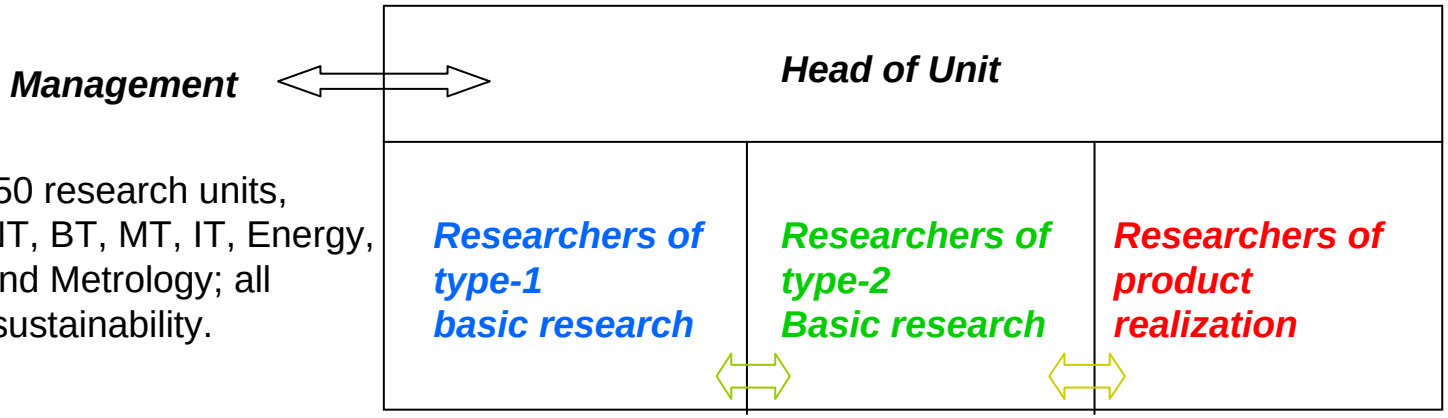
(7) Type-1 basic research is normally conducted within a single scientific discipline but type-2 basic research is basically discipline-free.

**** The word “value” is used here in a broad sense: some knowledge effective to society***

Research Unit in AIST for Full Research

Aim of AIST : Create technologies necessary to realize sustainable industry

AIST has 50 research units, covering NT, BT, MT, IT, Energy, Geology and Metrology; all aiming at sustainability.

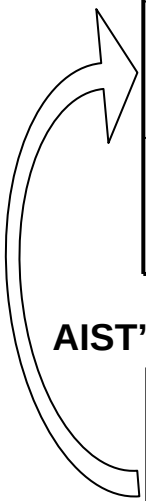


(1) Unit has a mission to innovate particular knowledge/technology for society/industry.
(2) Head of unit directly communicates the management of AIST.
(3) Head of unit is given full autonomy for conducting the research.
(4) Management keeps the authority of start/reform/abolition of unit.
(5) All researchers in the unit always bear its mission in mind.
(6) Type-1 basic researchers aim at generating new scientific knowledge.
(7) Type-2 basic researchers aim at creating new values for society.
(8) Product-realizing researchers aim at creating products/knowledge for society.
(9) Three groups are integrated by the head to conduct research coherently and concurrently.
(10) Researchers are free to move among three categories.
(11) In order to realize such research unit, head of unit must be an "autonomous thinker", who is ethical and philosophical.

AIST's Strategy for Type-2 Basic Research

Present Status

Phase	*Target*	*Fund*	*Output*
Dream	**Knowledge**	**Public**	**Scientific papers**
Nightmare	**Value**	**Nothing but mercy**	**Not visible**
Reality	**Product**	**Private**	**Product in society**



AIST's Strategy

Modern dream (type-2 basic research)	**Value and utilization knowledge**	**Public and Private**	**New type authorized papers**

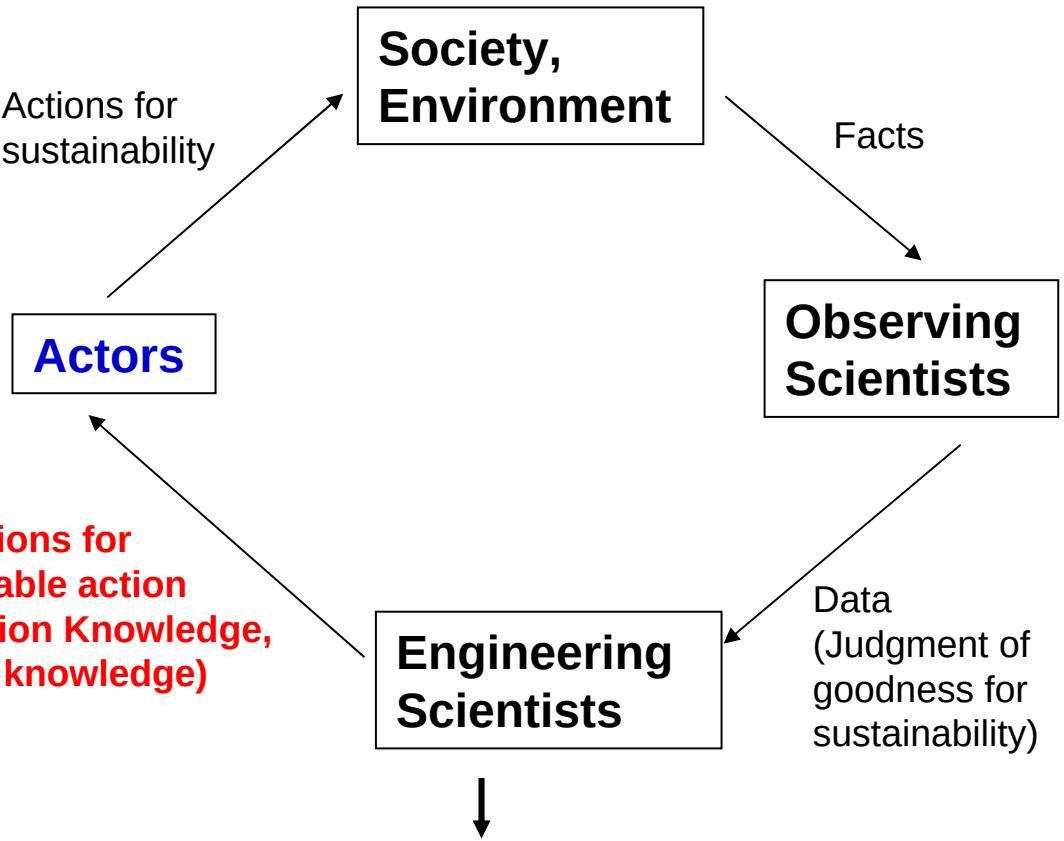
END

Establishment of Engineering for Sustainability through Information Cycle in Society

Actors in Society

engineers
business humans
statesmen
policymakers
administrators
educators
writers
artists
journalists

etc…



Engineering scientists for sustainability are requested to make **Innovation**

Technologies which contribute toward sustainability

1. Monitoring technology for environment
2. Remedying technology for deteriorated environment
3. Renewable energy
4. Energy conservation technology
5. Design of sustainable products
6. Sustainable manufacturing
7. Waste processing technology
8. Life cycle management
9. Maintenance technology etc

These technologies can not be developed by applying just a traditional engineering discipline, but will be realized through integration of several engineering disciplines, which accompanies systematized method of synthesis.

New Engineering based on New Science

Engineering for sustainability is to establish useful principles for people who work to realize sustainability on the earth. Sustainability consists of diversified elements to be described in terms of many disciplines: physical, social and humanities. There remain still many facts influencing sustainability that are not yet well understood scientifically. Therefore, the engineering discipline of sustainability is neither an application of existing sciences nor mix of existing engineering disciplines.

It is a new engineering domain that is based on scientific knowledge not found easily in traditional scientific disciplines. It requires basic researchers to create new knowledge and sometime requests to establish new domains of science.

Methodically, the engineering for sustainability must be synthetic because the target of this domain is clearly and concretely given, unlike conventional engineering disciplines such as mechanical engineering.

Then, how shall we establish the engineering for sustainability?