Future Trends in Machine Tools and Manufacturing

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POLITECNICO MILANO 1863

MUSP
Macchine Utensili e Sistemi di Produzione

RETE ALTA TECNOLOGIA EMILIA-ROMAGNA HIGH TECHNOLOGY NETWORK

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Why this Workshop?

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Future Trends in Manufacturing References:

1. PCAST Report on Ensuring America Leadership in Advanced Manufacturing – June 2011
2. U.S. Manufacturing Competitiveness Initiative – Make: An American Manufacturing Moment – Dec 2011
3. IDA Report on Emerging Global Trends in Advanced Manufacturing – March 2012
4. AMP Report on Capturing Domestic Competitive Advantage in Advanced Manufacturing – July 2012
5. McKinsey Global Institute; McKinsey Operations Practice, Manufacturing the future: The next era of global growth and innovation – Nov 2012
6. MIT Paper; Trends in Advanced Manufacturing Technology Innovation- Feb 2013
7. NAMRI/SME Position Paper; Advanced Manufacturing Initiatives: A National Imperative – March 2014

Examples of advanced manufacturing technologies at MIT

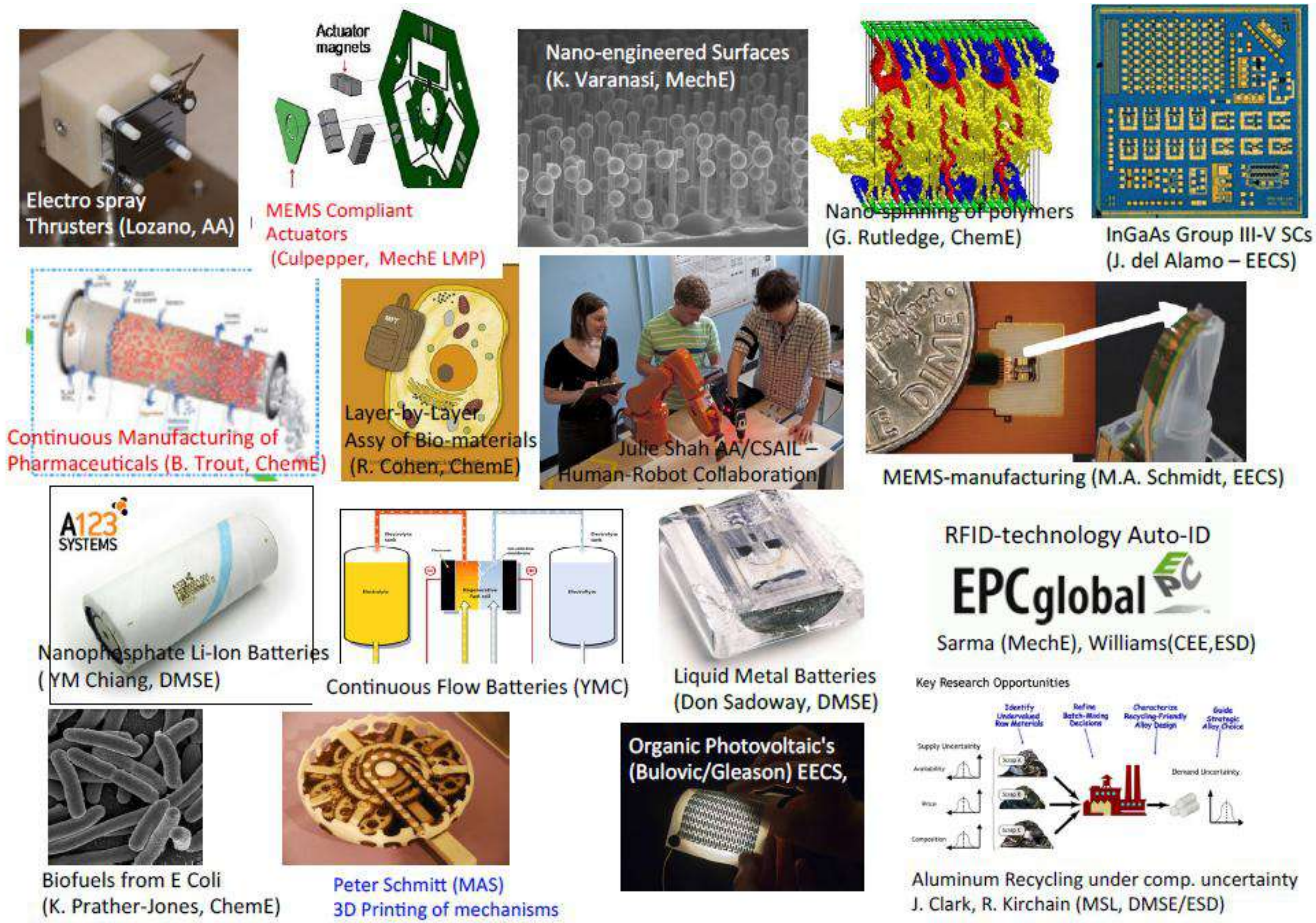
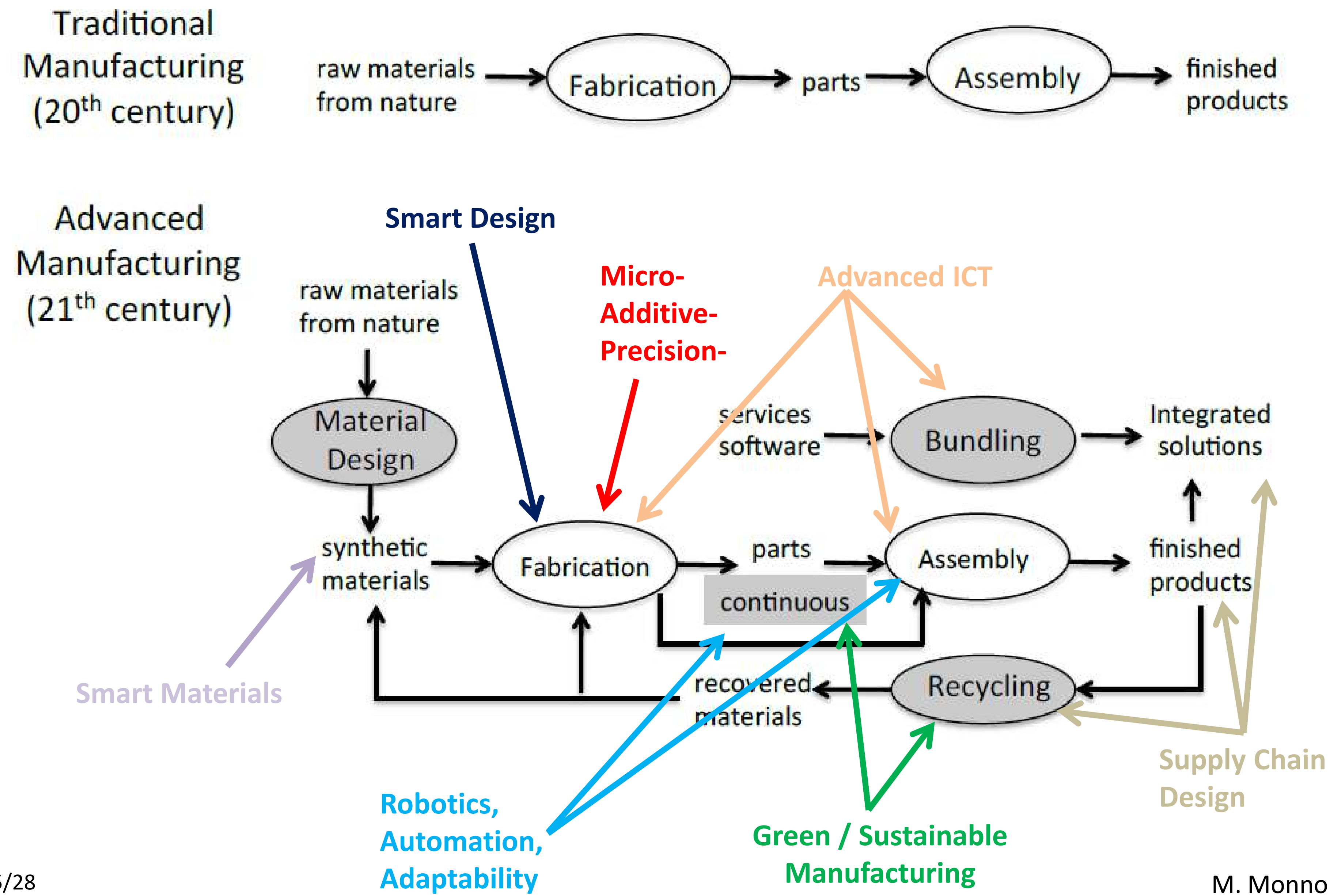


Table 1: Cross-comparison of Advanced Technology Research Areas

Topic	1 - PCAST	2- AMP Report	3- IDA Report	4 - US Manufacturing Competitiveness Initiative	5- McKinsey Global Instutute Report
Additive and Precision Manufacturing		Additive manufacturing Advanced forming and joining technologies	additive manufacturing		Additive Manufacturing
Nano-Materials and Surfaces	Nano-scale carbon materials materials by design Nanotechnology enabled medical diagnostic devices and therapeutics	Advanced materials design, sythesis, and processing Nanomanufacturing	advanced materials	materials science advanced materials	Nanomaterials Lightweight materials
Next Generation Electronics	Flexible electronics nanoelectronics Next generation optoelectronics	Flexible electronics manufacturing	semiconductors		
Robotics, Smart Automation, and Adaptability	advanced robots flexible manufacturing facilities	Industrial robots Advanced sensing, measurement, and process control	move towards rapid changability in manf		Advances in industrial robotics
Green/Sustainable Manufacturing		Sustainable manufacturing	support for sustainable manf	smart manufacturing	Green Manufacturing
					Cicular economy

From Traditional to Advanced Manufacturing:



Some considerations:

Advanced Manufacturing is the creation of integrated solutions that require the production of physical artifacts <u>coupled</u> with valued-added services and software while exploiting custom-designed and recycled materials and using ultra-efficient processes.

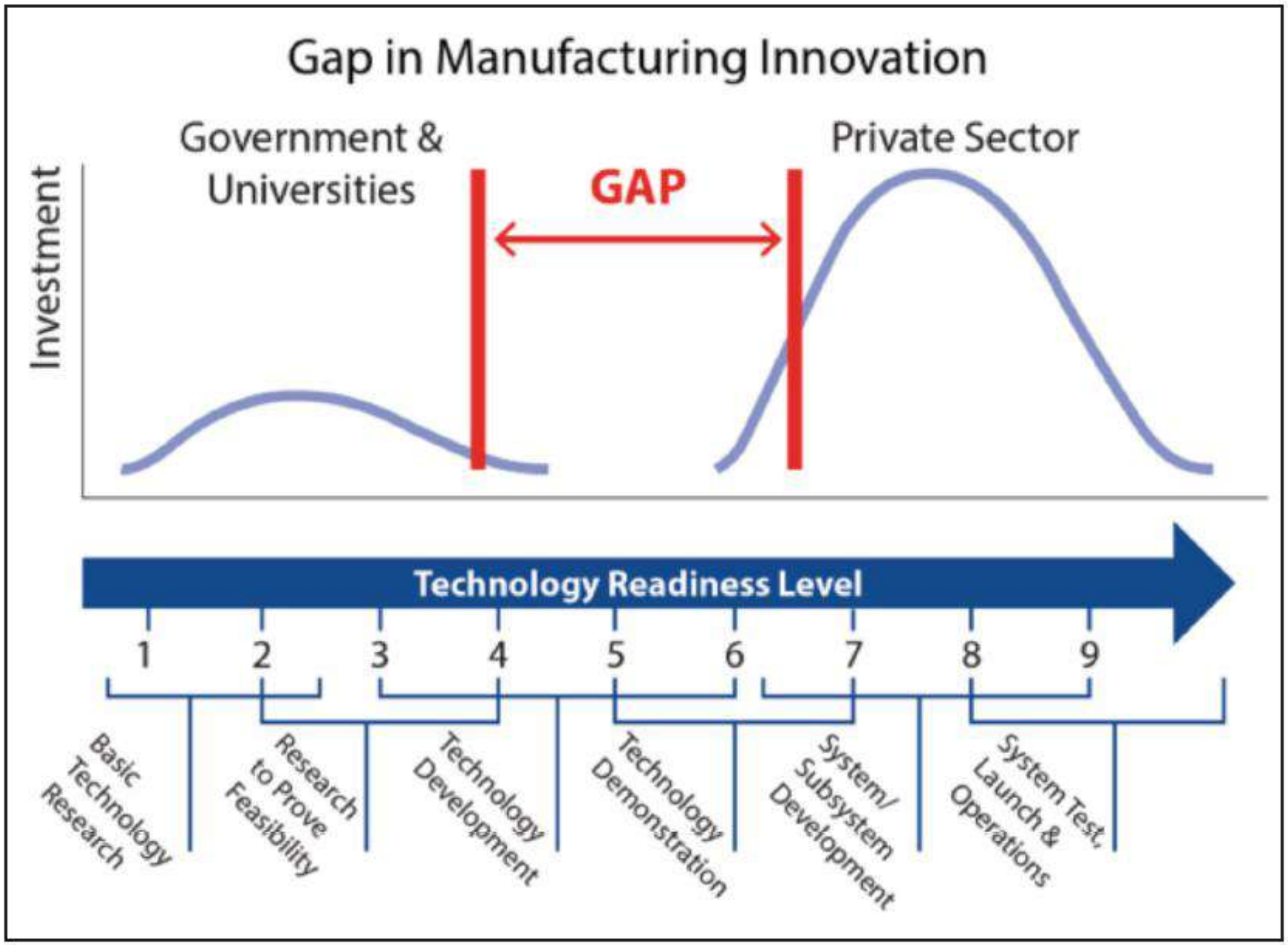
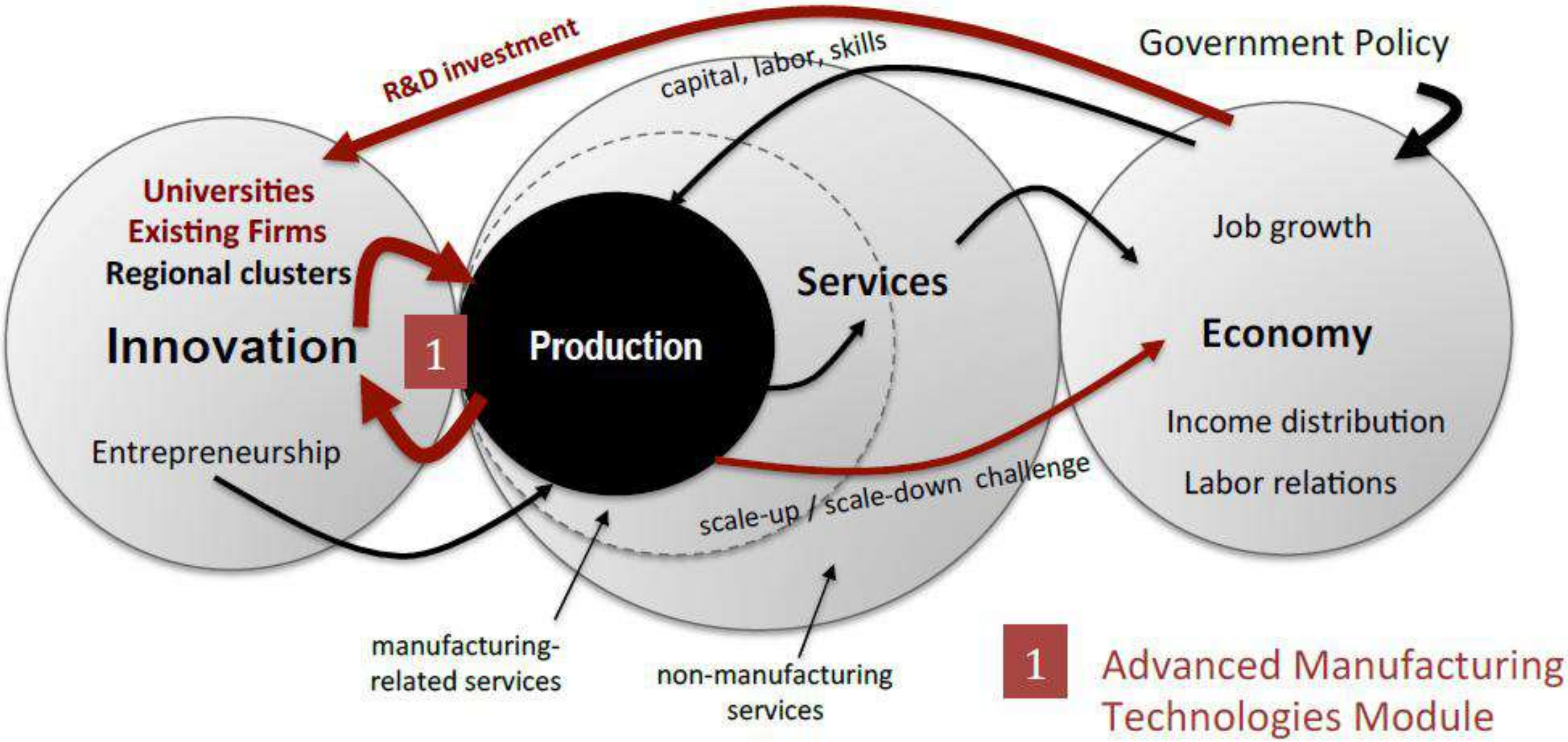


Table 2: Comparison of Invstment Levels in Manufacturing Research

Country	Program and Summary	Investment in U.S. dollars1 (billions)	Equivalent U.S. investment2 (billions)
Germany[5]	**Fraunhofer Program.** World's most established and premier manufacturing research program; complements Max Plank Institutes (German analog to National Science Foundation).	1.0[3]	3.0[3]
	Spitzencluster. Supports the best or 'leading-edge' German industrial clusters.	0.25[3]	0.75[3]
	Central Innovation Program. Provides grants to small and medium enterprises to finance research and innovation projects.	0.64[3]	1.92[3]
United Kingdom[6]	**The Catapult Program.** Established seven centers in advanced manufacturing.	0.264	1.6
Australia[7]	**Industry and Innovation Program.** Collaborations between academic, government and industry researchers to commercialize discoveries; $500 million over four years.	0.50	5.0
Japan[8]	**New Energy and Industrial Technology Development Organization.** Promotes R&D for energy and industrial technologies.	1.64[3]	4.89[3]
	Other programs (Kohsetsushi Centers, Technology Advanced Metropolitan Area Association, Kawasaki Business Incubation Center)	0.51[3]	1.45[3]
Taiwan[9]	**Industrial Technology Research Institute** (ITRI)	0.60[3]	18.9[3]
Finland[10]	**Finland Science and Technology Council**	0.63[3]	35.5[3]
South Korea[8,11]	**Ministry of Education Science and Technology.** Research programs in the 577 initiative target semiconductors, automobiles, machinery, health care and software.	12.8[3]	175.0[3]
Singapore[12]	**Future of Manufacturing Program**	0.5[3]	25.5[3]
	Other programs (Satellite Industry Development, Collaborative Industry Projects)	0.19	9.7
France[13]	**Competitiveness Clusters.** Similar to the German Fraunhofer program; 71 competitive clusters in "cutting edge and key technology sectors."	0.75[3]	4.9[3]
China	No government figures. Estimates are 1.7% of GDP, 82.7% of which supports manufacturing sector.[14]	108[3]	222[3]

Authors observes three main development directions (trends):

1. **Technologies that are truly enablers of classes of products that do not yet currently exixts (i.e. non-Si based semi-conductors, fuels from biology, micro-satellites with propulsive capabilities). Many of these have the potential to create new industries.**



Structure of the Production in Innovative Economy (PIE) Project

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At the end, they underline that none of these trends may lead to a lot of new jobs. However, they preserve and transform exixting jobs and the new jobs they do create will be meaninful, and require higher levels of skill and knowledge.

A Sustainable Development for the Industrial Production

"Efficency as the relationship between employed resources and achieved results"

"From profit maximization with minimal investment"

"To the optimal use of materials and energy resources"

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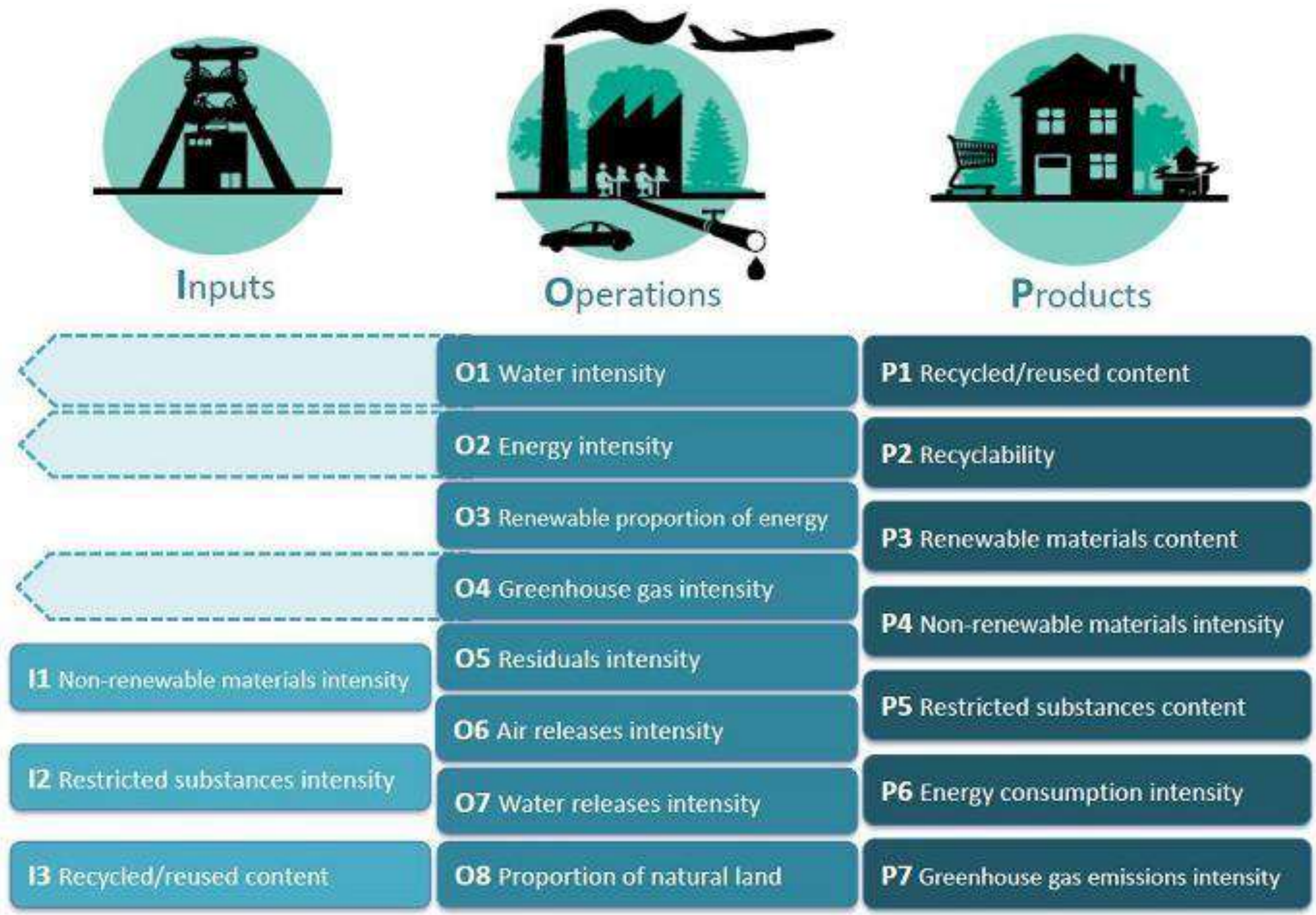
Improving Energy Efficiency



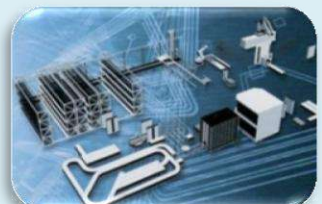
Improving Energy Efficiency

An experimental approach for energy consumption quantification (3W approach).

Experimental Energetic Assessment

- How much energy
- Where and How
  - *Components and Subsystems*
- When
  - *Productive phases, stand-by*
- Why
  - *Movements, temperature, control, friction, electrical losses, inertia, …*

Productive Process



Productive System

Machine

Part Program

Improving Energy Efficiency

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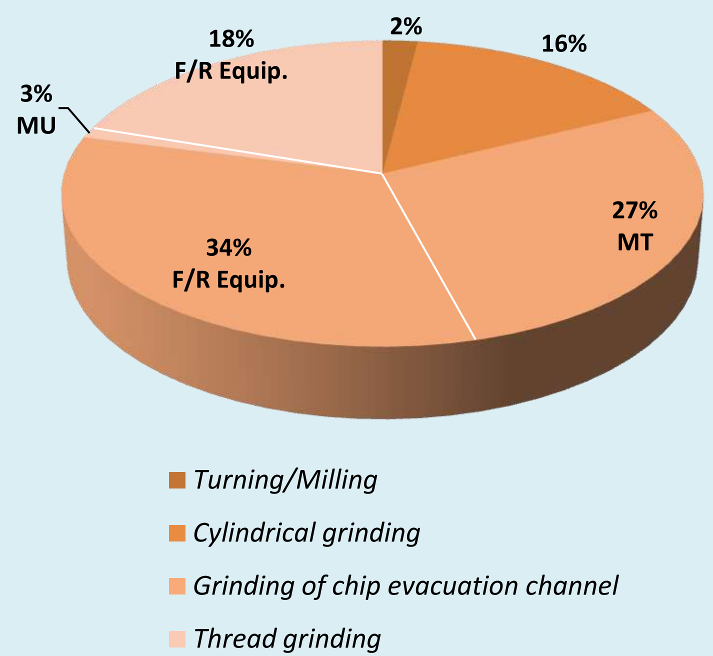

An example of phases distribution for a boring tap production process.

Source: Logisci G., Priarono P. C., Settineri L., Cutting tool manufacturing: A sustainability perspective Politecnico di Torino, GCSM , Berlin, 2013

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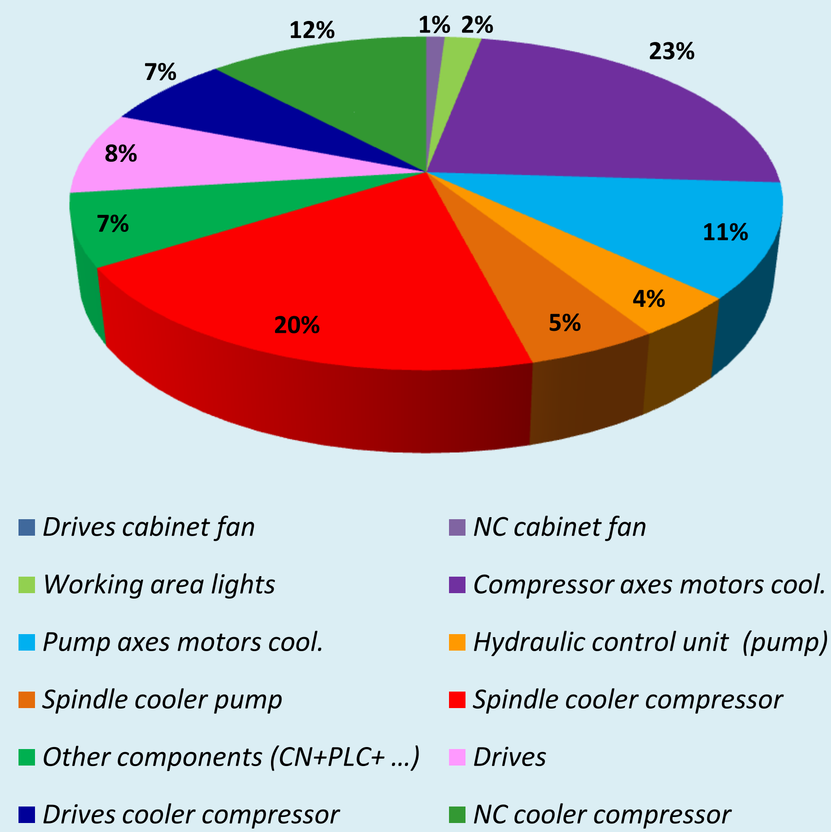
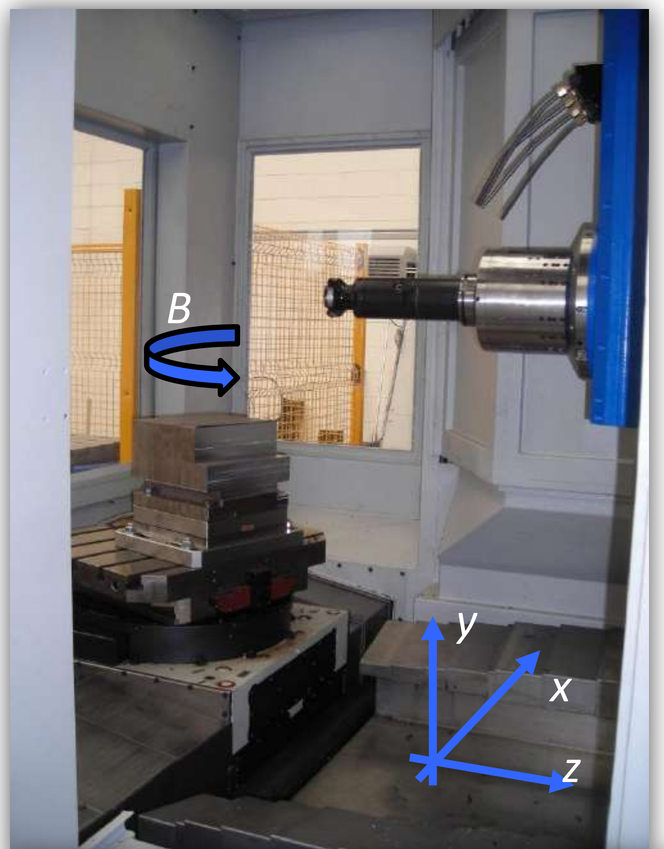


Source: EROD project, MUSP

Improving Machine Tools Energy Efficiency

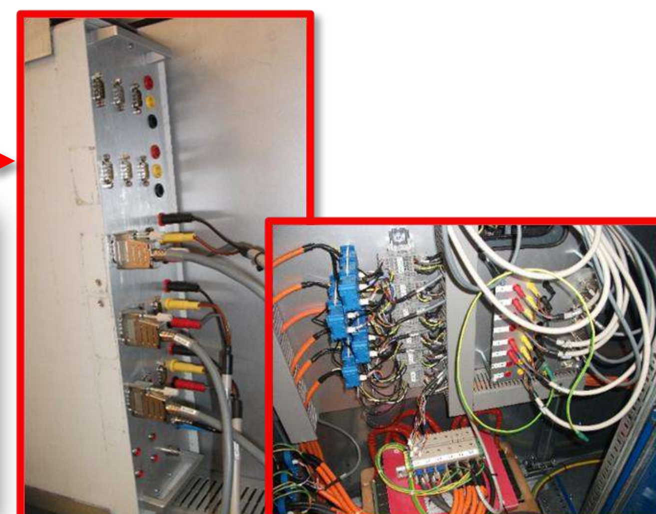


Features

- 4 axes
- Max feed: 10.000 mm/min
- APC: 2 posizioni
- ATC: 40 posizioni
- Spindle: hydrostatic, 120Nm (S1) – 65 kW
- CN: Siemens 840D Solution Line

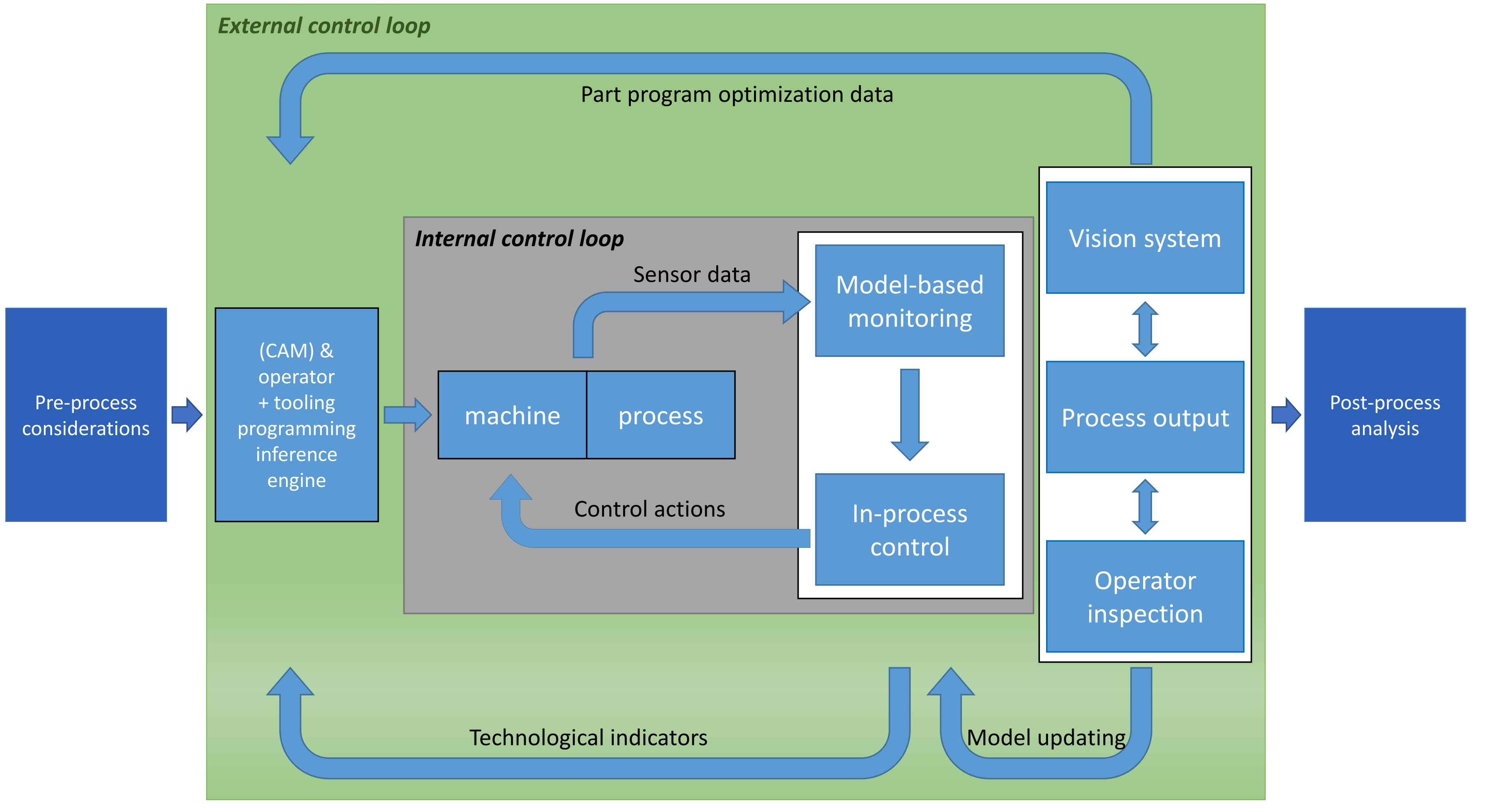
Sensors

- Triaxial accelerometer inside the spindle housing
- Inductive position sensors inside the spindle housing
- Acoustic sensor
- Dynamometer table
- **El. Power sensor**



Smart Machining

Advanced monitoring and control systems for machine tools



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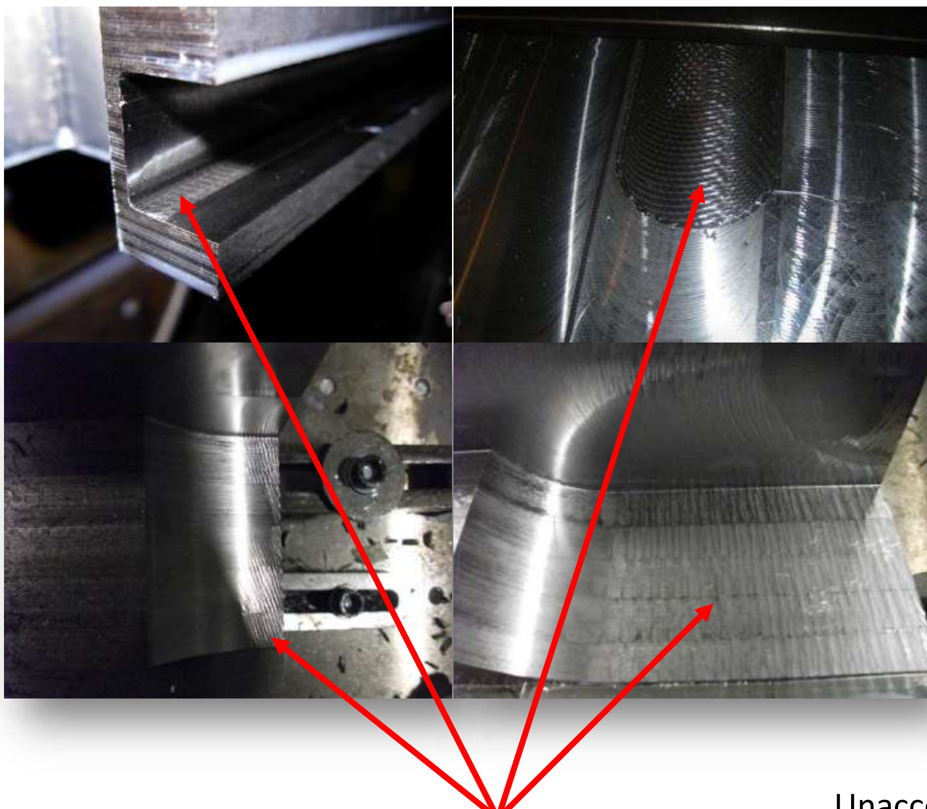
Instability effects in machining



Unwanted vibrations → Unacceptable surface quality

Vibrations effects →

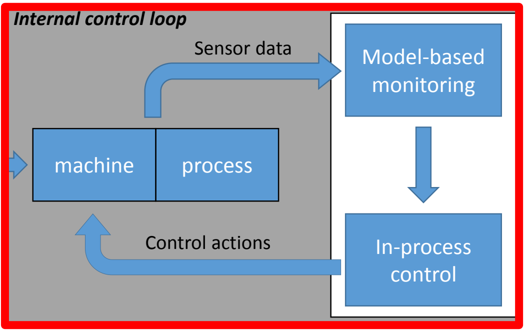
- Tool breakage

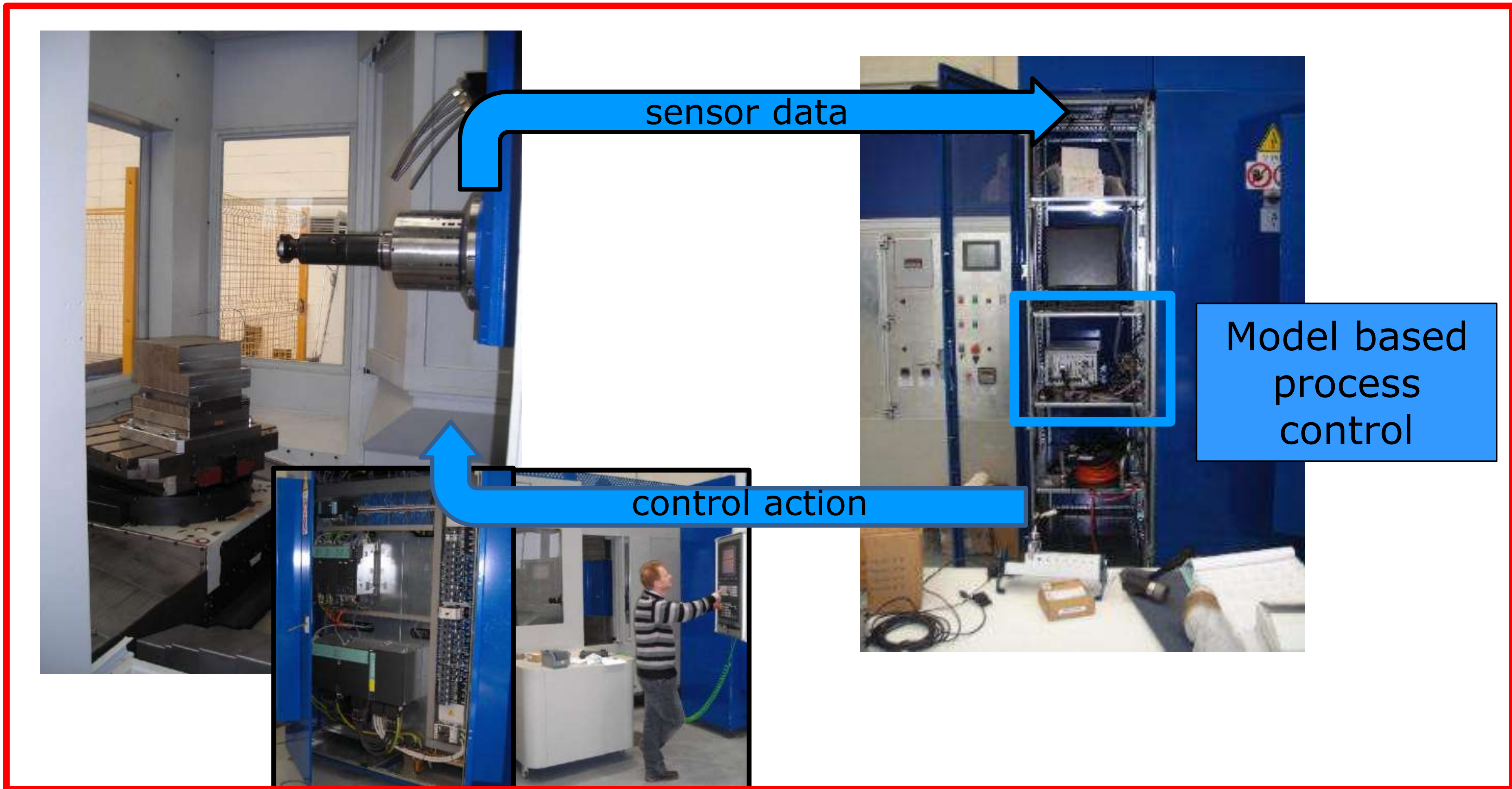
- Tool chipping

- Spindle bearings damaging

- Excessive vibrations -> downtime

Advanced system for monitoring and control vibrations in milling

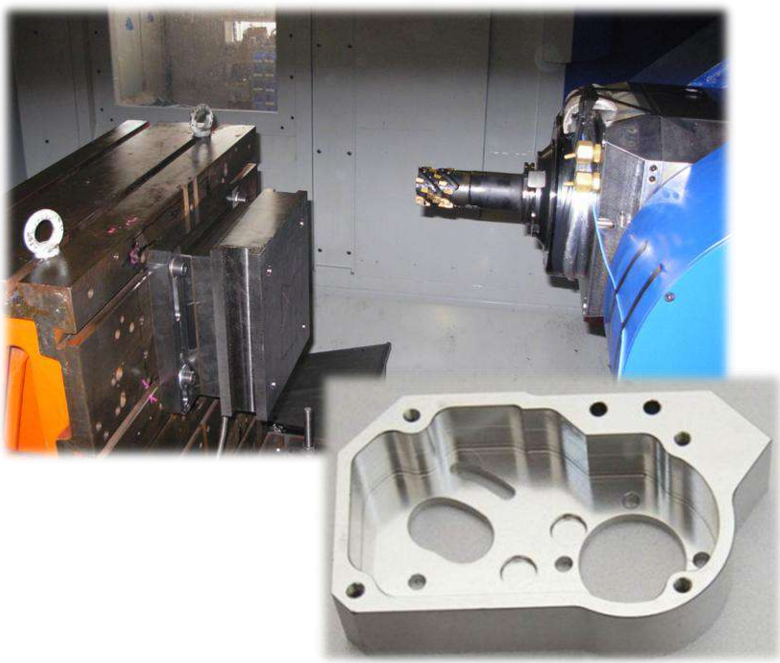


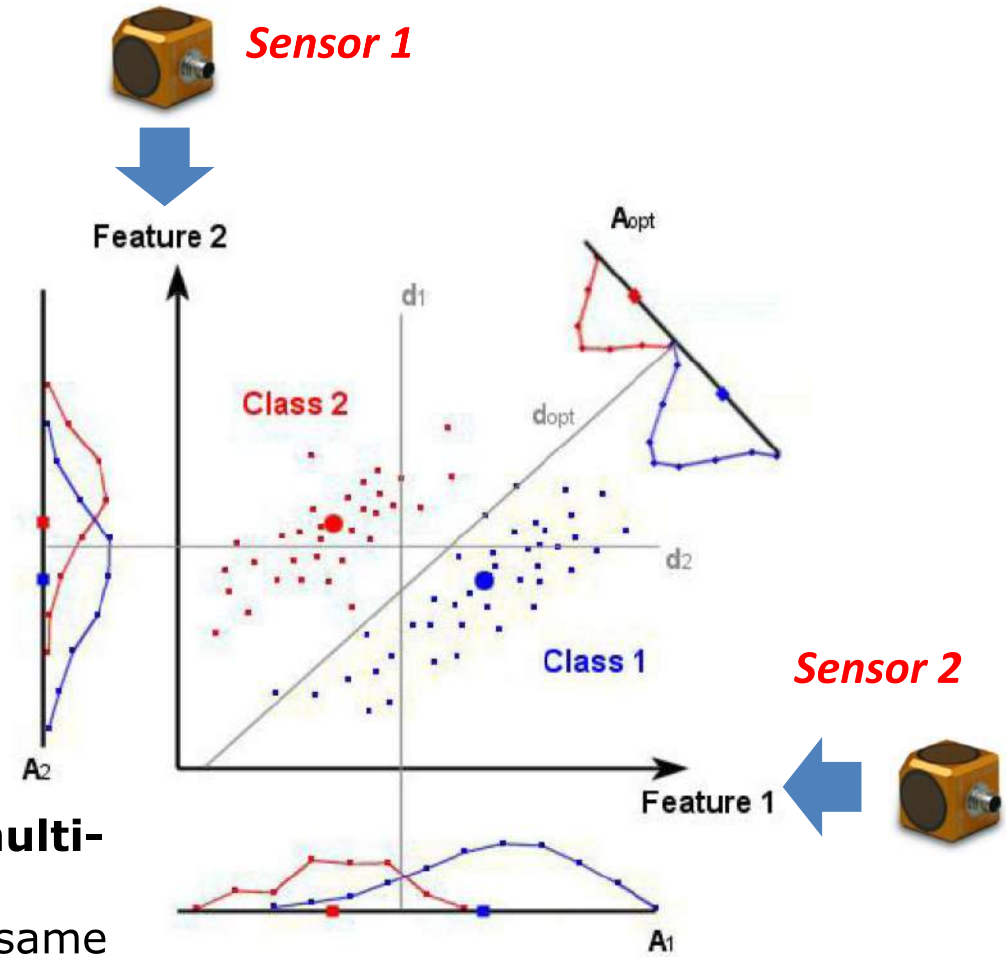


Sensors for High Performance Machining

Why should we "merge" information coming from different sensors?

Ability to distinguish in-control behavior from out-of-control behavior





- Multivariate analysis techniques for **multi-dimensional datasets**
- **Dimensional reduction** and, at the same time, **fusion** of data coming from different sources

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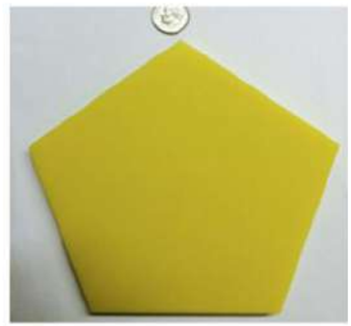
What's next?

New technologies, new challenges…

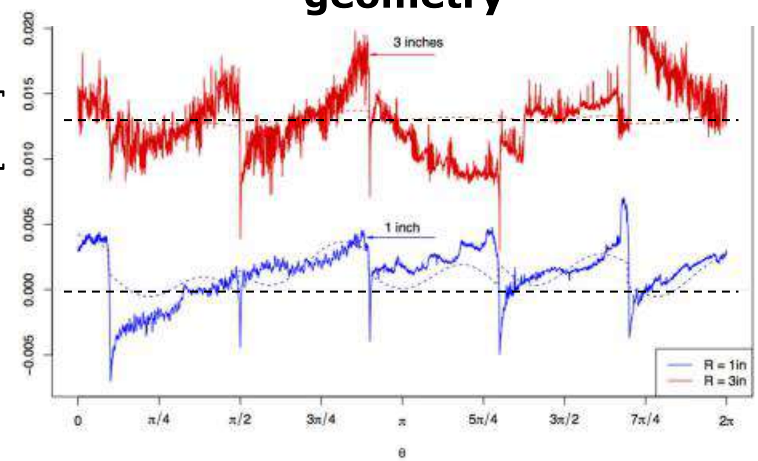
Additive manufacturing:
- Error assessment
- In-process compensation
- Sensorization?

[Huang, 2014]

Sample piece

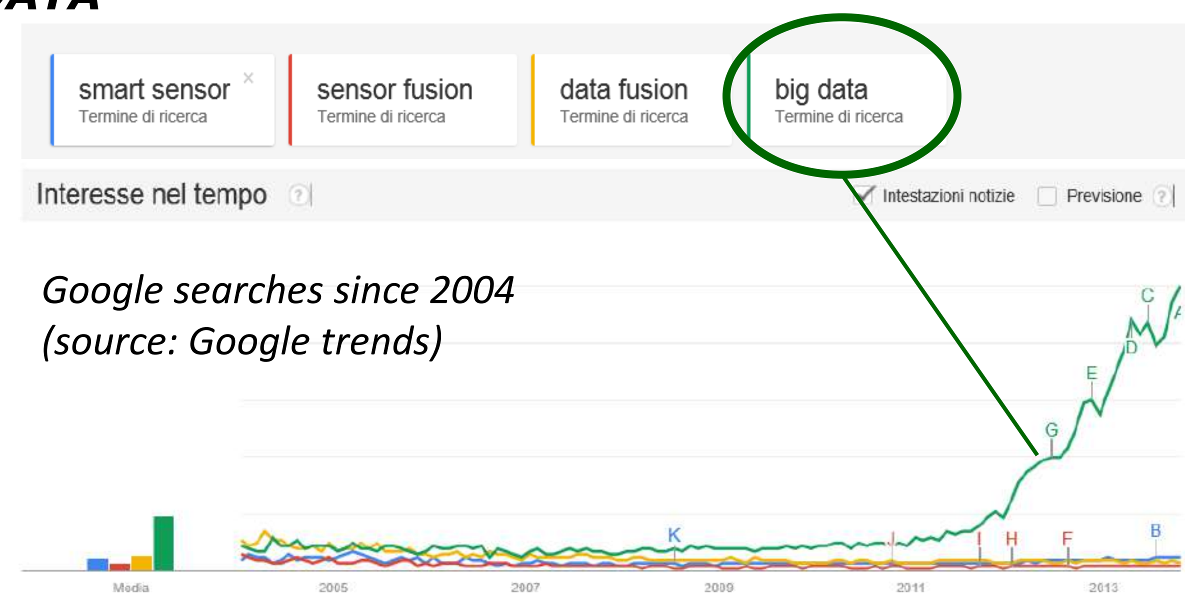


Deviation from nominal geometry



Da DATA FUSION and BIG DATA

In order to manage large amount of data we need:
- *New analysis paradigms*
- *New managing methods*
- *New data acquisition and access methods*
- *New representation methods*



Google searches since 2004 (source: Google trends)

New approaches for machining processes optimization

The machine tools of the future will be able to cut "hard to machine" materials with a low environmental impact

- Titanium alloys
- Inconel
- Hardened steel

Low thermal conductivity

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Extremely high temperatures at the tool-chip interface

Low cutting speeds → **Low productivity**

Large use of cooling and lubricating oils

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Cryogenic machining

Replacing the traditional water-oil cooling emulsions with a liquid nitrogen jet delivered at the tool-chip interface

Liquid Nitrogen (LN2):

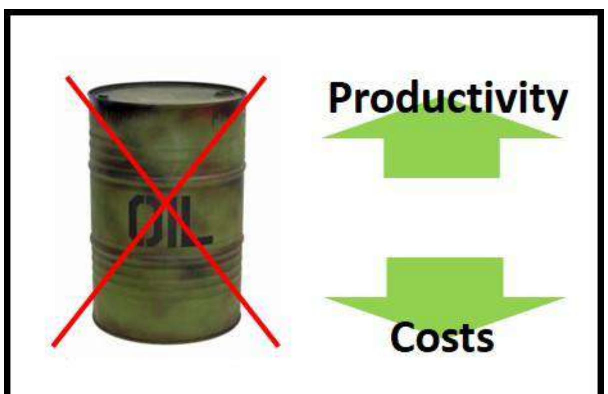
- Inert
- Non polluting
- Non flammable
- Non toxic
- Boiling point at -196°C

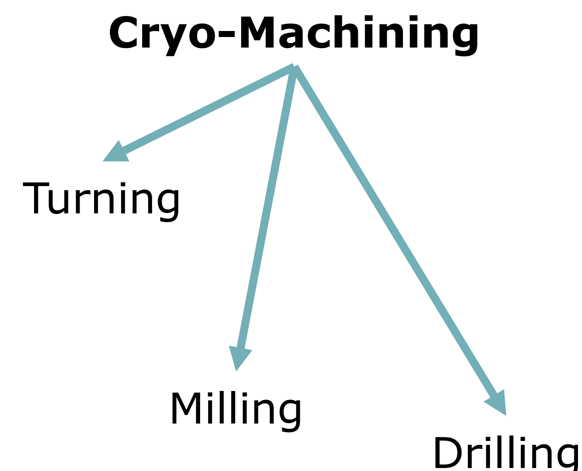
Advantages for the process:

- Strong temperature reduction
- Improvement of tool life
- Improvement of MRRs
- Clean and dry chip and workpiece

Environmental benefits:

- Complete elimination of cutting oils and their disposal / filtering problems
- Improvement of the healthness of the working area





Reverse Engineering and Additive Manufacturing

A Reverse Engineering process is necessary when a component needs to be re-designed without the original drawings or detailed technical information

- 3D Scans
- Coordinate Measuring Machines

R.E. can be coupled with Additive Manufacturing processes

Investigation on:
- Original geometry
- Material features

3D virtual model for the AM process

Storage of the virtual model

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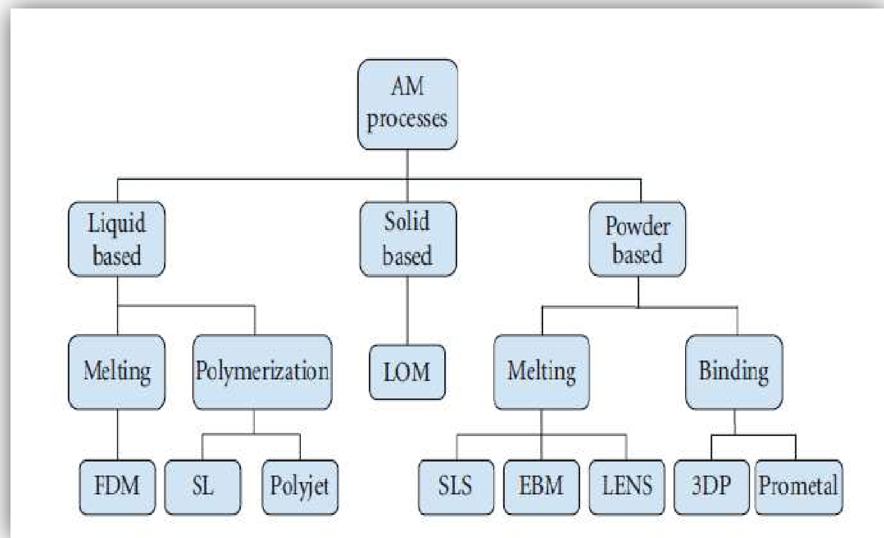
Additive Manufacturing

At present AM technologies are efficient just for prototypal or single parts productions

Wax or plastic models are already easily and cheaply producible

Innovative experimental technologies for industrial metallic parts



Powder based technologies are still too expensive for large scale productions

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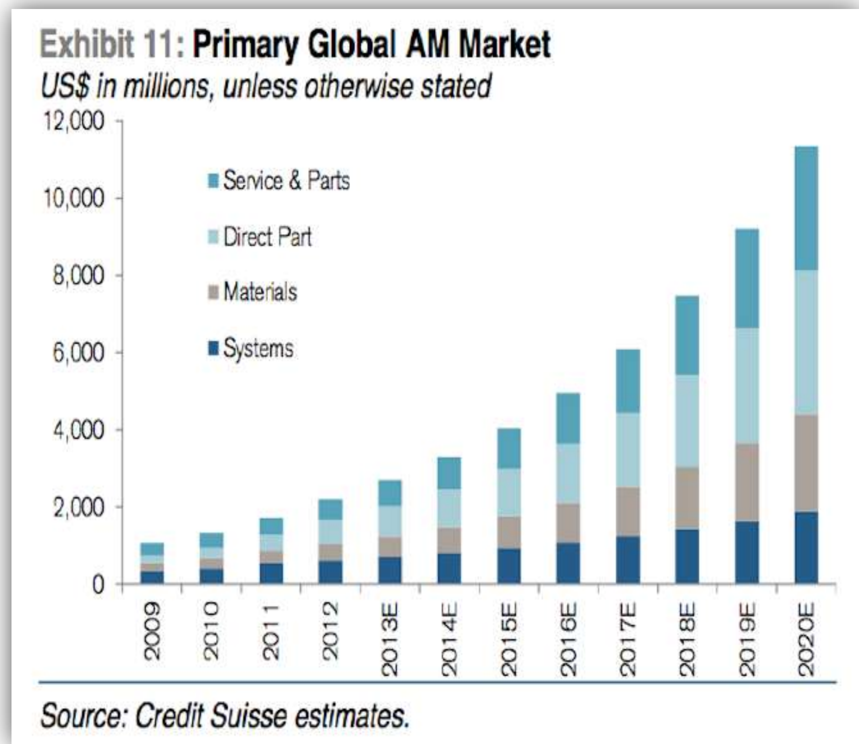
Hybrid manufacturing can be considered the best compromise for the future



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Additive Manufacturing

Conclusions

Present time is full of questions that we are unable to answer:

Breaking news (few days ago): "This year selfies have killed more than sharks"

How is it possible?

According to Wikipedia, the twelve selfie deaths that have occurred in 2015 are as follows:

1. An American woman fell to her death while taking a selfie with her boyfriend on a cliff in South Africa.

2, 3. Two Russian men were killed while taking a selfie with a hand grenade.

4, 5, 6. Three Indian students were killed by an oncoming train while taking selfies on train tracks.

7. A Romanian teenager was electrocuted when she was taking a selfie on top of a train and touched a high-voltage wire.

8. A Russian teen was also electrocuted after touching live wires while taking a selfie near railway tracks.

9. A Russian woman shot herself in the head while trying to take a selfie with a gun.

10. A woman in Moscow City died falling from a bridge, where she was trying to take a selfie.

11. A teenager in Houston, Texas, fatally shot himself while taking a selfie with a gun.

12. A Japanese tourist died falling down the stairs while taking a selfie at the Taj Mahal. This last incident, which occurred just this past Tuesday, has sparked renewed concern over the very real dangers presented by irresponsible selfies.

It's Official – In 2015 Selfies Have Killed More People Than Sharks!

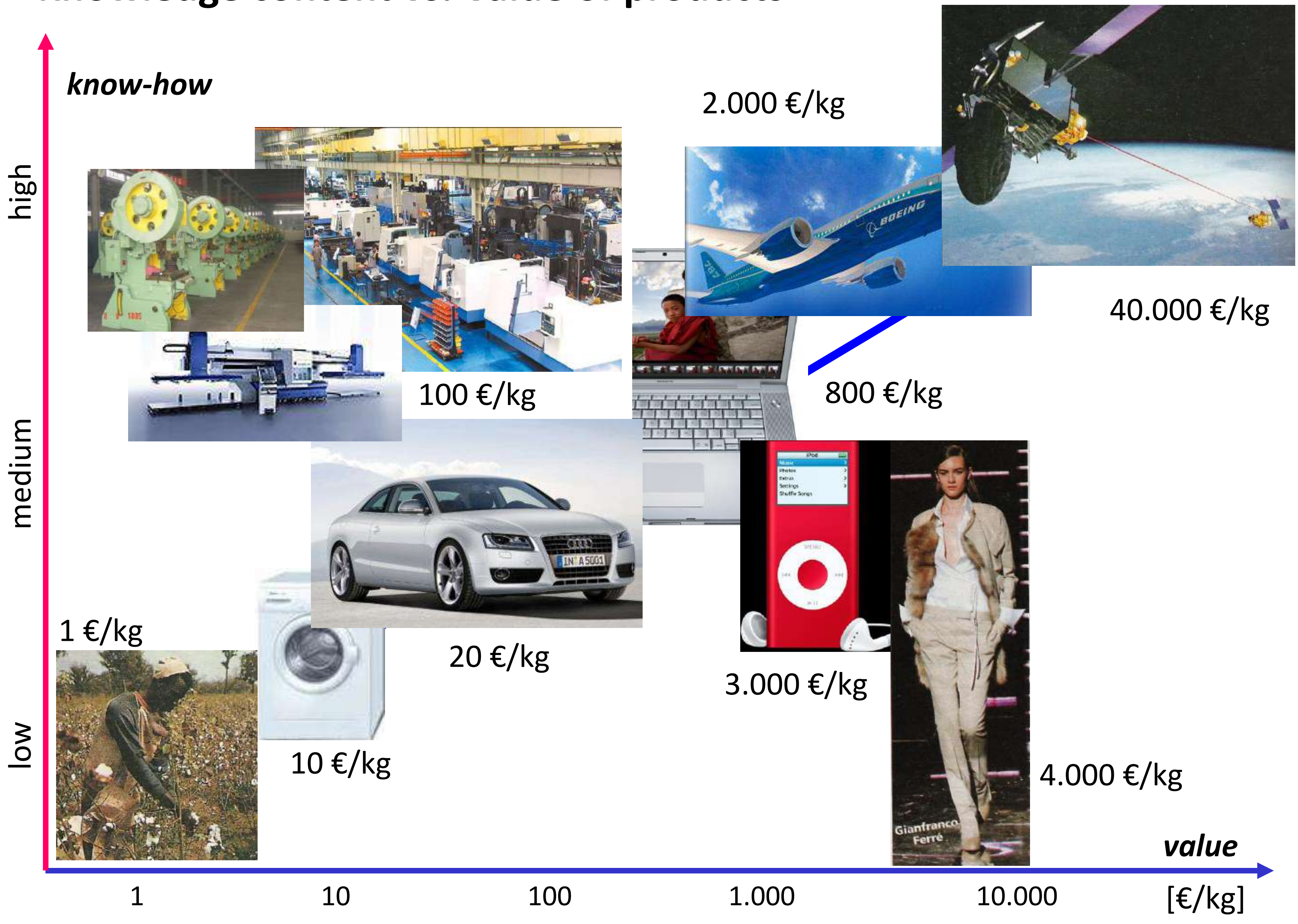
Be careful where you snap, and always be aware of your surroundings.
You never know when a Kodak moment could turn killer.

Conclusions

But there are questions that need to be answered:

Why take care of
Future Trends of Machine Tools and Manufacturing?

Knowledge content vs. Value of products



Thanks for your attention!

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