

FUTURE TRENDS IN MACHINE TOOLS AND MANUFACTURING

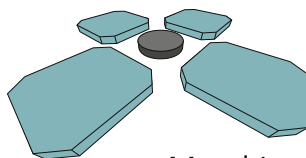


EMO Milano
October 8, 2015

Prof. Michele Monno



POLITECNICO
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MUSP

Macchine Utensili e Sistemi di Produzione



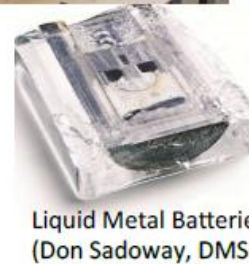
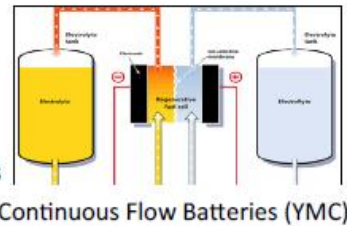
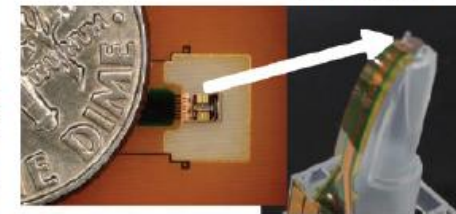
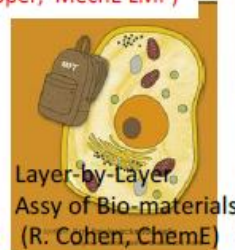
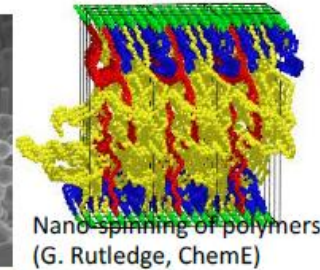
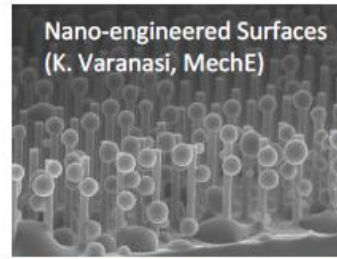
Future Trends in Machine Tools and Manufacturing

Why this Workshop?

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



RFID-technology Auto-ID



Sarma (MechE), Williams(CEE,ESD)

Key Research Opportunities



Aluminum Recycling under comp. uncertainty
J. Clark, R. Kirchain (MSL, DMSE/ESD)

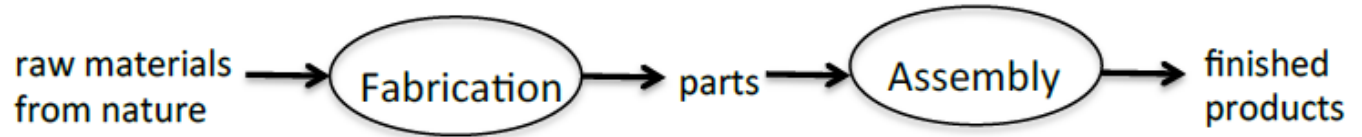


Table 1: Cross-comparison of Advanced Technology Research Areas

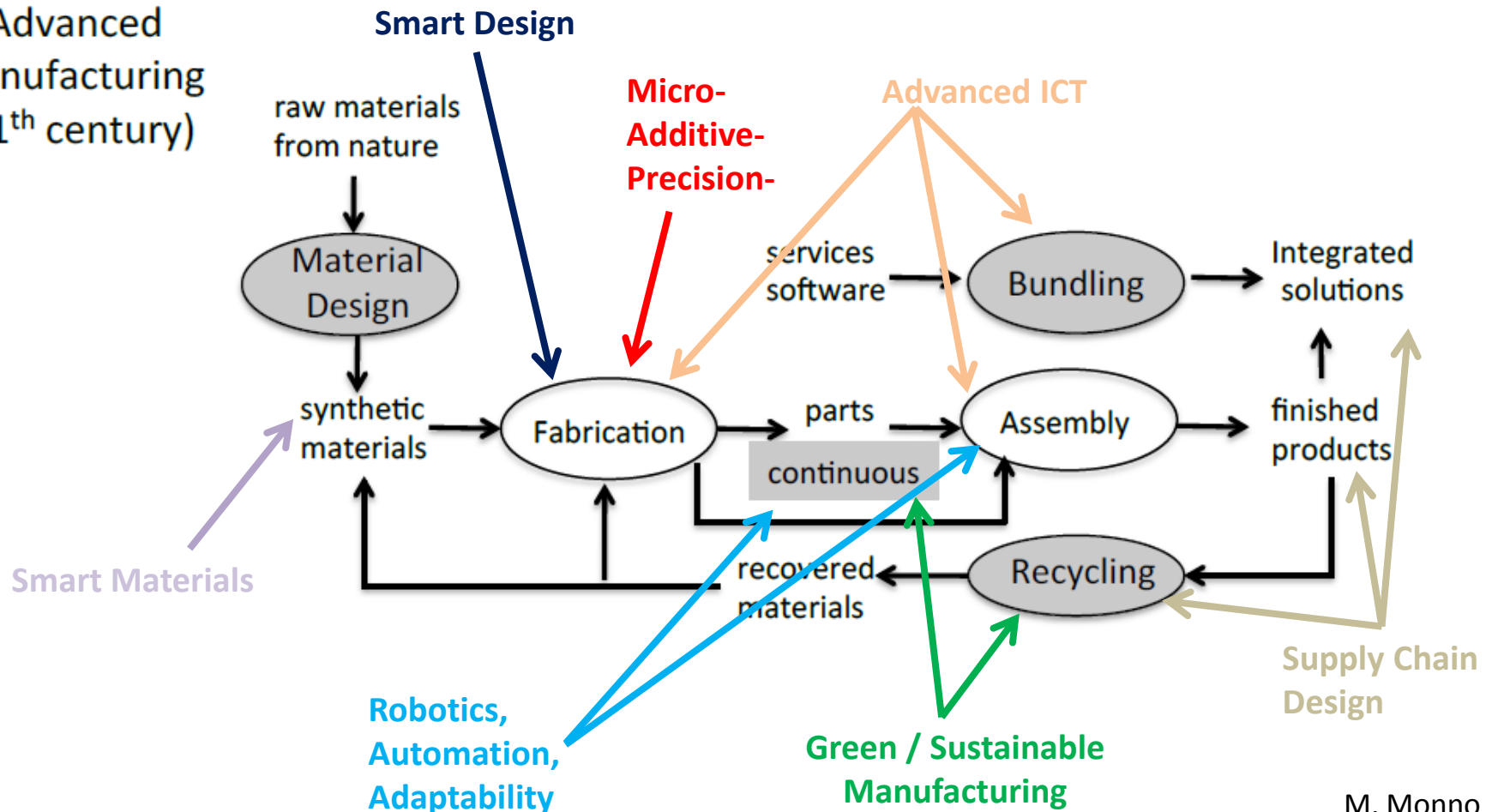
Topic	1 - PCAST	2- AMP Report	3- IDA Report	4 - US Manufacturing Competitiveness Initiative	5- McKinsey Global Institute Report
Additive and Precision Manufacturing		Additive manufacturing Advanced forming and joining technologies	additive manufacturing		Additive Manufacturing
Nano-Materials and Surfaces	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:

Traditional
Manufacturing
(20th century)



Advanced
Manufacturing
(21th century)



Some considerations:

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

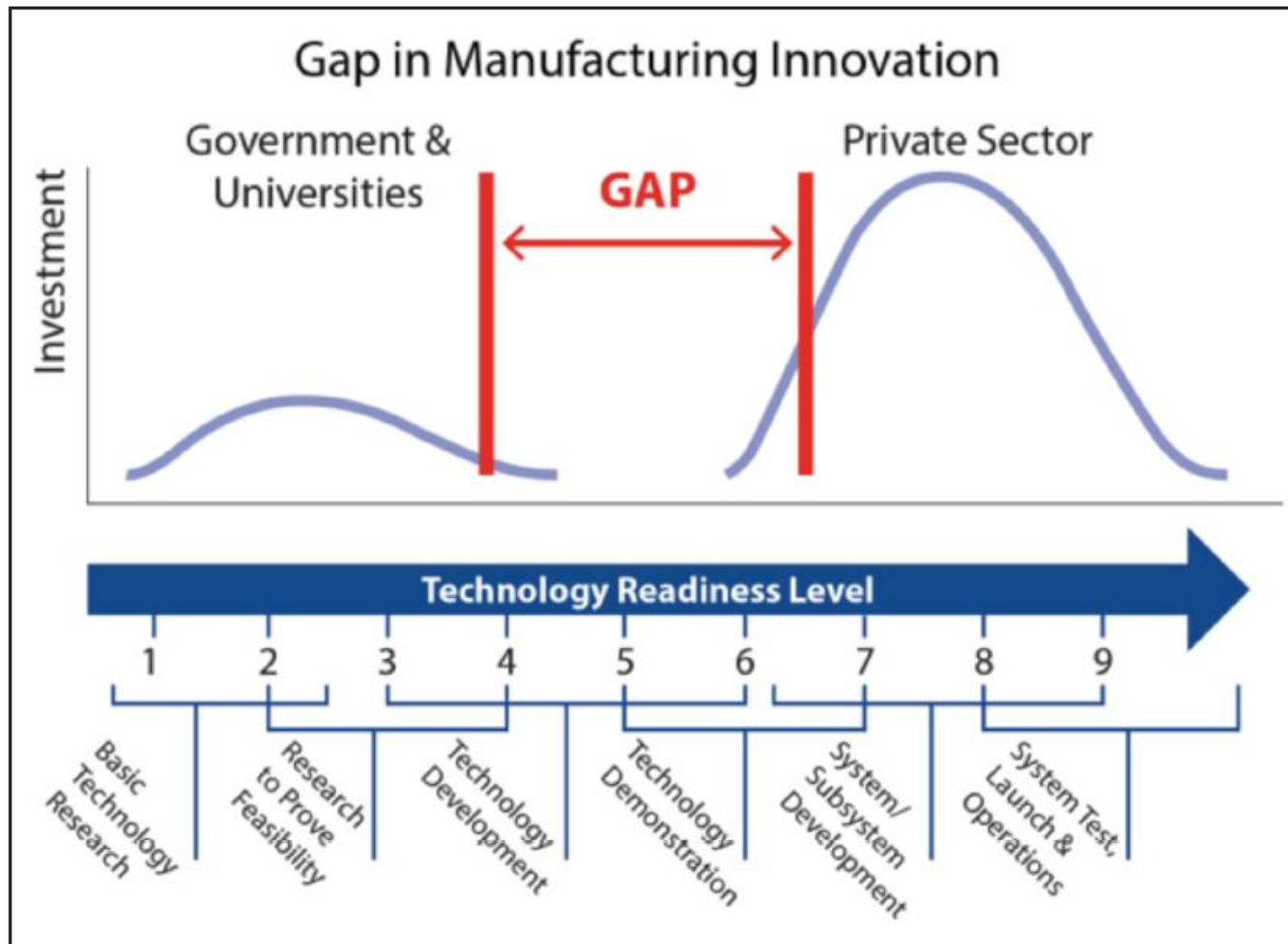
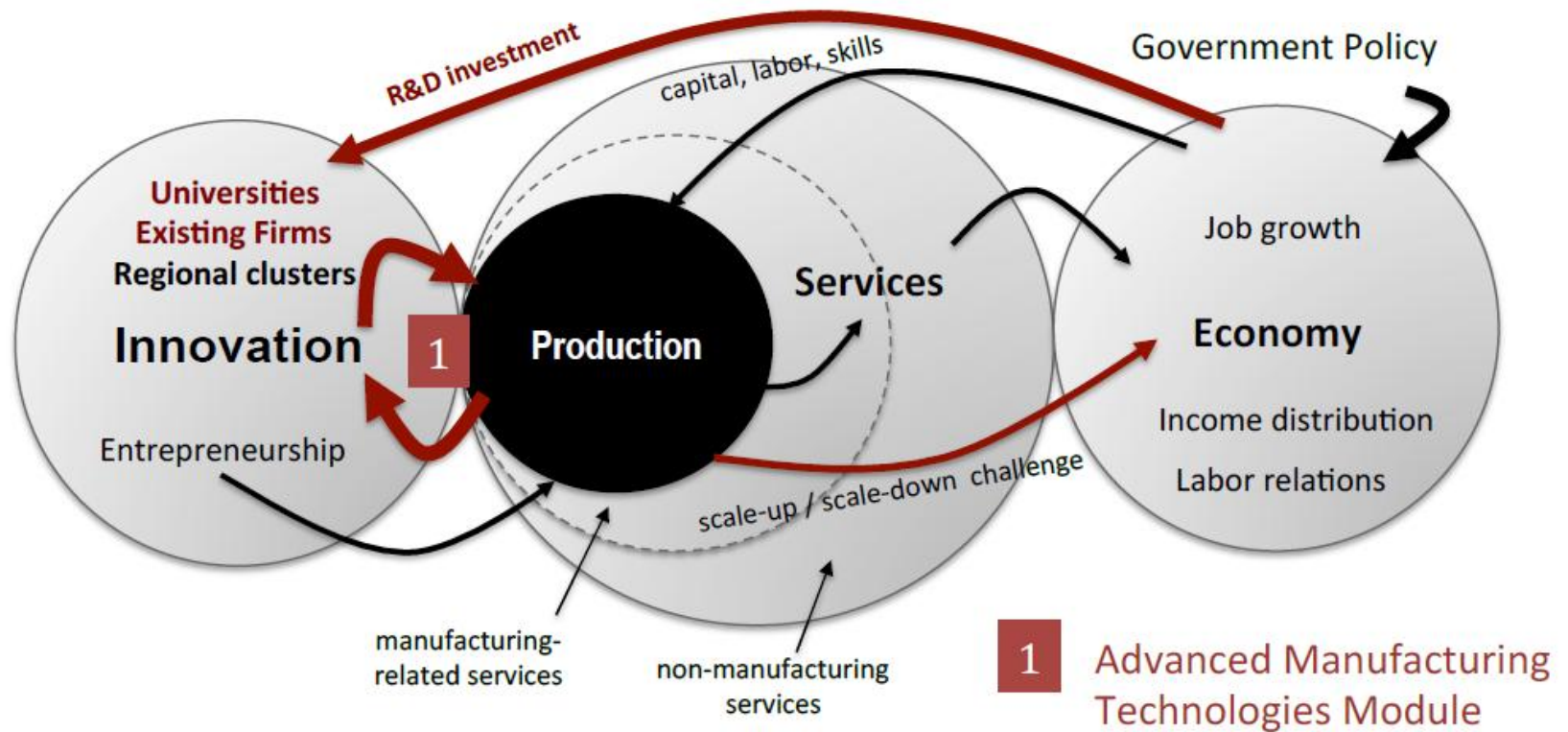


Table 2: Comparison of Investment Levels in Manufacturing Research

Country	Program and Summary	Investment in U.S. dollars ¹ (billions)	Equivalent U.S. investment ² (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 observe three main development directions (trends):

1. Technologies that are truly enablers of classes of products that do not yet currently exist (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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2. **“Programmable” manufacturing processes that do not rely on capital-intensive tooling and fixtures. Examples of such technologies include: computer vision, 3D printing, maskless micro-lithography, etc.**

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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 existing jobs and the new jobs they do create will be meaningful, and require higher levels of skill and knowledge.

A Sustainable Development for the Industrial Production

“Efficiency as the relationship between employed resources and achieved results”



“From profit maximization with minimal investment”



“To the optimal use of materials and energy resources”

Improving Energy Efficiency



Inputs



Operations



Products

	O1 Water intensity	P1 Recycled/reused content
	O2 Energy intensity	P2 Recyclability
	O3 Renewable proportion of energy	P3 Renewable materials content
	O4 Greenhouse gas intensity	P4 Non-renewable materials intensity
I1 Non-renewable materials intensity	O5 Residuals intensity	P5 Restricted substances content
I2 Restricted substances intensity	O6 Air releases intensity	P6 Energy consumption intensity
I3 Recycled/reused content	O7 Water releases intensity	P7 Greenhouse gas emissions intensity
	O8 Proportion of natural land	

Improving Energy Efficiency

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

Experimental Energetic Assessment

How much energy

Where and How

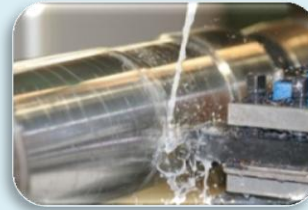
Components and Subsystems

When

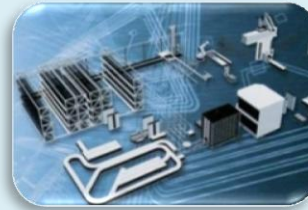
Productive phases, stand-by

Why

Movements, temperature, control, friction, electrical losses, inertia, ...



Productive Process



Productive System



Machine



Part Program

Improving Energy Efficiency

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

Experimental Energetic Assessment

How much energy

Where and How

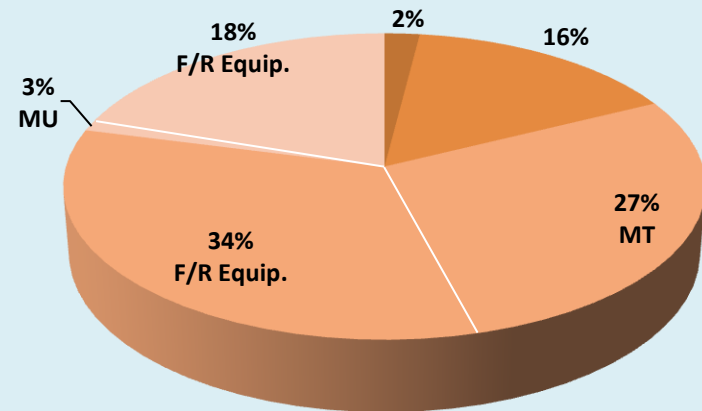
Components and Subsystems

When

Productive phases, stand-by

Why

Movements, temperature, control, friction, electrical losses, inertia, ...



- Turning/Milling
- Cylindrical grinding
- Grinding of chip evacuation channel
- Thread grinding

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

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

Improving Energy Efficiency

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Experimental Energetic Assessment

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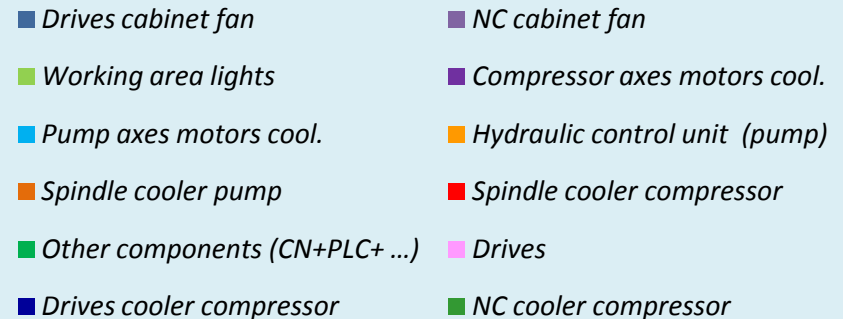
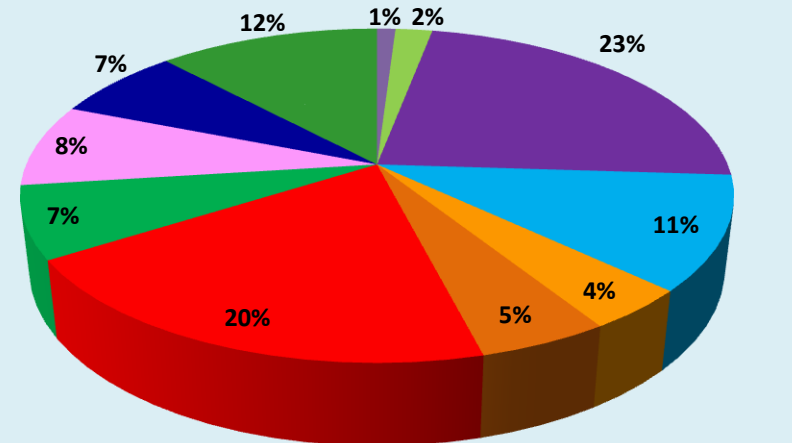
Components and Subsystems

When

Productive phases, stand-by

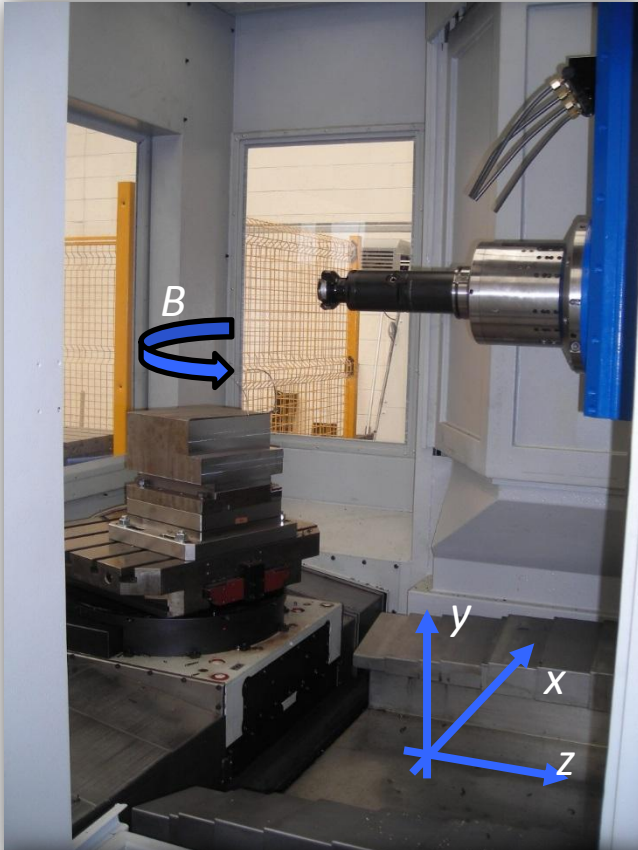
Why

Movements, temperature, control, friction, electrical losses, inertia, ...



Source: EROD project, MUSP

Improving Machine Tools Energy Efficiency

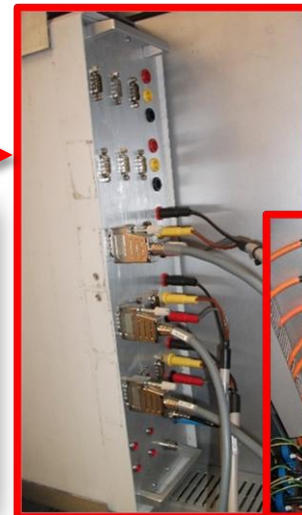


Features

- 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

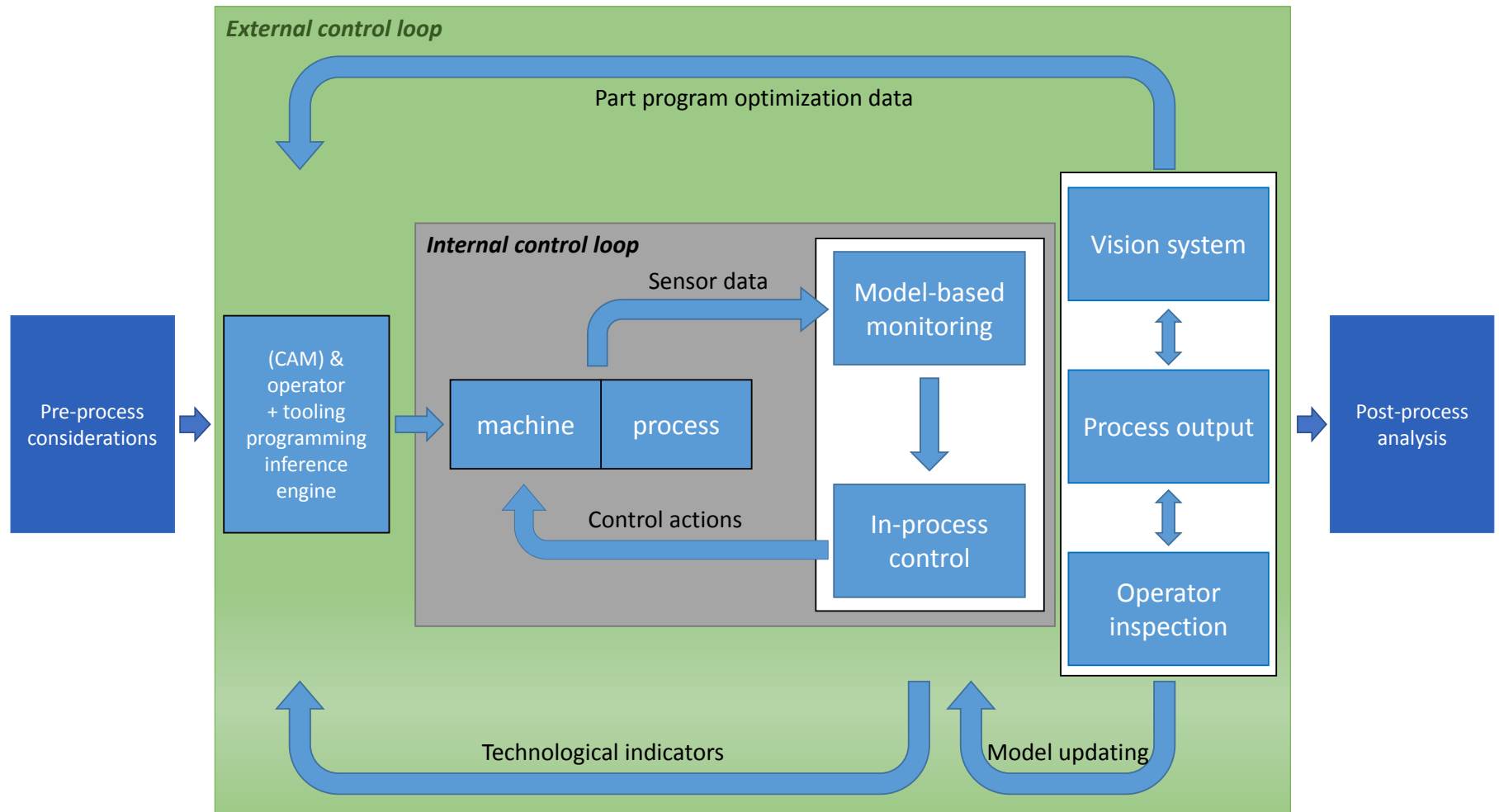
Sensors

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



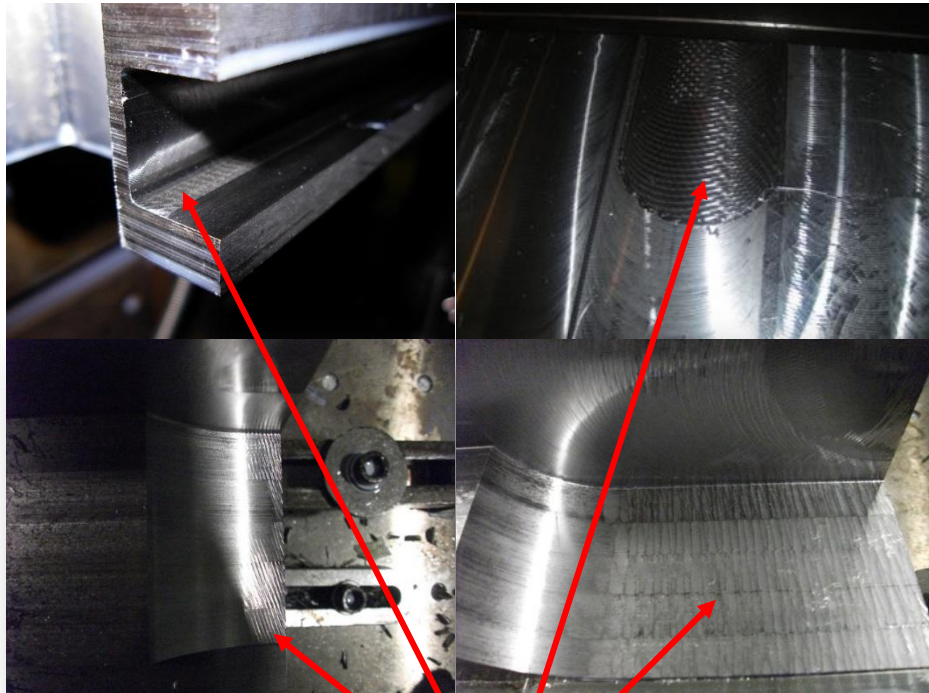
Smart Machining

Advanced monitoring and control systems for machine tools



Smart Machining

Instability effects in machining



Unwanted vibrations

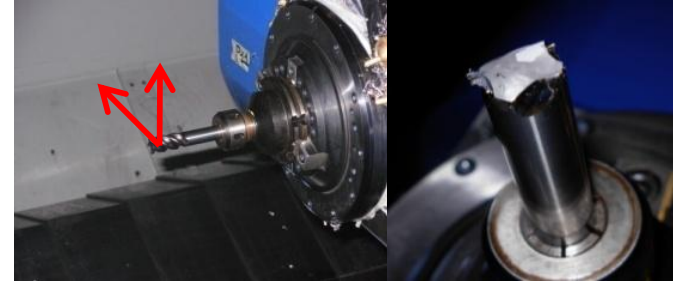


Unacceptable
surface quality

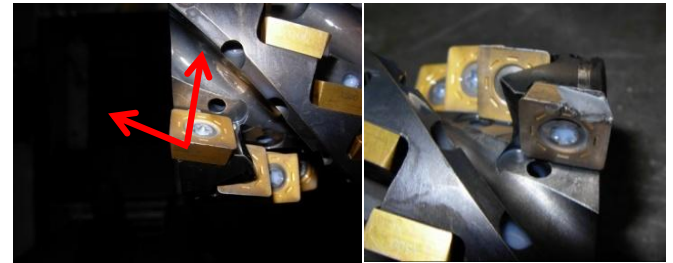
Vibrations effects



- Tool breakage



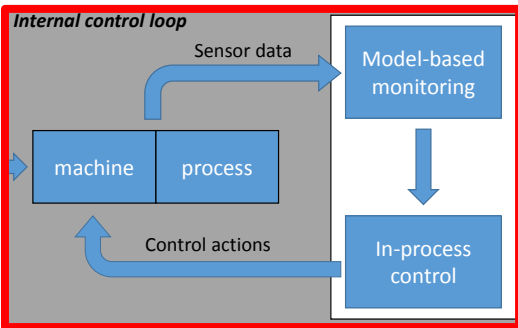
- Tool chipping



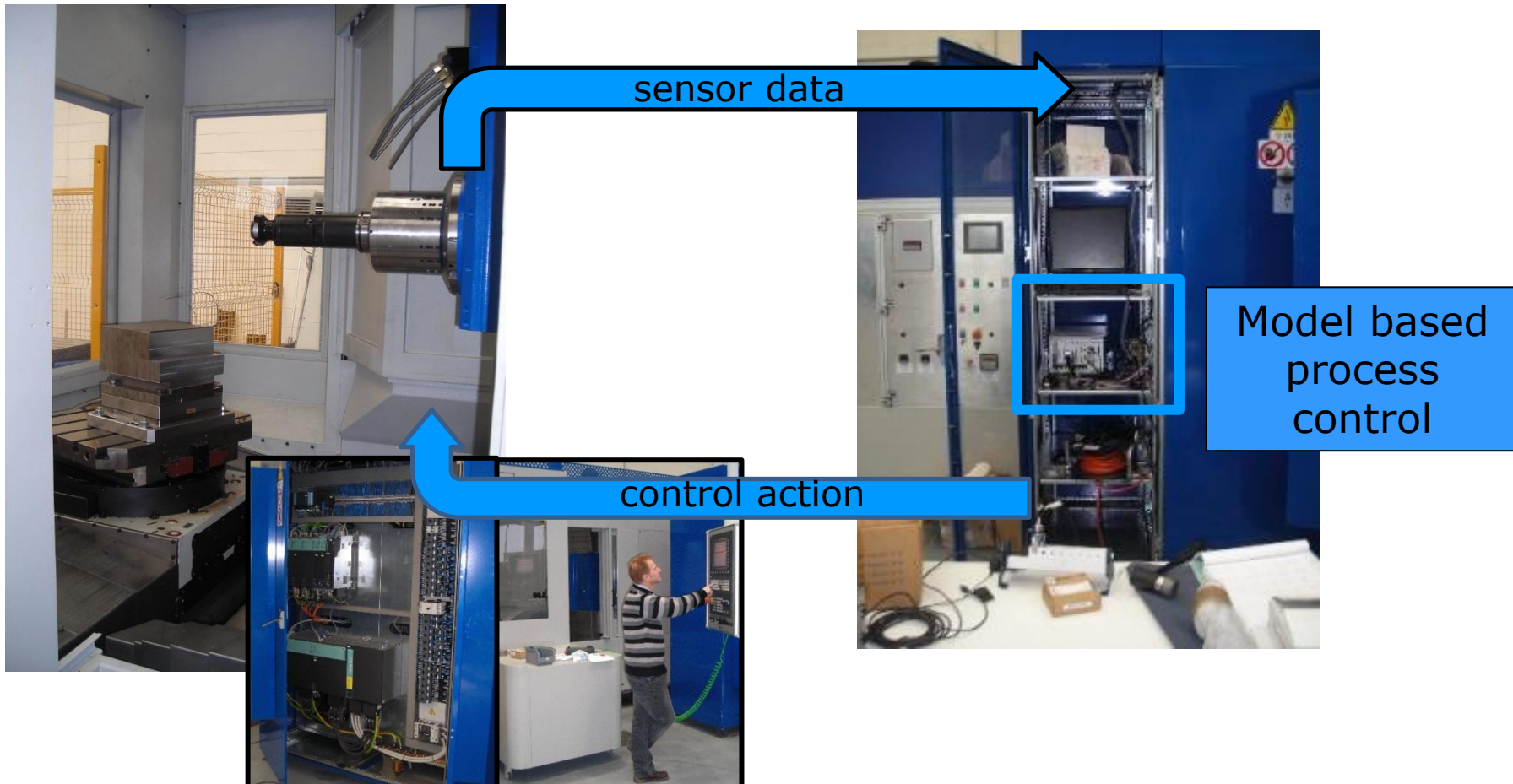
- Spindle bearings damaging



- Excessive vibrations -> downtime



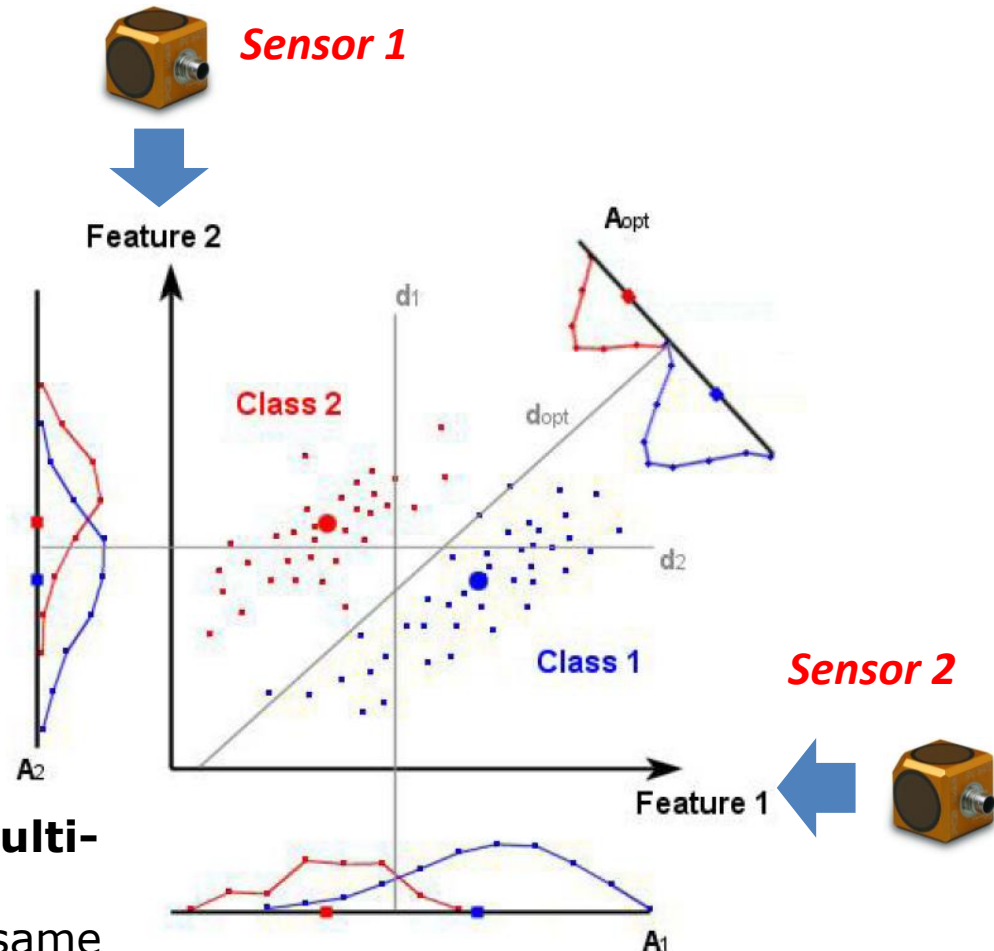
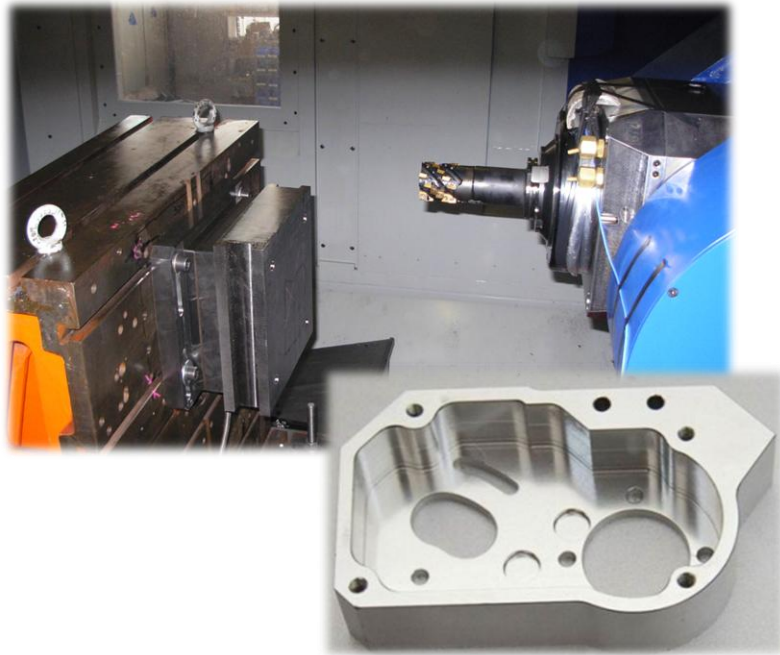
Advanced system for monitoring and control vibrations in milling



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

What's next?

New technologies, new challenges...

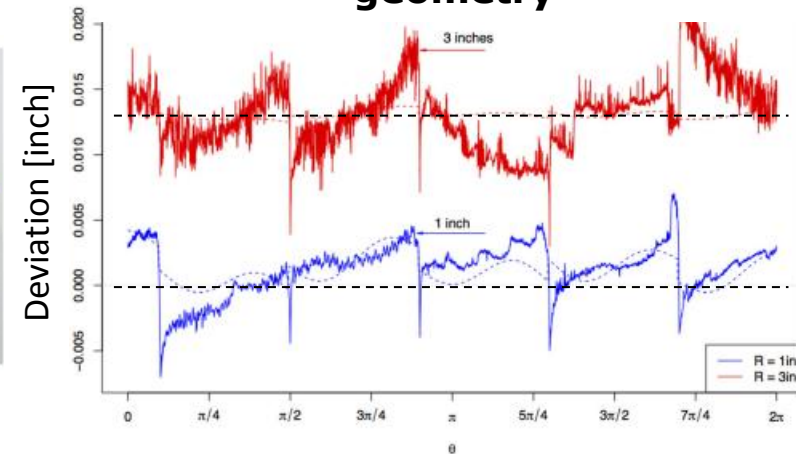
Additive manufacturing:

- Error assessment
- In-process compensation
- Sensorization?

[Huang, 2014]



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*



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



Extremely high temperatures at the tool-chip interface



Low cutting speeds

Large use of cooling and lubricating oils



Low productivity



Cryogenic machining

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

Liquid Nitrogen (LN2):

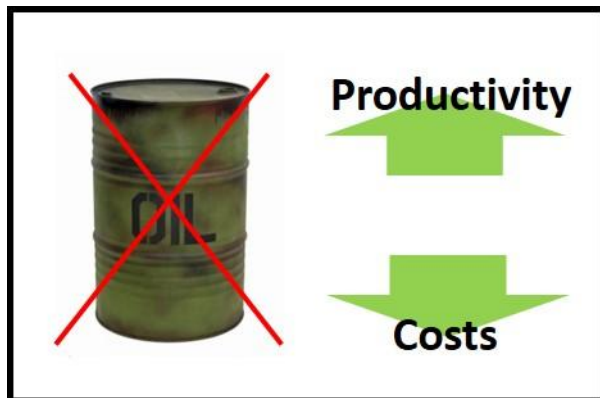
- Inert
- Non polluting
- Non flammable
- Non toxic
- Boiling point at - 196°C

Advantages for the process:

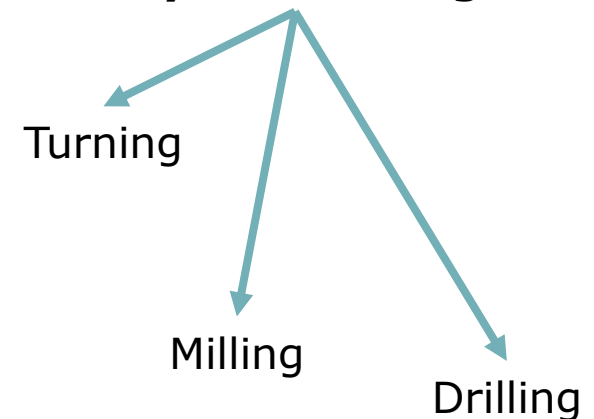
- Strong temperature reduction
- Improvement of tool life
- Improvement of MRRs
- Clean and dry chip and workpiece

Environmental benefits:

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



Cryo-Machining



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

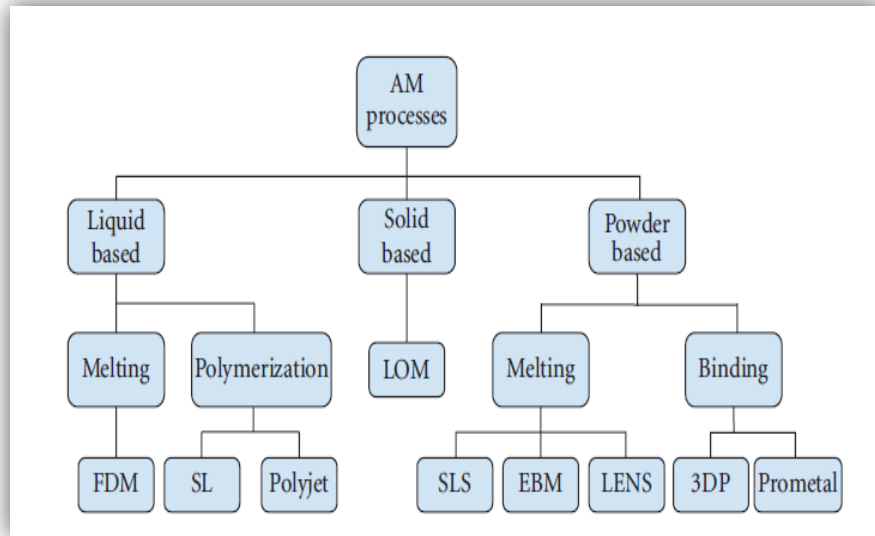
Storage of the virtual model

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



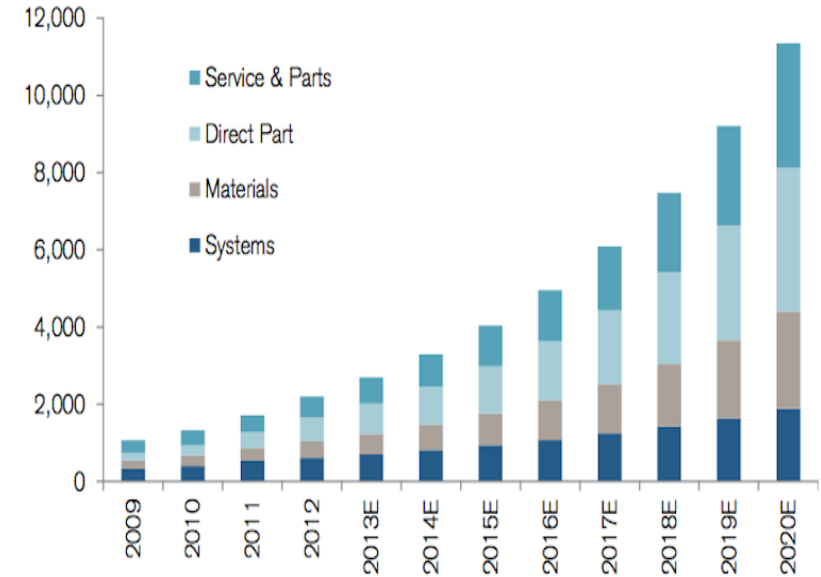
Powder based technologies are still too expensive for large scale productions



Hybrid manufacturing can be considered the best compromise for the future

Exhibit 11: Primary Global AM Market

US\$ in millions, unless otherwise stated



Source: Credit Suisse estimates.



Fraunhofer

USA

Center for Coatings
and Laser Applications

Laser Additive Manufacturing of Turbine Blade Demonstrator (Direct Metal Deposition Process)



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!



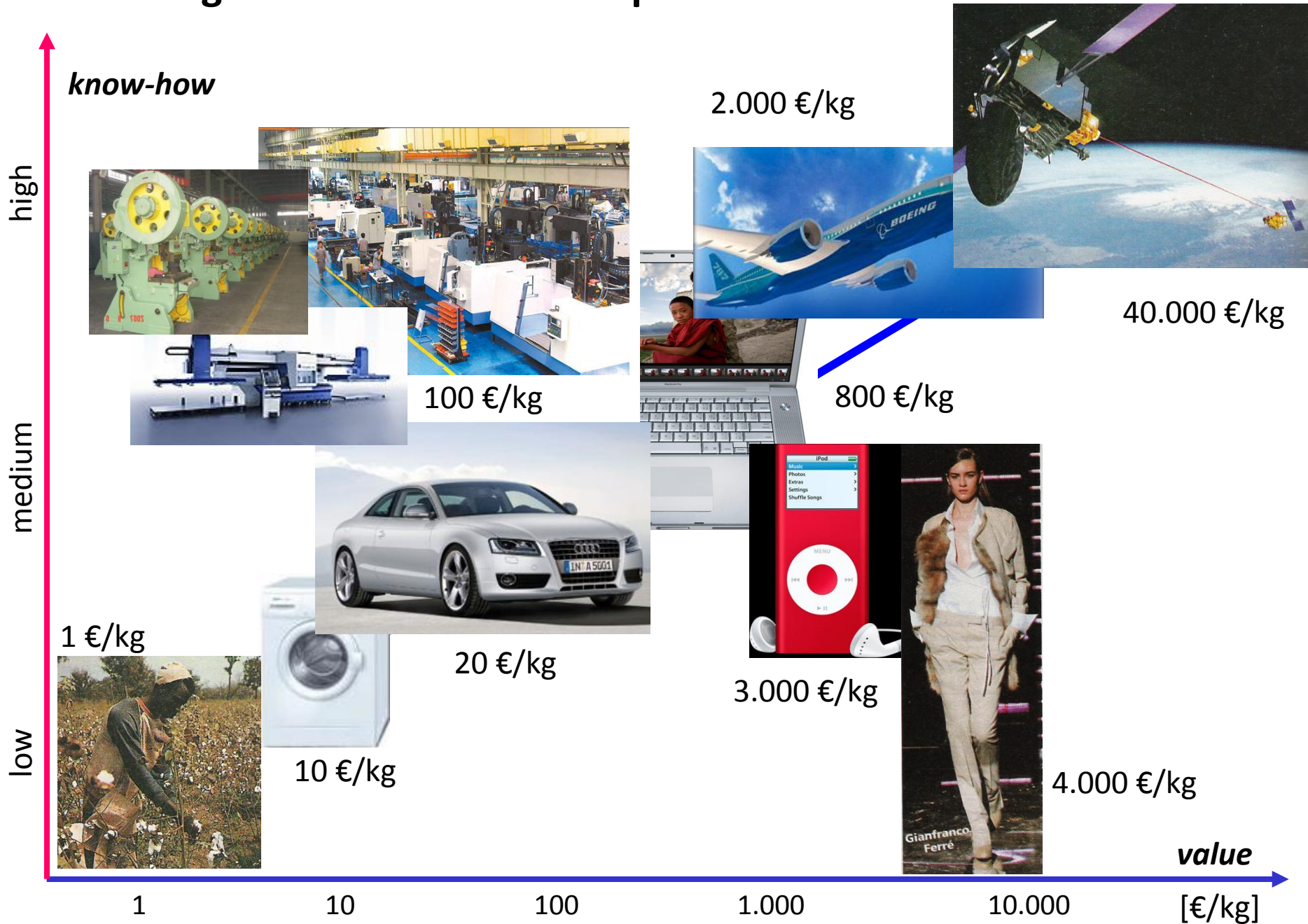
Be careful where you snap, and always be aware of your surroundings.
You never know when a Kodak moment could turn killer.

Conclusions

But there are questions that need to be answered:

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

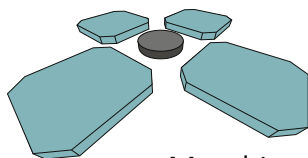
Knowledge content vs. Value of products



THANKS FOR YOUR ATTENTION!



EMO Milano
October 8, 2015



MUSP

Macchine Utensili e Sistemi di Produzione

Prof. Michele Monno



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