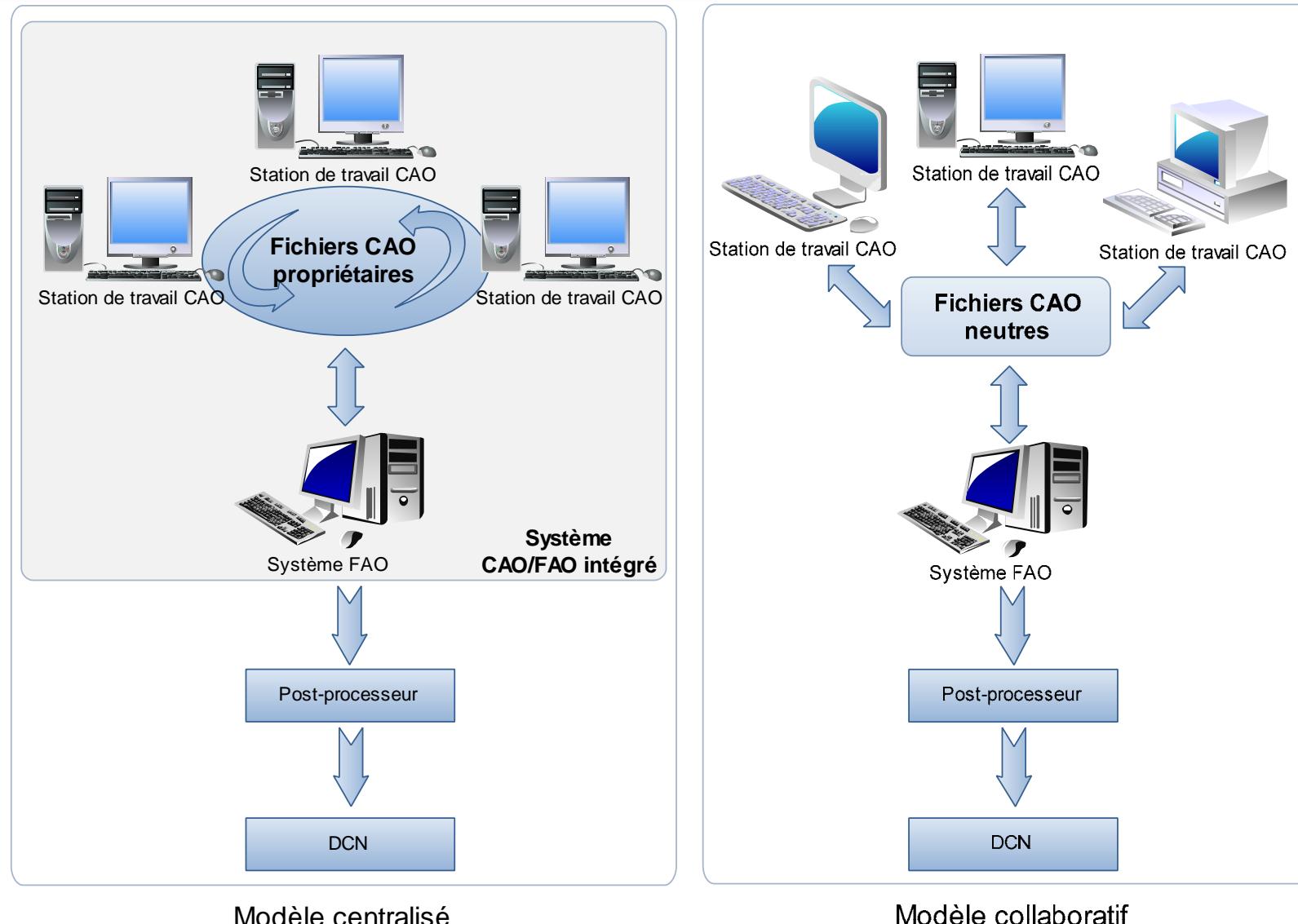


Raphael LAGUIONIE

# Feature based CNC programming in a multi-process environment

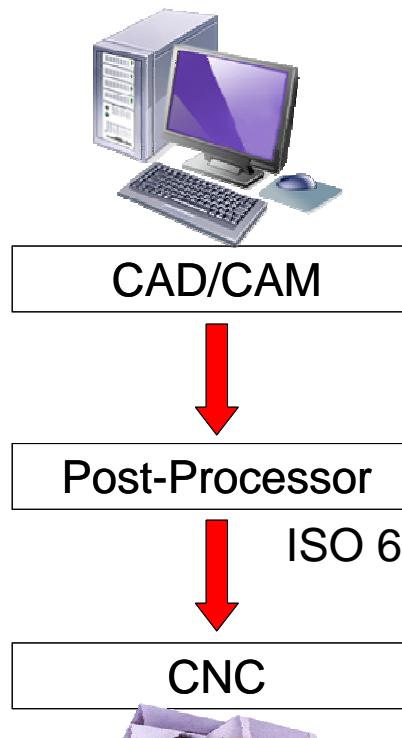
*Institut Recherche Communications Cybernetique Nantes (IRCCyN)*  
*1, rue de la Noé, BP92101, 44321 Nantes – France*

# Numerical chain models



# La programmation basée entités

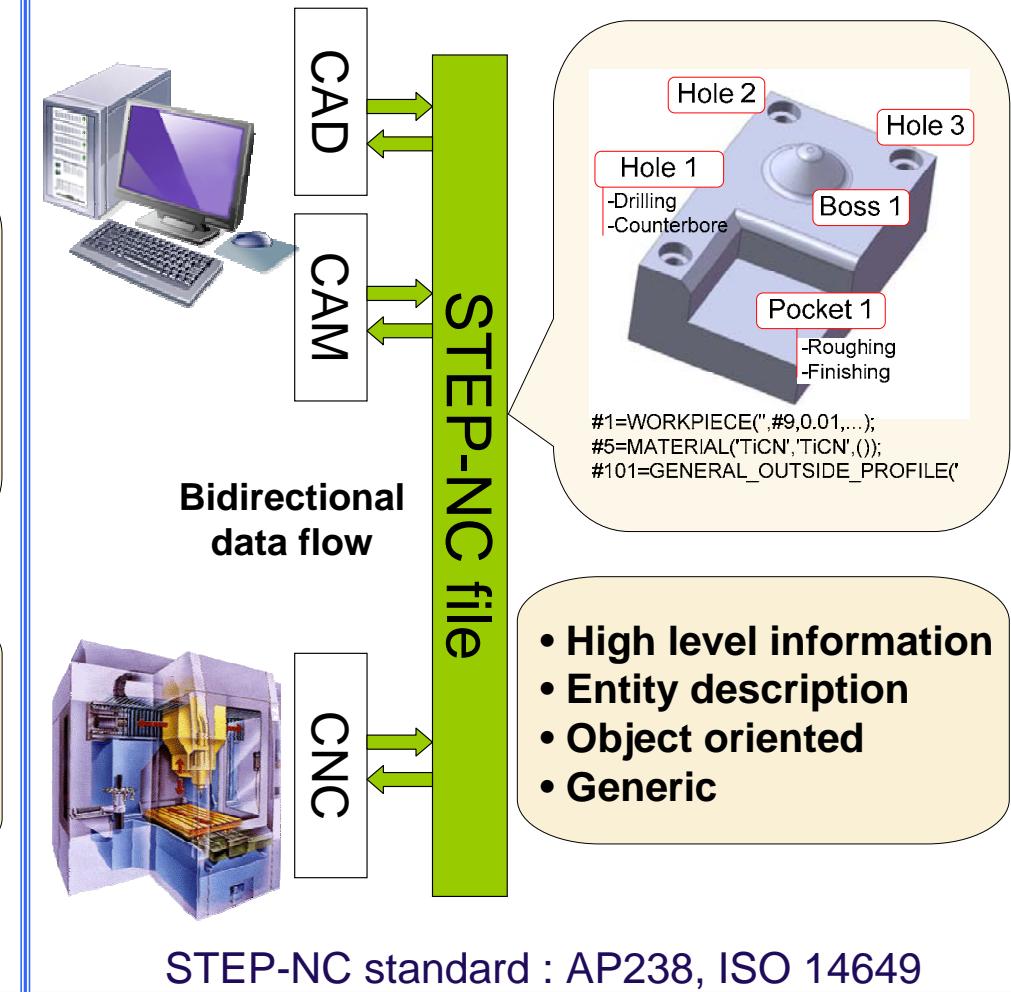
## Current numerical chain



N10 G54  
N20 G0 Z20  
N30 G2 X31Y29 I28  
J29  
N40 G3 X13 Y22 I13  
J27  
N50 G641  
N60 T2 D2 M6

- Low level information
- Elementary actions
- Vendor specific extensions

## STEP-NC numerical chain



# Research at IRCCyN

Technology covered :	Milling	Turning	Additive Manufacturing	Incremental Sheet Forming	Multi-process
STEP-NC oriented	CAM-CNC Model	●	○	●	●
	Simulation tools	●	○	●	●
	Manufacturing Platform	●		●	●
STEP-NC compatible	On machine tool inspection	●		●	
	e-manufacturing	●		○	●
	Demonstration means	●	●	●	●

● Available ○ Work in progress

# Agenda

## ● **STEP-NC: standard development**

- Integration of new toolpaths generation strategy
- Development of machine tool functional model

## ● **Presentation of the eXtended Manufacturing Integrated System XMIS**

- Presentation
- eXtended CAD and eXtended CNC

## ● **Integration of multi-process context**

- In a STEP-NC Workplan
- Simulation spaces concept
- Illustration of the concept

## ● **Application on industrial means**

- SPAIM : STEP-NC Platform for Advanced and Intelligent Manufacturing
- Application in SPAIM
- Test parts



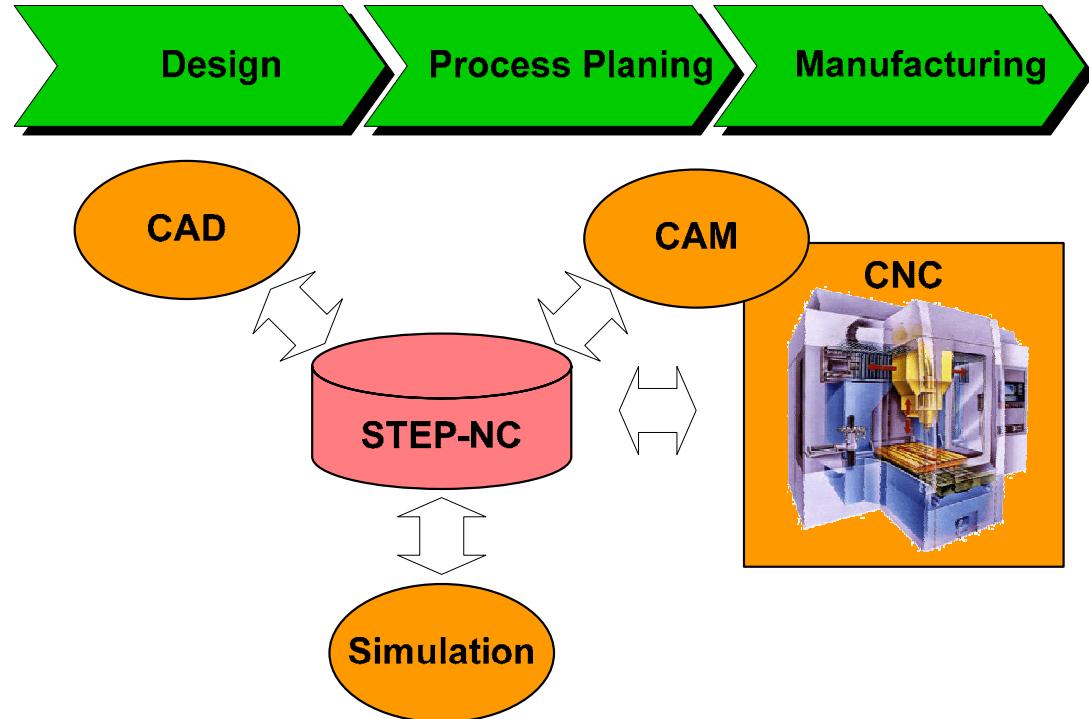
# *STEP-NC : A new vision of numerical chain*

Total integration of  
CAD-CAM-CNC chain

No information  
lost

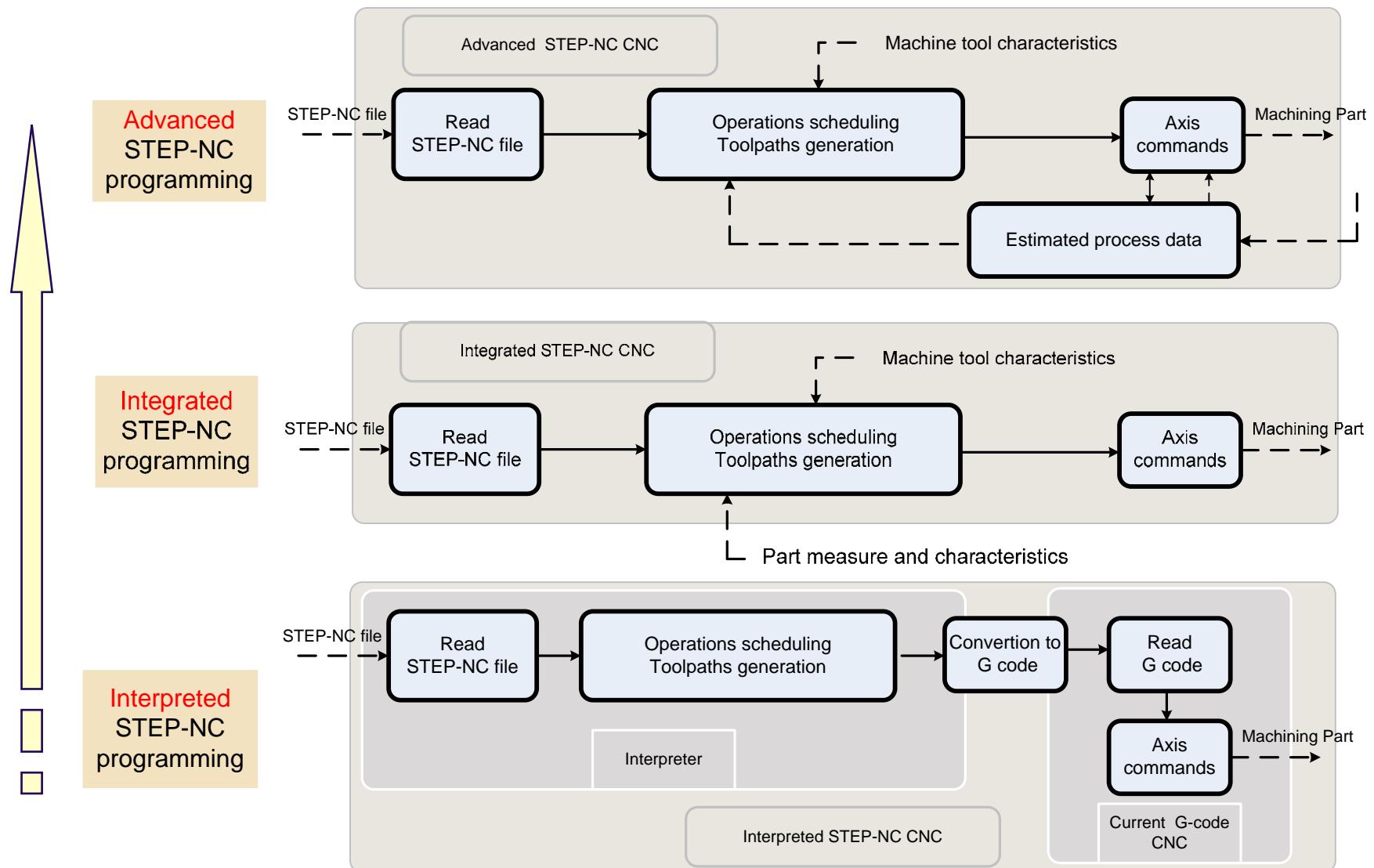
Implementation of a  
single file

Bidirectional  
data flow



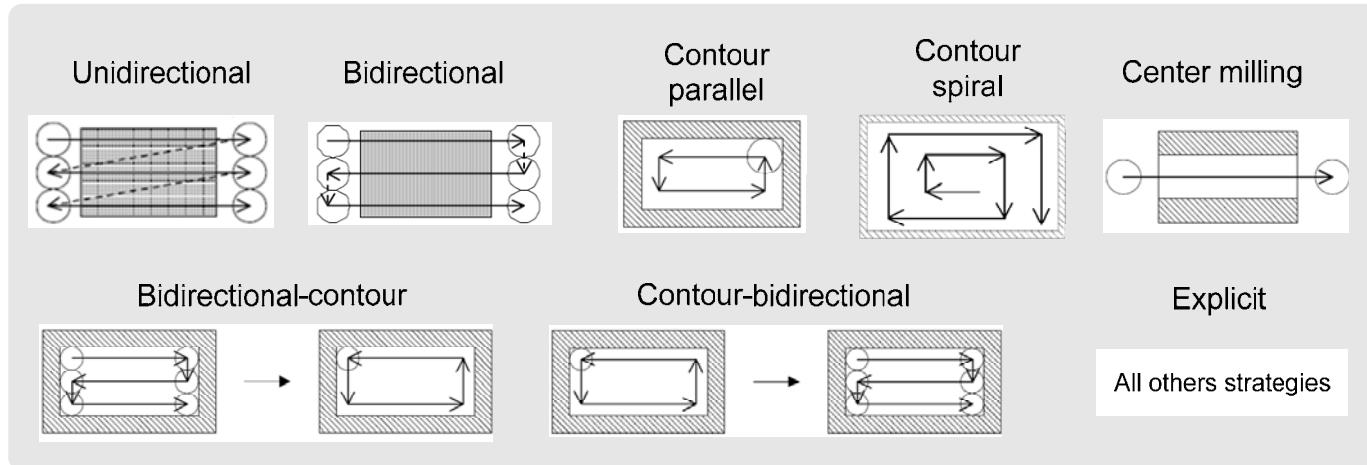
- End of post-processors
- Machine tool independent adaptation

# *Situation of the study in STEP-NC development*



# Contribution to standard development

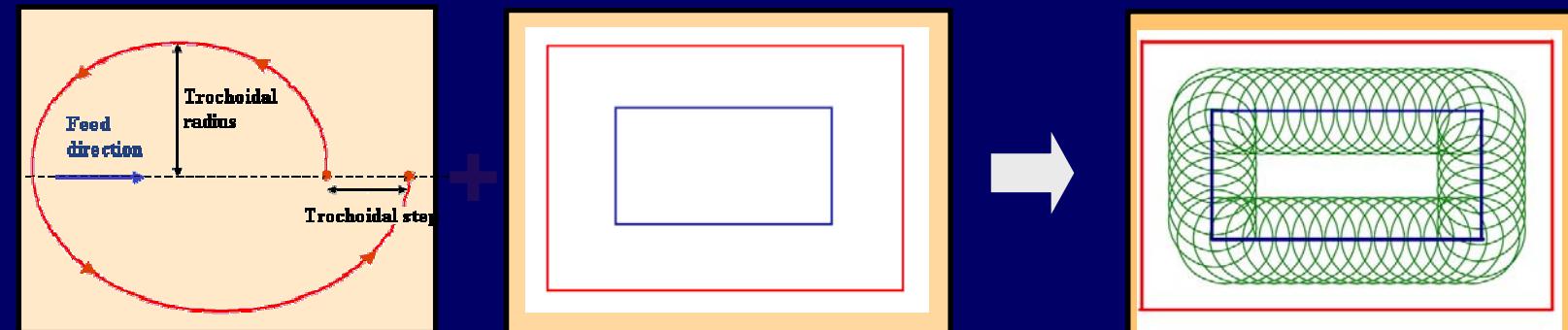
Enrichment of strategies proposed in STEP-NC :



## Pattern strategies : PATTERN + GUIDE CURVE

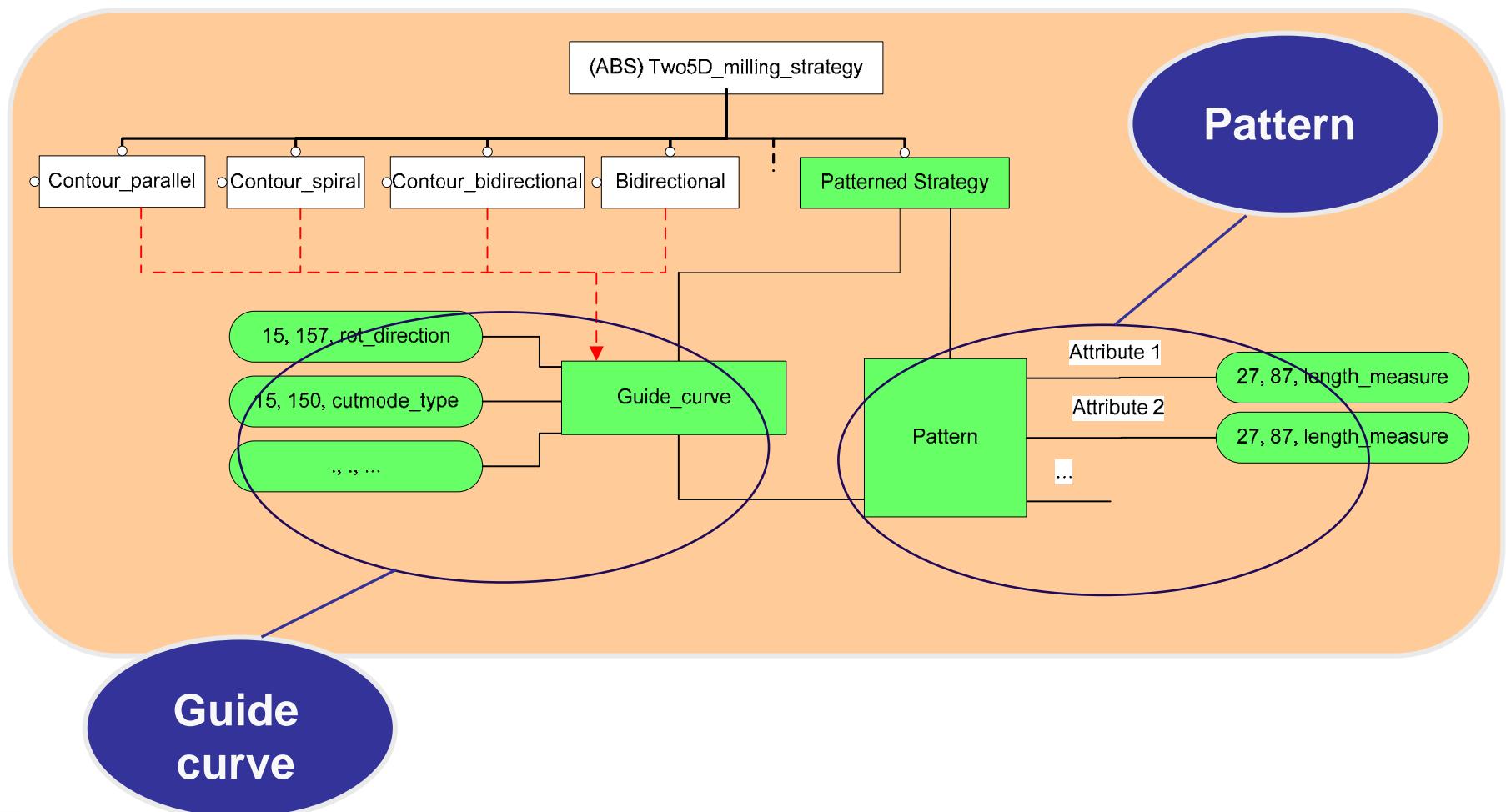
Exemples of strategies built on pattern curves : - Plunge milling,Trochoïdal milling, etc

Trochoïdal milling :



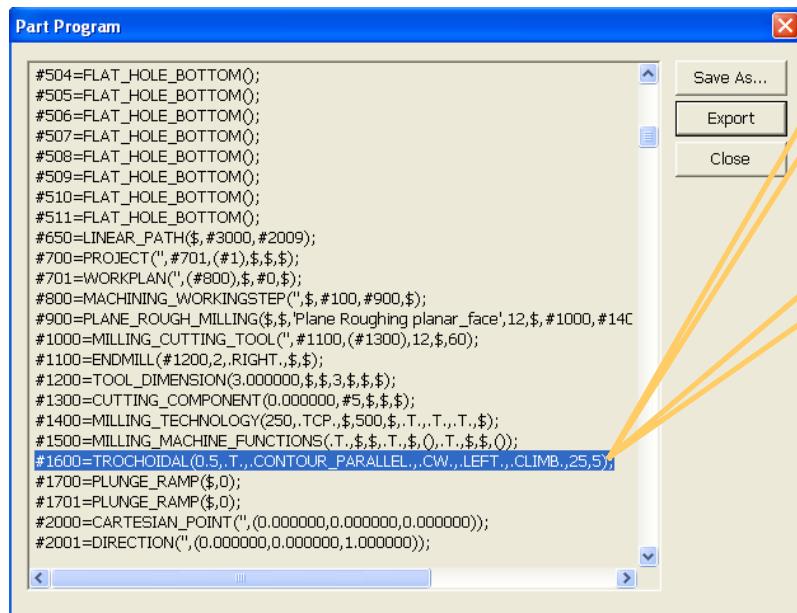
# *Proposition to integer pattern strategies in Step\_NC standard*

Integration of new strategies using strategies already implemented:



# *Proposition to integrate pattern strategies in STEP-NC standard*

*STEP-NC file generated by PosSFP*



```
#504=FLAT_HOLE_BOTTOM();
#505=FLAT_HOLE_BOTTOM();
#506=FLAT_HOLE_BOTTOM();
#507=FLAT_HOLE_BOTTOM();
#508=FLAT_HOLE_BOTTOM();
#509=FLAT_HOLE_BOTTOM();
#510=FLAT_HOLE_BOTTOM();
#511=FLAT_HOLE_BOTTOM();
#650=LINEAR_PATH($,#3000,#2009);
#700=PROJECT(",$701,(#1,$,$,$);
#701=WORKPLAN(",$800),$#0,$);
#800=MACHINING_STEP(",$#100,#900,$);
#900=PLANE_ROUGH_MILLING($,$,'Plane Roughing planar_face',12,$,#1000,#14C
#1000=MILLING_CUTTING_TOOL(",$1100,(#1300),12,$,60);
#1100=ENDMILL(#1200,2,RIGHT,$,$);
#1200=TOOL_DIMENSION(3.000000,$,$,3,$,$,$);
#1300=CUTTING_COMPONENT(0.000000,$,$,5,$,$,$);
#1400=MILLING_TECHNOLOGY(250,.TCP,$,$,500,$,T,,T,,T,$);
#1500=MILLING_MACHINE_FUNCTIONS(T,$,$,T,$,0,T,$,$,0);
#1600=TROCHOIDAL(0.5,T,,CONTOUR_PARALLEL,,CW,,LEFT,,CLIMB,,25,5),
#1700=PLUNGE_RAMP($,0);
#1701=PLUNGE_RAMP($,0);
#2000=CARTESIAN_POINT(",(0.000000,0.000000,0.000000));
#2001=DIRECTION(",(0.000000,0.000000,1.000000));
```

Trochoidal milling

```
TROCHOIDAL(0.5,T,,CONTOUR_PARALLEL,,CW,,LEFT,,CLIMB,,25,5);
```

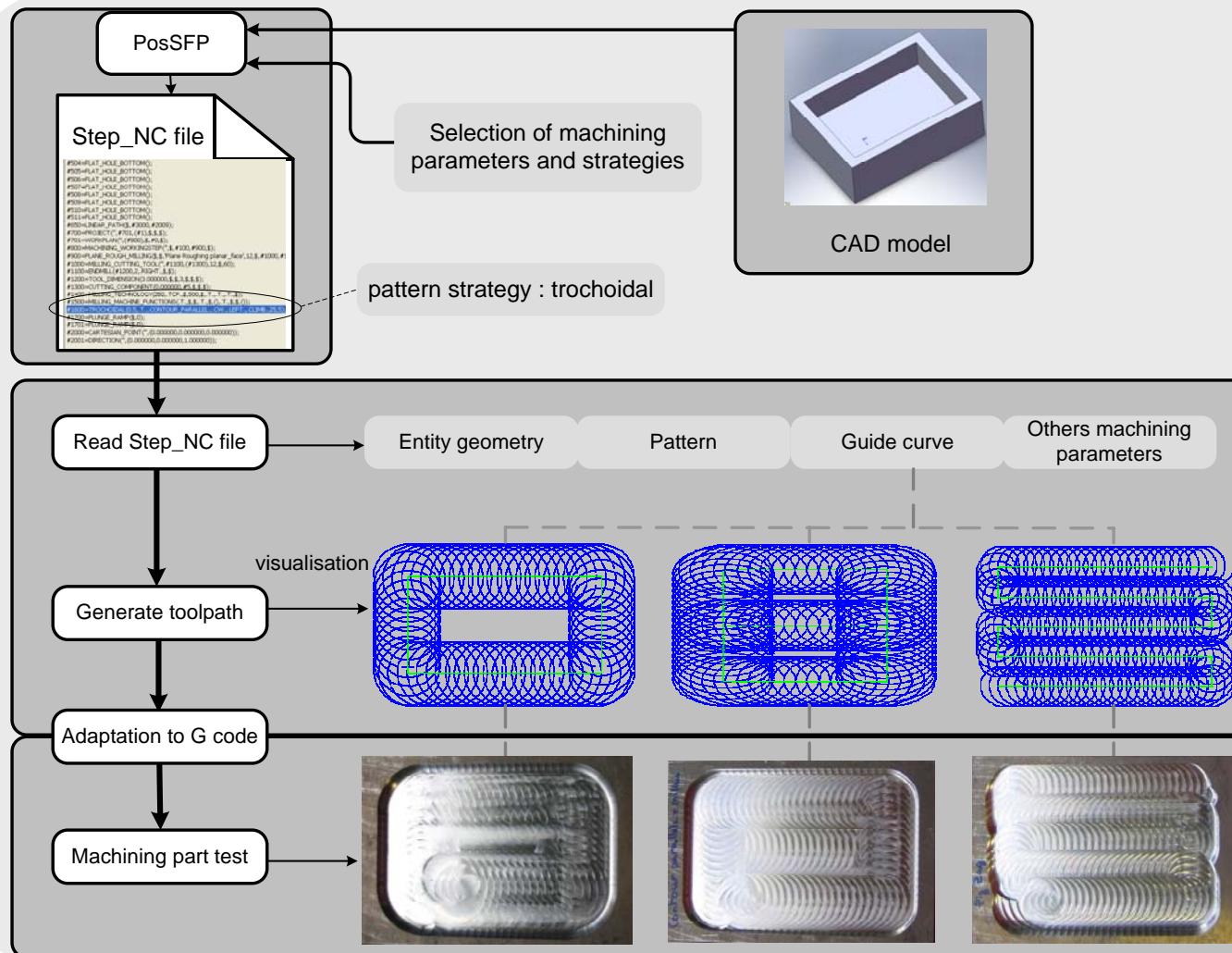
Plunge milling

```
PLUNGE_MILLING(0.5,T,,CONTOUR_PARALLEL,,CW,,LEFT,,CLIMB,,1,2,4,5,1);
```

Proposed syntax for pattern strategies in STEP-NC file :

**f=STRATEGY(*overlap,allow\_multiple\_passes,#guide\_curve,strategy parameters*)**

# Validation of proposition : interpreter implemented with pattern strategies



# Conclusion

- Interest of pattern strategies
- Generation **simplicity**
- **Few attributes** needed to generate a complete toolpath
- Easy **portability**
- Compatibility with Step NC standard and high level programming
- Enrichment of Step\_NC possibilities

Pattern strategies

Step\_NC

- Creation of an interpreted Step\_NC numerical chain
- First Step through advanced programming
- possibility to work with Step\_NC on conventional means

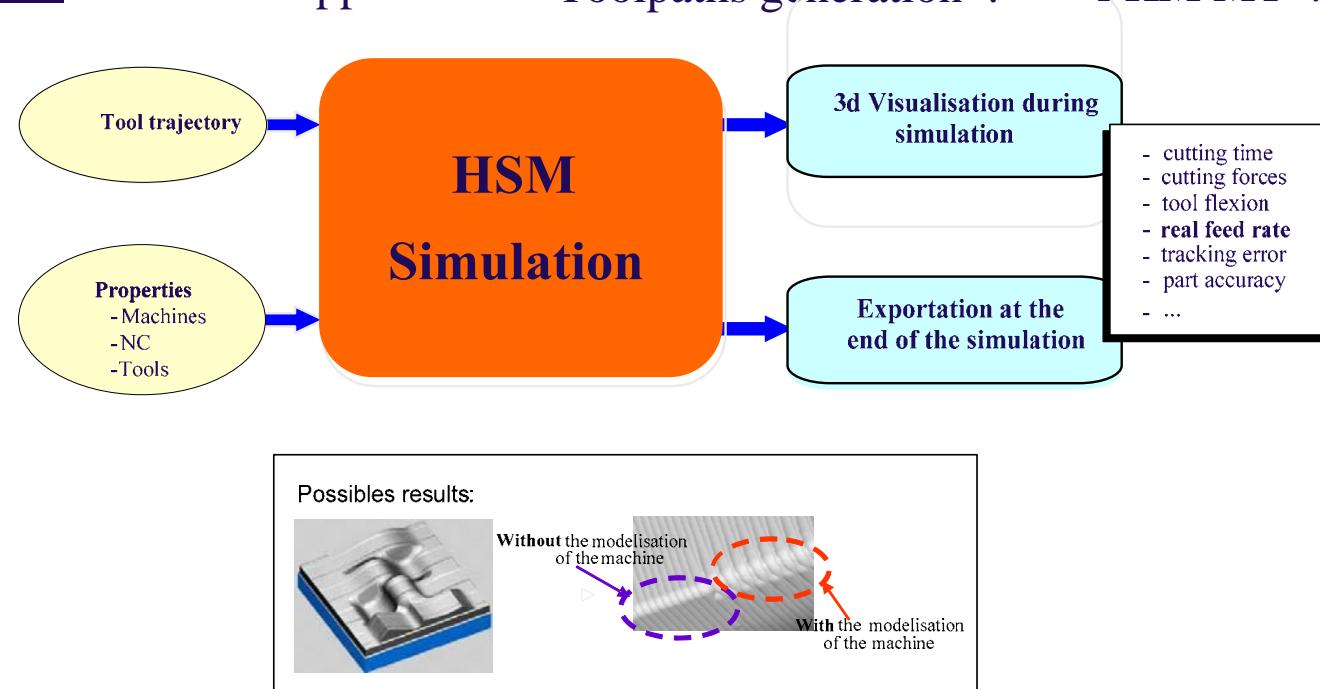
# *Machine tool functional model*



# Machine tool functional-requirement model

Use cases proposed :

HSM simulation : ICAM approach : Toolpaths generation : PKM MT :

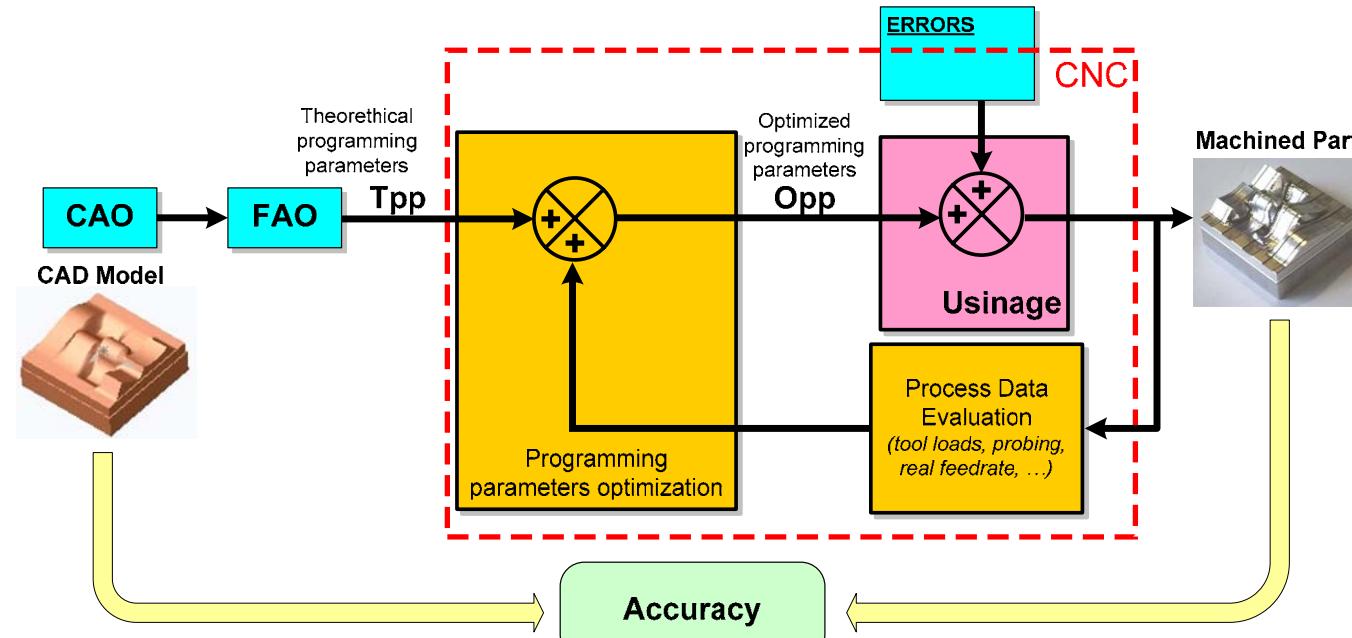


- Kinematics model, velocities, accelerations, deceleration, jerk
- geometric model (geometrical transformation errors for PKM for example)
- Controller properties (look ahead, computation capacities, etc.)
- (Tool properties for cutting tool forces estimation and deflection)

# Machine tool functional-requirement model

Use cases proposed :

HSM simulation : ICAM approach : Toolpaths generation : PKM MT :

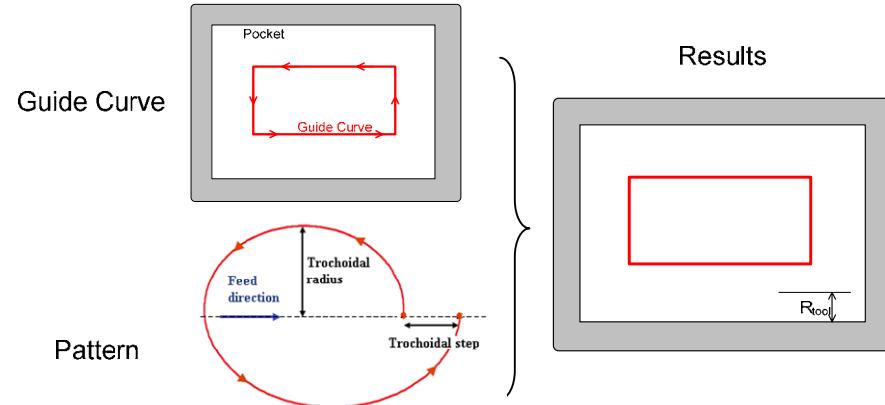


- Geometric model (MGI and resolution algorithms for PKM)
- Servomotor characteristics (max power, currents, etc )
- Process data available online in the controller
- NC controller computation power, memory, time sampling
- Sensors equipment
- Measurement characteristics and capability

# *Machine tool functional-requirement model*

Use cases proposed :

HSM simulation : ICAM approach : Toolpaths generation : PKM MT :



- Dynamic possibilities, velocities, accelerations, deceleration, jerk
- Rigidity, deformations
- NC controller computation power, memory, time sampling

# *Machine tool functional-requirement model*

Use cases proposed :

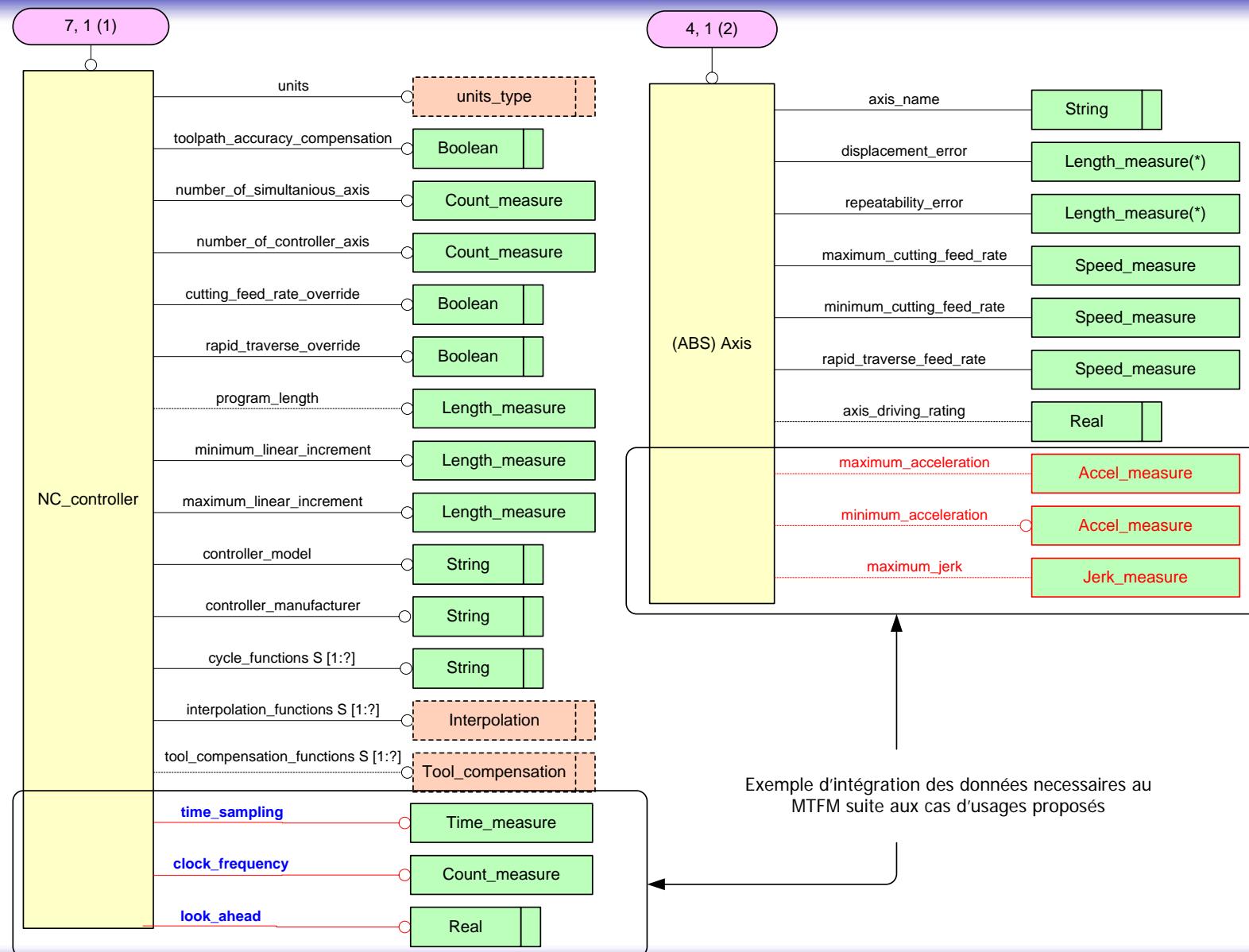
HSM simulation : ICAM approach : Toolpaths generation : PKM MT :



Spindle	24 000 tr/min
Power	40 000 Watts
Axis velocity	50 m/min
Acceleration	1.5 G

- Geometric model, MGI and resolution algorithms
- Singular points
- Calibration
- Deformations
- Workspace (dynamic behaviour sometimes depending of the situation of the tool in workspace)

# EXPRESS-G



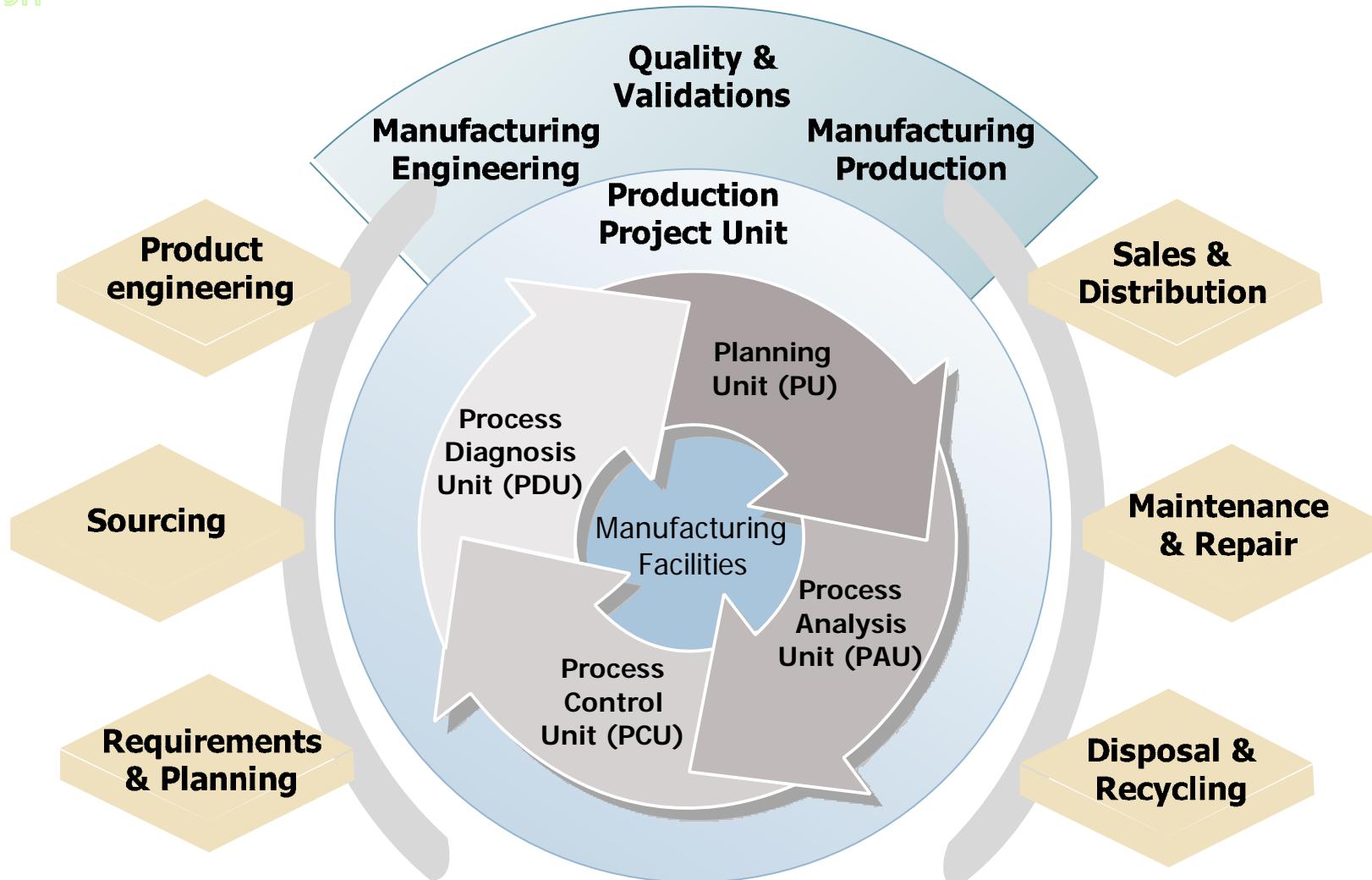
## Conclusion

- *Intégration de nos propositions*
- *Travaux en cours de procédure au niveau normatif*
- *Disponibilité d'un MTFM complet au format STEP-NC (CN étendue...)*

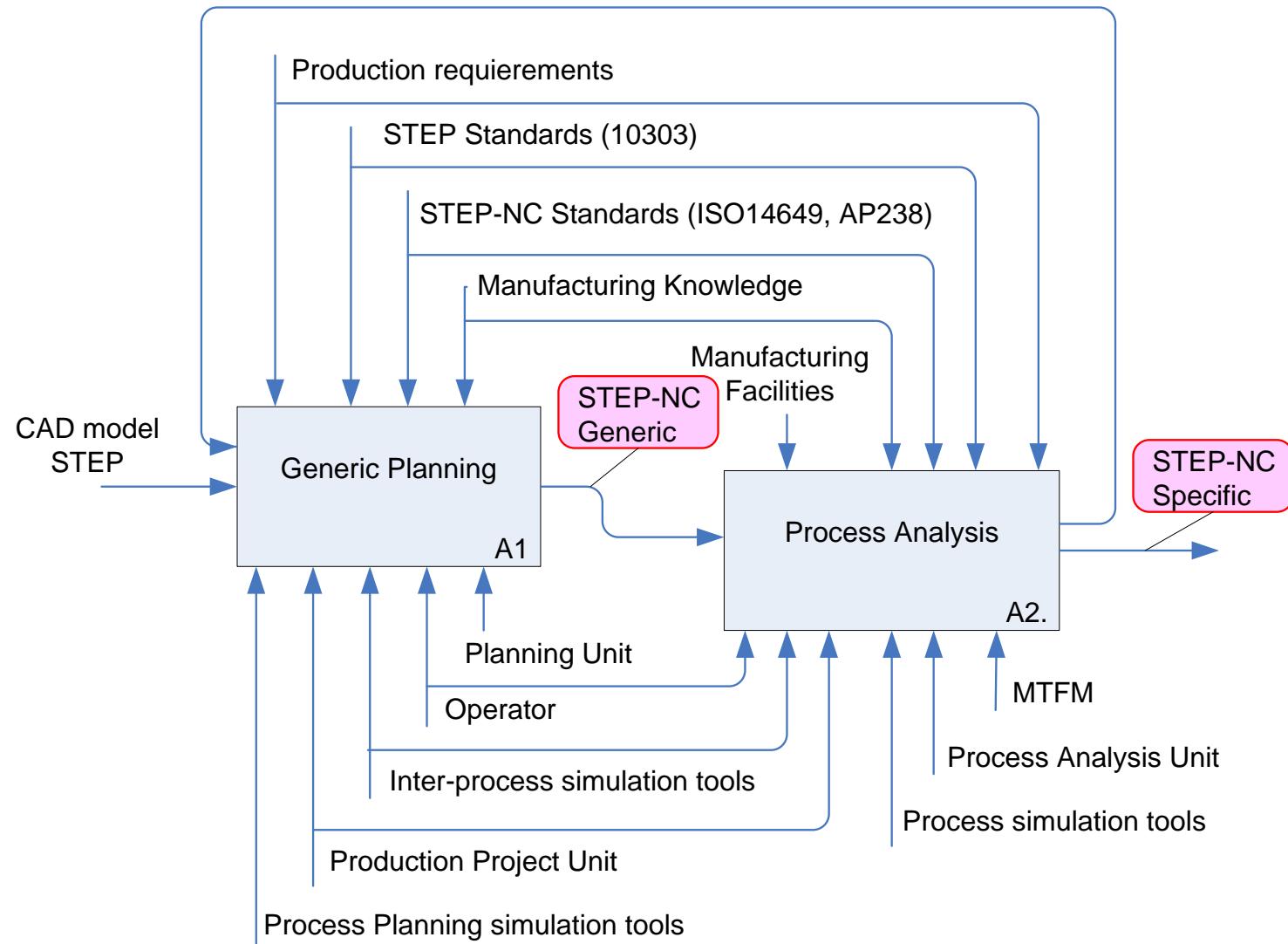
Verrous technologiques et idéologiques à la mise en œuvre de STEP-NC :

- *Travaux d'intégration et de mise en œuvre de STEP-NC faibles sur des moyens industriel*
- *Propositions restreintes à notre vision traditionnelle de la chaîne numérique descendante*
- *Manque système complet de fabrication intégrant STEP-NC*
- *Exploration plus fine de la notion de CN étendue*
- *Intégration des possibilités nouvelles dans un contexte multi-process*
- *Application et démonstrations sur des moyens industriels*

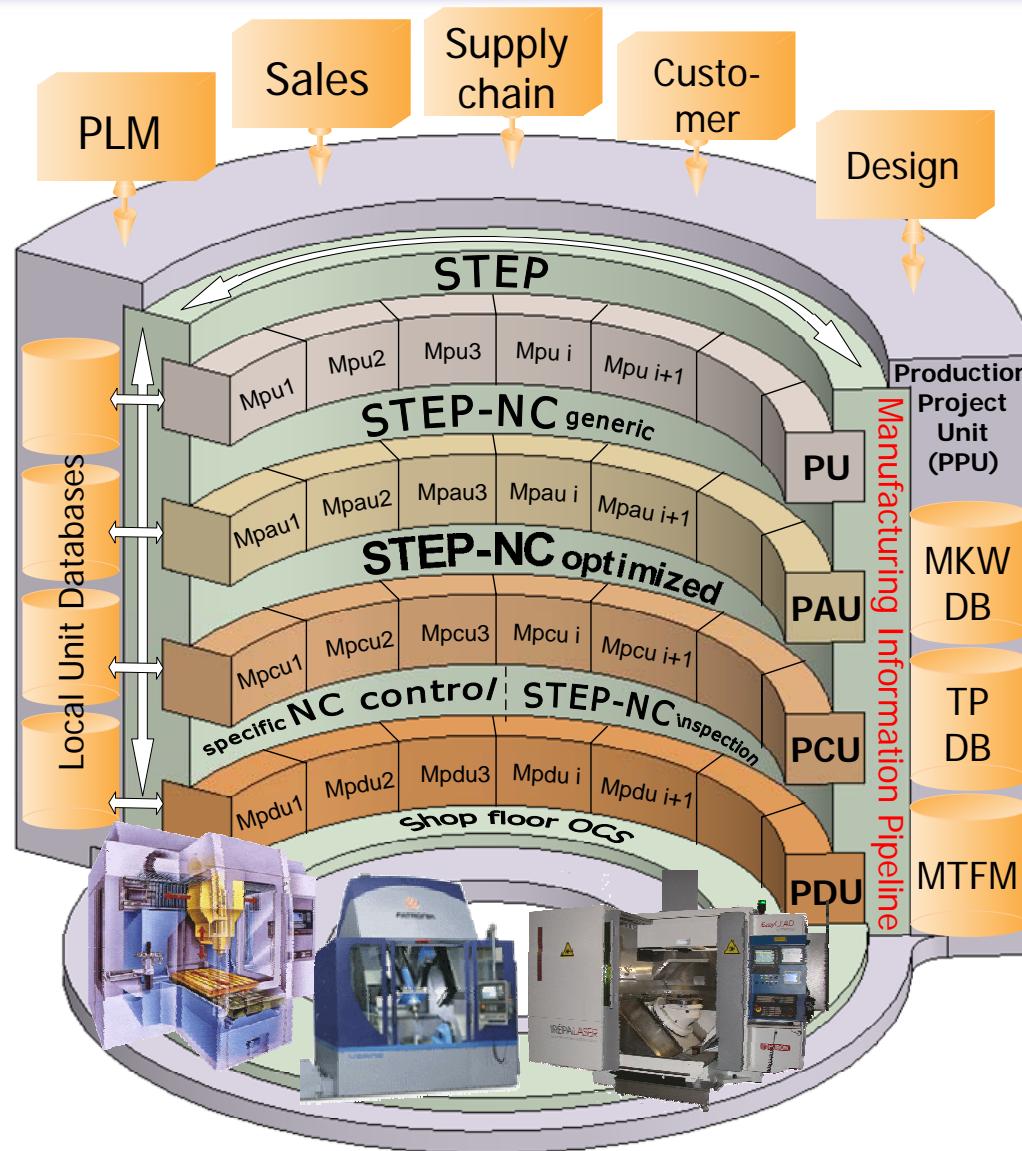
# *Manufacturing System*



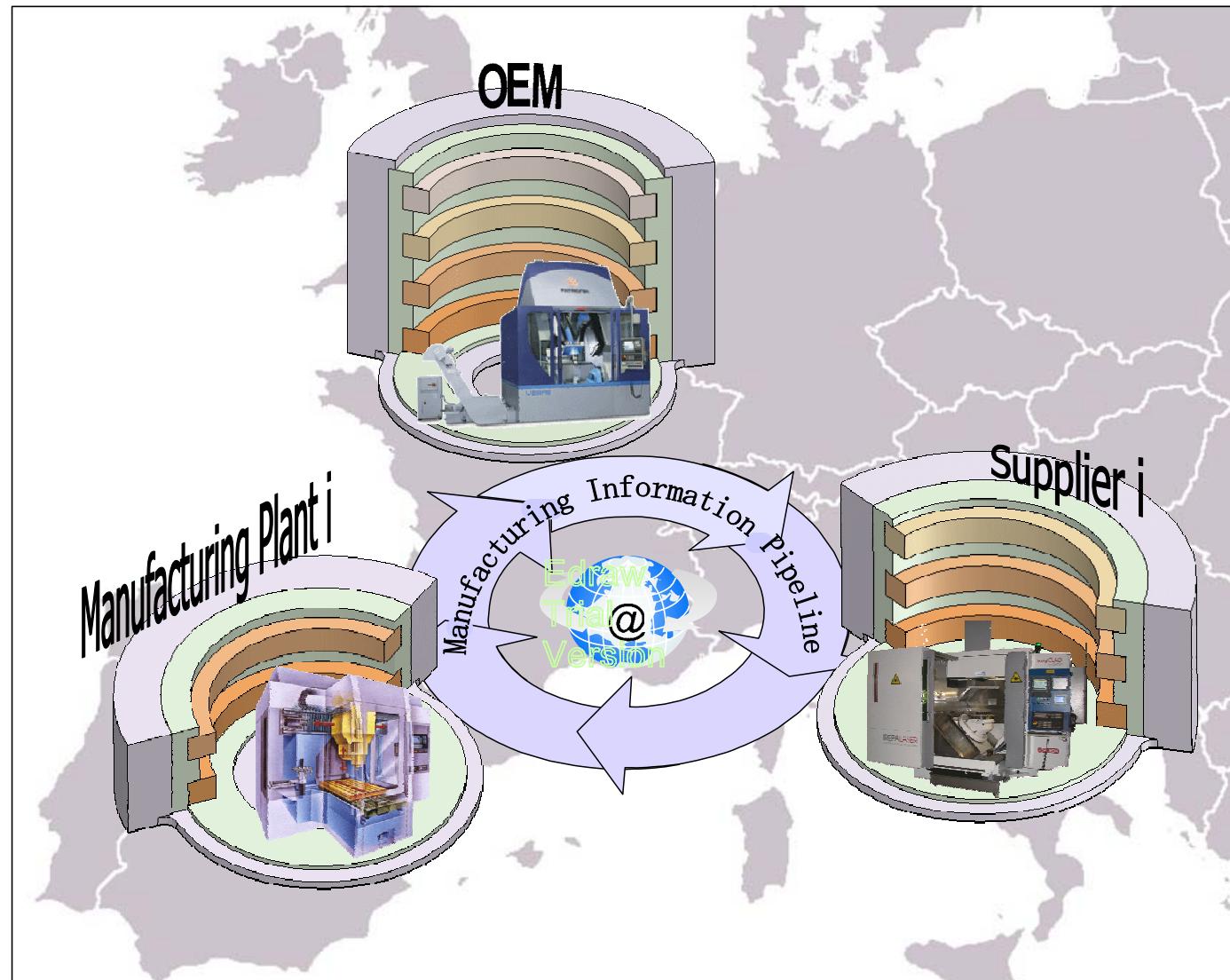
# *Generic and Specific STEP-NC Data*



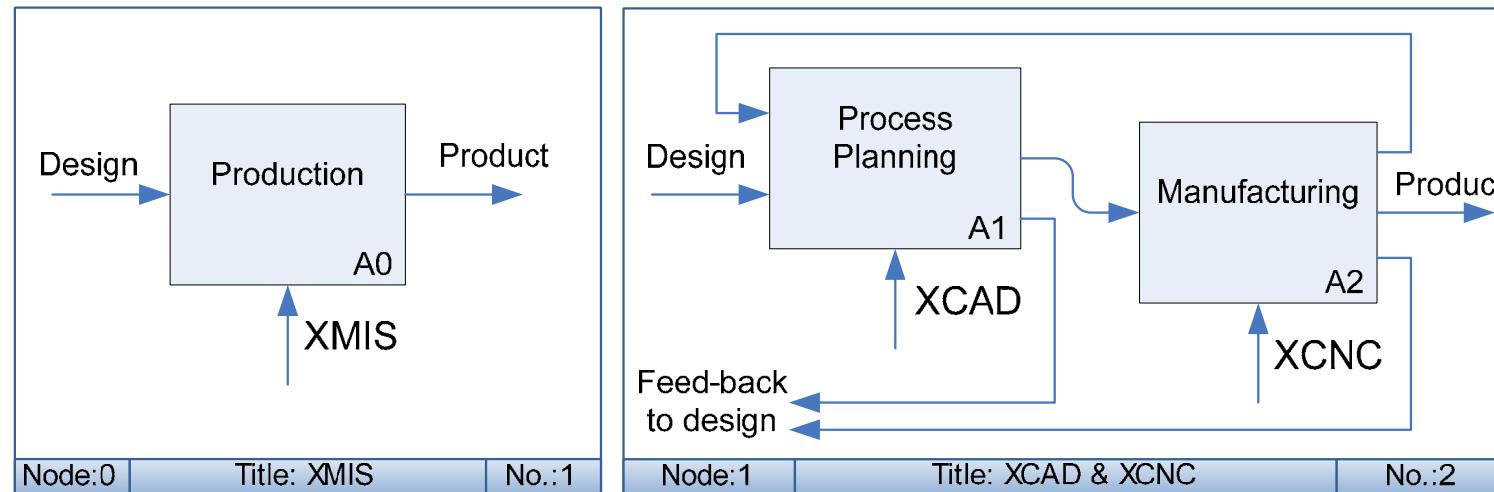
# *Overview of manufacturing data exchange in XMIS*



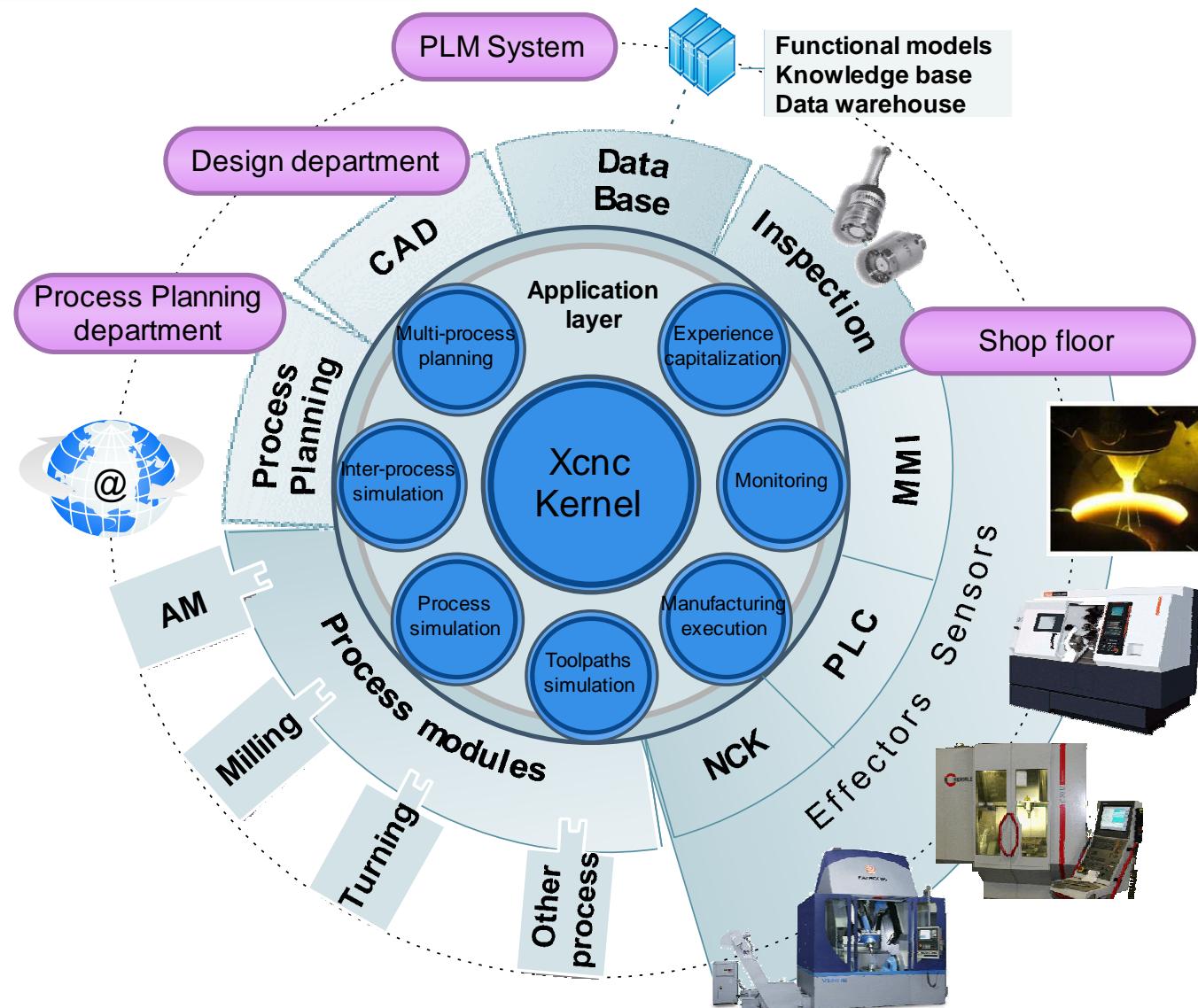
# eXtended enterprise XMIS



# *Application of XMIS : eXtended CNC & eXtended CAD*

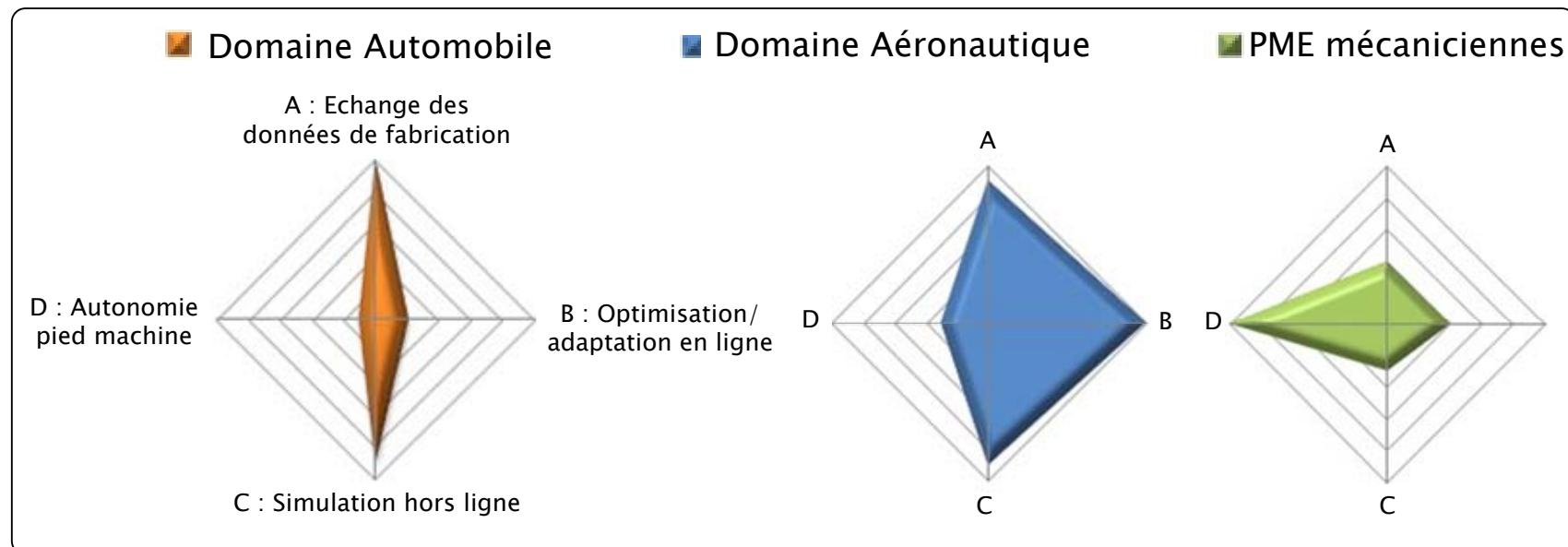


# eXtended CNC



# Conclusion

- **XMIS : modularité, Interopérabilité, Visibilité des données, Intégration numérique de l'ensemble des données de fab, longévité et intégrité des données, ouverture à l'e-manufacturing**
- **Intégration complète de la CN dans la chaîne numérique avec la CN étendue**
- **Adaptation de la CN étendue aux besoins de l'entreprise**



- **Intégration du contexte multiprocess...**

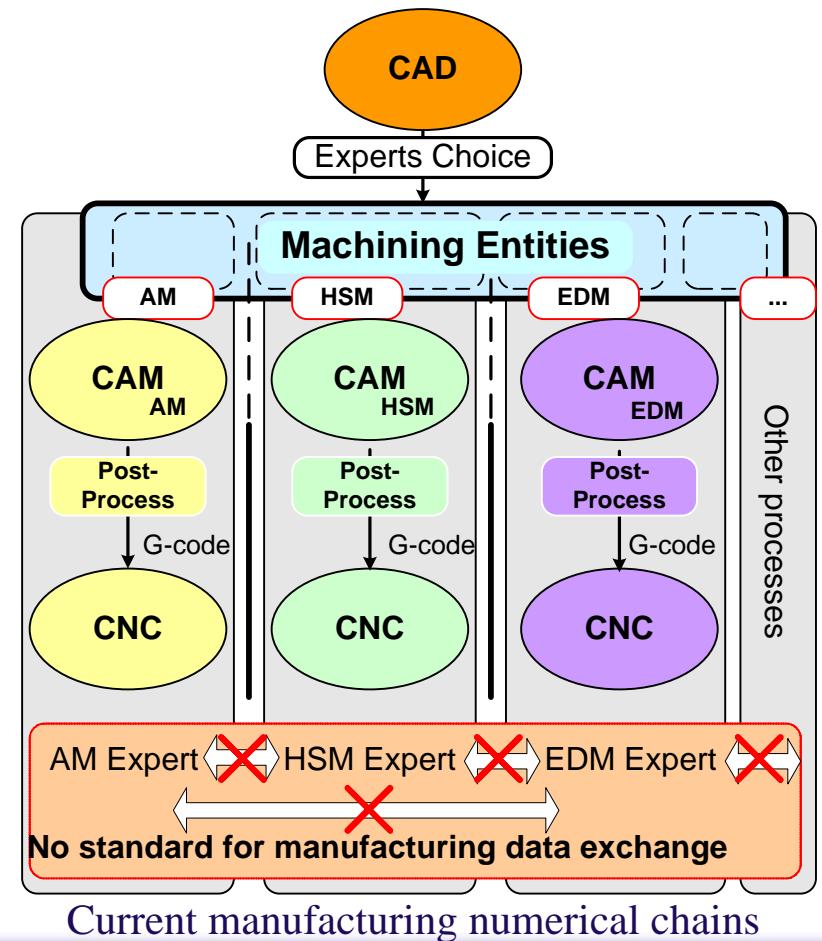
# Multi-process approach

## Context :

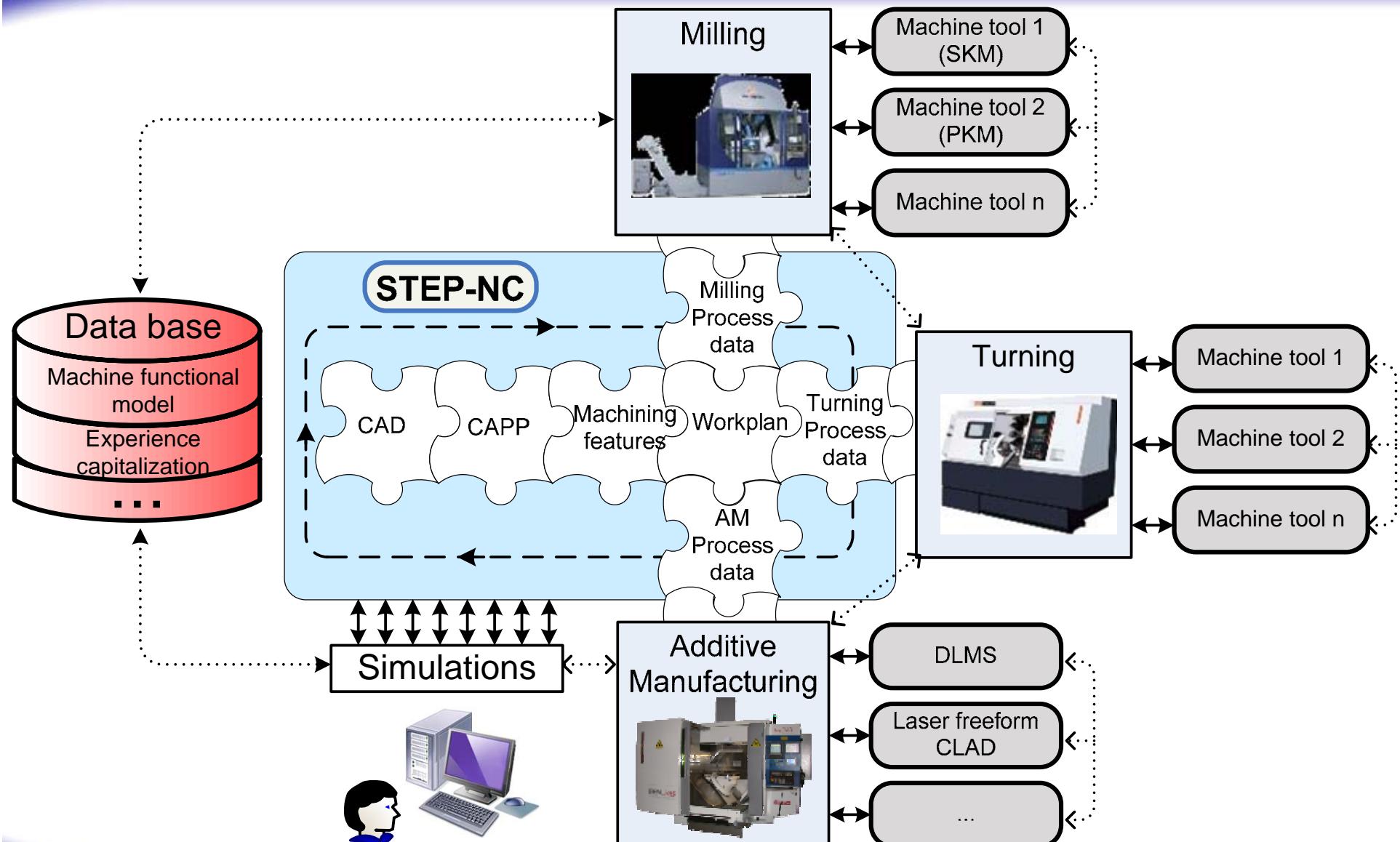
- No data exchange possible between manufacturing processes in the current numerical chain
- No link allowed between manufacturing processes
- ISO 14649 Parts 11 (Milling), 12 (Turning),  
13 (Wire EDM), 14 (Sink EDM), 17 (AM)
- Multi-process machine tools and environment

## Objectives :

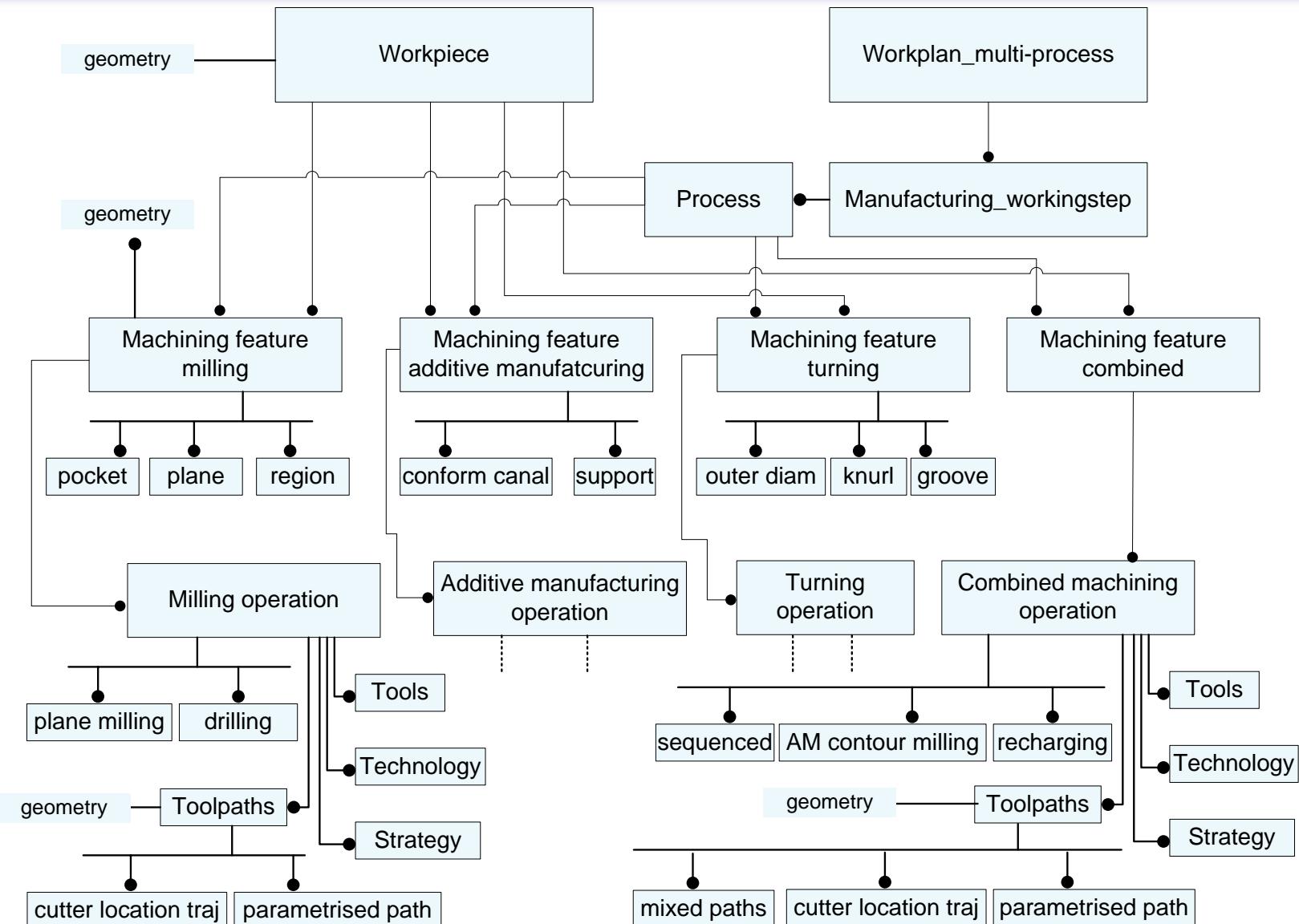
- Build a multi-process STEP-NC data
- Rely on a unique data exchange standard for different processes
- Integrate a supervision numerical chain with adapted tools
- Integrate Simulation and Optimization new possibilities
- Envisage evolutions



# *Multi-process STEP-NC file*

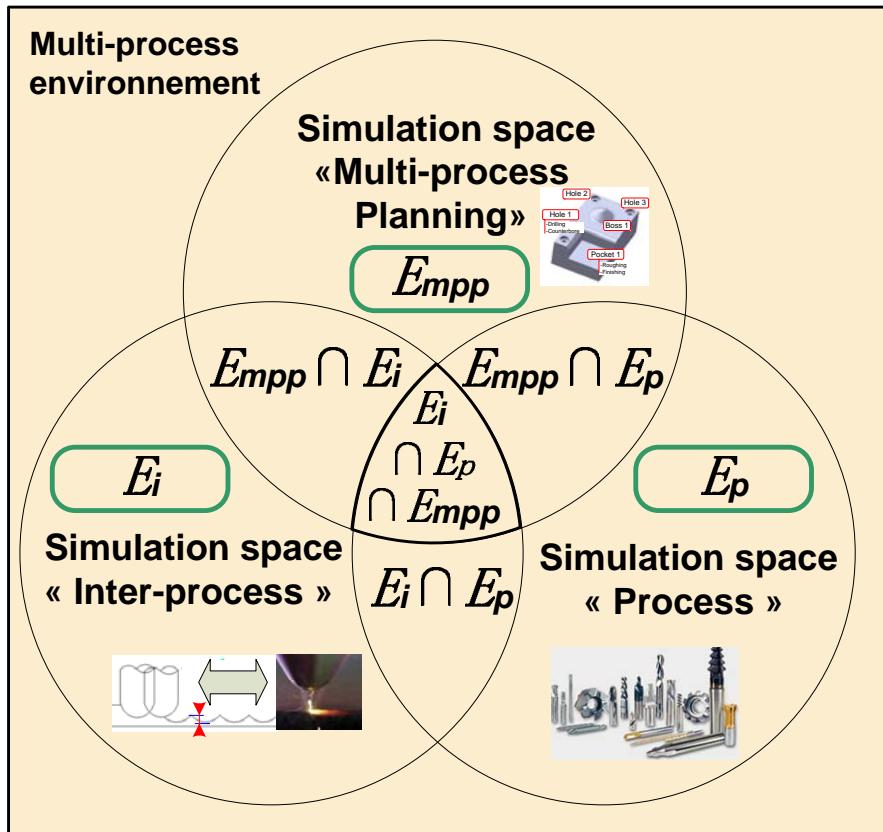


# Données STEP-NC multi-process



# *Simulation spaces concept*

- Increasing complexity of scenarios
- Need simulation tools but also methodologies and approaches to treat the problems



Definition of three simulation spaces :

## *Process simulation space :*

- One selected process
- Process data & machining parameters simulation
- Online/offline (TPG, adaptation, monitoring)
- Ex: ICAM, HSM simulator, TP simulator, tools choice

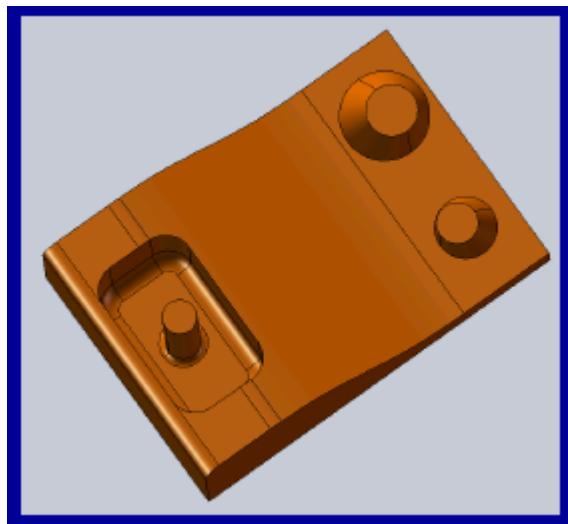
## *Multi-process Planning simulation space :*

- From CAD to manufacturing features and process plan
- Feature extraction associated with process
- Management of the workplan, operation scheduling

## *Inter-process simulation space :*

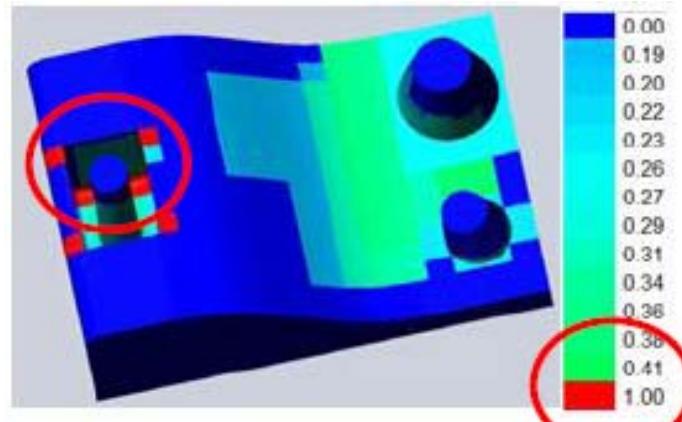
- Relations – rules – interactions between processes
- Missing link between  $E_{mpp}$  and  $E_p$
- Have now a common data exchange standard support (not only relies on experts choices or feelings)

# *Simulation spaces concept*

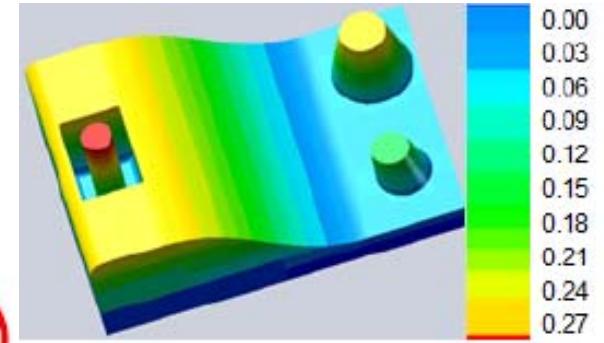


CAD model

[Kerbrat 09]

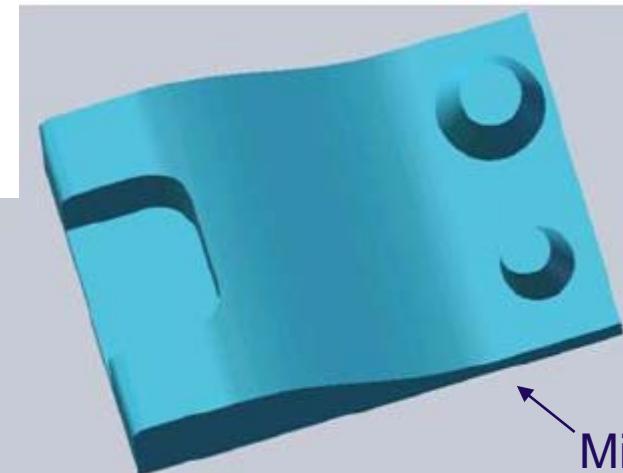
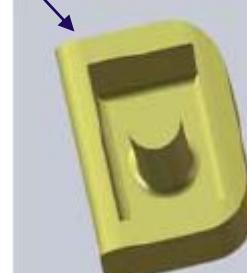


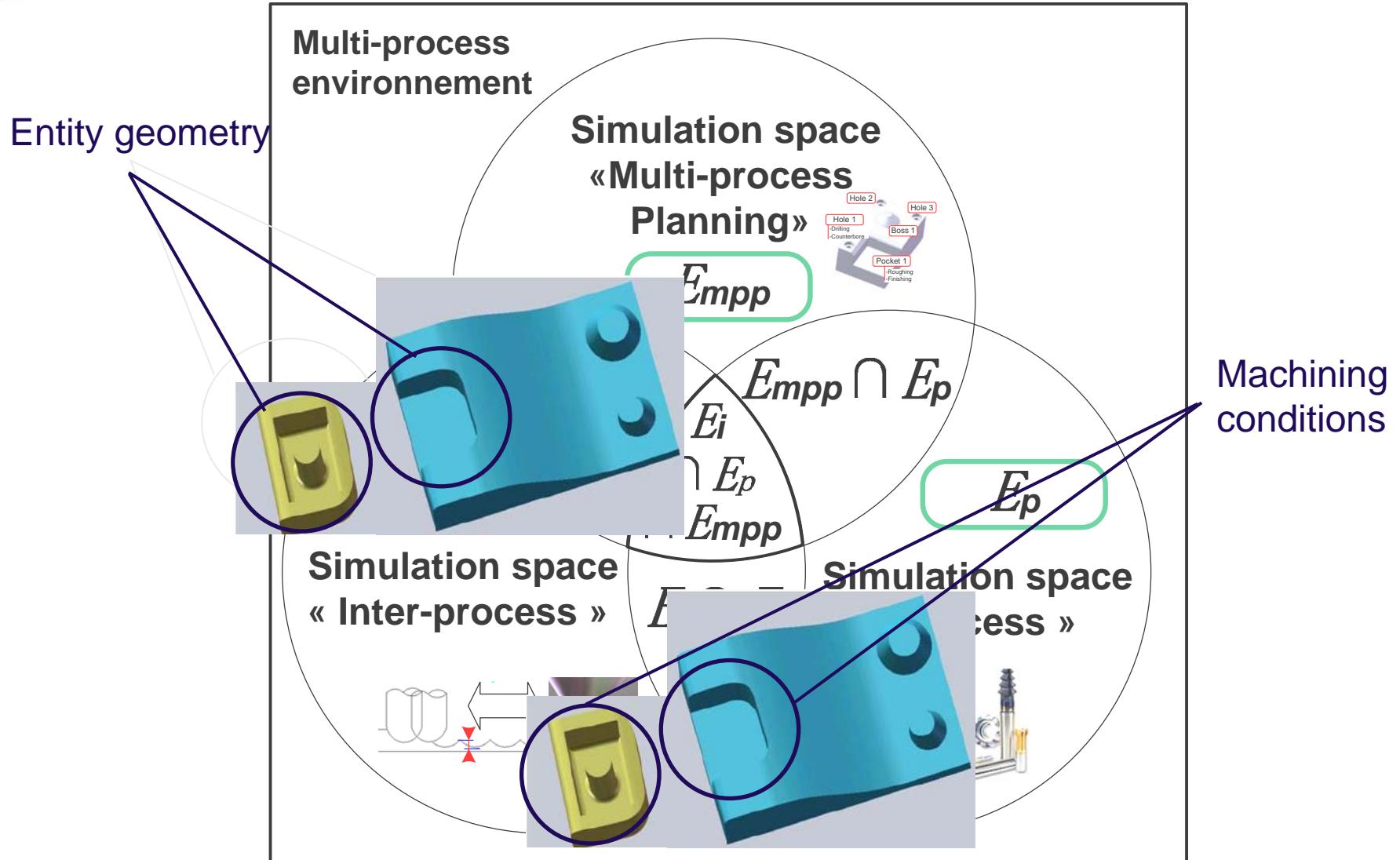
Milling complexity  
simulation



AM complexity  
simulation

Additive  
Manufacturing





## ***Conclusion for multi-process manufacturing***

- Opening the way of multi-process integrated manufacturing
- New possibilities with STEP-NC feature-based programming
- Intelligence at the eXtended CNC level
- Development of new tools and models well adapted to STEP-NC standard
- Integration of simulation and optimization tools based on already existing experience at IRCCyN (HSM simulator, ICAM method, etc.)
- Lack of studies on inter-process interactions and simulations
- Gathering multi-process data on a unique standard
- More intelligence, interoperability, flexibility and transportability with a STEP-NC eXtended CNC
- STEP-NC platform on current industrial machine tools

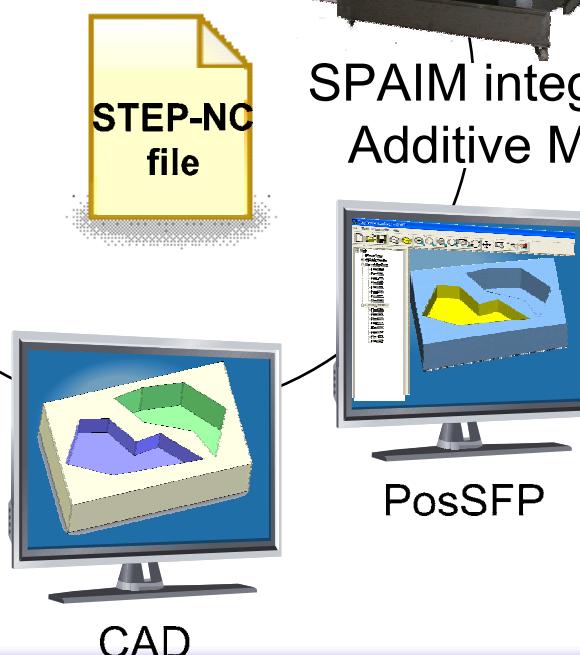
# *Application with a STEP-NC compliant NC controller*



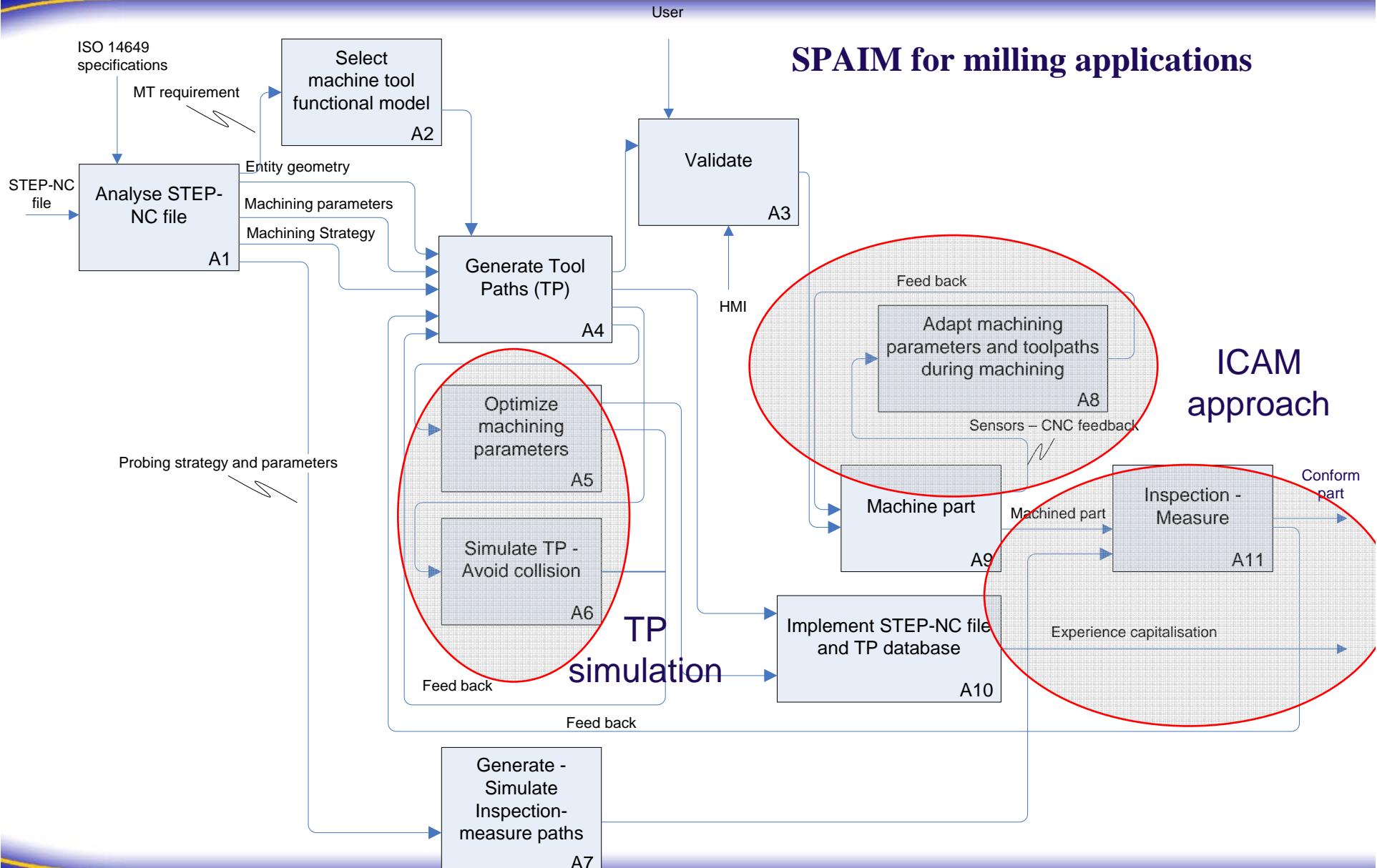
SPAIM integrated CNC  
for milling



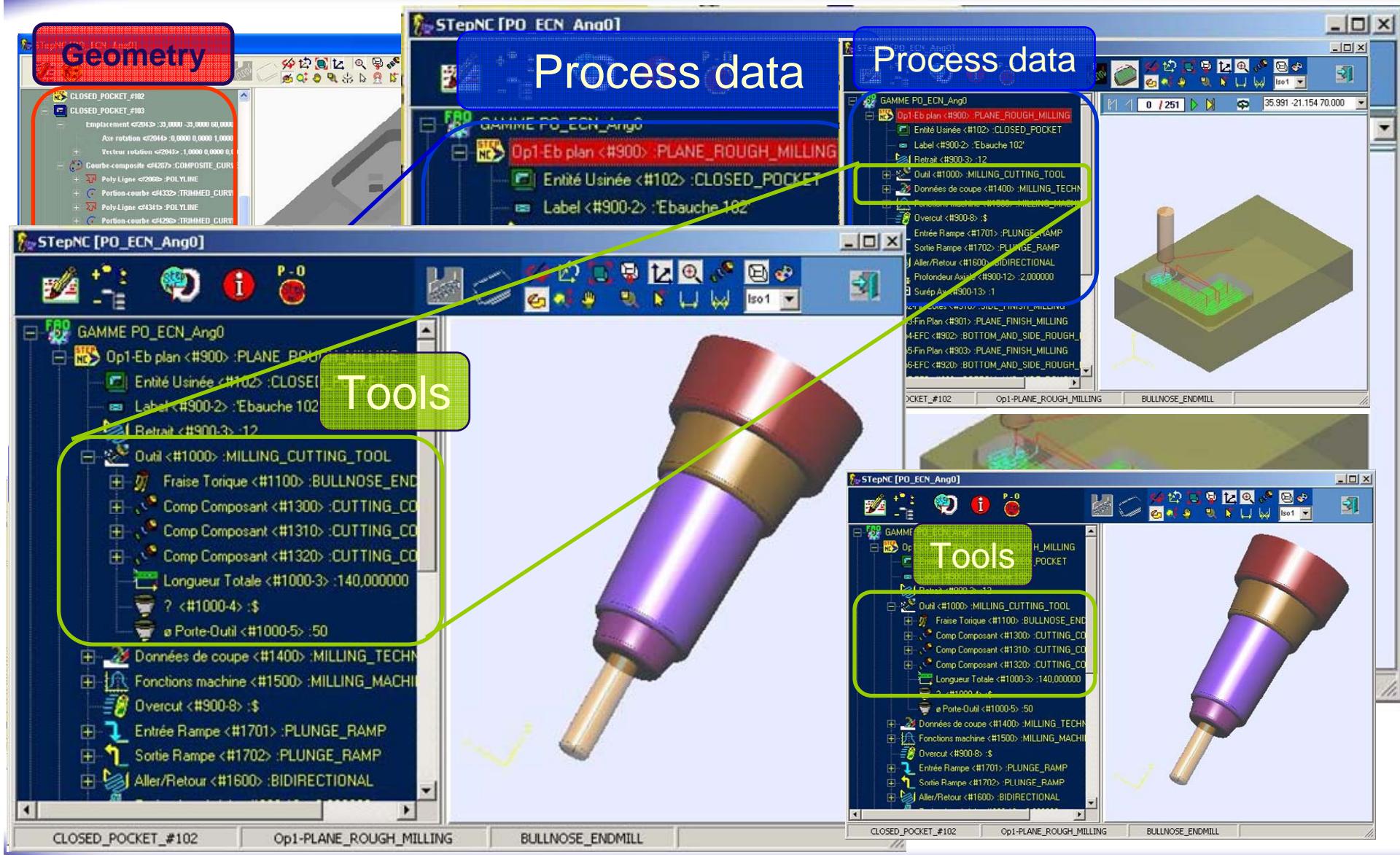
SPAIM integrated CNC for  
Additive Manufacturing



# ***SPAIM application of the extended CNC Concept***

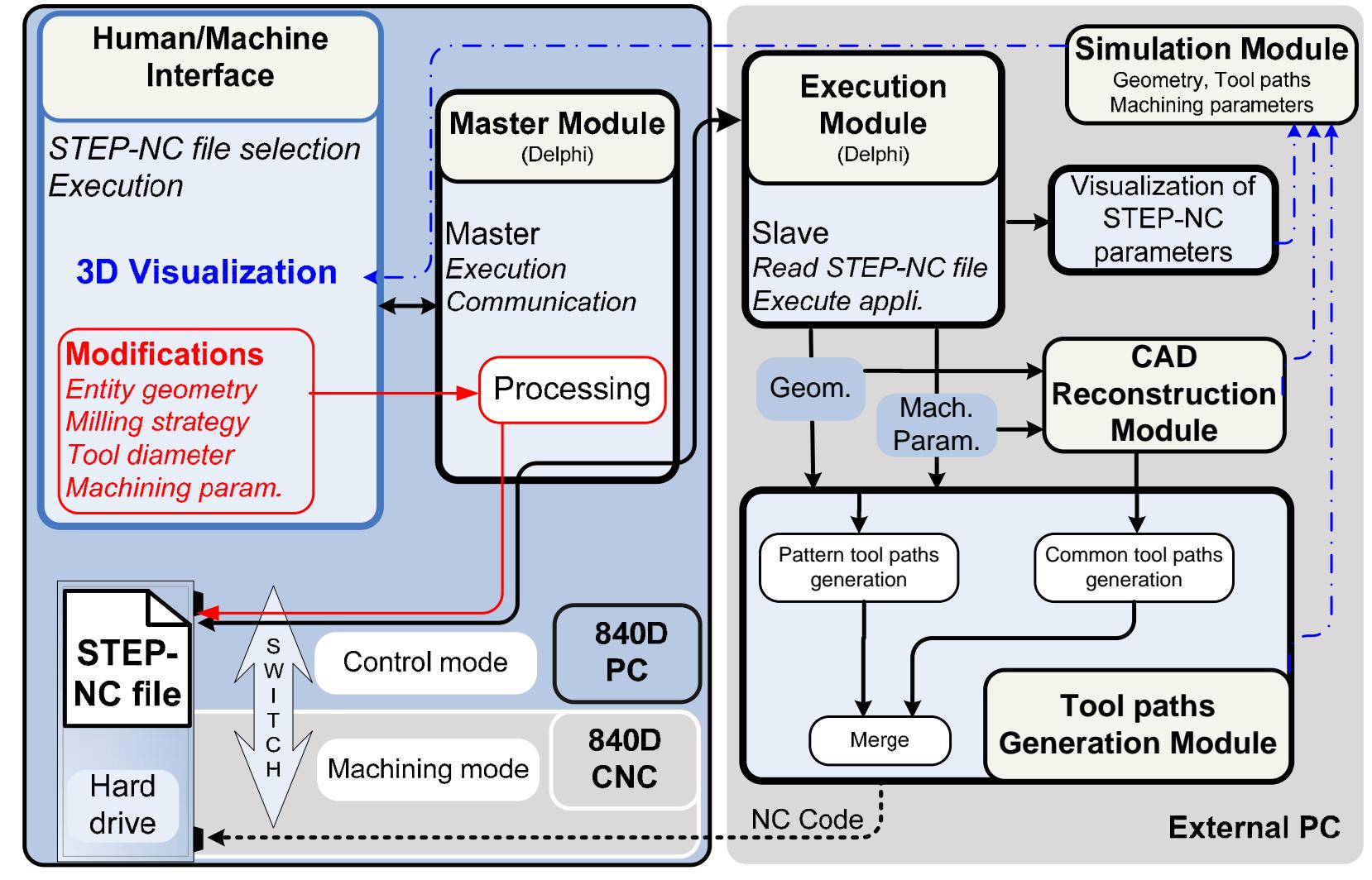


# SPAIM Human/Machine Interface

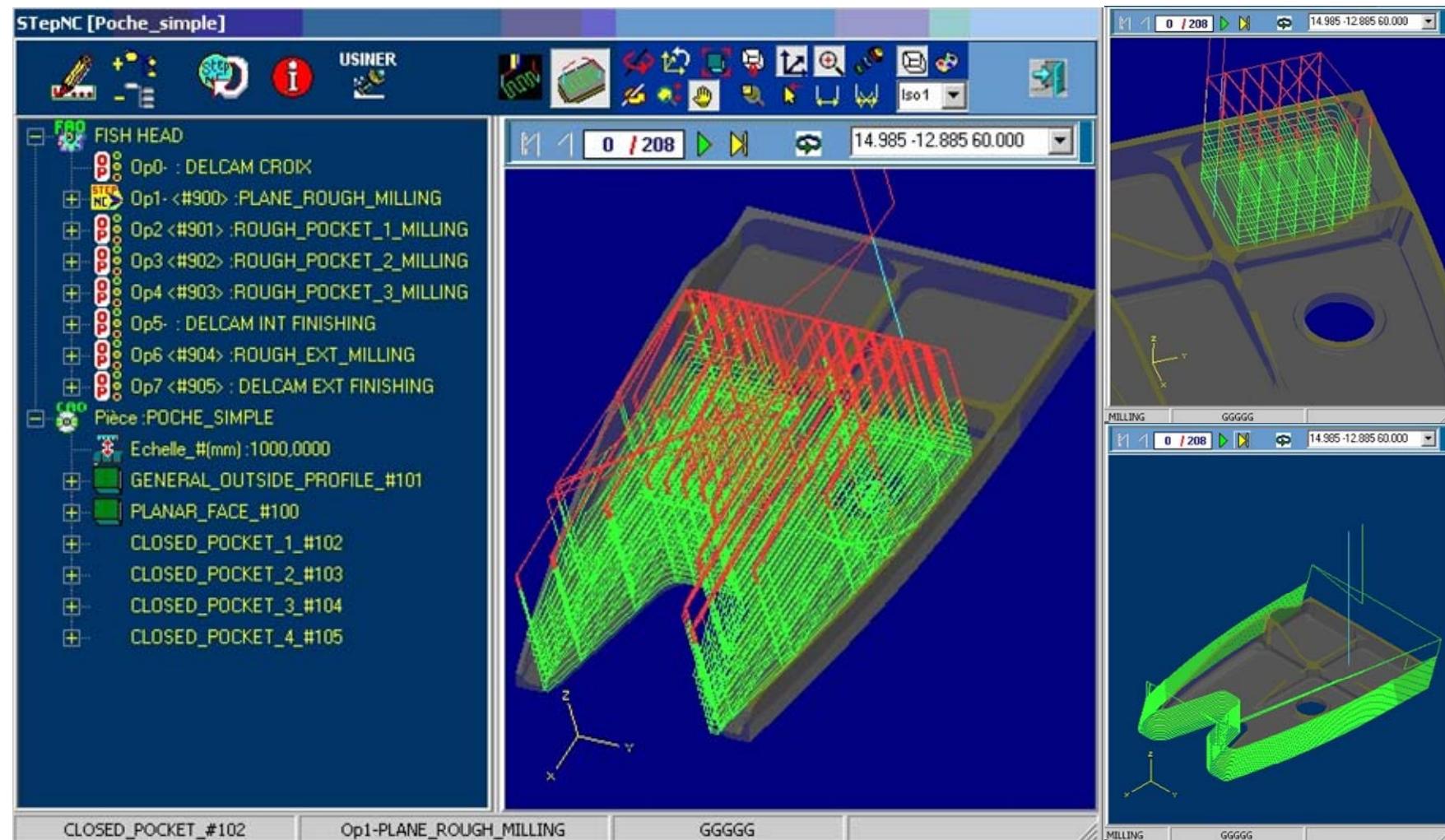


# Architecture of SPAIM platform

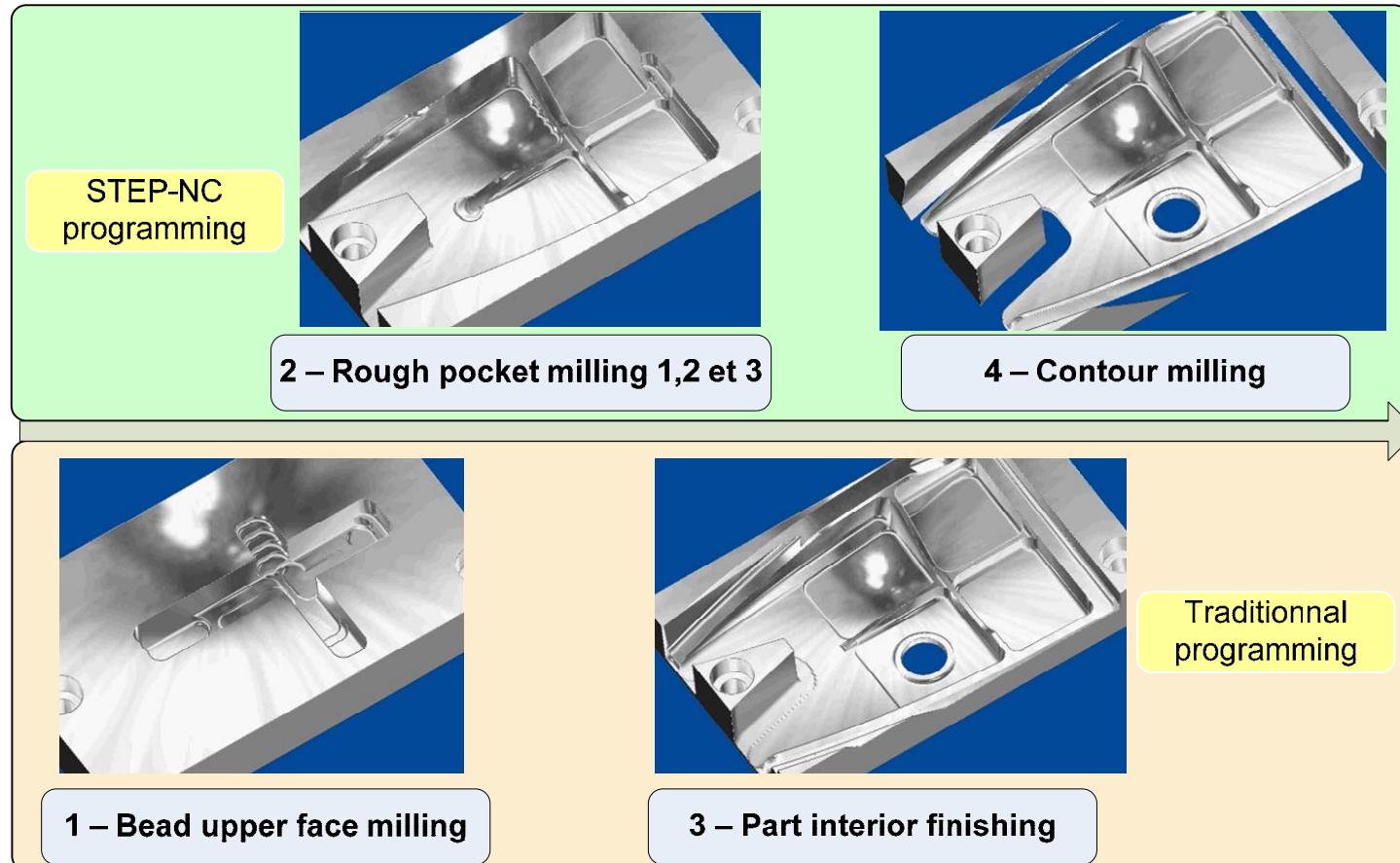
IRCCyN STEP-NC Platform for Advanced and Intelligent Manufacturing



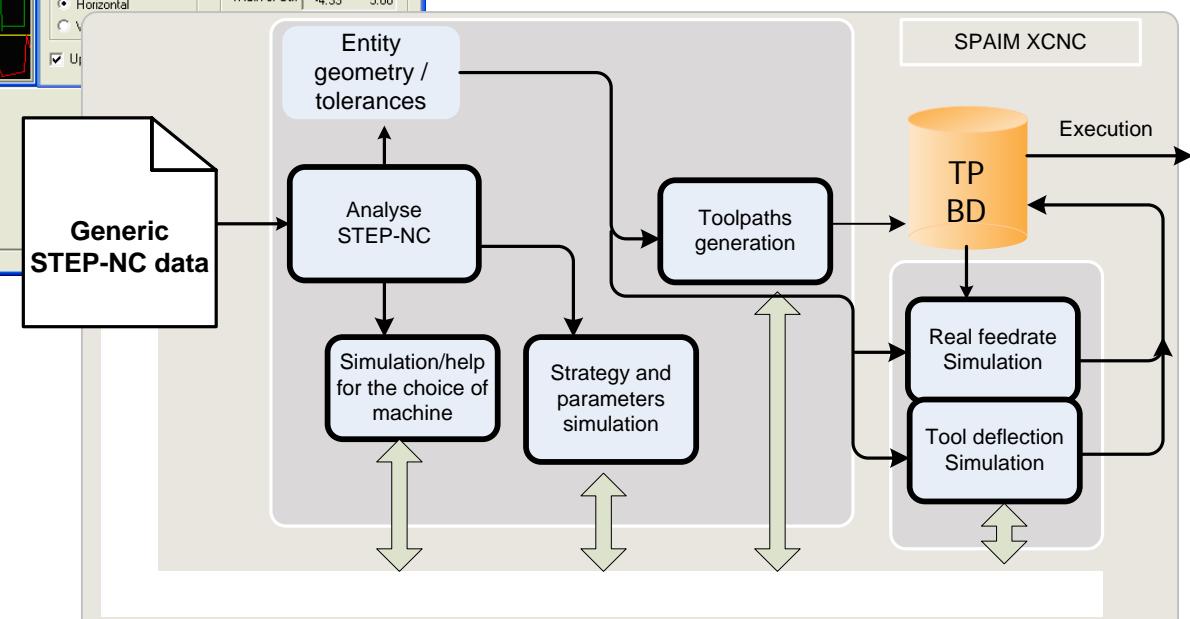
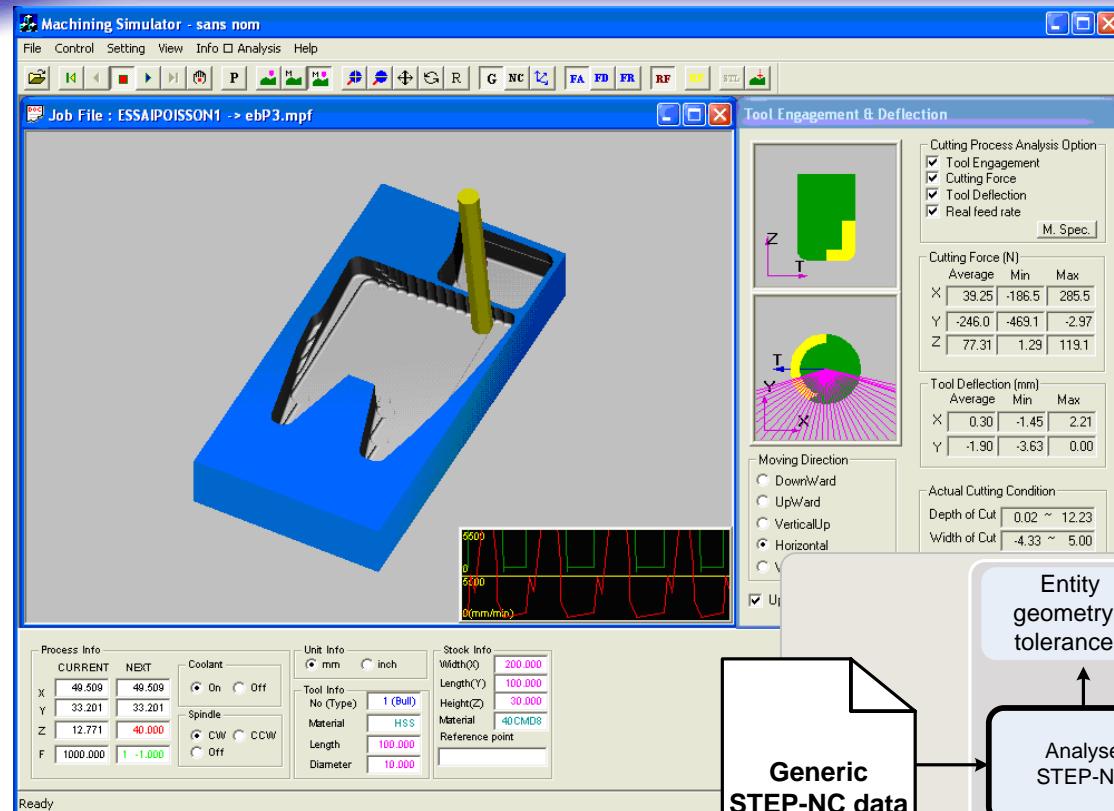
# *Extension of possibilities : exemple of fish head part*



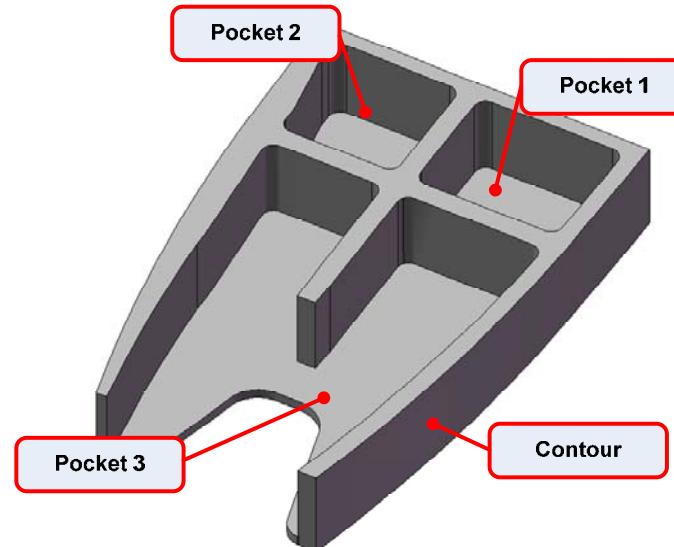
# *Extension of the possibilities : exemple of fish head part*



# Use of simulation tools in SPAIM XCNC



# Milling with STEP-NC



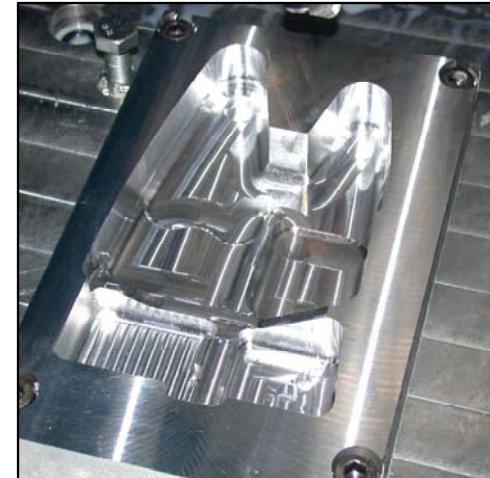
Pocket 1 milling



Pocket 2 milling



Pocket 3 milling

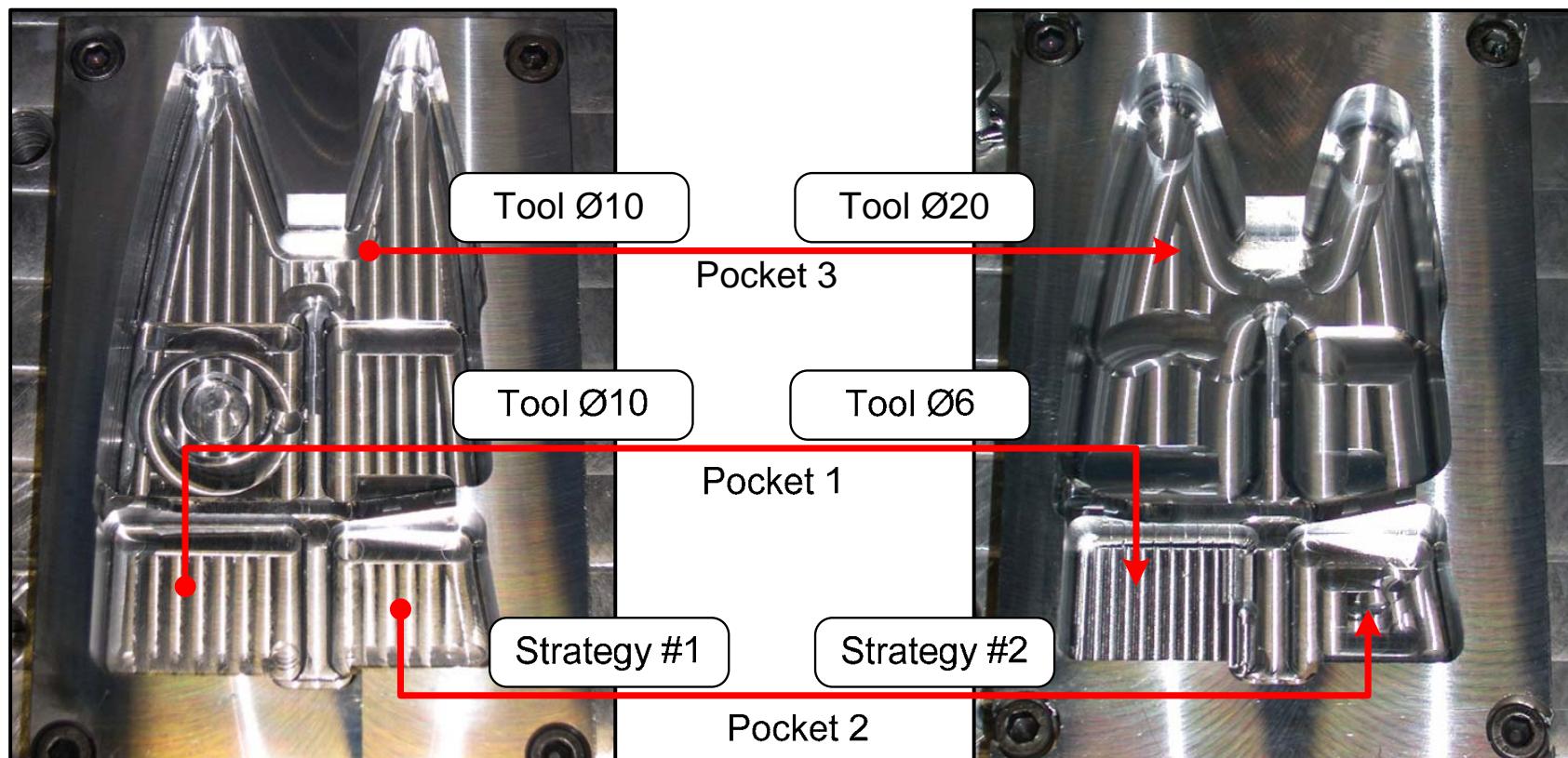


## ***Modifications on SPAIM HMI***

## Rough milling #1

## Manufacturing attributes modifications in the eXtended CNC

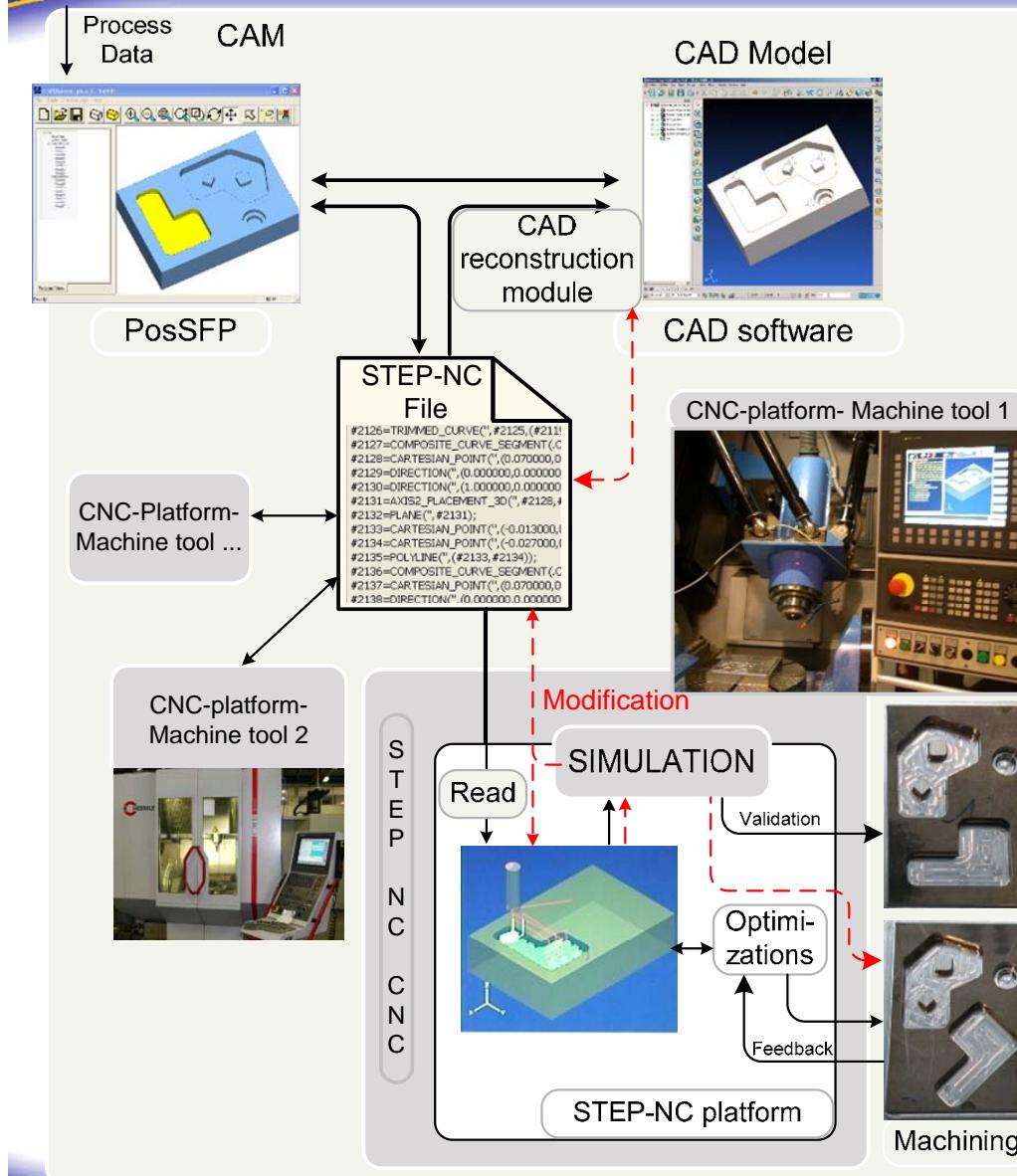
## Rough milling #2



## *Finishing operations*



# The numerical chain with SPAIM



A unique STEP-NC file can be treated on several different machine tools

Easy software implementation on the NC controller

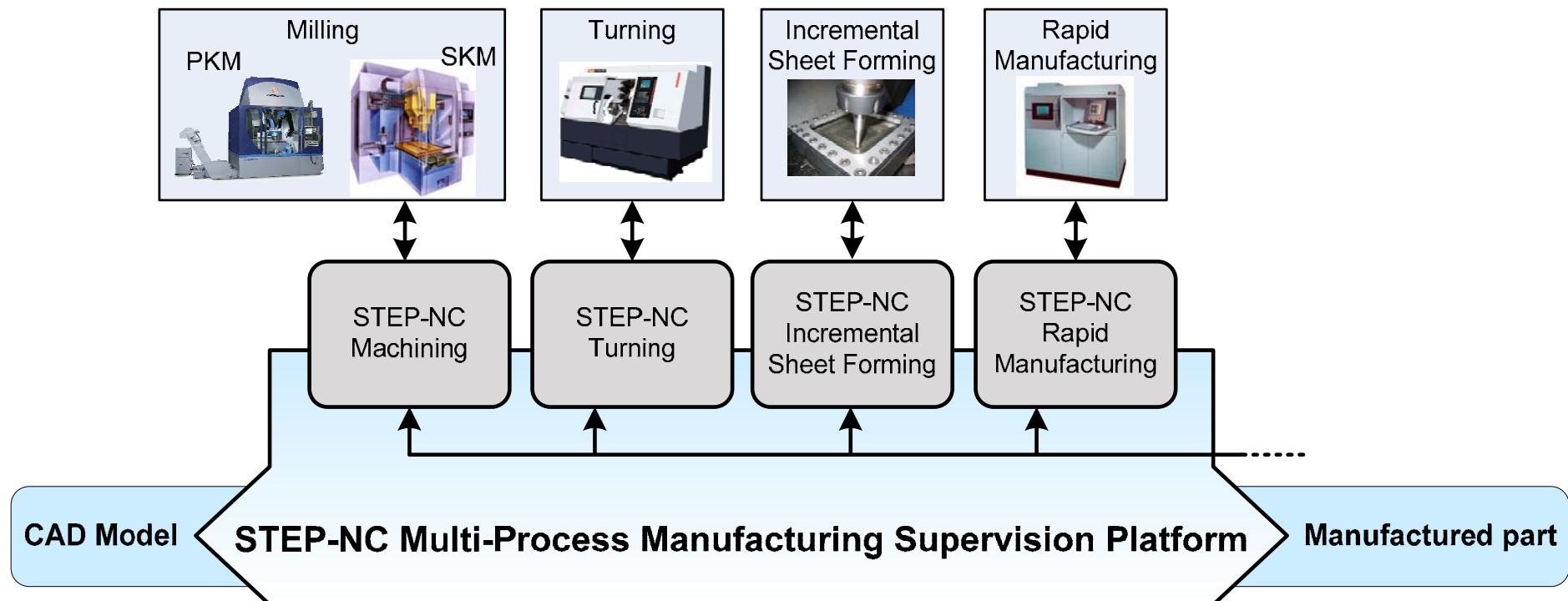
Intelligence transfer to CNC

Feed-back from CNC to CAD/ CAM

Shop floor modifications enabled for geometry and machining parameters (ex: machining strategies)

New possibilities for simulation and optimization in the CNC

# *Intégration du contexte multi-process*

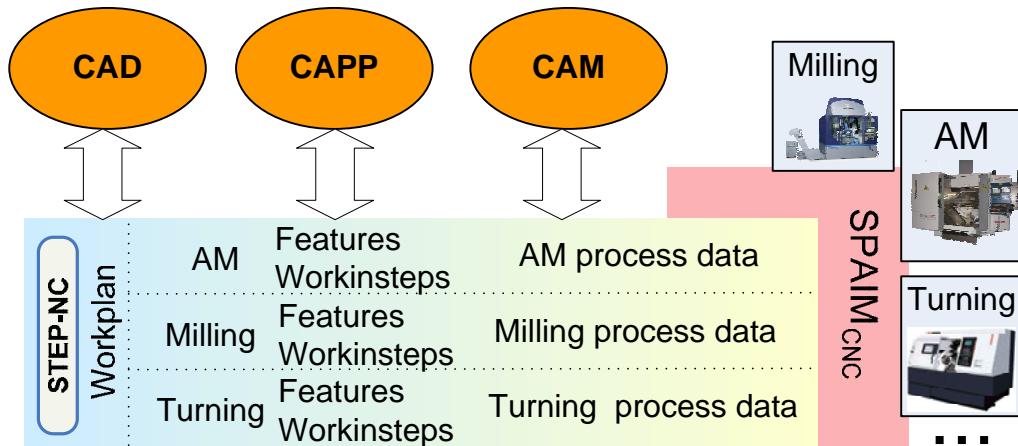


# *Implementation of simulation in SPAIMcnc*

## 3 steps method :

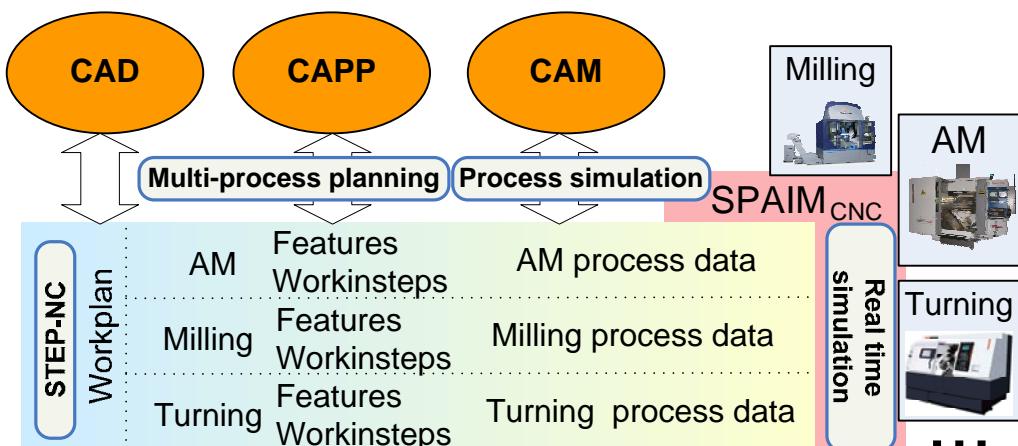
### 1st Step :

- Multi-process manufacturing platform
- Multi-process Workplan enabled
- SPAIM implemented on different processes (Milling, RM, Turning)
- Current developments



### 2nd Step :

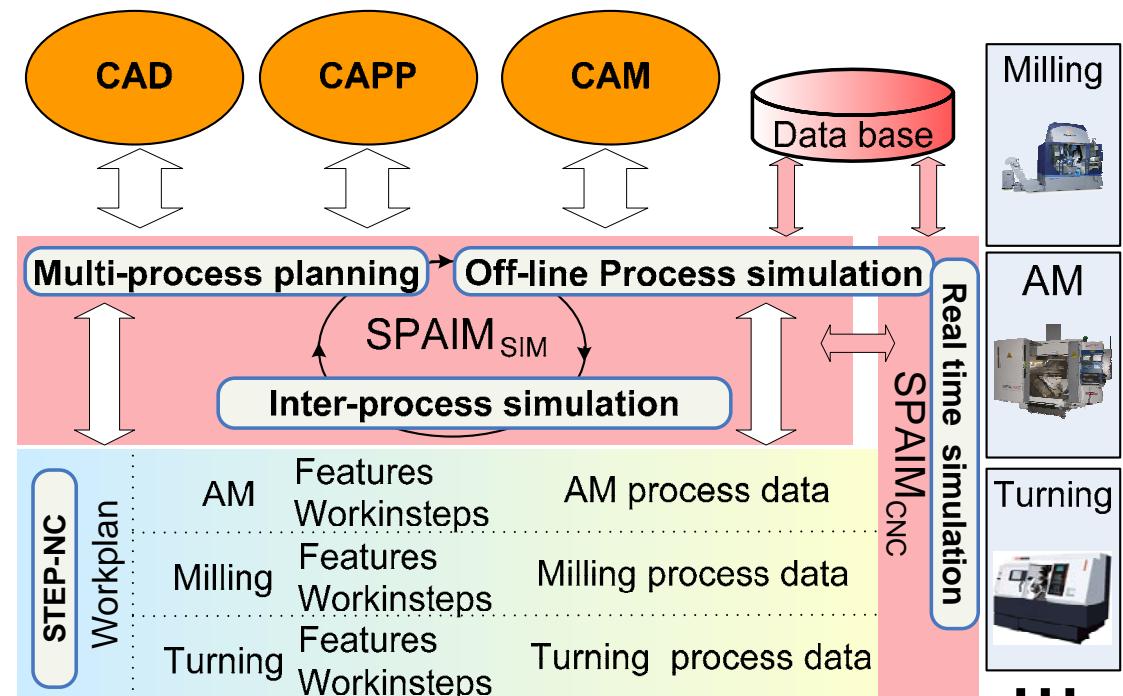
- Integration of simulation modules
- Example of process simulation :  
Offline : Real feed rate simulation module, tool deflection compensation module  
Online : ICAM approach, real time optimizing machining parameters (ex: feedrate)
- Multi-process planning simulation tools  
(From CAD to features taking into account the process)



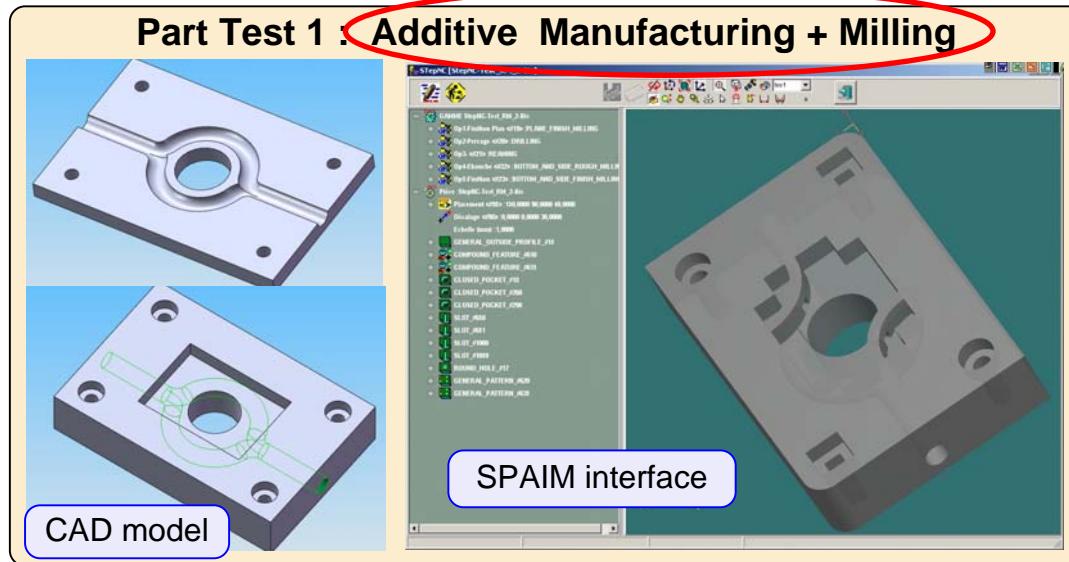
# *Implementation in SPAIMcnc - SPAIMsim*

## 3rd Step :

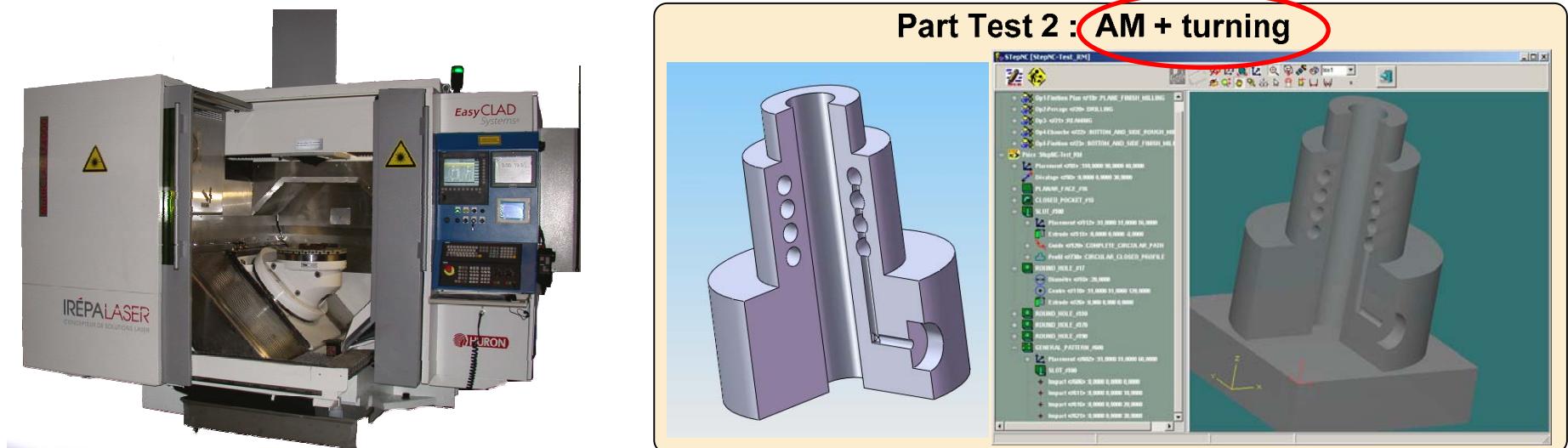
- Intelligent STEP-NC multi-process supervision platform
- Integration of inter-process simulation tools
- Comprehensive SPAIMsim
- Cross interactions possible between processes



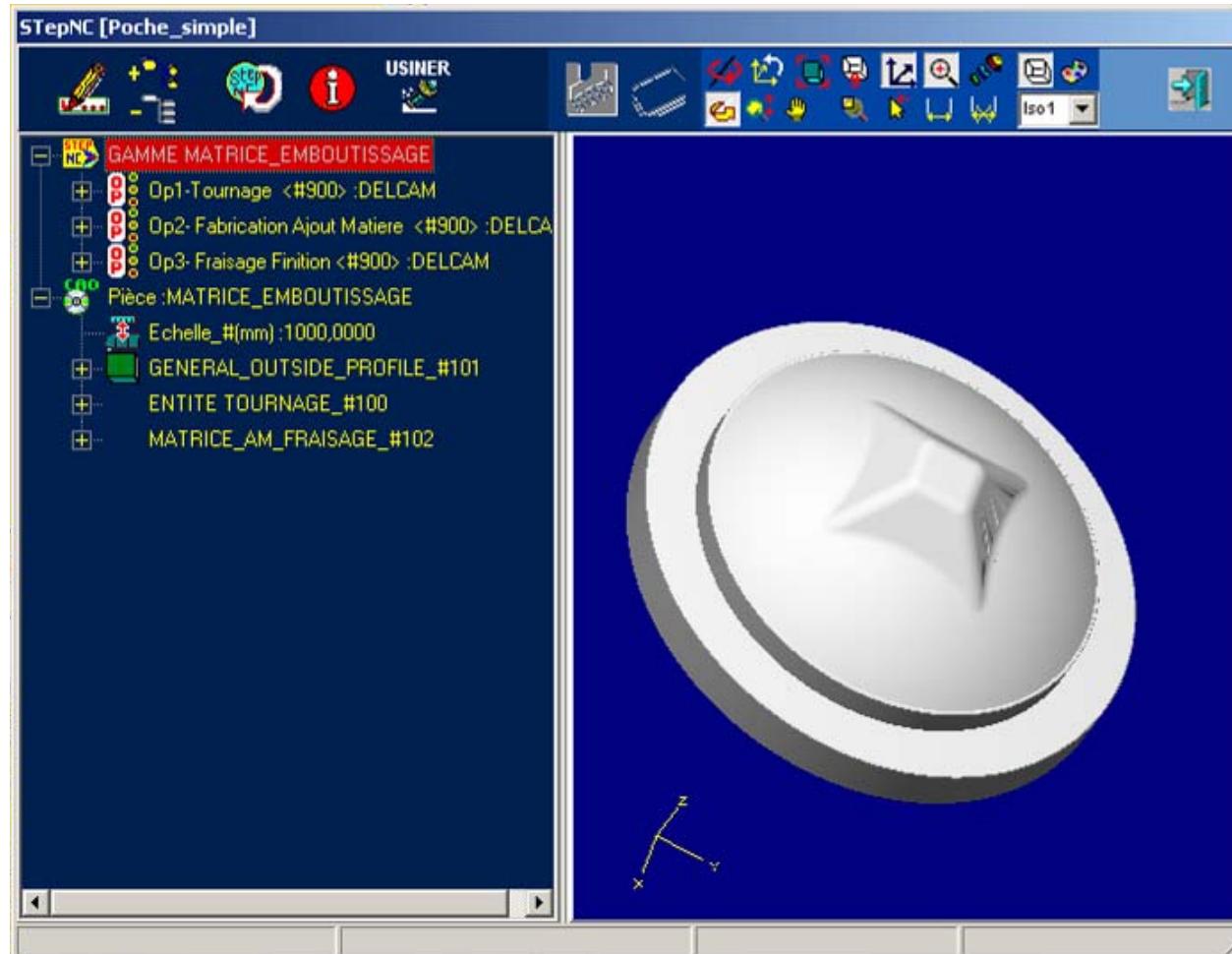
# *Current development in SPAIM: test parts #1 #2*



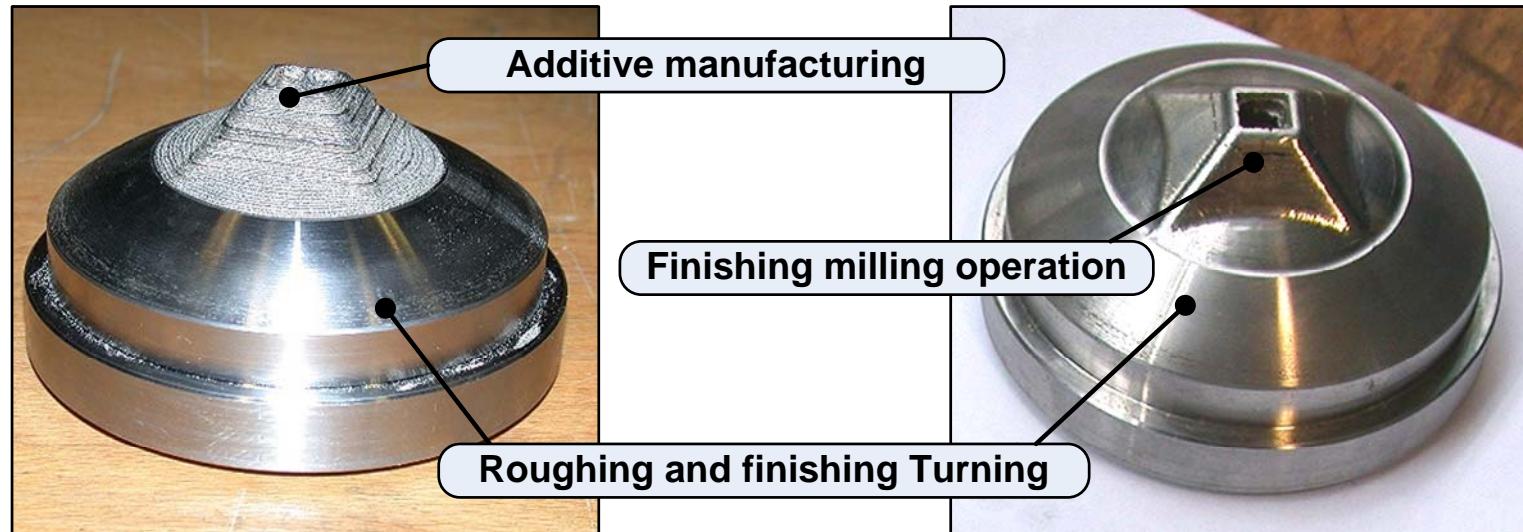
- SPAIM able to treat milling, turning, AM geometry parts
- Under development for manufacturing part processing for turning and AM
- Implemented on the new Powder laser CLAD of the lab



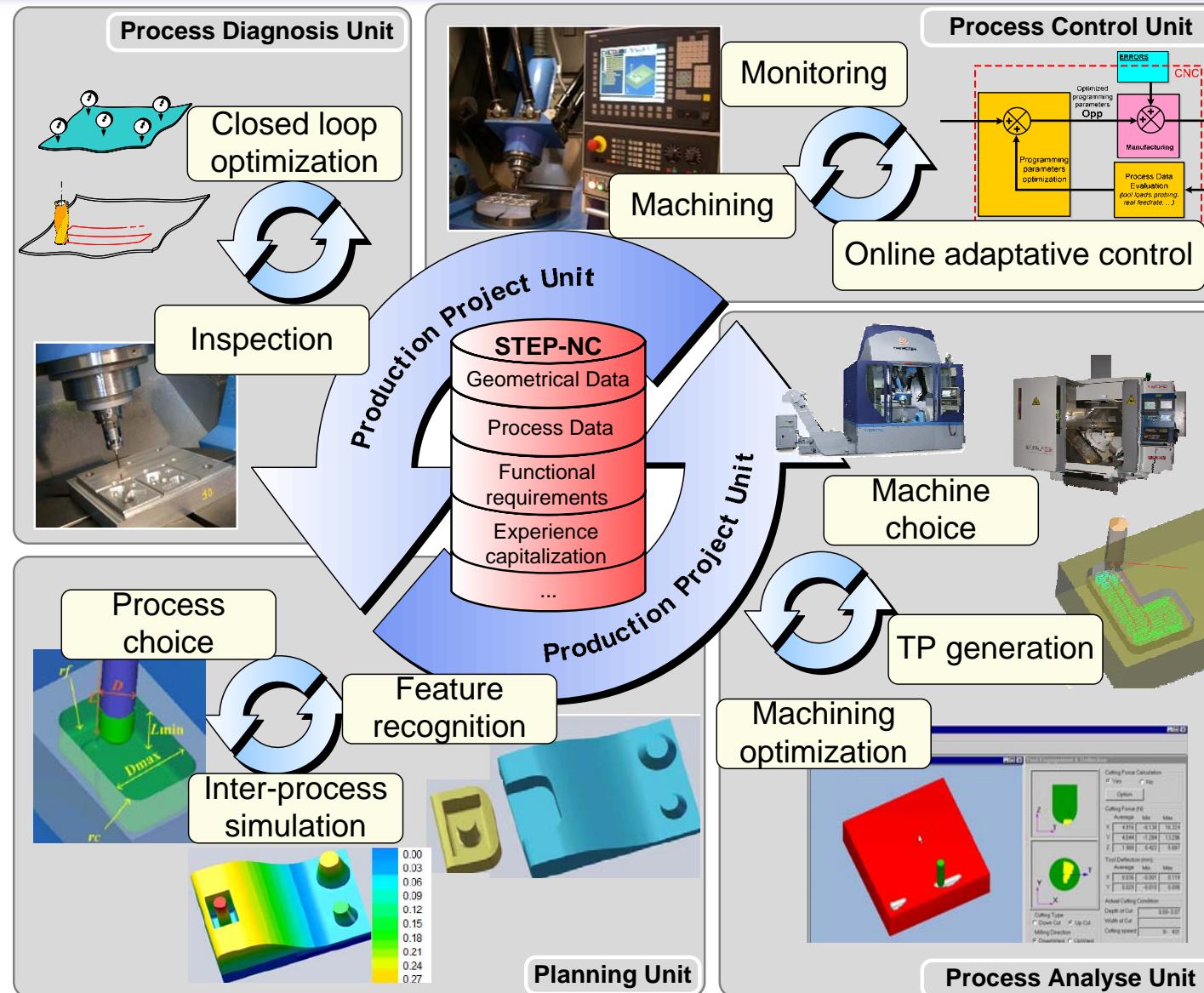
# *Test part #3 in SPAIM XCNC*



# *Multi-process manufacturing of Test part #3*



# Overview of SPAIM application of XMIS



# **Conclusion**

- Opening the way of multi-process integrated manufacturing
- New possibilities with STEP-NC feature-based programming
- Intelligence at the extended CNC level
- Development of new tools and models well adapted to STEP-NC standard
- Integration of simulation and optimization tools based on already existing experience at IRCCyN (HSM simulator, ICAM method, etc.)
- Lack of studies on inter-process interactions and simulations
- STEP-NC based on a widespread STEP standard
- Gathering multi-process data on a unique standard
- More intelligence, interoperability, flexibility and transportability with a STEP-NC extended CNC
- STEP-NC platform on current industrial machine tools

Raphael LAGUIONIE

Intégration de la programmation basée entités pour la fabrication sur MOCN dans un contexte multi-process

*Institut Recherche Communications Cybernetique Nantes (IRCCyN)*  
*1, rue de la Noé, BP92101, 44321 Nantes – France*