Computer Integrated Manufacturing 4.0

An Ecosystem of Cloud-based CNC Integrated with Cloud-based CAD, CAM and CAPP

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Local vs. Cloud

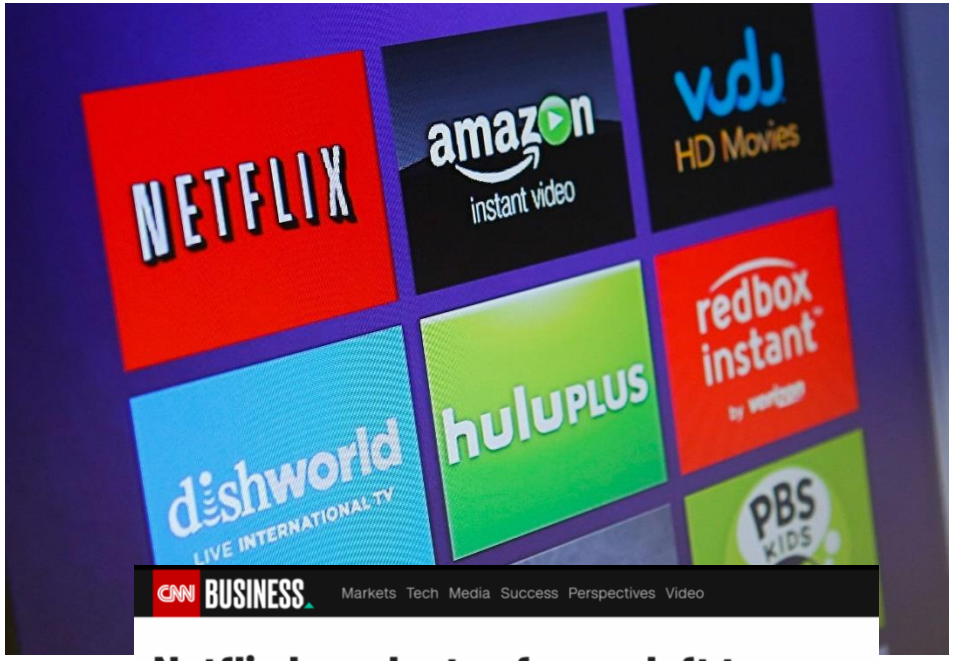
vs.

Netflix seized a **grand opportunity** to use the Cloud to provide **far superior** service at **lower cost**

Local vs. Cloud

There's now only one Blockbuster left on the planet

vs.



Netflix has plenty of room left to grow

As a result Netflix has **disrupted** the industry!

Disruptions often come from seizing grand opportunities

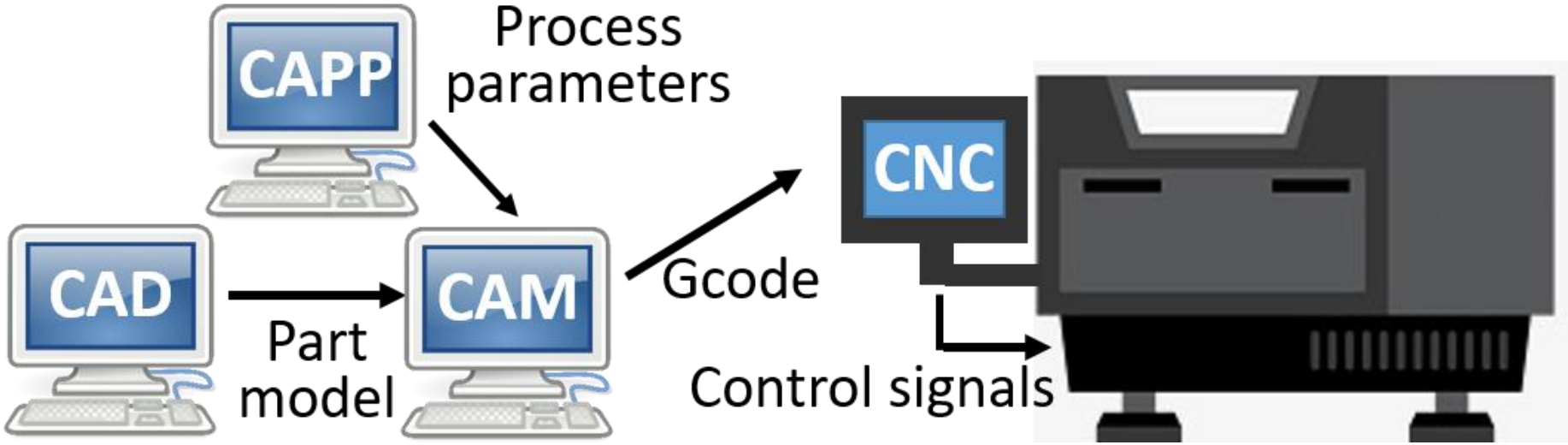
Goal

Present a *grand opportunity*:

- Of CIM 4.0, a Netflix-like concept with *potential to transform* Computer Integrated Manufacturing
- For U.S. to benefit economically and national security wise by investing in CIM 4.0.

Computer Integrated Manufacturing (CIM)

Epitome of Industry 3.0 – Era of the (digital) computer



CAD, CAM, CAPP and CNC all running on *local computers*

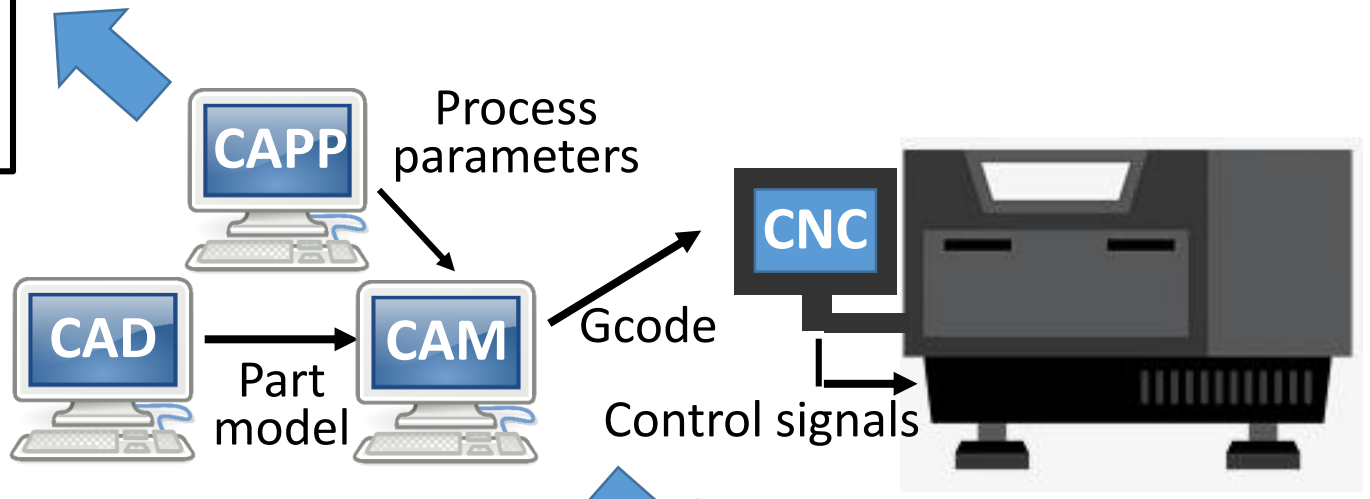
Local Computing Moving to Cloud Computing

"Rent" *powerful* computing resources at *low cost* over the internet

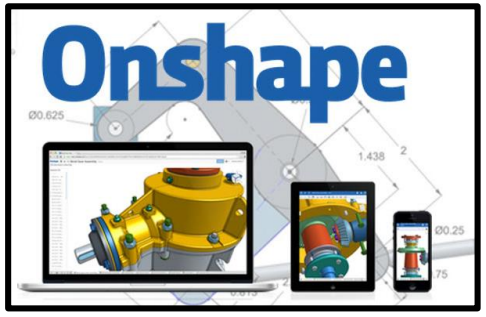
CIM is Gradually Transitioning to the Cloud

Cloud-based CAD, CAM and CAPP are emerging!

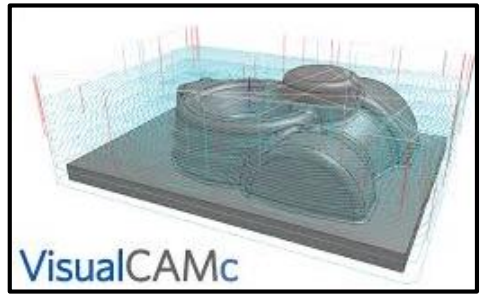
C-CAPP



Cloud connectivity for CNC



C-CAD



C-CAM

C-CNC is yet to emerge

C- = Cloud-based

CIM 4.0 – Vision

Cloud-based CNC that provides ***far superior functionalities*** securely and reliably at ***much lower cost*** than local CNC, and is ***fully integrated*** with cloud-based CAD, CAM and CAPP

Why C-CNC? Betty's Story

- ChatterWiz can **double** the productivity of her machines
- Must spend **a lot** to upgrade her old machines to the new model…

… or access ChatterWiz from C-CNC via Wi-Fi at a **low** monthly fee

Benefit #1: Upgrades at Lower or No Cost

Upgrade CNC functionality without need to upgrade hardware

Machine tools often become obsolete because of their CNC!

10 x

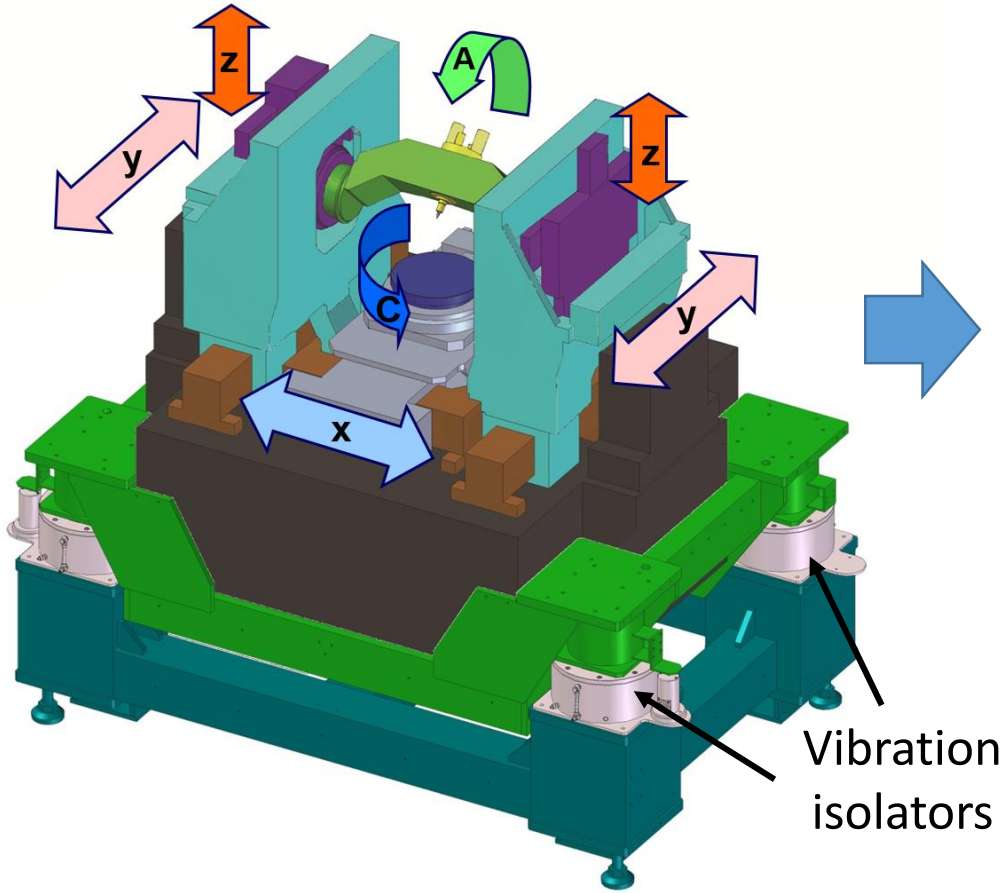
Wi-Fi Enabled CNC Milling Machine

5 years later…

Wi-Fi Enabled CNC Milling Machine with **ChatterWiz**

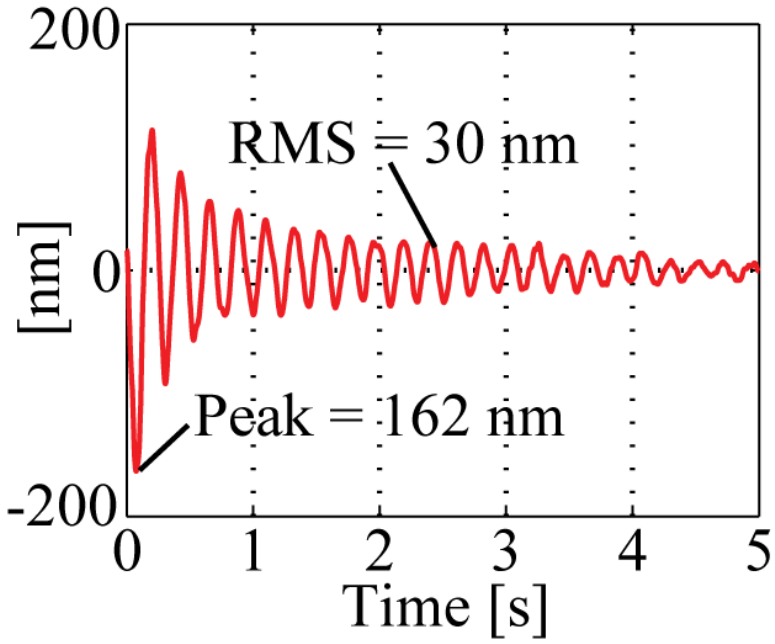
Benefit #2: Superior Performance at Low Cost

Example 1: Run advanced (high-computational-cost) **algorithms** in Cloud



5-Axis Ultra-precision MT

(NN 1000 from DMG Mori)



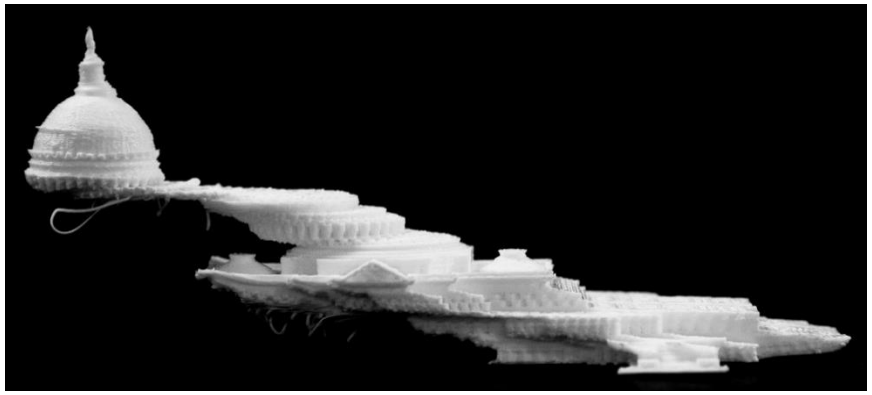
Unacceptably large servo errors due to rocking of machine on vibration isolators

Typical solution in CNC systems: Slow down – loss of productivity!

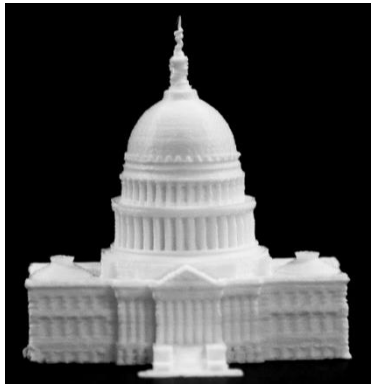
Benefit #2: Superior Performance at Low Cost

Example 1: Run advanced (high-computational-cost) **algorithms** in C-CNC

No vibration comp.
(0.1 g acceleration)
Printing Time: 4 h



No vibration comp.
(1 g acceleration)
Printing Time: 2 h



With vibration comp.
(1 g acceleration)
Printing Time: 2 h

10x higher acceleration

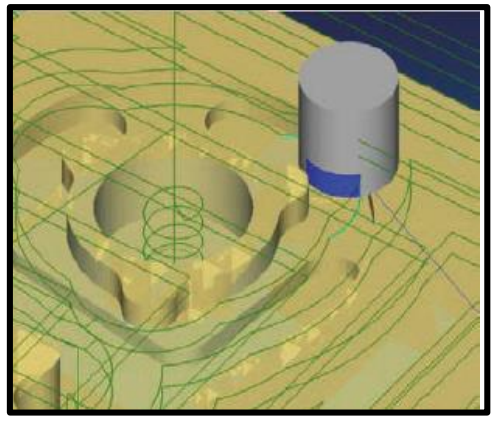
2x faster printing

Advanced Vibration Compensation Algorithm:

- No need for machines to slow down to avoid vibration
- High computational cost – **perfect for C-CNC!**

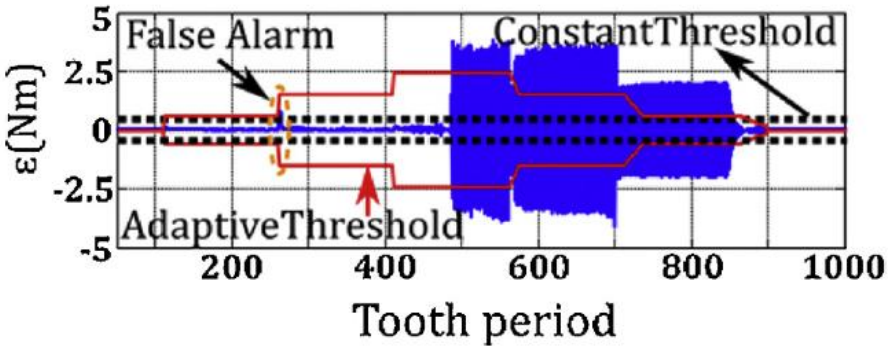
Benefit #2: Superior Performance at Low Cost

Example 2: Run advanced (high-computational-cost) **simulations** in C-CNC



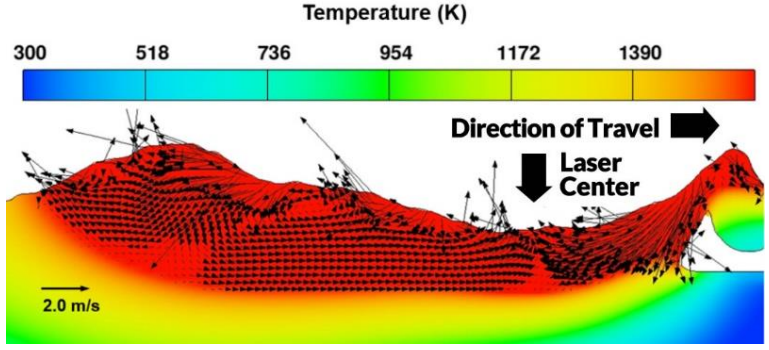
Process simulation on local PC

Altintas & Aslan 2017



Process simulation provides adaptive force thresholds to improve online tool breakage detection

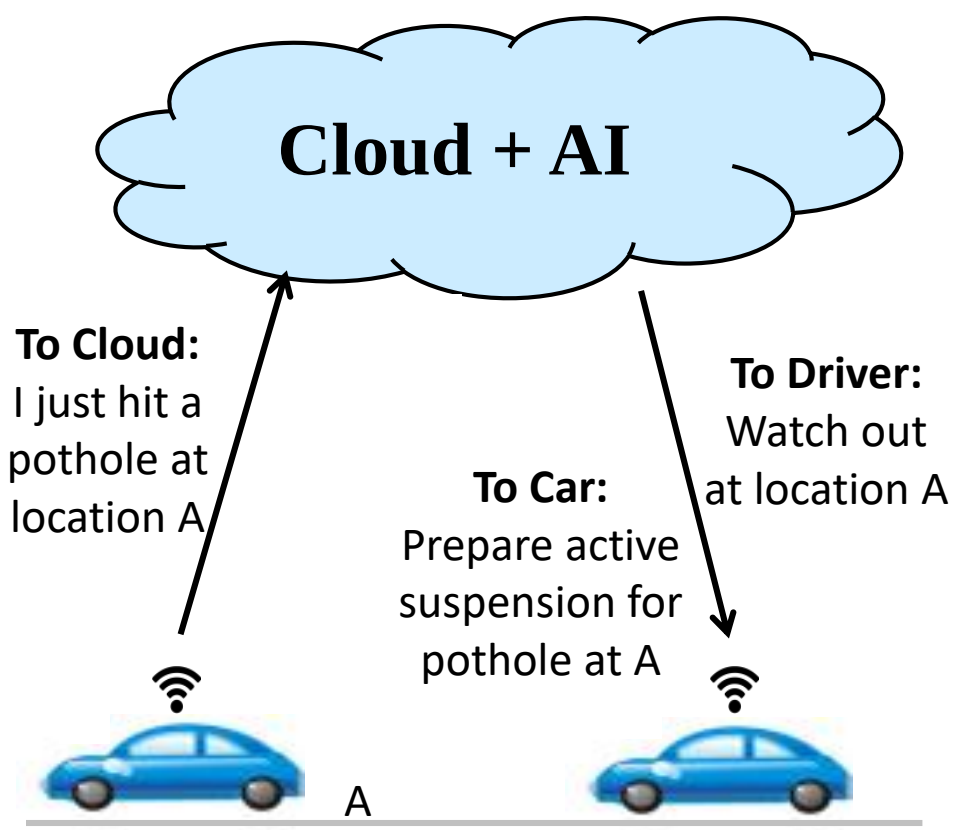
Use process simulations in **C-CNC** to guide machine tool control in real time



Flow3d.com

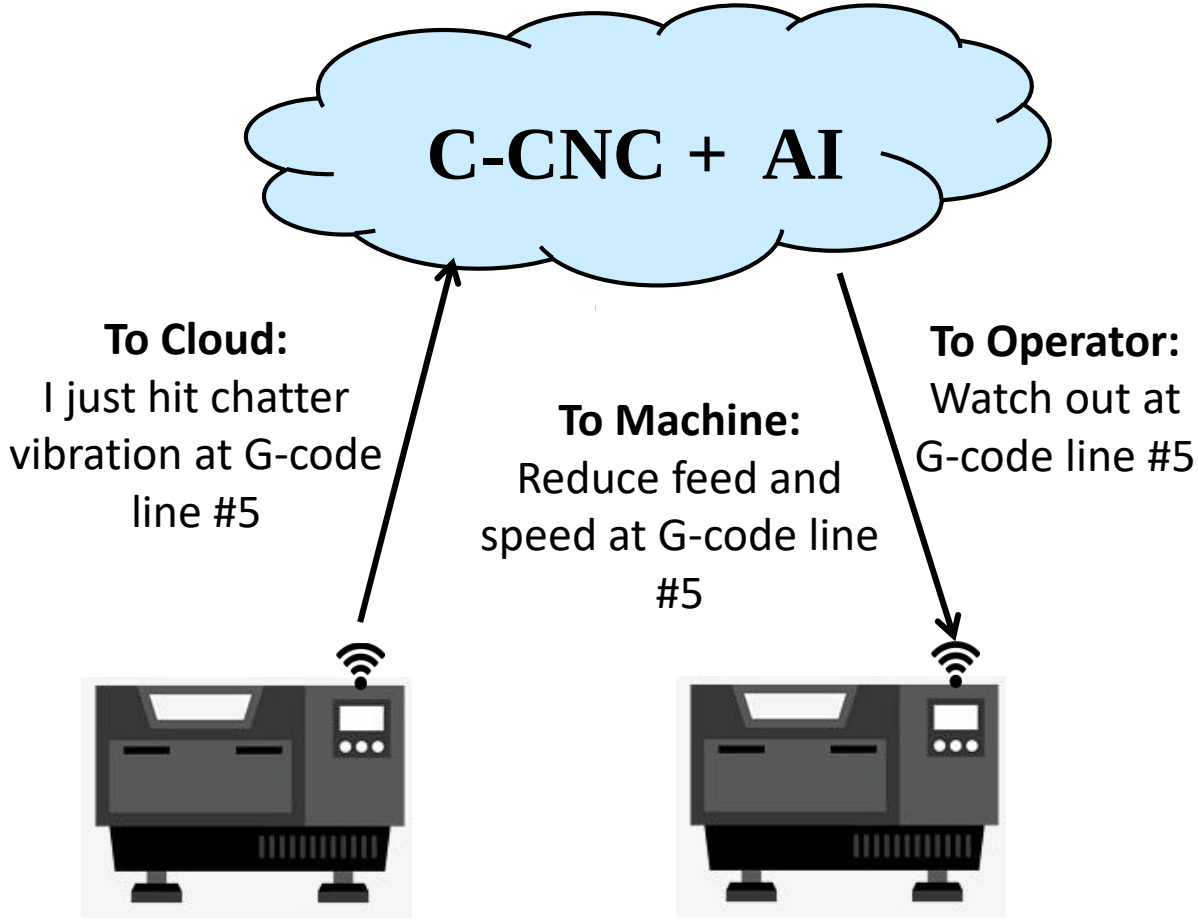
Could help improve real-time temperature control for metal additive manufacturing!

Benefit #3: Data Sharing and Machine Learning



Inspiring example from automotive

Li et al. 2015



Connected infrastructure enables machine-to-machine learning

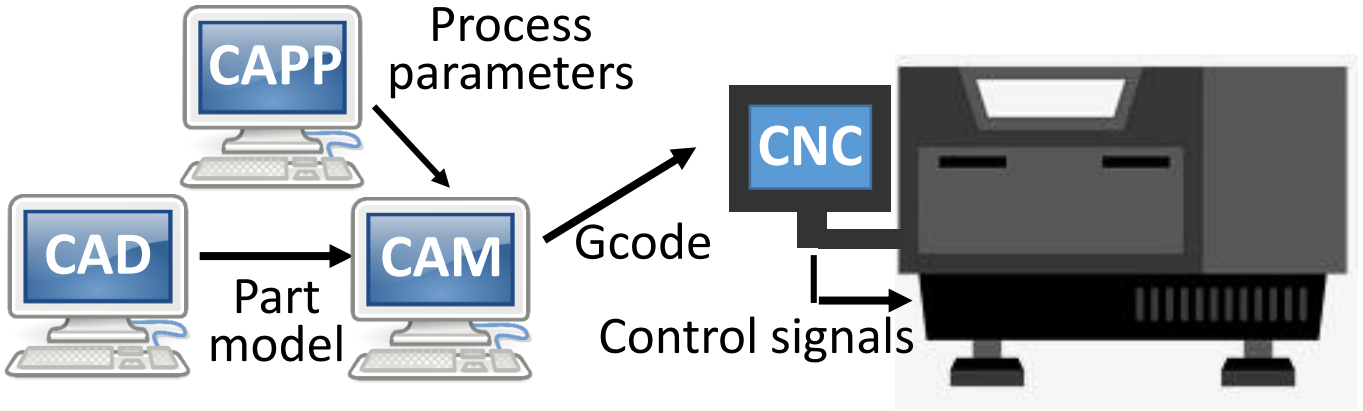
Benefit #4: U.S. can Regain Leadership

- U.S. **lags far behind** Asia Pacific and Europe in CNC and machine tool production ($ 70 billion industry)
- This is a serious national security vulnerability
- U.S. is **by far #1** (60% in revenue) in public cloud services (over $200 billion industry)
- C-CNC is an opportunity for U.S. to play to its strengths

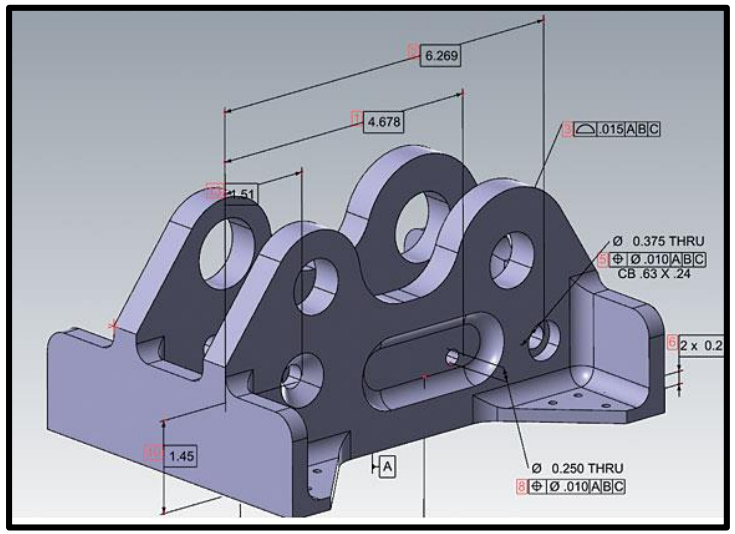
Instead of FANUC or Siemens CNC why not Google or Amazon or Microsoft C-CNC?

U.S. should own the remote brain of the machine tool

Benefit #5: A Chance to Better Integrate CIM



Potential of CIM 3.0 is restricted by poor integration



Information-rich CAD model

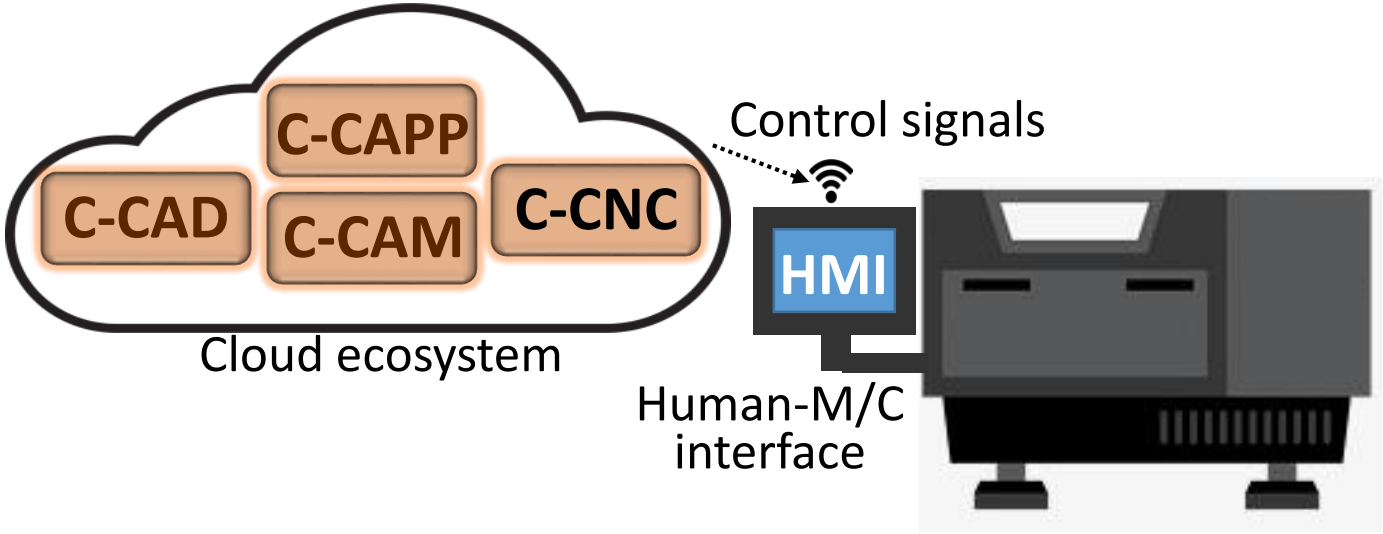
```
G00 X-25 Y20
G91 X-10
G02 X10 Y-10 I10 J0 F200 M3
G02 X-10 Y10 I0 J10;
```

Information-poor G-code
(relic of punched card era)

Old bottle:
Entrenched local CNC and CIM 3.0

Past efforts to integrate have faltered

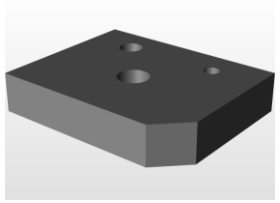
Benefit #5: A Chance to Better Integrate CIM



Transition to Cloud provides rare opportunity to integrate

E.g., C-CNC can give C-CAD "alternative routes," like Google Maps does, to improve speed or accuracy

C-CAD



C-CNC

You can reduce cycle time 20% by changing chamfer to round

New Wine: Better integrated solutions for CIM (e.g., STEP-NC)

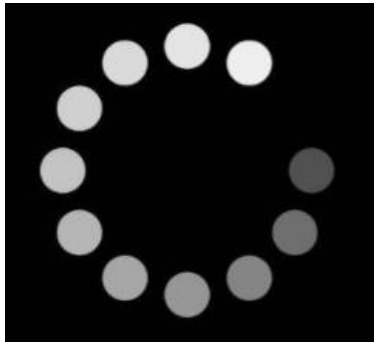
New bottle:
Cloud ecosystem

Challenge #1: Cybersecurity

- Challenge faced by virtually all cloud-based services
- Other security-critical applications like banking are adopting cloud solutions
- Though important, ***we must not be paralyzed*** by cybersecurity concerns – they are not insurmountable

Challenge #2: Internet Reliability

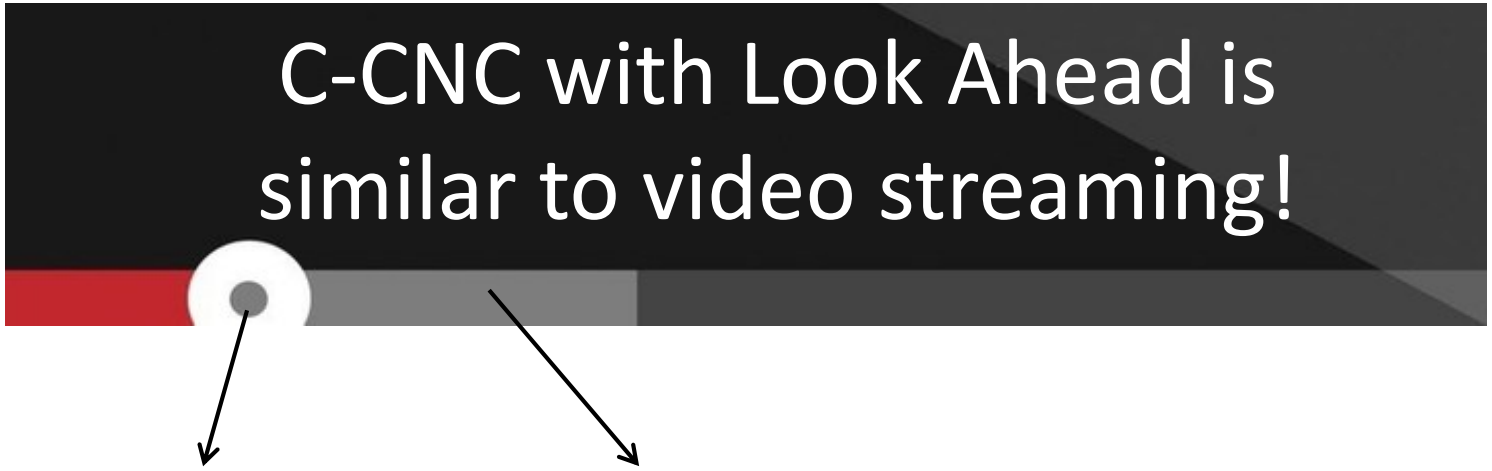
Reliability Issues: Delays, dropped packets, etc.



- Timing is critical to CNC applications
- Specialized networks (e.g., fog, 5G, TSN, SDN) can help

Challenge #2: Internet Reliability

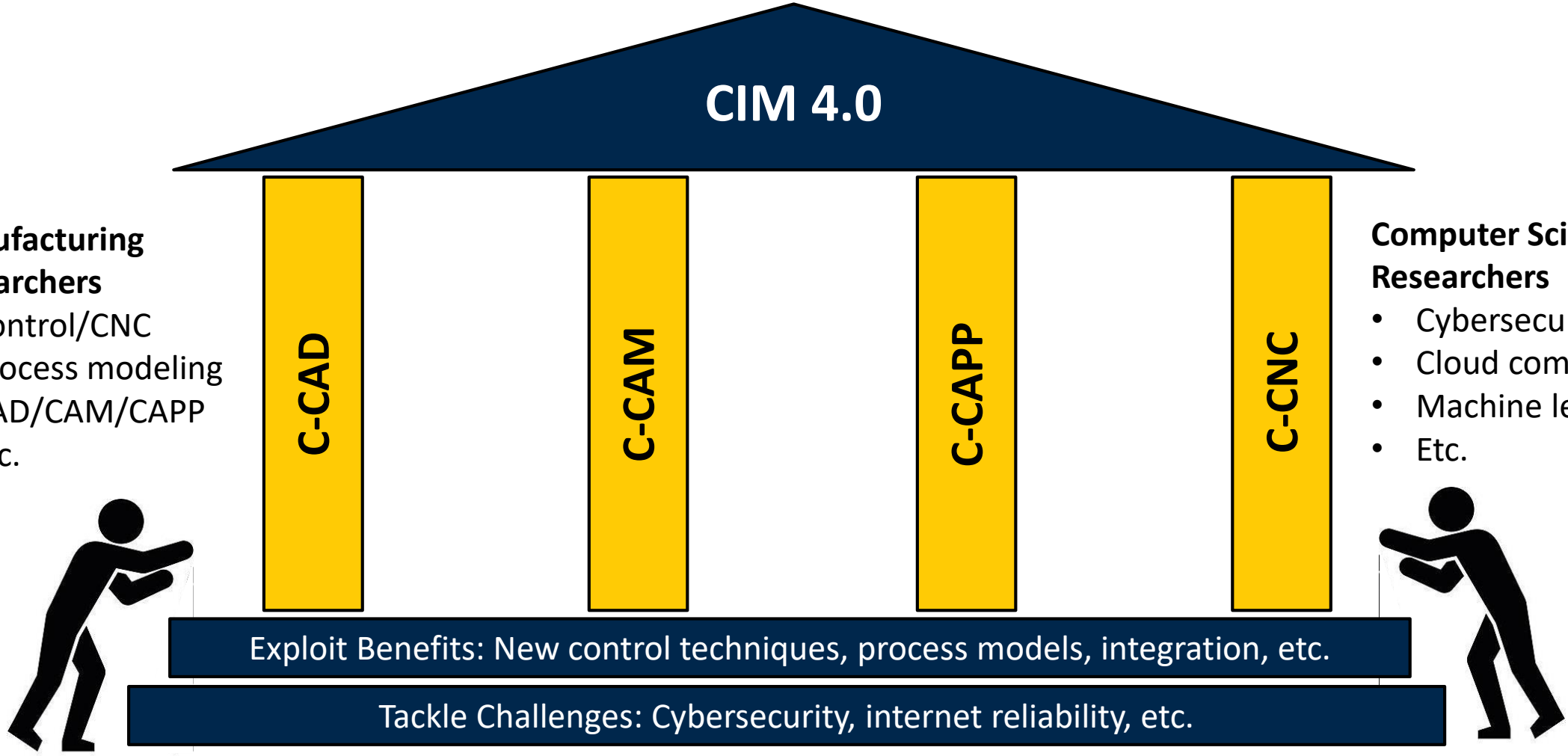
On *regular networks*, look ahead can also help reduce sensitivity to delays in C-CNC **through buffering** – as in video streaming



Control command being executed by machine

Control commands pre-calculated and pre-transmitted to mitigate internet delays

Concerted Research is Needed!



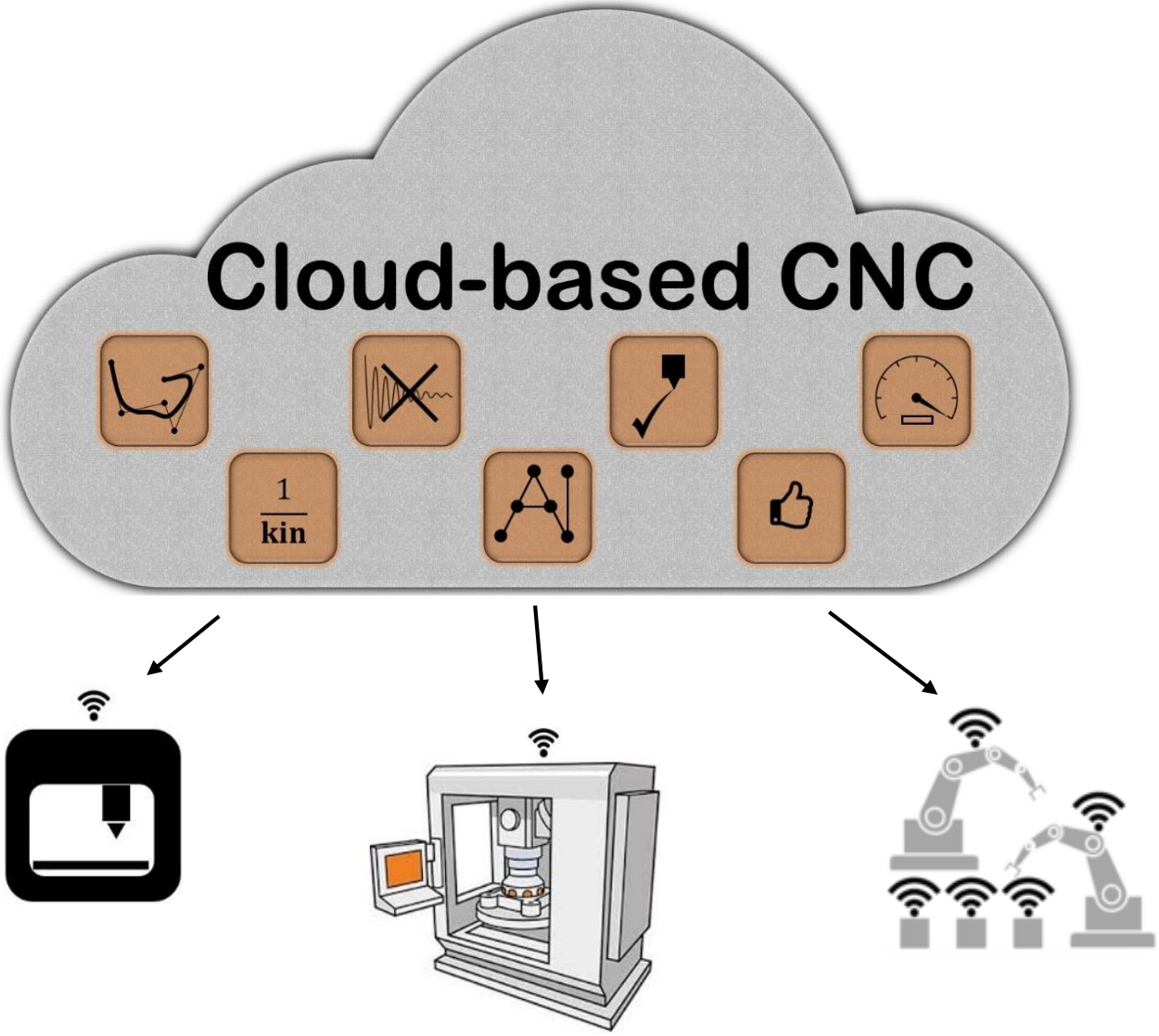
Manufacturing Researchers

- Control/CNC
- Process modeling
- CAD/CAM/CAPP
- Etc.

Computer Science Researchers

- Cybersecurity
- Cloud computing
- Machine learning
- Etc.

C-CNC.org Coming Soon!



A cloud-based platform for researchers to collaborate and test various algorithms for C-CNC and CIM 4.0 on actual machines

Sampling of Relevant References

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Thank You!

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