Low Cost Development Testbeds for Implementing the Digital Thread

Russ Waddell, AMT – The Association For Manufacturing Technology

Roby Lynn, Georgia Tech

Kyle Saleeby, Georgia Tech

Stephen LaMarca, AMT – The Association For Manufacturing Technology

Shaurabh K. Singh, AMT – The Association For Manufacturing Technology

Background

[redacted]

Digital Thread is great

Digital Thread is

(going to be)

great

1. Research platforms are helping fill gaps.

2. PocketNC desktop 5-axis is cheap*.

Research Platforms

Research platforms

are helping fill gaps.

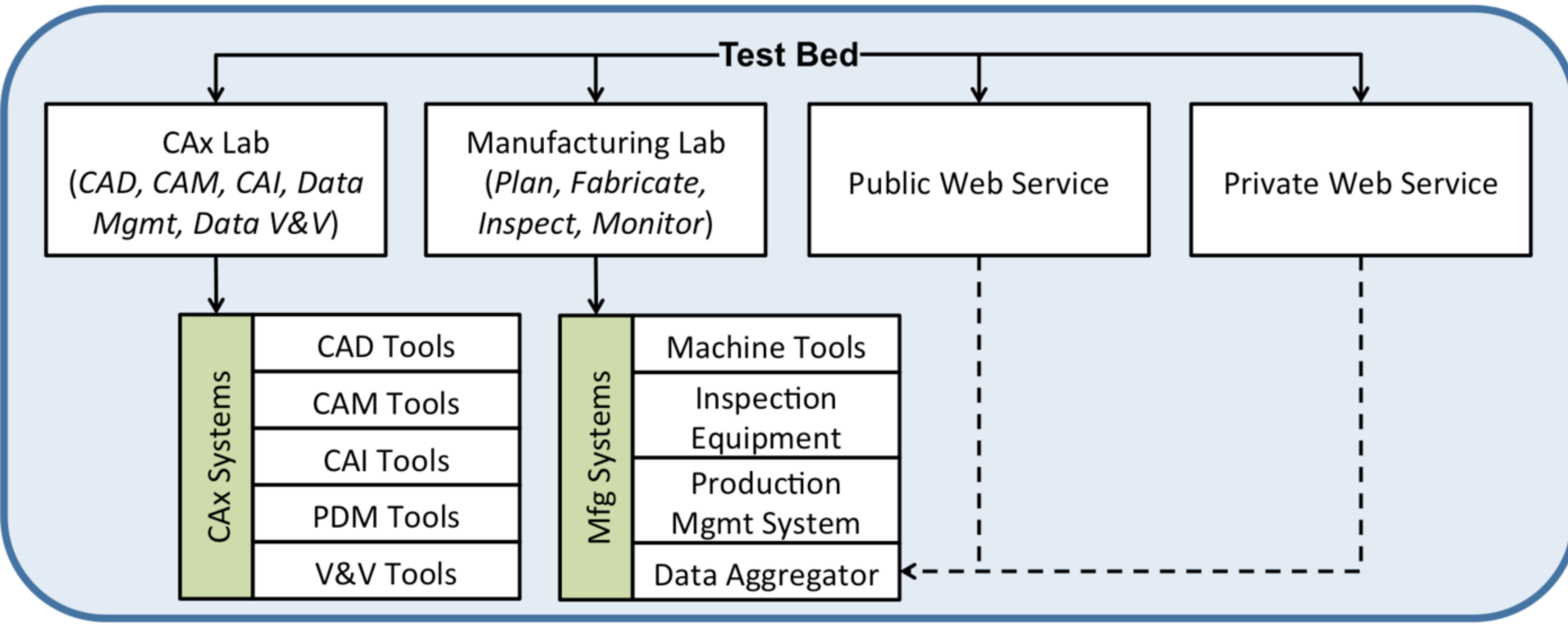
NIST

AMT

Georgia Tech

NIST

Smart Mfg Systems Testbed


Test Bed
CAx Lab
(CAD, CAM, CAI, Data Mgmt, Data V&V)
Manufacturing Lab
(Plan, Fabricate, Inspect, Monitor)
Public Web Service
Private Web Service
CAx Systems
CAD Tools
CAM Tools
CAI Tools
PDM Tools
V&V Tools
Mfg Systems
Machine Tools
Inspection Equipment
Production Mgmt System
Data Aggregator

AMT

Pop Up Shop

http://blognewsweekly.com/2018/07/08/popup-shop-designs/

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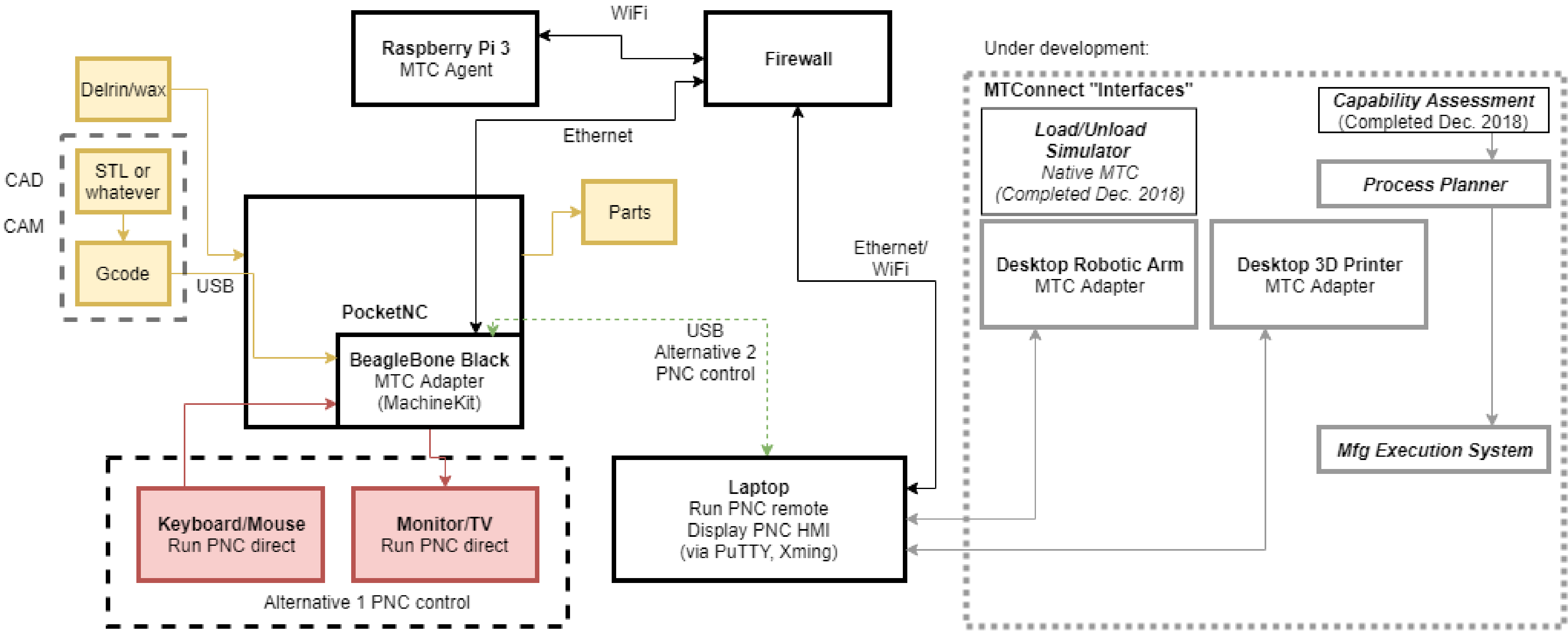
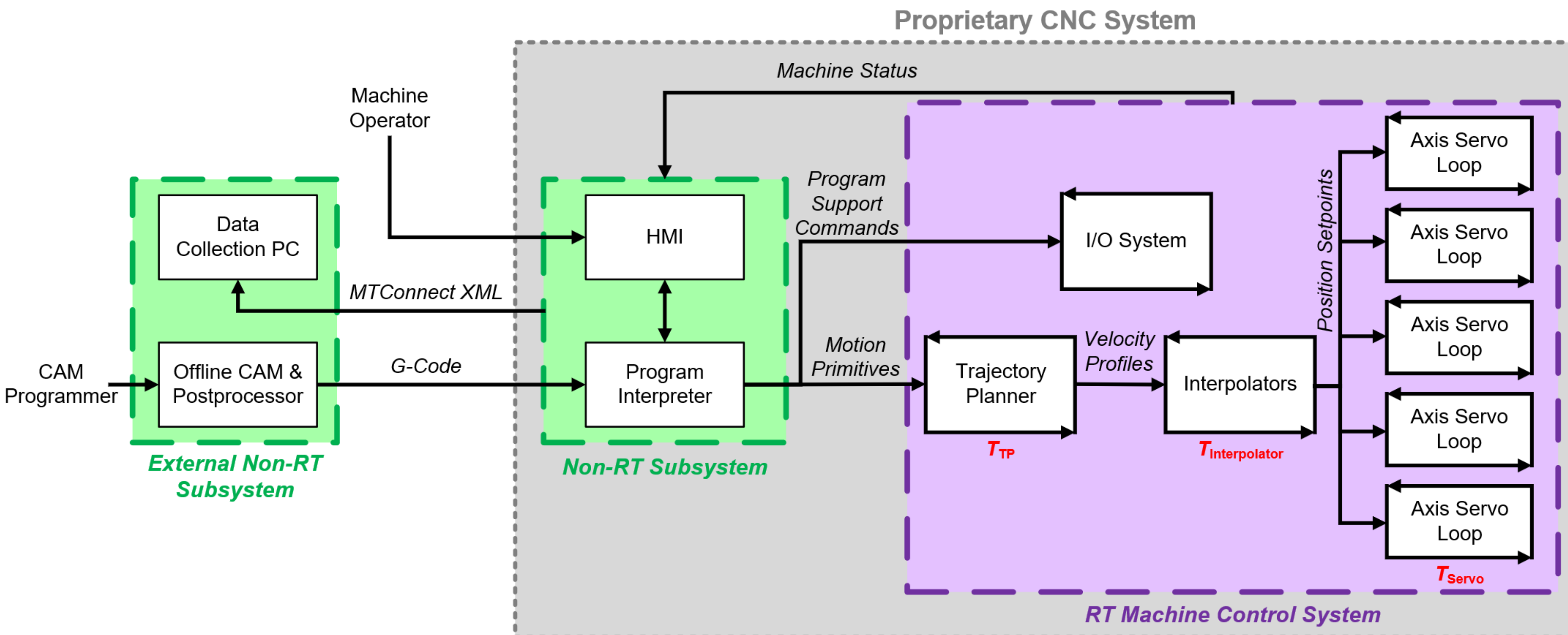
https://www.blocalpdx.com/news-feed/b-corp-store-opens-at-lloyd-center



Raspberry Pi 3
MTC Agent
WiFi
Firewall
Delrin/wax
CAD
STL or whatever
CAM
Gcode
USB
Ethernet
Parts
PocketNC
BeagleBone Black
MTC Adapter
(MachineKit)
USB
Alternative 2
PNC control
Ethernet/
WiFi
Keyboard/Mouse
Run PNC direct
Monitor/TV
Run PNC direct
Alternative 1 PNC control
Laptop
Run PNC remote
Display PNC HMI
(via PuTTY, Xming)
Under development:
MTConnect "Interfaces"
Load/Unload Simulator
Native MTC
(Completed Dec. 2018)
Capability Assessment
(Completed Dec. 2018)
Process Planner
Desktop Robotic Arm
MTC Adapter
Desktop 3D Printer
MTC Adapter
Mfg Execution System

Georgia Tech

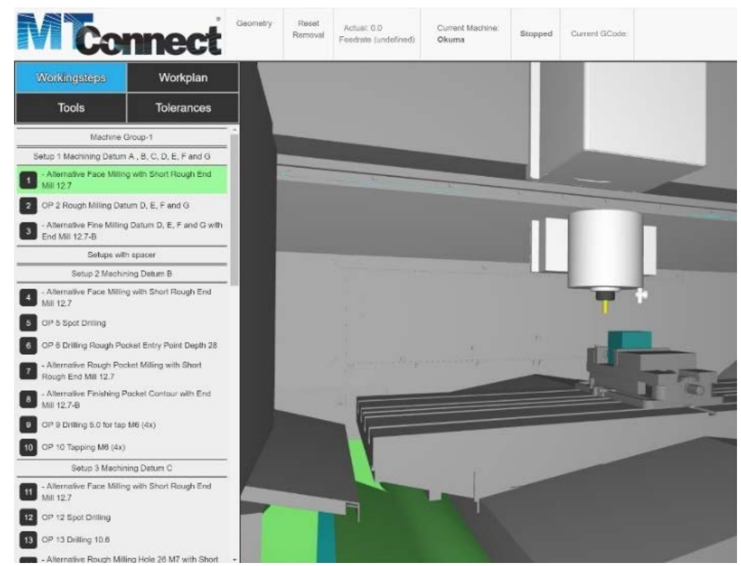
Typical CAM → CNC System



[3] R. Lynn, M. Sati, M. Helu, T. Kurfess. *The State of Integrated CAM/CNC Control Systems: Prior Developments and the Path Towards a Smarter CNC (in Preparation)*. SME Journal of Manufacturing Systems, 2019.

Alternative Data Flow Standards

- *Feedback*: MTConnect, OPC-UA, proprietary APIs
  - Low frequency feedback: typically less than 100s of Hz for *some* data items
  - Limitations on flow direction
  - Okuma THINC, Mazak Smooth API
- *Control*: STEP-NC
  - Object-oriented machine tool programming
  - Interoperability between different types of machine tools
  - Online trajectory planning
- NC.js
  - Realtime machining simulation of a STEP-NC program using MTConnect data

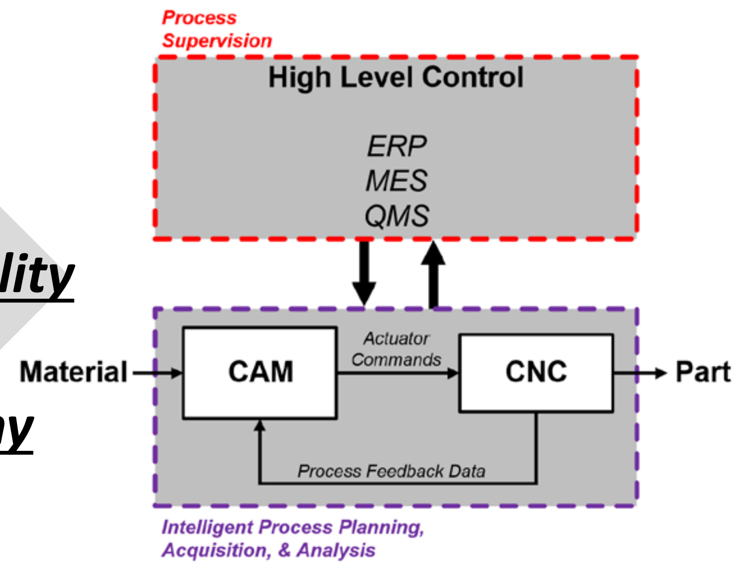


Direct Servo Control from Voxel-Based CAM: Research Objectives

More Control

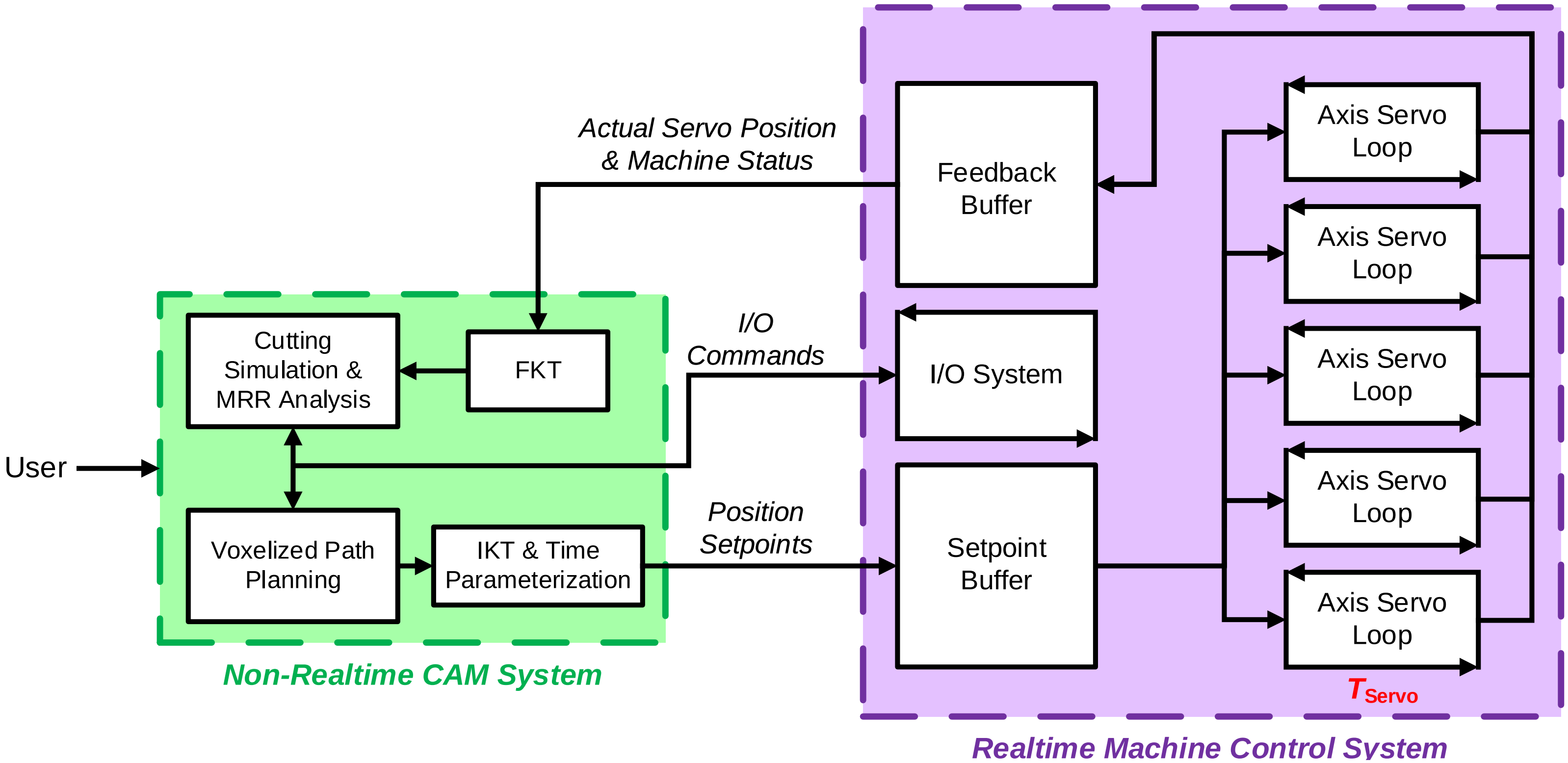
Higher Data Availability

Increased Autonomy



- *Framework for a <u>smarter and more integrated</u> realtime machine tool control system*
  - Software and hardware, experimental motion profiles, performance analysis

Direct Servo Control from Voxel-Based CAM: System Architecture



[9] R. Lynn, M. Sati, T. Tucker, J. Rossignac, C. Saldana, T. Kurfess. *Realization of the 5-Axis Machine Tool Digital Twin Using Direct Servo Control from CAM.* NIST Model Based Enterprise (MBE) Summit, 2018.

Future Factory Software Architecture & Supporting Applications

Boeing PI: Al Salour

Ga. Tech PIs: Dr. Tom Kurfess; Andy Dugenske

Research Team: Daniel Newman, Kyle Saleeby

- Digital Architecture Implementation
- PocketNC Connect Desktop Implementation
- Live Machine Monitoring Testbed

Digital Architecture Implementation

- MQTT machine monitoring architecture
- JSON data structure
- Many-to-many communication pattern
- Robust and flexible for diverse machines and processes

Live Machine Monitoring Testbed

- Three OKUMA Genos machines connected and monitored
- 800 Parts machined each semester via ME2110: Creative Decision and Design
- Data integration with Digital Twin modeling efforts

PocketNC

*Cheap = Total cost under $10,000 for a reasonable facsimile of a manufacturing cell

PocketNC

desktop 5-axis mill

Georgia Tech (x2)

AMT

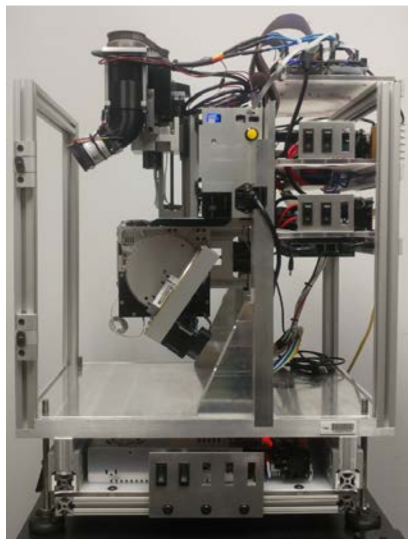
Tec De Monterrey

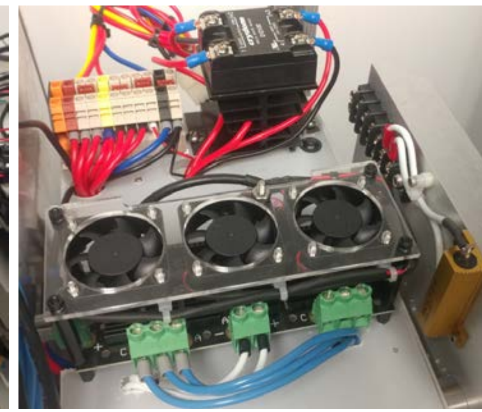
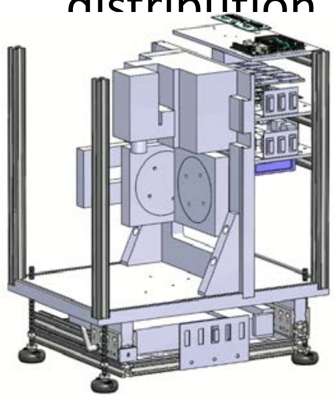
Georgia Tech

Roby Lynn

Research Machine Tool: Hardware

- VMC conversion of PocketNC
  - Expandability, $50 BBB
  - Axis encoders
  - Closed-loop spindle control
  - Power distribution
  - ion,
    ng




CAM-Controlled PocketNC	
Pocket NC (V1)	4,000
Frame	700
Electronics	300
Sensors	600
Control PC	2,000

TOTAL, Directly-Controlled Desktop CNC	**$7,600**

Georgia Tech

Daniel Newman
Kyle Saleeby

PocketNC Connect Desktop Implementation

- PocketNC 5-axis desktop CNC machine
- Full in-house implementation without cloud connectivity
- Secure for classified facilities
- Increased sample frequency and higher data quality

PocketNC Connect Desktop Implementation

AMT

Pop Up Shop

AMT Pop Up Shop, current scope	
Pocket NC (V2)	5,500
Pocket NC enclosure	549
Vise	60
Travel case	299
Raspberry Pi (bundle)	85
Laptop	600
TOTAL, Desktop CNC	**$7,093**

AMT Pop Up Shop, future scope	
Ufactory xArm	7,000
xArm gripper	1,500
TOTAL, Desktop CNC + Desktop Robotic Arm	**$15,593**

CONCLUSIONS

Researchers should:

Review existing testbed models
Publish system architectures
Share findings with suppliers
Bridge gaps from lab to shop

See also:
research platform, manufacturing system architecture, low-cost hardware

Russ Waddell rwaddell@amtonline.org

Standards developers should pursue:

Openness
Modularity
Pluggable architectures
Harmonization

Russ Waddell rwaddell@amtonline.org