NSRP Robotic Arc DED AM – Advanced Capabilities Workshop

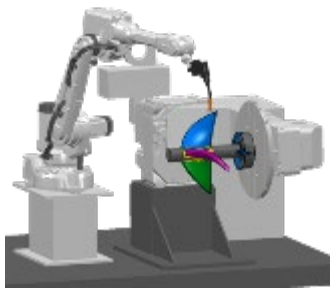
Robotic DED Test-beds for Collaboration

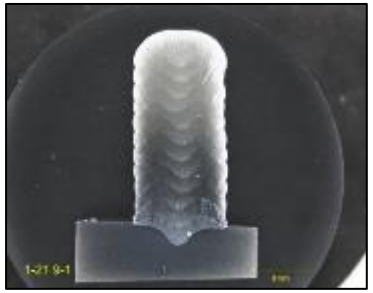
Dennis Harwig, EWI
Senior Tech. Leader

Acknowledgement

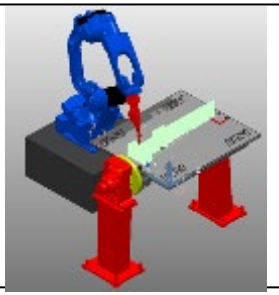
- Much of the content presented was developed in the National Shipbuilding Research Program – Advanced Shipbuilding Enterprise (NSRP-ASE) Research Announcement (RA) Project 2019-375-004.

NSRP Robotic Arc Directed Energy Deposition (DED) Additive Manufacturing (AM) for Shipbuilding



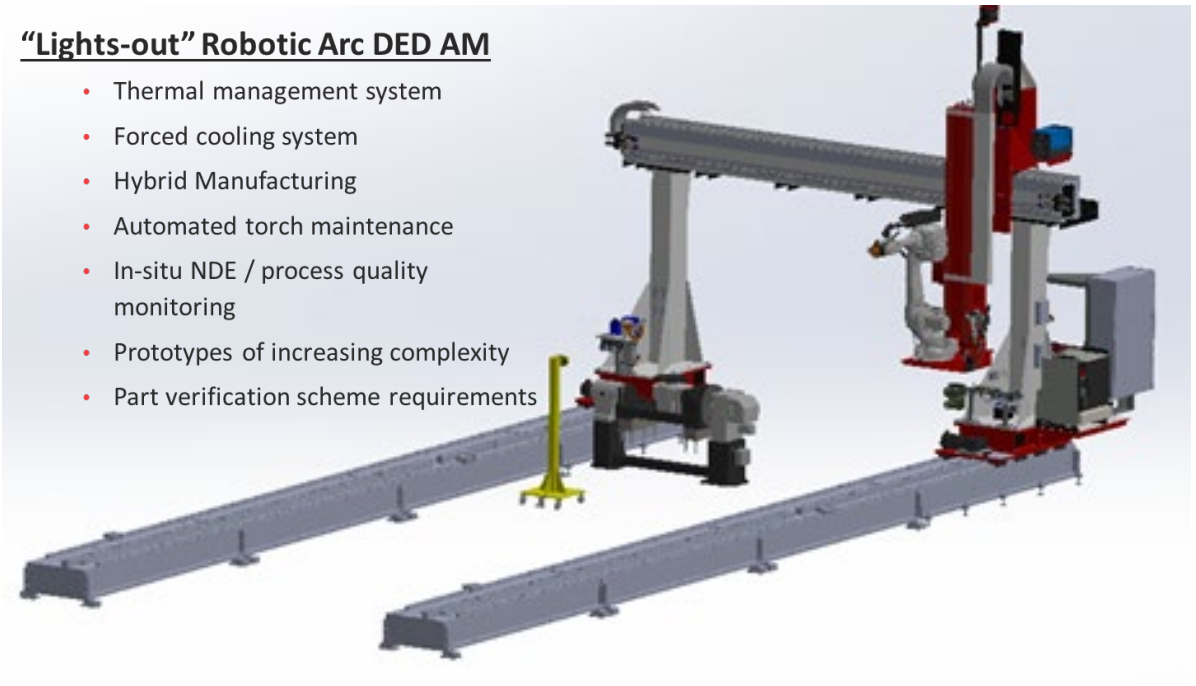


Project Team
EWI – Project PI
Navus Automation
Austal USA
NSWCCD
ABS



"Lights-out" Robotic Arc DED AM

- Thermal management system
- Forced cooling system
- Hybrid Manufacturing
- Automated torch maintenance
- In-situ NDE / process quality monitoring
- Prototypes of increasing complexity
- Part verification scheme requirements



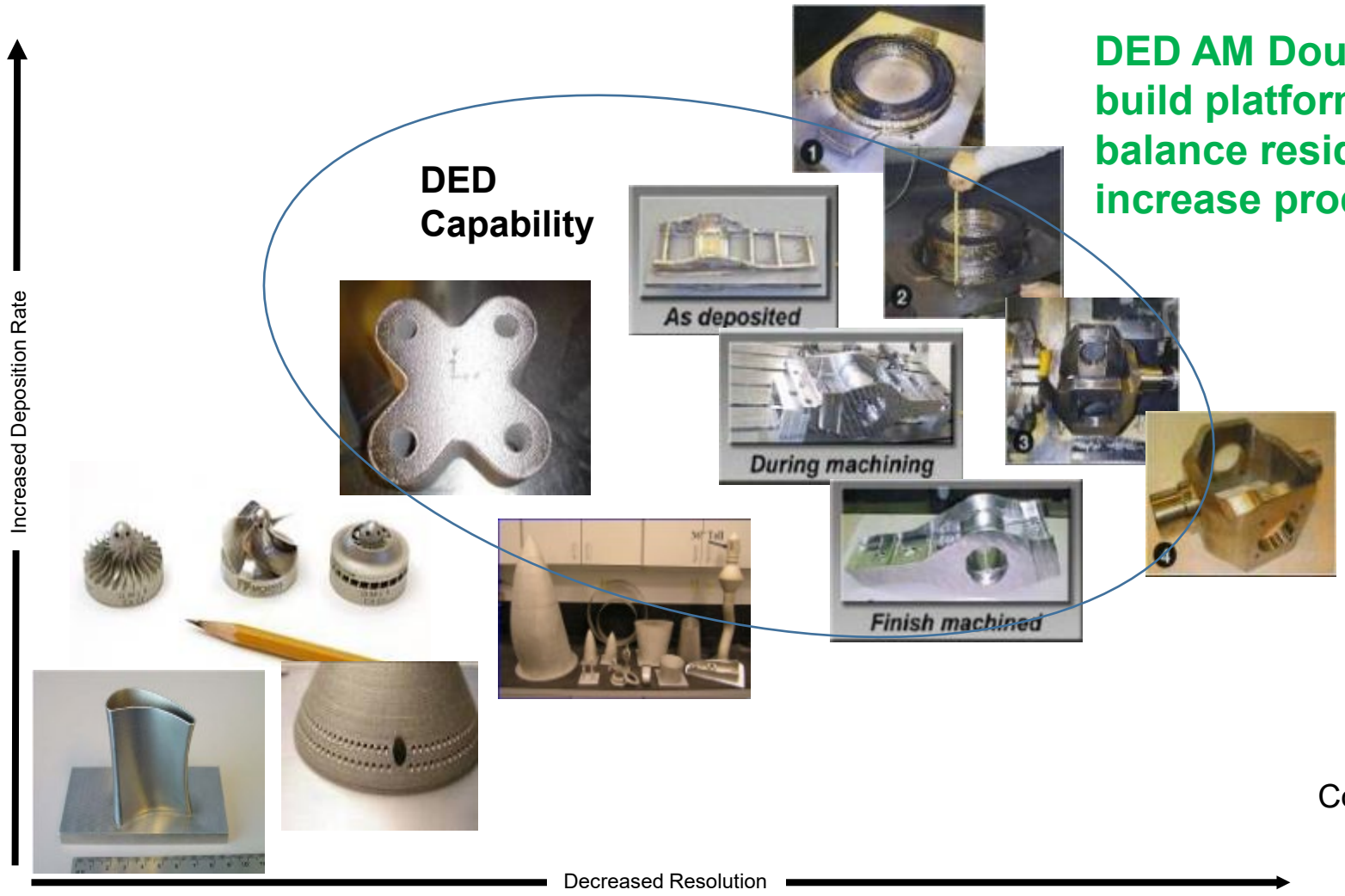
Objectives:

- **Convert multiple robotic weld systems to DED systems**
- **Design standardized large-scale gantry DED system**
- **Develop digital data workflow processes**
- **Develop advanced training materials - workforce**
- **Demonstrate representative qualifications**
- **Provide standardized equipment & services**
- **Build prototypes of increasing complexity**
- **Identify implementation opportunities**

Reducing barriers to implement DED AM

Project Period: June 2019 – July 2021

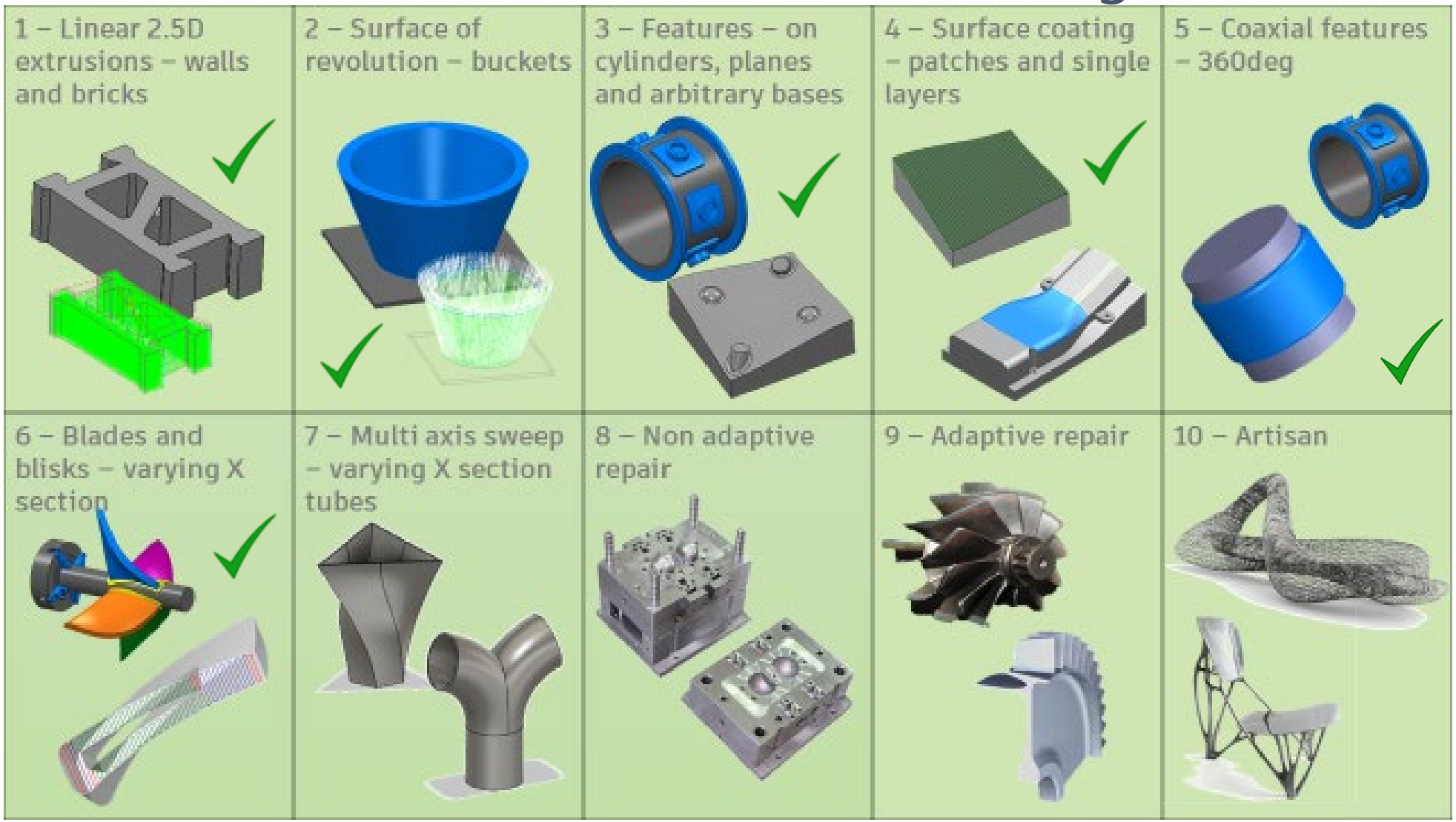
DED Deposition Rate vs Resolution



DED AM Double-sided integrated build platform (DS-IBP) used to balance residual stresses and increase productivity

Courtesy Boeing

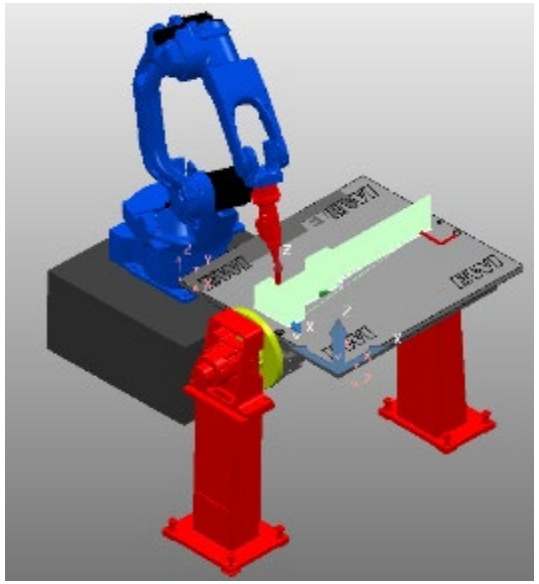
Autodesk PowerMill Additive – DED Build Categories

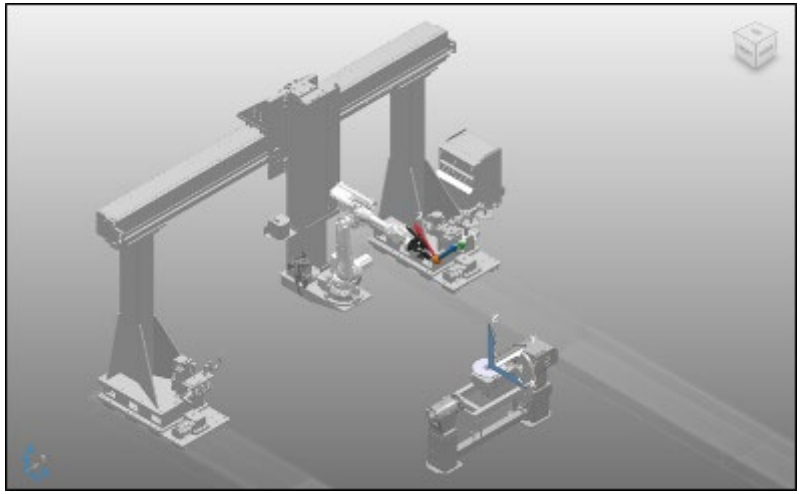


*Courtesy Autodesk

Robotic DED Training & Build Test-beds

- Basic & Adv PowerMill DED AM Launched
  - Autodesk Authorized Training Center (pending)
- Multiple test-bed systems - training, process, prototyping
  - IR-based preheat & inter-pass control
- Robot DED AM systems available
  - 7-axis Motoman Fronius Arc DED System
  - 8-axis Motoman Powder Laser DED System
  - (2) 8-axis OTC Arc DED Systems*
  - Dual 8-axis Genesis Fanuc MP-Arc DED System
  - 9- & 11-axis Navus ABB MP-Arc DED Gantry
- Additional robotic DED AM systems planned
  - 9-axis Cloos MP-Arc DED System*
  - 6-axis Motoman Wire Laser DED System





* Shared EWI/OSU Systems (MP) Multi-process / torch changer

Robotic Arc DED Systems

Fanuc - Fronius & SBI
(CMT/GMA-P & Plasma)

Navus ABB Gantry
(Multi-process DED)

Motoman - Fronius
CMT/GMA-P/GMA

Fanuc - Lincoln
GMA-P/GMA/TW-GMA

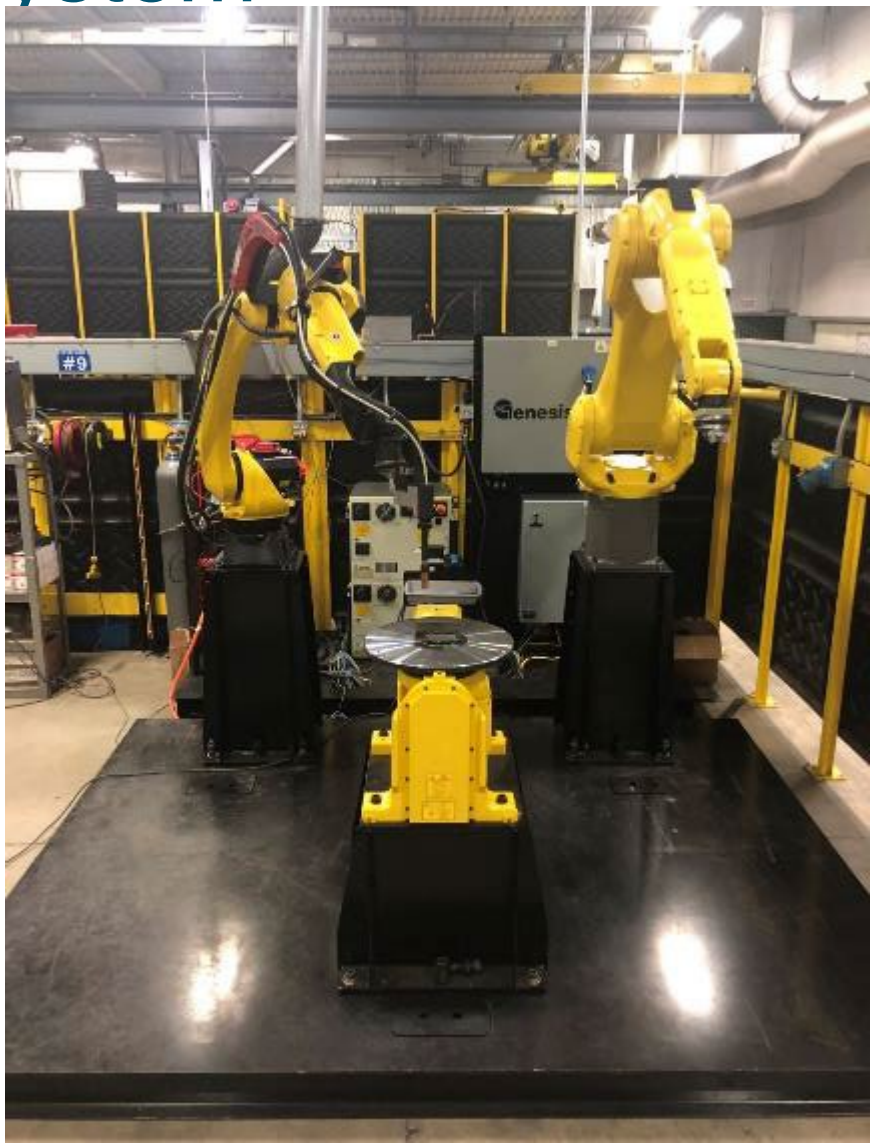
OTC-Daihen
SyncroFeed

OTC-Daihen
GMA-P/GMA

Cloos
Motion / GMA-P & T-GMA

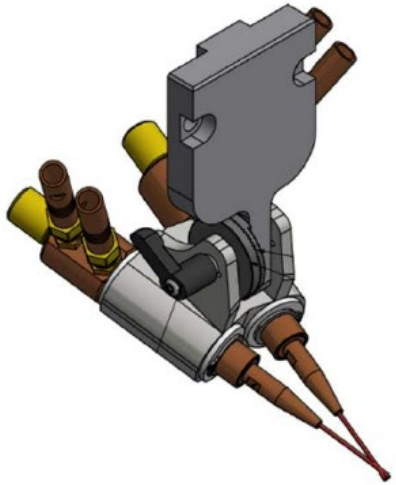
Genesis / Fanuc Robotic Arc DED System

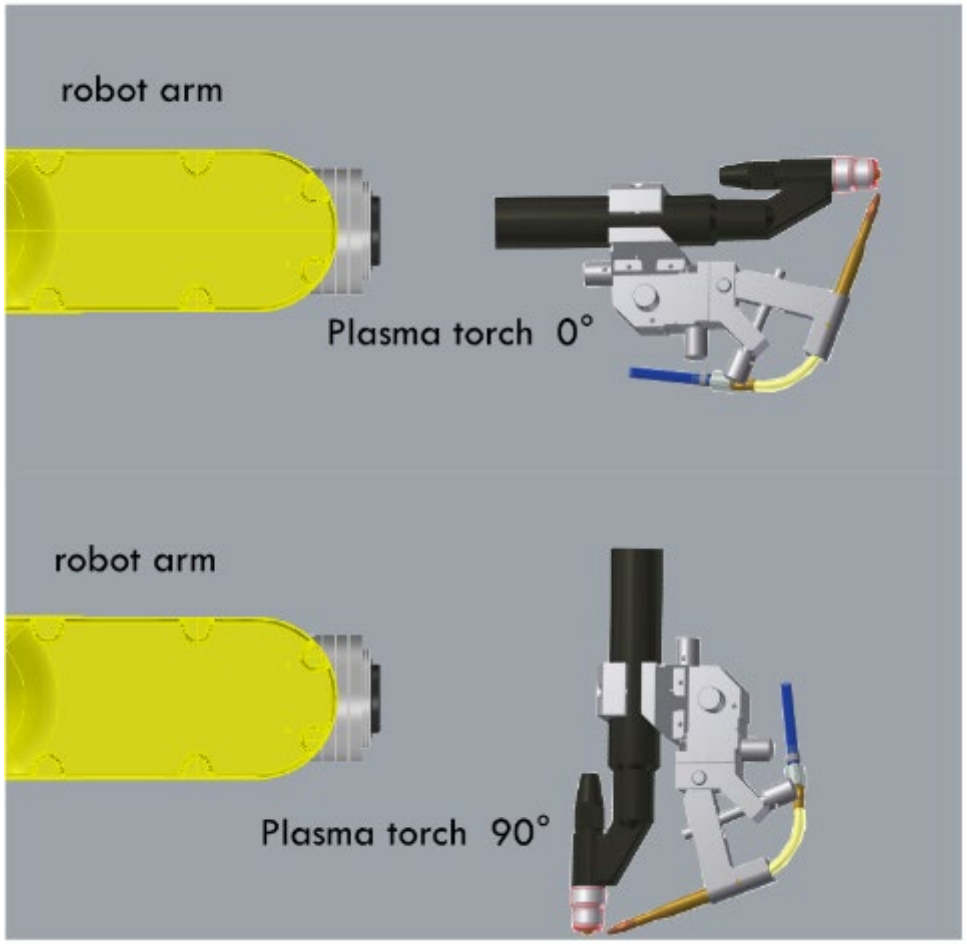
- Dual-arm system
  - Primary welding deposition arm
    - Fronius TPS 5000CMT
      - CMT, GMA-P, GMA
    - Change waveform conditions based on build features
  - Second arm – flexibility
    - SBI Plasma Arc DED System (being acquired)
      - Dual-wire feed
    - Auxiliary equipment: scanners, grinding, inspection
- Automated inter-pass temperature control
- Two axis positioner capable of building single- or double-sided build platform structures



SBI Plasma Arc DED

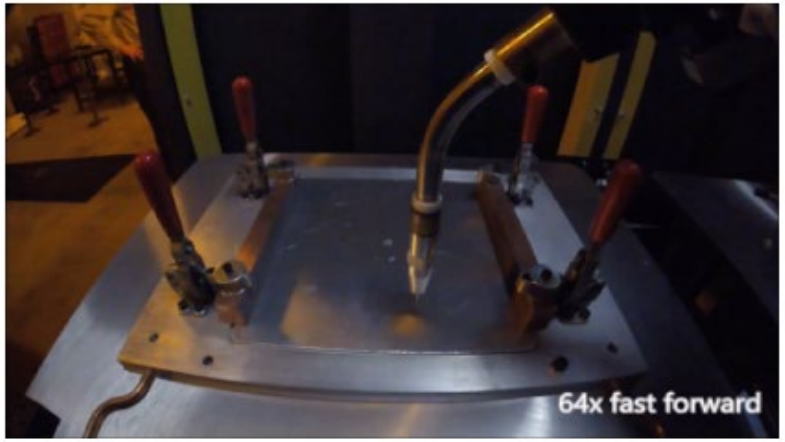
- 350 Amp AC/DC Invertor System
  - 290 Amp DC 100% Duty
- Multifunctional plasma system:
  - Plasma joining and hardfacing
  - Plasma spot welding
  - Plasma powder welding
  - Plasma brazing
  - TIG welding (GTAW)
  - Plasma metal deposition (directed energy deposition) with wire and powder
- Single/dual hot wire & powder feed

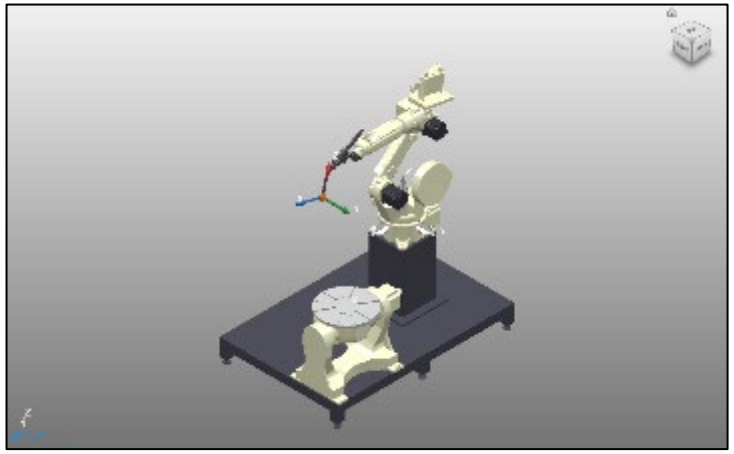




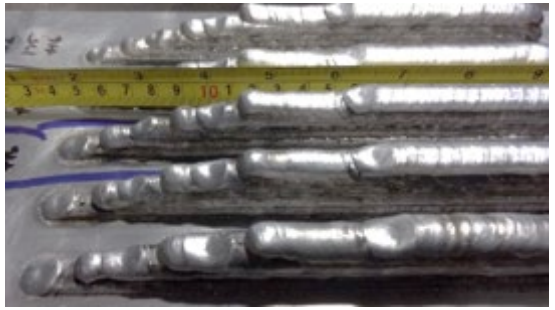
EWI/OSU OTC Robotic DED Systems

Synchro-feed
100% CO_2
No Spatter





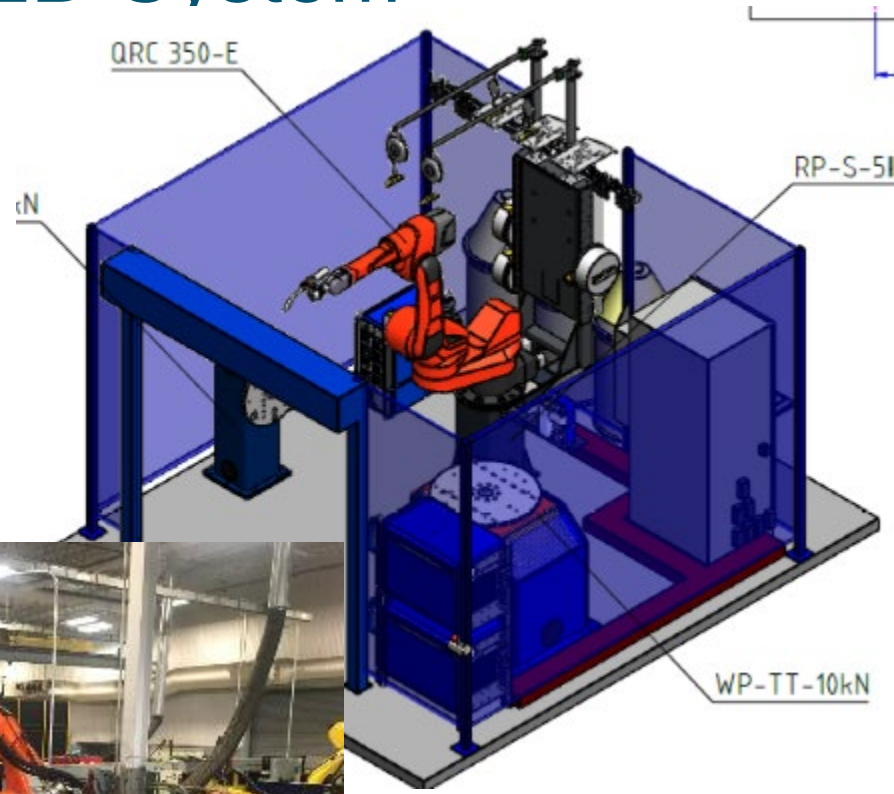
- Two (2) OTC 8-axis GMA-P DED Systems
  - Synchro-Feed™ Robotic Welding
  - Welbee WB-P500L power source
  - Inter-pass temperature control
  - Two axis positioner
- Current Ma2JIC focus
  - ER5183 GMA-P DED
  - Walls & Block Procedures
  - 6- & 8-axis Builds



Ma²JIC
MANUFACTURING & MATERIALS JOINING INNOVATION CENTER

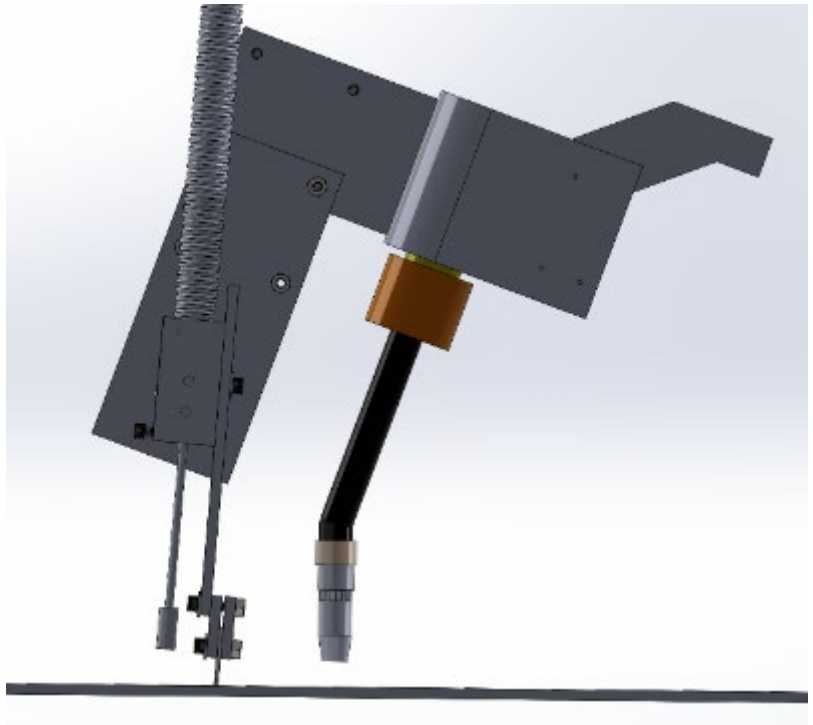
EWI/OSU Cloos Robotic Multi-process DED System

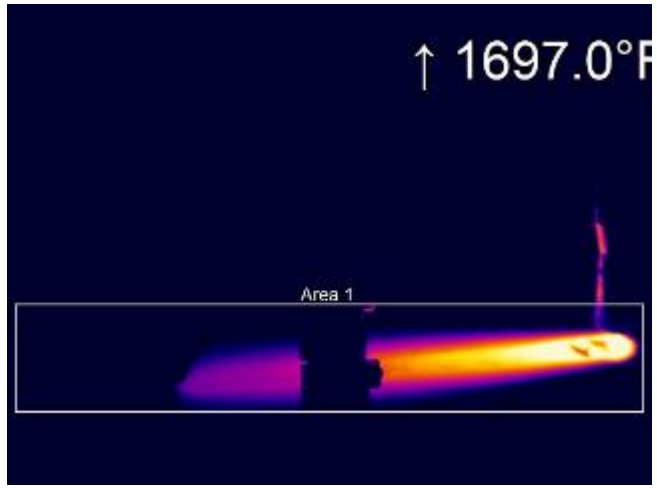
- Dual Process Test-bed
  - Motion, GMA, and Tandem GMA
  - High melting rate T-GMA control
  - Laser depth & IR sensors
  - 2-ton capacity double-sided builds
- Feature - cooling rate – property control
  - Cryogenic cooling support process
  - Maximum duty and build rate
- Adapt waveform conditions based on build conditions to max productivity and control properties.
- Current Ma2JIC focus
  - Adv. High Strength Steels

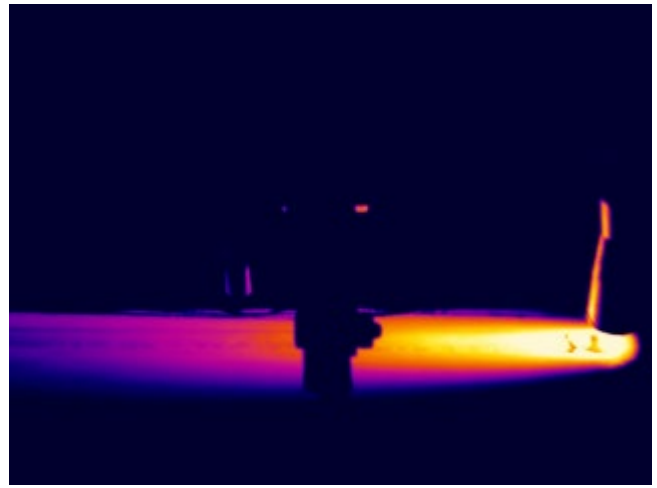


Ma2JIC
MANUFACTURING & MATERIALS JOINING INNOVATION CENTER

Air Products In-situ Liquid Nitrogen Cryogenic Cooling (ILNCC)





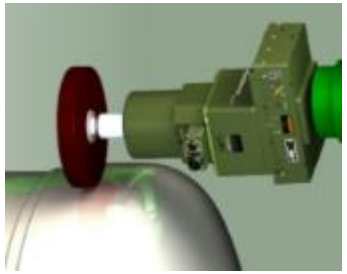


Large-scale Multi-process Robotic Gantry DED System – Commission July 2020

Pre-engineered (COTS) System

- 8-10-ft high x 14-ft wide x 30-ft long
- 60 Kg ABB IRB 4600 Robot
- Multi-process
  - Fronius CMT, Lincoln Power Wave
  - Arc, Laser, Hybrid laser-arc
  - PushCorp Grinder/brusher/burring spindle
- 11-axis w /1-ton tilt/turn positioner
- Sensor platform for development of quality control and part certification technologies
- Unique resource for prototyping metal DED AM structures and components

System available for large-scale DED application development

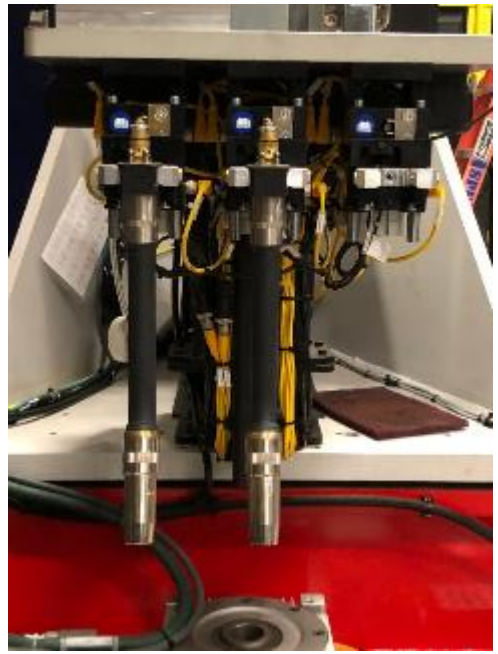


Large-scale Multi-process Robotic Gantry DED System

Welding Processes

- Welding systems
  - Fronius TPS 500i CMT system
    - Fronius WF 60i Robacta Drive CMT Torch
    - Fronius CU 1100i Water Cooler
  - Lincoln S500 system
    - Binzel ROBOWH-WC Torch
    - Lincoln Cool Arc 55 S Water Cooler
    - STT Power Wave module

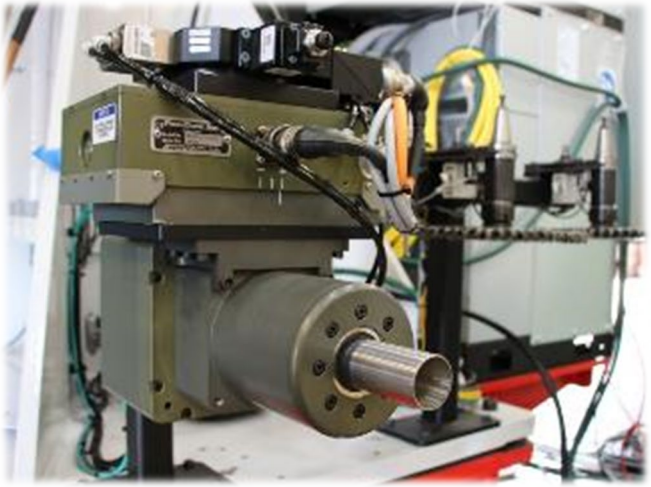
- Binzel Torch Maintenance Station
  - Services Both Torch Types
- Binzel Torch Exchange Stations
- ABB Bullseye
- Additional Wire Clipper at Robot Base

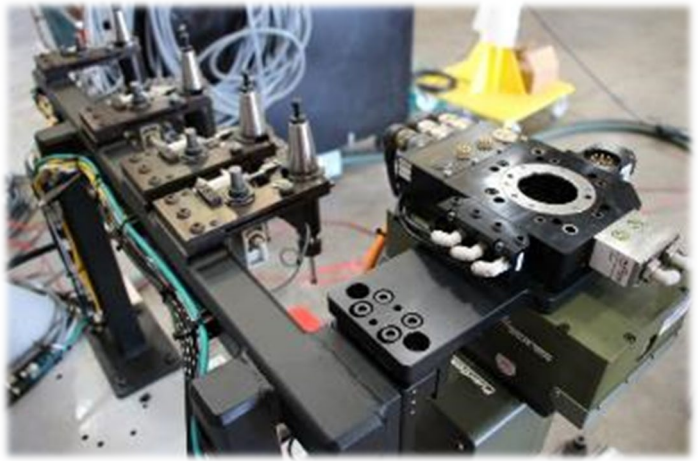


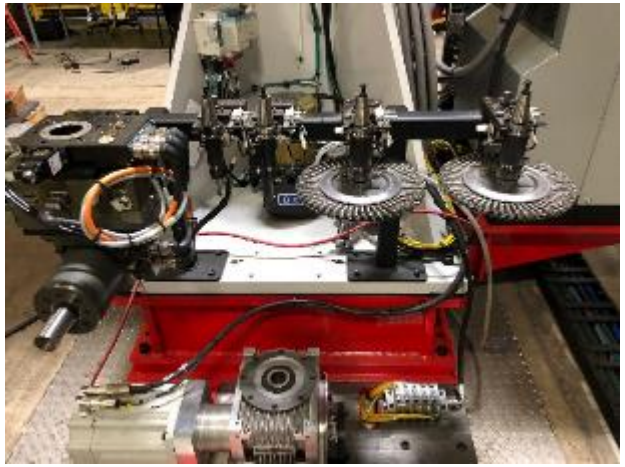
Large-scale Multi-process Robotic Gantry DED System

Metalworking processes

- PushCorp 5-HP spindle
  - AFD340 Active Compliance Device
  - BT30 Tool Changing Station
    - Grinding, burring, brushing
  - Miller Coolmate 3 Water Cooler
- ATI Tool Changer







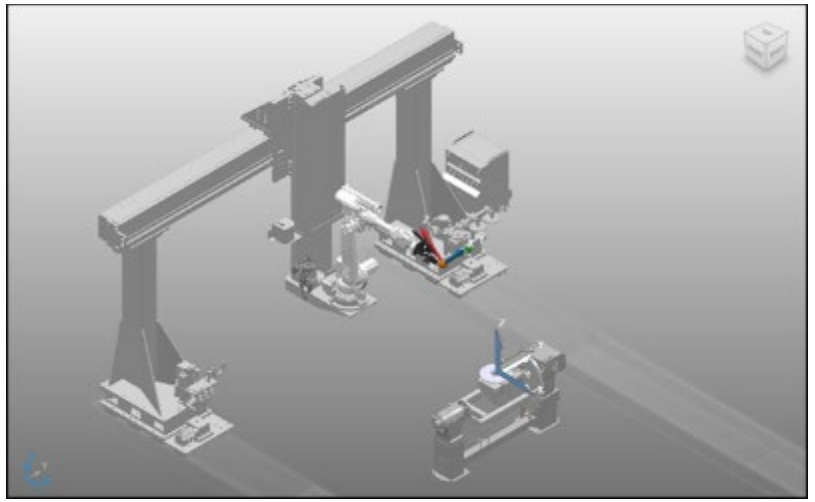
Large-scale Multi-process Robotic Gantry DED System

Monitoring Sensors

- Synchronized weld parameter data acquisition
- Melt Tools camera
  - Weld pool monitoring
- Micro-Epsilon TIM 640 Thermal Imaging Camera
  - Non-contact measurement of surface temperature from -4°F to 4442°F
  - Inter-pass Temperature control
- Binzel TH6D-GF Sensor
  - Seam tracking and finding
  - Profile measurement and documentation during DED AM
  - Used with both welding systems
    - Mount for Binzel Torch
    - Mount for Fronius Torch

Pre-Engineered Large-scale Robotic Gantry DED Systems

- Digital-twin available for build simulations
- Post-processors solved for 9- & 11- axis
  - Large-scale single-sided builds
  - Large scale double-sided builds
- System Derivatives
  - Large/smaller work envelope
  - Head stock/tail stock – double-sided builds
  - High deposition arc DED packages
  - Laser DED packages
  - Digital manufacturing
    - DED, Welding, Cladding, Machining



New Capabilities - Summary

- Established digital twin and post-processor for 7 robotic DED systems (1-Motoman, 3-Fanuc, 2-OTC, 1 ABB)
- Developed, integrated and installed large-scale robotic DED Test-bed (supplied by Navus/ABB)
- Developed 9- and 11-axis digital twin model & post-processor for large-scale robotic gantry DED system installed at EWI
- Developed DED procedure models for 308L stainless steel and nickel aluminum bronze
- Demonstrated single-sided integrated build platform standard qualification builds
- Built basic components of increasing complexity (coupler, propeller blade) with platform robotic DED systems
- Developed basic PowerMill Robotic DED training seminar
- Developed advanced PowerMill robotic DED training program
- Launching Autodesk Authorized Training Center (ATC)
- Building basic & advanced components of increasing complexity with gantry test-bed
- Offering (Navus) pre-engineered/standardized large-scale DED system(s) for industry acquisition
- Planning development of “Lights-out” support processes (thermal mgmt., auto-maintenance, quality monitoring & control, etc.)

Ongoing Development Needs - Lights-out Technology

- Thermal management system
  - Infrared camera
  - Preheat/Inter-pass control
  - Forced cooling system and methods
  - Cooling rate control (long range)
- Hybrid Manufacturing/In-situ Clean Machining
  - 3-axis gantry milling for hard metals
    - Z-axis upgrade concept
  - Robotic grinding for hard metal
  - Robotic routing for soft metals
  - Start/stop contour grinding
  - Incremental feature grinding/milling
  - Clean Machining with In-situ Clean Cryogenic Cooling
- Automated torch maintenance
  - Torch cleaners
  - Wire cutter
  - Neck/tip changer
  - Cloos Sparematic auto nozzle and tip changer
  - Binzel neck changer station
- Process quality monitoring
  - Process behavior & parameter analysis
  - Pool behavior
  - Feature - cooling rate – property modeling
  - Dimensional data & management
- In-situ NDE
  - PowerInspect Software Suite
  - Vision processing
  - UT, ET, AET

Ongoing Development Needs

- **Develop advanced large-scale builds and prototypes for candidate shipyard applications**
  - **Develop DED models for different materials and features**
    - **Demonstrate qualification builds and feature prototypes**
  - **Evaluate alternative DED processes (plasma arc, wire arc)**
- **Develop Part (Component) Verification Scheme Requirements**
  - *Technical Publication - NAVSEA Process Requirements for Metal Directed Energy Deposition*
  - **Develop DED AM operations and process prototypes for:**
    - **Part Verification Build Procedure(s) Workflow**
    - **Quality Assurance System**
    - **Process Control Plan**
    - **Training Plan**

Accelerate shipyard implementation and impact

Questions