ONR DCN #43-7915-21

Implementation of Cold Spray technology in Navy Shipyards and Future of Cold Spray

National Shipbuilding Research Program
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Timothy J. Eden, Ph.D.
Head of the Materials Processing Division
Applied Research Laboratory, Penn State University
P:814-865-5880
Email: tje1@arl.psu.edu

Janice Bryant
Strategic Technology Manager
NAVSEA 05T1
#GETSHIPSDONE
P:360-507-8745
Email: janice.k.bryant@navy.mil

Dan Stanley
Norfolk Naval Shipyard
P: 757-701-7828
Email: daniel.p.Stanley@navy.mil

Jeff Campbell
Cold Spray Program Manager
NAVSEA 04
P: 360-900-8715
Email:
jeffrey.d.campbell@navy.mil

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Cold Spray Description

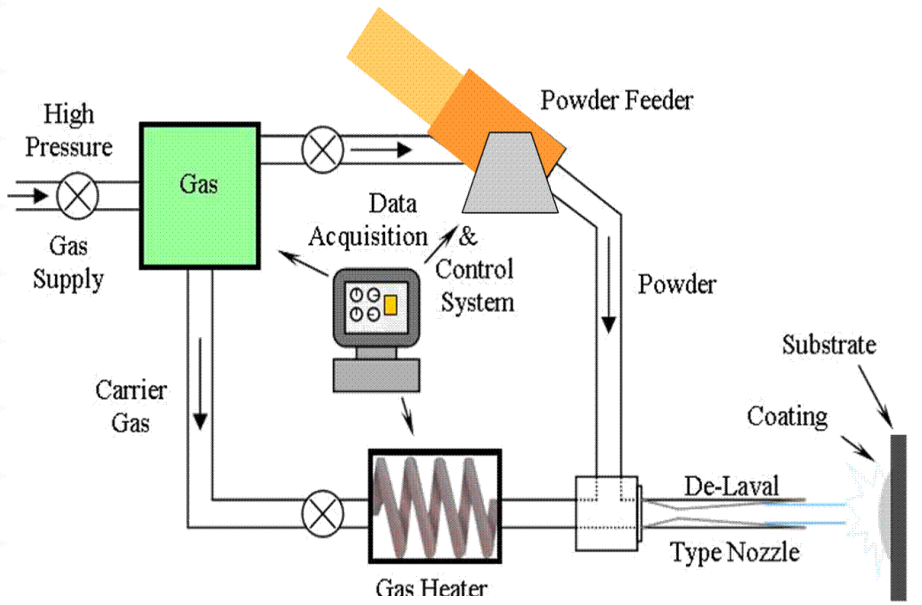
- Low temperature deposition process
- Supersonic particles imbed into substrate and adhere through impact consolidation.
- Helium, nitrogen, air
- Max gas temperature/ pressure at nozzle
- 800 C, 6.9 MPa

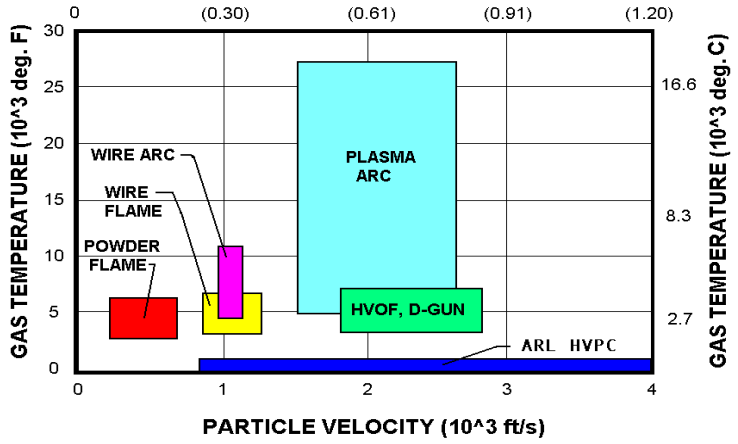
Advantages of Cold Spray:

- No substrate melting
- Minimum residual stresses
- Good bond strength
- Thick coatings possible
- Application of reactive coatings

Other names

- High Velocity Particle Consolidation
- Supersonic Particle Deposition (SPD)
- Cold Gas Dynamics





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ARL/PSU Cold Spray Capabilities

VRC Gen III Cold Spray System - Paladin

- **Max Gas Pressure 6.9 bar**
  - **Max Gas Temp at gun 750° C**
  - **Max Heater Power 45 kw**
- **Deposition rate 7 kg/hr**
- **Data logging and storage**

HAAS VF-3 CNC Mill

- **Rotary Table**
- **Pallet Changer**
- **Dimensional probe and tool setter**

Fully Integrated ABB Robot

- **SolidWorks**
- **SolidCam**
- **Robot Programing Software**

Touch Probe - Renishaw OMP40-2 Optical Transmission Probe

Helium Recovery System

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ARL/PSU Cold Spray Capabilities

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Portable Cold Spray System

Dragonfly

- Module for powder feeder, gas control and heater
- Modules weigh less than 80 lbs – two person lift
- Footprint 15 in x 18 in

Raptor

- Ruggedized system housed in a container with wheels and lifting hooks for easy transportation
- Same capability of the VRC, Gen III (55 bar (800 psi) and 700°C)
- Portable dust collection system adaptable to different milling/machining stations in the shop to allow repair and machine components without removing them from the machining center

Dragon Fly Hatchable Cold Spray System

Raptor Cold Spray System

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Qualification and Implementation

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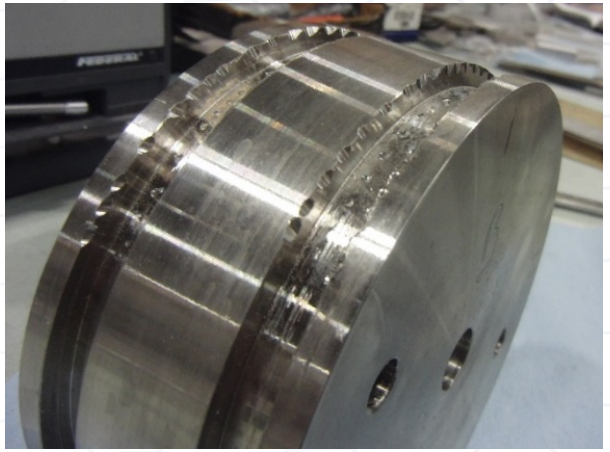
Uniform Industrial Process Instruction Cold Spray, Processes and Quality Control of

- Document for applying Cold Spray to repair components in Navy ships and submarines
- Classification of repairs
- Categories
  - Non-sealing or non-bearing surface
  - Sealing or bearing surface
  - Dimension repair in non-load bearing areas
  - Structural Repair – not currently authorized
  - Subcategories
    - Static vs. dynamic
    - Corrosive vs. non-corrosive
- Testing and qualification requirements based on repair
  - Metallography
  - Adhesion
  - Corrosion
  - Lug shear
  - Tensile
  - Wear
  - Mockup



70/30 CuNi Flange Mockup
prior to Cold Spray Repair

WIP-C1 Cold Spray Coating

Upper ring – repaired
Lower ring – not repaired
100 hrs ASTM B117 Salt Fog

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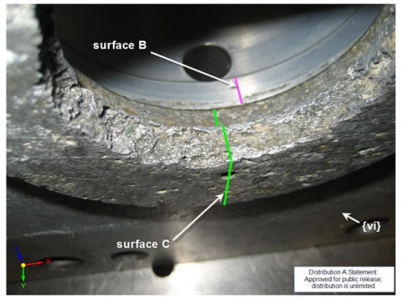
Qualification and Implementation

NAVSEA NAVAL SEA SYSTEMS COMMAND

Qualified Spray Procedure

- Developed for each repair specific to a Cold Spray system, powder/substrate, process parameters
- Detailed process instructions including robot path program
- Can use the same QSP for similar repairs or parts of a repair



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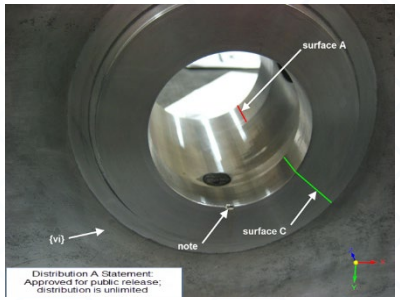
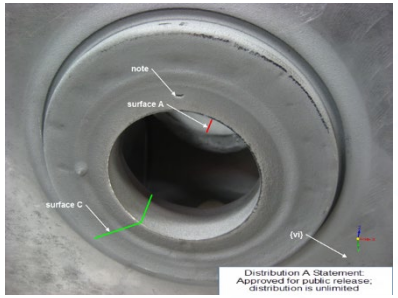
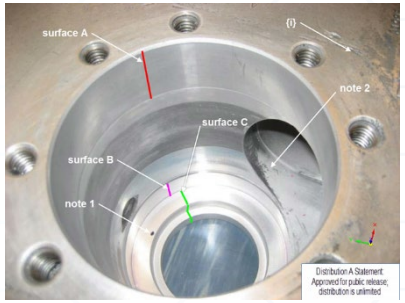


Pre-machined

Cold Spray Repair TD-16 Al-6061 Hydraulic Actuator Body



As-deposited



Final machined

QSP Name	Substrate	Coating
Nulka Electric Access Panel	Al6061	Al6061
Nulka Door Panel	Al6061	Al6061
Nulka Canister	Al6061	Al6061
Nulka Frame	Al6061	Al6061
Nulka Moog Control Valve	Al6061	Al6061
HSU for AAV	Cast Iron	Ni-Blend
BPS-16 Mast	Monel 400	Ni-Blend
Bellhousing Bore	A36	Ni-Blend
WIP-C1 on A36 Plate	A36	WIP-C1
WIP-C1 on C71500 Plate	C71500	WIP-C1
WIP-C1 on Cast Iron Plate	Cast Iron	WIP-C1
WIP-C1 on HY80 Plate	HY80	WIP-C1
WIP-C1 on K Monel Plate	K Monel	WIP-C1
WIP-C1 on Monel 400 Plate	Monel 400	WIP-C1
Motor End Bracket	A36	WIP-C1
AAV Impeller	A356	5056+Microblast
DT-31 Blend on C93200	C93200	DT-31 Blend
Cu-Ni Submarine Flanges	Cu-Ni	Cu-Ni Blend
NSWC Crane Seal Plates	Aluminum	Al6061
NSWC Crane Transmission Housing	Al6061	Al6061
TRF Bangor Radar Transmission Housing	CRES	WIP-C1
PSNSY Capstan Gearbox	1020 Steel	WIP-C1

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Cold Spray Repair of CVN #1 Main Circulating Water Pump Casing

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Material

- **Bronze C90300 Bronze Repair**

Damage to surfaces that hold the shaft

- **Corrosion / Pitting**

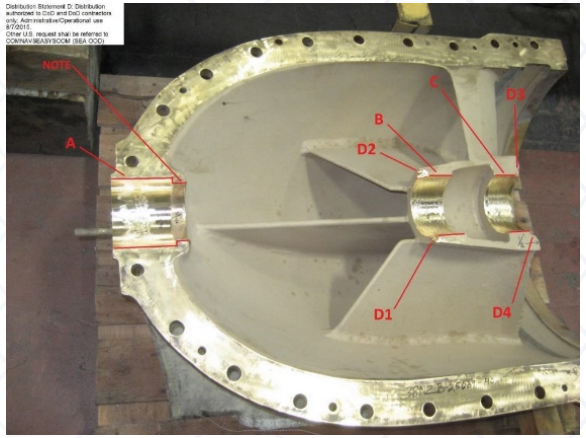
Repair

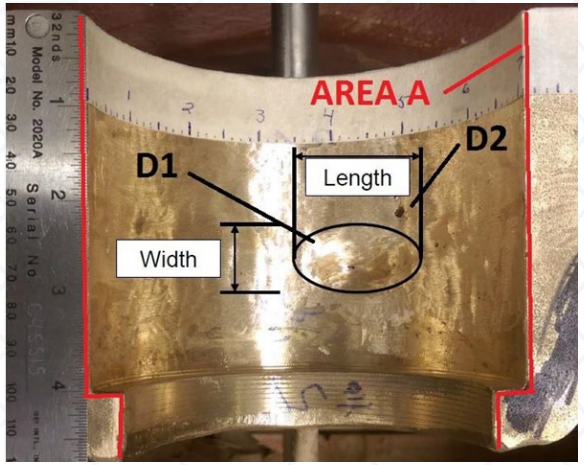
- **Remove Damage Material**
- **Roughen Surface**
- **Apply Cold Spray**
- **Machine to final dimensions**

Acceptance of Cold Spray Repair 12-16-15:

DFS technically reviewed and approved by SEA 05Z4, SEA 05P2, and SEA 05V1

- **Programmatically approved by PMS312E, concurred to by SEA 08**
- **Major temporary approval for unrestricted operations until 30-April-2019 (FY18 DPIA3) at which time pump inspections will be performed.**





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Implementation NAVSEA

NAVSEA NAVAL SEA SYSTEMS COMMAND

Locations

Norfolk Naval Shipyard	**VRC Gen III**	**Operational**
Pearl Harbor Naval Shipyard	**VRC Gen III**	**Operational**
Portsmouth Naval Shipyard	**VRC Raptor**	**System at PSU for training**
Puget Sound Naval Shipyard	**VRC Raptor**	**Budgeted FY21**

Future Locations

TRFs

NSWC-KP

NSWC-CD

Marine Corp Logistics Bases

- **Albany**
- **Barstow**

NAVAIR Fleet Readiness Centers

ARL/PSU –certified by NSWC-CD to perform Cold Spray Repairs
Other sites are currently being certified

ARL/PSU developed training and certification program for NAVSEA

Mr. Keith DeVries is leading a cross-service working group for implementation across the DoD

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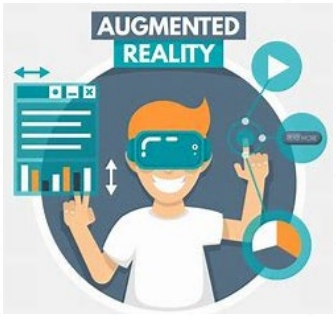
NAVSEA Cold Spray 3 Horizon Model

NAVSEA NAVAL SEA SYSTEMS COMMAND

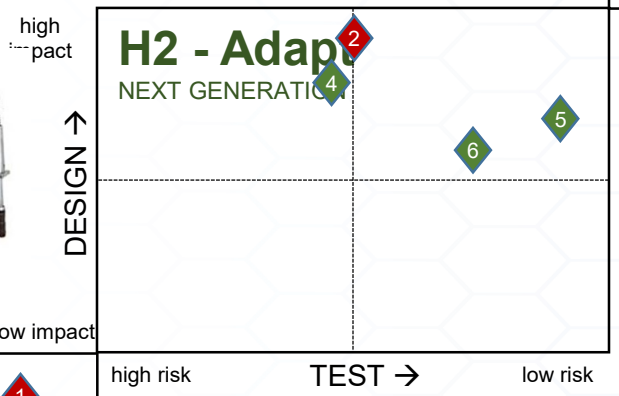
Legend

- # NAVSEA 04X project
- # NAVSEA 05T project



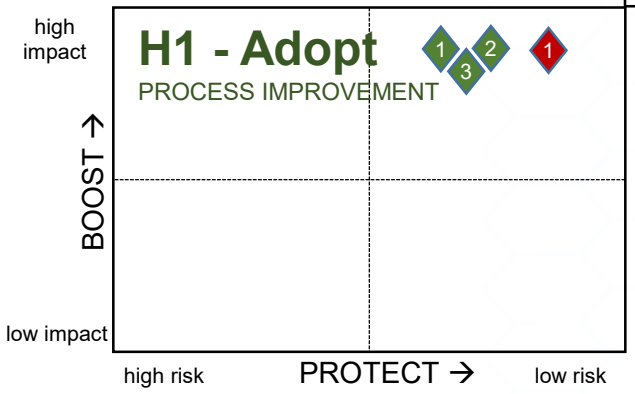
Design

- 7 Develop Cold Spray for structural repair.
- 8 Develop Cold Spray for coatings.
- 9 Develop Inspections for CS using Drones.
- 3 Develop expeditionary Cold Spray capability.
- 4 Develop Autonomous Cold Spray repairs.



Adapt

- 4 Develop hand held Cold Spray applications.
- 5 Develop Powder qualities and packaging pipeline.
- 6 Develop common testing protocols.
- 2 Field portable robot and multi purpose end effector for shipboard cold spray repair.



Adopt

- 1 Initial fielding of Cold Spray technology in NSY's.
- 2 Develop shareable QSP's.
- 3 Field portable "Raptor" Cold Spray technology.
- 1 Setup Cold Spray Pop-up Cells.

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Cold Spray Capabilities-NNSY

NAVSEA NAVAL SEA SYSTEMS COMMAND

- Cold Spray Machine – VRC Gen III
- Dust Collection – 21000 CFM Dry Dust Collector

Spray Room #1	Spray Room #2
Size 7 FT x 13FT W/ Retractable Roof Cold Spray Nozzle Positioner(s) Robot – Fanuc M20i/D25 Mechanical traversing unit (attached to spray hood) Workstation 5 FT Spray Hood	Size 11FT x 40FT W/ Removable Roof Cold Spray Nozzle Positioner(s) Robot – Fanuc M20i/D25 Mechanical Traversing unit (8 feet of travel/mobile) Workstation 36” 2 axis Rotary Table 36” Swing lathe 28 feet long Stationary Spray Box

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Nitrogen Generation / Helium Recovery

NAVSEA NAVAL SEA SYSTEMS COMMAND

Nitrogen Generation

- Utilizes shop air to produce 99.99% pure Nitrogen
- Cascade system capable of supporting 6 hours of spray time.

Helium Recovery System

- Non traditional system that utilizes a recovery pump to remove and boost normally “unusable” helium.
- Cascade system capable of supporting 4 hours of spray time.

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NNSY Future Repairs/Objectives

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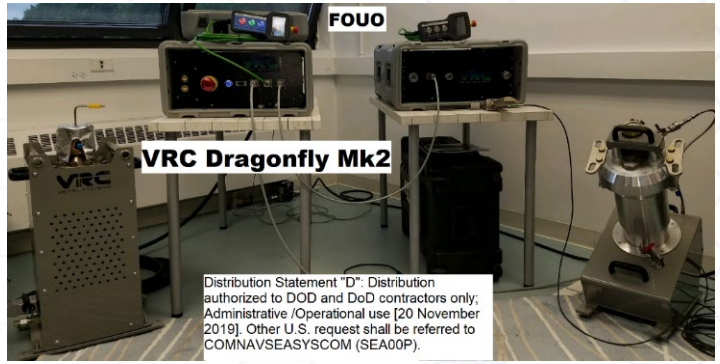
Goal	ECD
Complete NAVSEA Site Certification	May 2021
Receive Portable Cold Spray Equipment (Raptor)	June 2021
Develop portable Cold Spray containment with integrated robot	August 2021
Receive Hatch-able Cold Spray System (Dragonfly)	December 2021

Ship Class	Component(s)
CVN	Shaft Seal Carrier Ring(s)
CVN	MEGV Cylinder
SSN/SSBN	Hydraulic Accumulator Barrel
CVN	ALRE Components



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Production Pop Up Cell Model

NAVSEA NAVAL SEA SYSTEMS COMMAND

Objective: Set up and start performing repairs in 90 Days with a 21 day turn around on repairs

Issues:

- New technologies can take significant time and resources to implement in government facilities
- Need an ability to handle surge loads during an overhaul or extensive repair
- Training and certification of workforce on new technologies can be problematic

Solution: Pop Up Production Cell

- Pop Up Production Cells provide an ability to quickly implement technologies in an agile manner to provide immediate impact.
- Technology transition time is reduced to weeks vs. years and offers agility to renew and mature
- Located near public shipyards/repair facilities
- Implementation is modular vs. singular, and incorporates organic ties with industrial bases, industry and academia
- Contractor leases facility and provides equipment – initial savings >$2M
- Contractor provides trained personnel

Cell Locations:

Norfolk, VA - East Coast – Under contract

- Norfolk Naval Shipyard
- Mid-Atlantic Regional Repair Center
- Newport News Naval Shipyard
- Industry

Puget Sound, WA – West Coast

- Puget Sound Naval Shipyard
- RMF Bangor
- Local Industry

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NAVSEA NAVAL SEA SYSTEMS COMMAND

Multipurpose End Effector

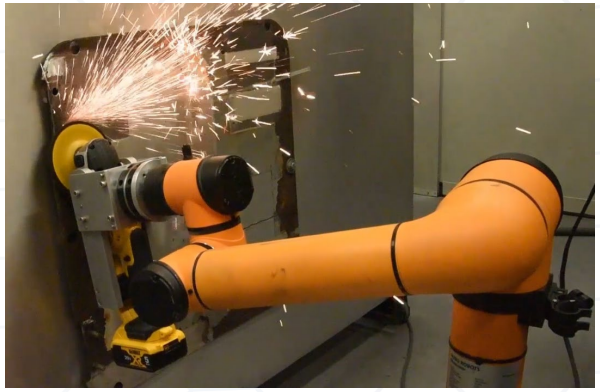
VRC METAL SYSTEMS

The Multipurpose End Effector system provides an automated, turn-key, fully portable preparation, repair, and inspection capability for emergent facilities including forward operating bases, ships, and shipyards. The system is configurable for a variety of repair applications from in-theatre battle damage repair to shipyard maintenance.

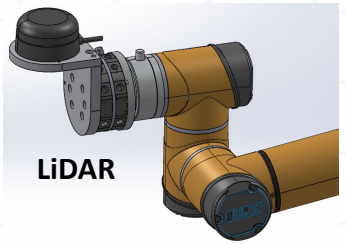
By the Numbers:

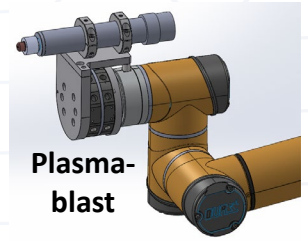
- **Currently Developing 10 End Effectors on Quick Change Fittings with Automatic Tool Recognition**
  - **Scanning/Sensing: LiDAR, Touch-probe, and Camera**
  - **Surface Preparation: Plasmablast and Grinder**
  - **Repair: Cold Spray and Welding**
  - **Inspection: Ultrasonic, Eddy Current, and X-ray Fluorescence (XRF)**
  - **Upgradable for additional end effectors and robot systems**
  - **Quick change fittings allow for tool changes in minutes**
  - **End effector tools usable with or without robot**
  - **Easily-configurable solution ships in as few as 4 Pelican cases**
  - **Cold Spray support equipment, nitrogen generation, and machining equipment ship in Conex container**
  - **User interface and control system adaptable to different robots**

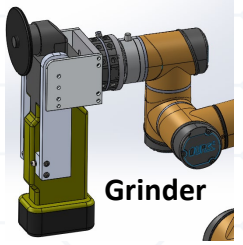
Grinder End Effector

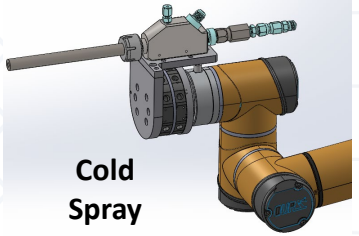


End Effector Examples









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NAVSEA NAVAL SEA SYSTEMS COMMAND

Multipurpose End Effector

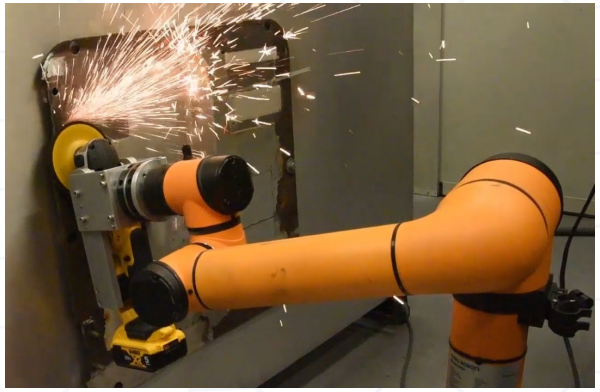
VRC METAL SYSTEMS

The Multipurpose End Effector system provides an automated, turn-key, fully portable preparation, repair, and inspection capability for emergent facilities including forward operating bases, ships, and shipyards. The system is configurable for a variety of repair applications from in-theatre battle damage repair to shipyard maintenance.

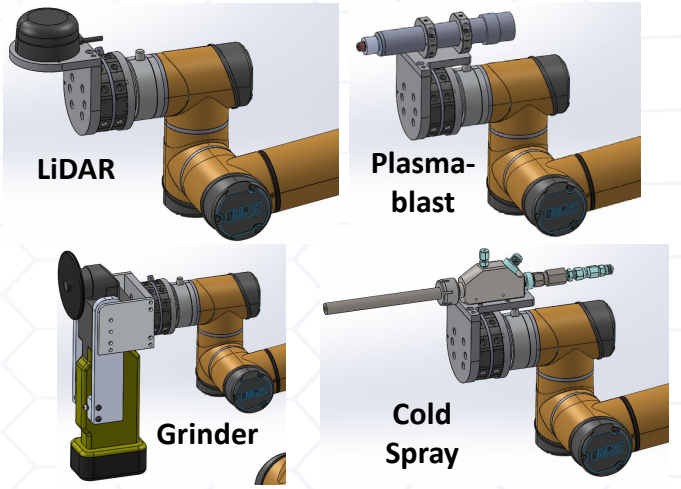
Benefits:

- **Iterative fielding demonstrations allow for incorporation of feedback from end users during system design**
- **User interface with built-in video tutorials and augmented reality for quick and effective training and fielding**
- **Speed and agility in implementation**
- **Technology maturation for all end effector technologies and robot systems**
- **Forward-deployable in a variety of locations and applications**
- **Easy-to-use, self-contained prep and repair capability**

Grinder End Effector



End Effector Examples



INITIAL CAPABILITY DEMONSTRATION – March 2021

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Production Pop Up Cell Model

NAVSEA NAVAL SEA SYSTEMS COMMAND

By the Numbers:

- 90 days from funding to open
- Capability as a Service (CaaS) Model
- TECHBRIDGE/MEP supported
- NAVSEA certified for repairs
- Transitions fully at end of project
- 3 week turnaround repair of ship/ submarine components
- Outreach and training
- Design basis to create Ideal layout for production
- Risk free engagement for DIB

Benefits:

- Interim Capability
- Speed and Agility
- Technology Maturation
- Franchise Model
- Strengthens Industrial Base
- Serves as an Implementation Standard
    - Can be used to implement other technologies

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What is next

NAVSEA NAVAL SEA SYSTEMS COMMAND

- Structural Repair
  - ONR Solid State Structural Repair (S3R)
- Qualify hand-held cold spray applications
- Field and qualify portable Cold Spray equipment
- Produce unique metallic cold spray powders & powder packaging system
- Coatings for wear and corrosion
- Hybrid/functionally graded materials
- Helium Recovery
- Laser Assisted Cold Spray
- Alternate surface preparation (laser – plasma blast)