U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Advanced Surface Treatment for Armament Weapon Systems

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CORE COMPETENCIES

RESEARCH

DEVELOPMENT

PRODUCTION

FIELD SUPPORT

DEMILITARIZATION

Munitions Engineering and Technology Center:

Provides life-cycle engineering research, development, production, field support and demilitarization for all integrated munitions systems.

Propellants; explosives; pyrotechnics; warheads; fuzes; insensitive munitions; environmental technologies and explosive ordnance disposal; aero ballistics and telemetry

Weapons and Software Engineering Center:

Generates technologies and executes life-cycle research, design development, production engineering and sustainment of programs related to weapons and weapon systems.

Small, medium and large caliber weapons design, experimentation, evaluation, manufacturing, and integration; digitization; and embedded system software; directed energy; technical and tactical fire control; homeland defense and e-business systems

Enterprise and Systems Integration Center:

Serves as ARDEC Executive Agent to ensure cost, schedule, performance adherence, and sustainability through the integration of technical and business competencies.

System engineering; quality engineering; logistics engineering; project management; business development; S&T; financial & knowledge managements

OBJECTIVES & EFFORTS

- Long Range Precision Fires
- Next Gen Combat Vehicle
- Future Vertical Lift
- Network
- Air & Missile Defense
- Soldier Lethality

OBJECTIVES

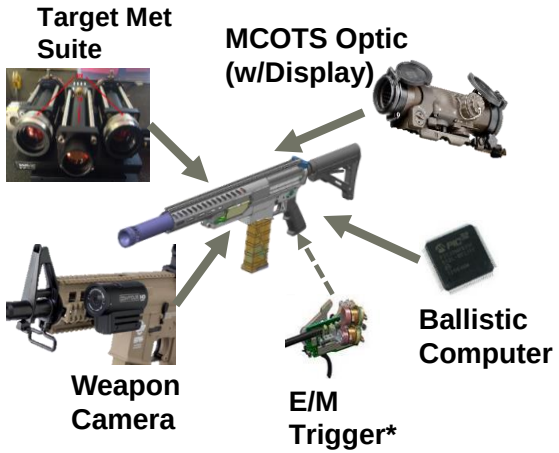
- Fight, win & survive in a multi-domain environment now & tomorrow
- Treat the Soldier/Squad same as a combat platform
- Initial focus on Close Combat soldiers

NEAR-TERM FOCUS

- Next Generation Squad Weapons (AR and Rifle (Carbine))
- Small Arms Fire Control
- Next Generation Family of Ammo

FUTURE THRUST AREAS

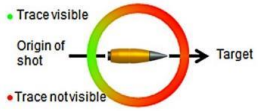
- Ensuring visibility of “Joint Service Small Arms” resources
- Counter defilade technology engagement effort for megacity, build up terrain



Next Gen. Common Cartridge (NGSWT)

General Purpose & Special Purpose

Reduced Range Training Ammo (RRTA)



One Way Luminescence (OWL)

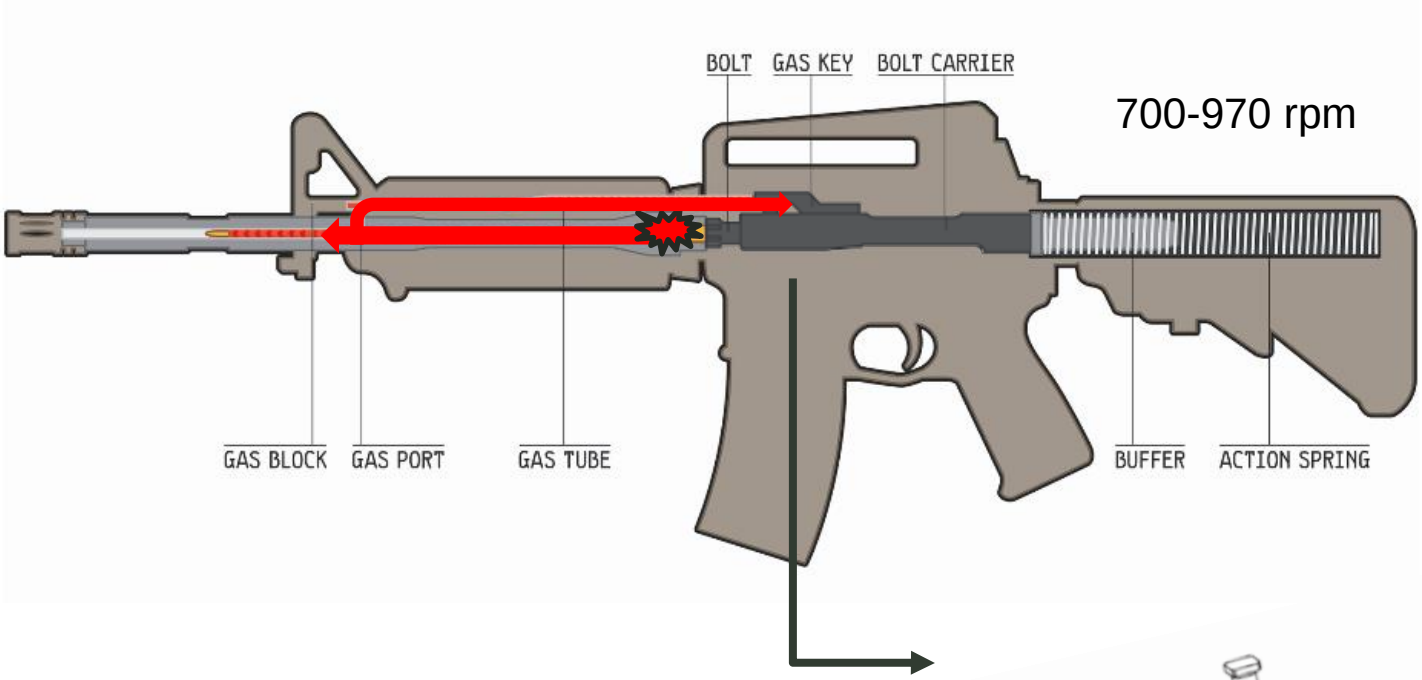
Develop the next generation of individual and squad weapons; improve body armor… and develop a synthetic training environment…

ADVANCED SURFACE TREATMENTS

- **Problem**
  - Reduce or eliminate lubrication requirement for reduction in maintenance and increased reliability for small arms
  - Ability to provide correct combination of wear resistance, optimized friction coefficient, corrosion resistance, and anti-fouling/material transport behavior in the presence of propellant residue and environmental debris
- **Approach**
  - Implementation of advanced surface treatment to provide Durable Solid Lubrication (DSL) (US Patent 10,415,904)
- **Objectives**
  - Improve reliability and maintainability of small arms with specific emphasis on operation in extreme environments: Promote ease of cleaning and reduction of Active Maintenance
  - Reduce or eliminate the need for conventional lubricants in weapon action components
  - Increase component wear life: More wear resistance and long lasting parts

ADVANCED SURFACE TREATMENTS

- **Application**
  - Gas Operated Weapon



BACKGROUND

Technology Details (US Patent 10,415,904)

1) A durable solid lubricant deposited on the surface of substrate material, characterized by specific properties based on
    a) Hardness
    b) Thickness
    c) Coefficient of Friction
    d) Corrosion Resistance
2) A durable solid lubricant eliminating the need for conventional liquid lubricants
3) A durable solid lubricant providing:
    a) low friction; elimination of jamming related failures of sliding components resulting in increase component reliability
    b) increased component wear life; highly resistant to wear and eliminating hydrogen embrittlement factors from standard phosphate treatments resulting in longer lasting parts
    c) corrosion protection in all relevant environments
    d) improved maintainability; promotes ease of cleaning and reduction in active maintenance

BACKGROUND

Hardness	8-20 GPa
Coefficient of friction	<0.2 in dry sliding
Coating thickness	10-20 microns
Maximum Operating Temp	400° C
Color	Grey-black
Corrosion	240 hours ASTM B117 / 96hr TOP
Adhesion	ASTM B571 compliant

- **Notes**
  - Materials must function reliably when sliding against both steel and aluminum Ultra-high hardness coatings tended to cut into the aluminum upper receiver
  - Coefficient of friction <0.2 for following material pairs: self-mating sliding, sliding against steel, sliding against anodized aluminum, sliding against bare aluminum
  - Grey-black color is preferred
  - Cost of coating

DEVELOPMENT TIMELINE

NGSW

M240 MG

M4A1 Carbine

2012
Technology Development

2013
M4A1 Baseline Testing

2014
LMUA Ft. Richardson Environmental Testing

2015
PM TTA
SOF Trials

2016
M240 Development
Process Scale Up
IP Validation

2017
M4A1 Reliability Testing (TRL 6)
M240 Reliability Testing

2018
M4A1 Process Parameter Optimization

2019
M4A1 Production Baseline Testing

2020-24
PPON

Prototype Project Opportunity Notice (PPON)
Next Generation Squad Weapons (NGSW)

W15QKN-19-9-1024 – General Dynamics-OTS Inc.
W15QKN-19-9-1025 – AAI Corp Textron Systems
W15QKN-19-9-1022 – Sig Sauer Inc.

BACKGROUND

Three Stage Approach: Innovative and Tailored Test Protocols Developed

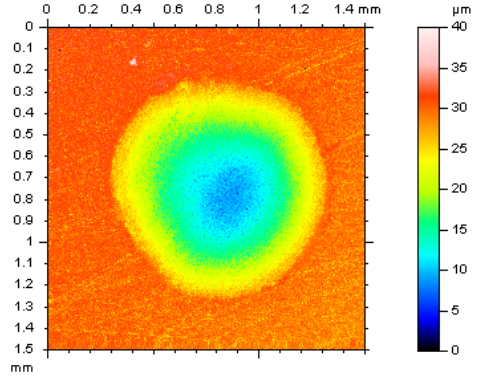
- **Stage 1**
  - Broad screening tests to include rapid Ball-on-three-disk (BOTD) tribological testing and coatings characterization
  - Down-select promising candidates

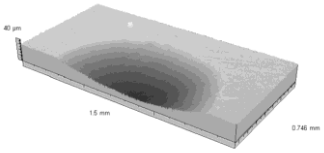
- **Stage 2**
  - Targeted bench-scale tribological testing
    - Testing to accurately simulate weapon action
  - Down-select promising candidates

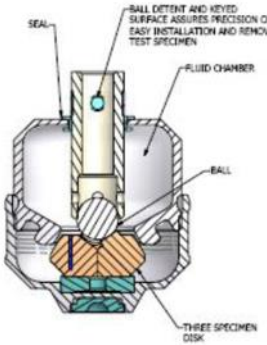
- **Stage 3**
  - Live Fire Testing

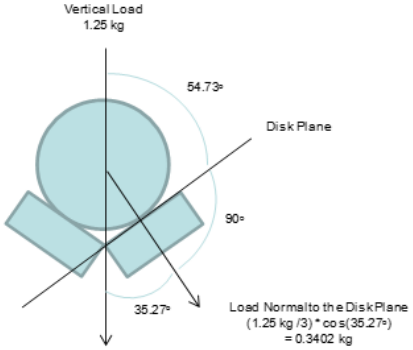
BACKGROUND – STAGE 1

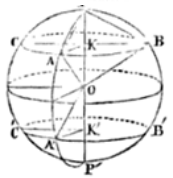
- Broad and rapid screening of fundamental properties using ball-on-three disk (BOTD) tribological testing apparatus
- Broad spectrum of environments tested for each
  - Dry or with CLP (lubricant)
  - Temperature - 25 versus 250 °C
  - Sand or no sand
- Apparatus allows for measurement of CoF vs time/cycles and average wear rate











$$r_{scar} = (d/2) + (w^2 / 8 * d)$$

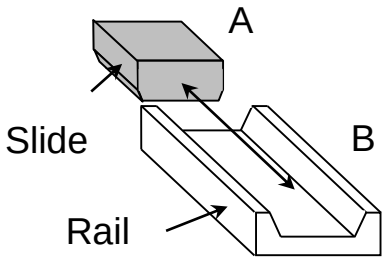
$$V_{scar} = \pi * d^2 * (r_{scar} - d / 3)$$

*Source: Institute of Tribology and Coatings, Sugar Grove, IL

Parameters (Rotational Speed, Test Duration, Cycles, Load, Contact Pressure, Environment, Temperature)

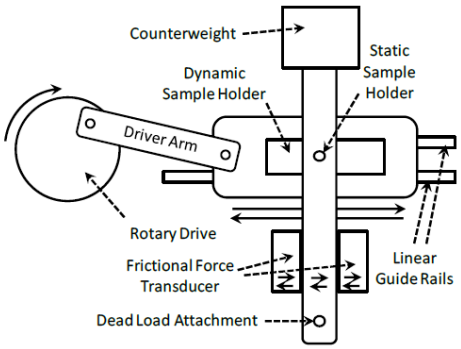
BACKGROUND – STAGE 2

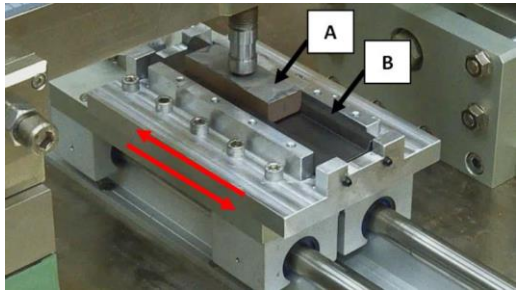
- CFD Modeling and Simulation, Peak force analysis, and Targeted bench-scale evaluation using Slide-Rail-Simulator for quantitative evaluation of weapon interfaces.



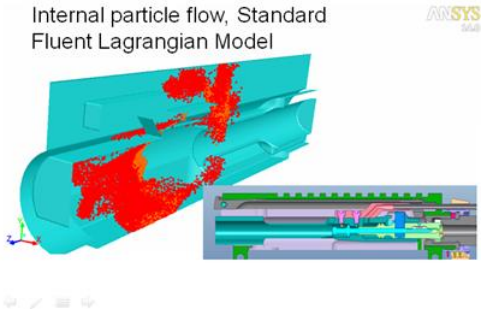
Slide-Rail Simulator (SRS)

- Wear and friction behavior in relevant configuration
- Cyclic reciprocation simulates weapon motion
- Contact geometry mimics weapon components
- Contact stresses based on dynamic modeling
- Fully instrumented for normal and tangential load

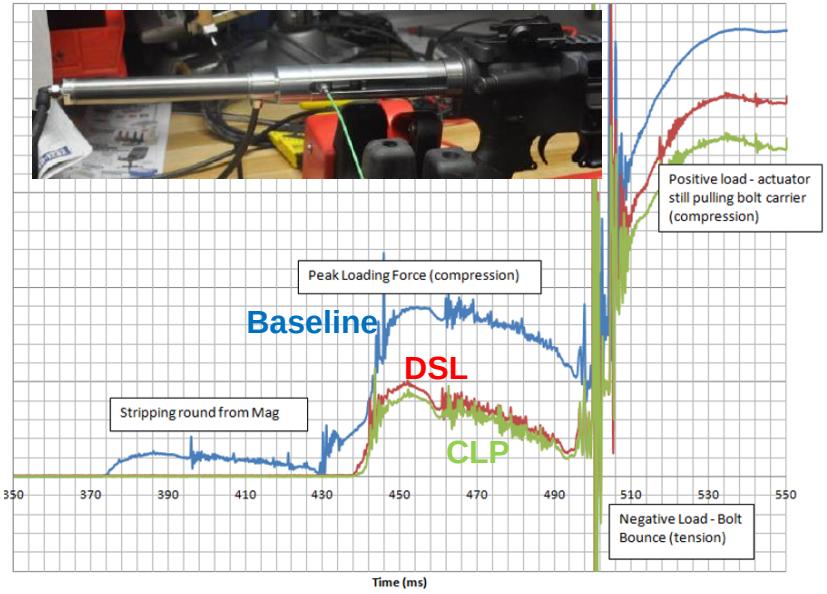




CFD:

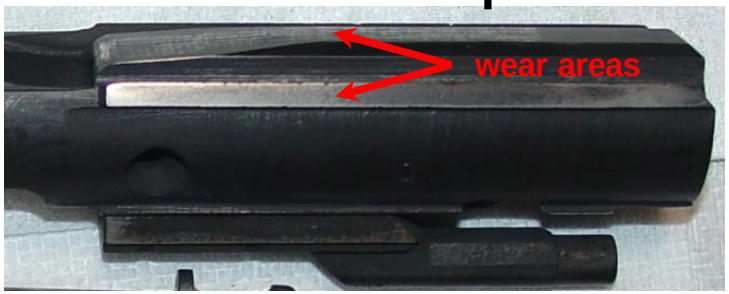


Peak Loading Force Actuator:



BACKGROUND – STAGE 3

After 15,000 rounds (ambient):

	Baseline Phosphate	Solid Lubricant Coating
Bolt carrier	 ~75% worn	 <5% worn
	 ~90% worn	 <5% worn
Bolt	 ~90% worn on body, ~50% on lugs	 <5% worn on body, ~10% on lugs
	FIRED WITH CLP	FIRED DRY

% worn = % totally exposed substrate

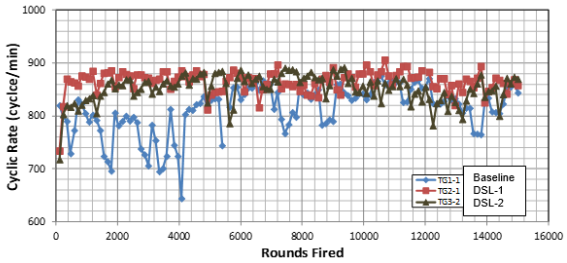
DEMONSTRATED – STAGE 3

Test Operating Procedures	Reference TOP 3-2-045
Ambient	Section 4.3
Hot (160F)	Section 4.5.1
Cold (-60F)	Section 4.5.1
Sand/Dust	Section 4.5.4
Salt/Fog	Section 4.5.7
Unlubricated Endurance	Section 4.22

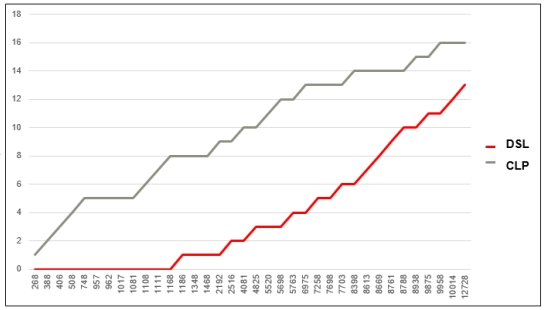
More Consistent Cyclic Rates

Improved Reliability

RoF



Malfunction Rates



96hr (wet/dry)

4X increase in rounds fired w/out stoppages compared to dry phosphate baseline

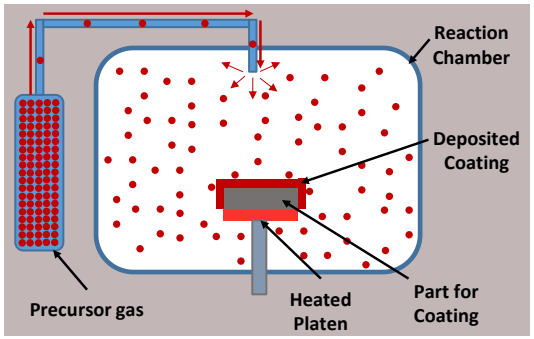
DURABLE SOLID LUBRICANT (DSL)

Chemical Vapor Deposition (CVD) is a technique in which a coating is produced on a substrate through surface reaction from a precursor gas.

PE-CVD is a CVD based process in which the reaction rate is enhanced through initiation of a plasma on the part to be coated. This allows for deposition of coatings at lower temperature and higher rate.

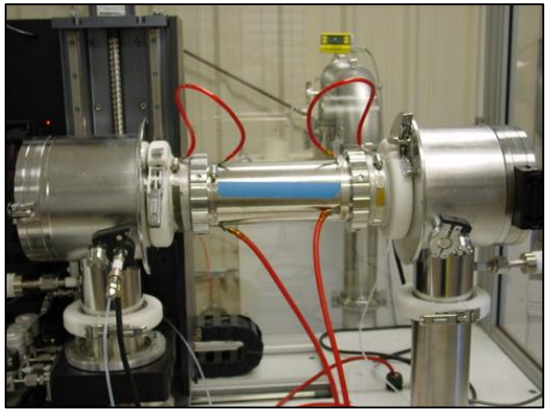
PE-CVD is also a directed deposition process allowing for uniform coating of complex shapes and internal diameters. This is in contrast to line-of-sight deposition processes such as Physical Vapor Deposition (PVD).

Chemical Vapor Deposition (CVD)



Parts Imersed in Plasma

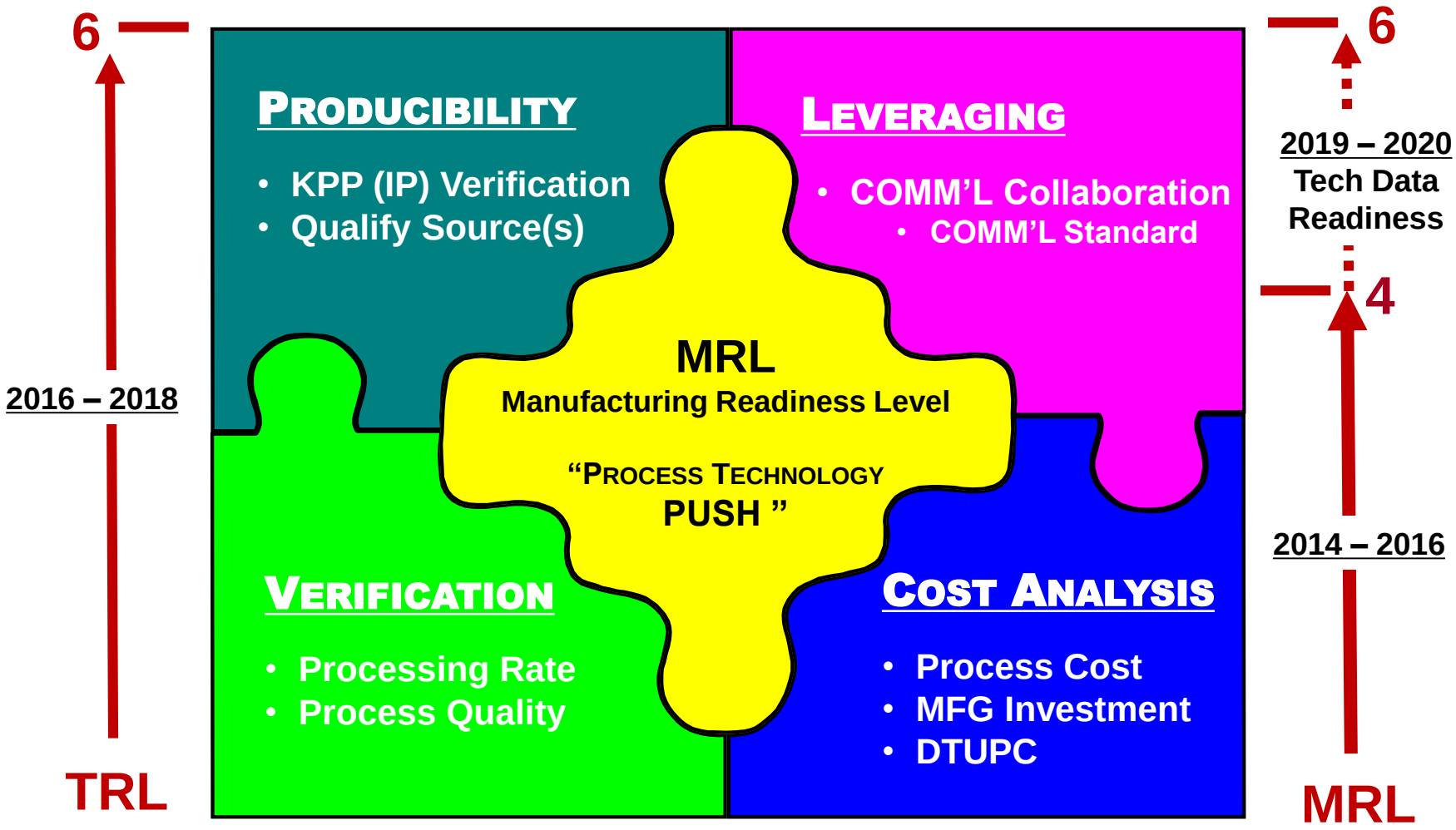
Process Verification and Production Scale-Up:



Small scale part processing

Production scale up – candidate DSL process technology

TRL / MRL



TRL / MRL

LEAD

The Army's unique suite of bench-scale diagnostics & test protocols
- **Use to advance DSL performance**
- **Use to challenge commercial industry to qualify advanced surface treatment technologies**

The Army's Ownership of "Intellectual Property" permits:
- **Coordination of a "DSL" Commercial Standard**

SHAPE

Near term strategy:
- **Use a Modernization-through-Spares (MTS) approach**
  - Incremental, Block Modernization of legacy M4A1 systems
- **Spiral-in innovative DSL technology**
  - Support legacy weapon system modernization

WATCH

Monitor and evaluate alternative commercial "DSL Type" technologies

CONCLUSIONS

- **Warfighter Payoff**
  - Increased component wear life
    - More wear resistant and long lasting parts
  - Increased reliability
    - Reduce/eliminate jamming related failures in weapon action components
    - More consistent cyclic rates
  - Improved maintainability
    - Promote ease of cleaning and reduction in Active Maintenance

- **Applications**
  - Weapon & vehicle action components
  - Manufacturing/Machining operations
  - Advanced oil-free turbomachinery

- **Path Forward / Future Work**
  - Production Baseline Testing (ATC) (2QFY20)
  - OEM and Future PPON Implementation
  - Explore additional Armament Systems applications
  - DOTC-19-04-016 Advanced Surface Treatment
    - Continue to leveraged existing coatings and surface treatment contracts with various surface treatment vendors
  - High Temperature Applications (Suppressors)

ADVANCED SURFACE TREATMENTS

Implementation of advanced surface treatment to provide Durable Solid Lubrication (DSL)

Problem

- **Reduce or eliminate lubrication requirement for reduction in maintenance and increased reliability for small arms**
- **Ability to provide correct combination of wear resistance, optimized friction coefficient, corrosion resistance, and anti-fouling/material transport behavior in the presence of propellant residue and environmental debris**

Objectives

- **Improve reliability and maintainability of small arms with specific emphasis on operation in extreme environments**
- **Reduce or eliminate the need for conventional lubricants in weapon action components**

Development of innovative lab scale test protocols

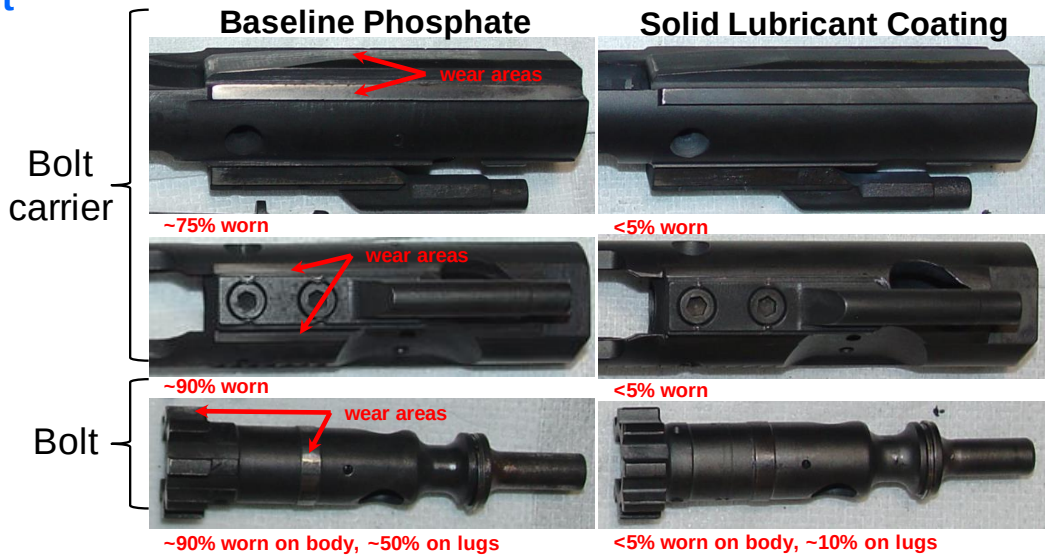
- Developed a standardized process to support future surface treatment characterizations

  Stage 1 – Broad screening; Ball-on-three-disk (BOTD) tribological testing and coatings characterization

  Stage 2 - Targeted bench-scale tribological testing; Slide Rail Simulator (SRS)

  Stage 3 – Live Fire Testing

After 15,000 rounds (ambient):



Warfighter Payoff

- Increased component wear life
  - More wear resistant and long lasting parts
- Increased reliability
  - Reduce/eliminate jamming related failures in weapon action components
- Improved maintainability
  - Promote ease of cleaning and reduction in Active Maintenance

Future development work supported through Joint Service Small Arms Program (JSSAP) Office

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