



Advanced Gun Barrel Technologies Program Status

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MK 45 / Mod. 2

Bore: 5-inch (127mm)
 Length: 54cal, 22.5 ft (6.9m)
 Operating Pressure: 55 kpsi (380 MPa)
 Range: 13 Nmi
 Volume of Fire: 16-20 rnds/min (20 round ready service)
Barrel Life: 8000 rnds
 Thermal Mgmt: Air Cooling
 Mark 67 charge with various projectiles

MK 45 / Mod. 4

Bore: 5-inch (127mm)
 Length: 62cal, 25.8 ft (7.9m)
 Operating Pressure: 63 kpsi (435 MPa)
 Range: 63 Nmi
 Volume of Fire: 90 @ 10 rnds/min
Barrel Life: 1,500 rnds
 Thermal Mgmt: Air Cooling
 ERGM Projectile/Propelling Charge

Advanced Gun System (AGS)*

Bore: 155mm (6.1 in)
 Length: 62cal, 31.5 ft (9.6m)
 Operating Pressure: 53 kpsi (365 MPa)
 Range: XX Nmi
 Volume of Fire: 10 rnds/min
 Continuous
Barrel Life: 3,000 rnds (Est.)
 Thermal Mgmt: Liquid Cooling
 Long Range Land Attack
 Projectile/Propelling Charge

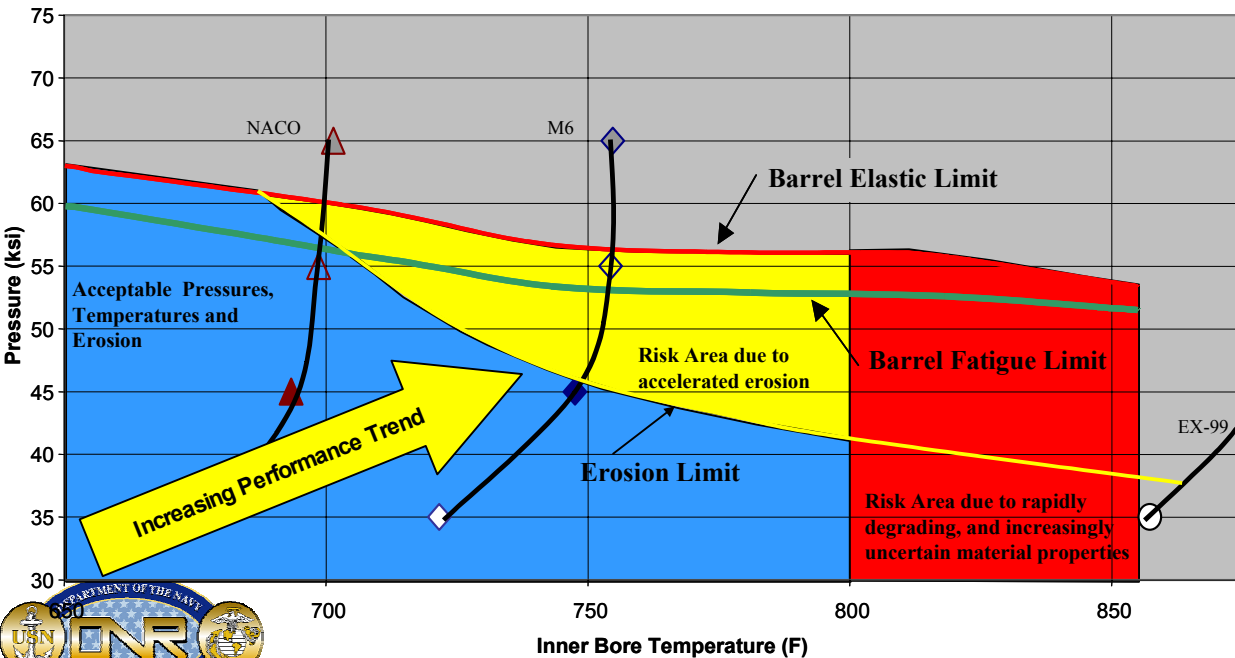
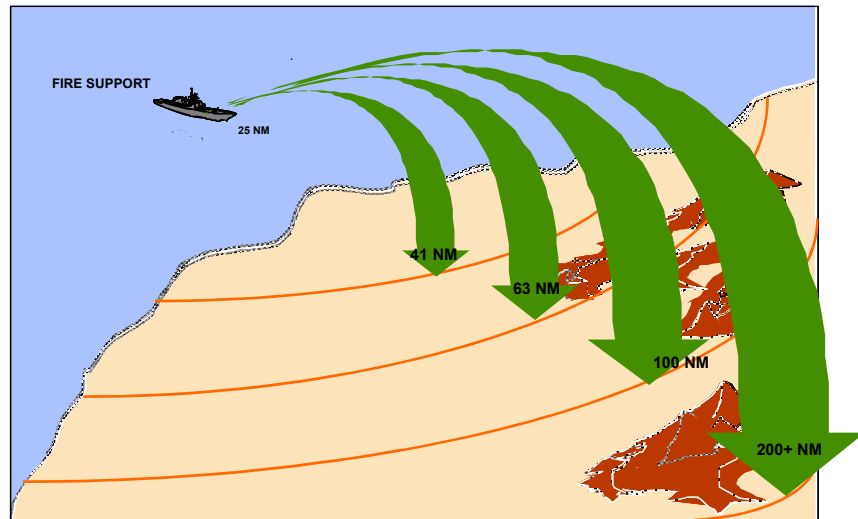
*Currently Under Development

Increased performance levels result in barrel life becoming a logistics cost driver





- The trend of gun performance requirements has been for increased range and rate of fire for centuries
- Wear and thermal management limit system performance
- Highest energy propelling charge and advanced projectile solutions are precluded by barrel limitations
- Improving wear, erosion or thermal management yields increased system performance



• Barrel Design Space Limits

- Elastic strength
- Fatigue strength
- Max bore temperature
- Wear and erosion





Future Naval Capabilities Program

Objectives

- Identify & develop Gun Barrel Technologies that enable upgrades to existing barrel capabilities for Naval gun propulsion missions
 - *Increased Gun Barrel Erosion & Fatigue Life*
 - *Improved Gun Barrel Thermal and Ballistic Performance*
 - *Reduced Life Cycle Cost*

Payoffs

- Increased Gun System Availability
- Improved Ballistic Capability (Higher KE for increased range)
- Lower Life Cycle Cost

Transition

- Develop/Demonstrate Improved Barrel Life and Ballistic performance over AGS Baseline for Transition into Future DD(X) Flights





Develop Two Advanced Barrel Technologies Concurrently

1- Refractory / Steel Barrel : Focus on the technologies providing longer barrel erosion and fatigue life.

- *Develop and apply alternate coating / liner material and processing to the existing Chromium plating.*

2- Composite Barrel : Develop Composite gun Barrel for improved thermal management and wider design space for enhanced ballistic performance for current and future gun barrels

- *Technologies such as Metal Matrix Composites that provide more flexibility in achieving desired material properties in radial and axial directions in the barrel*

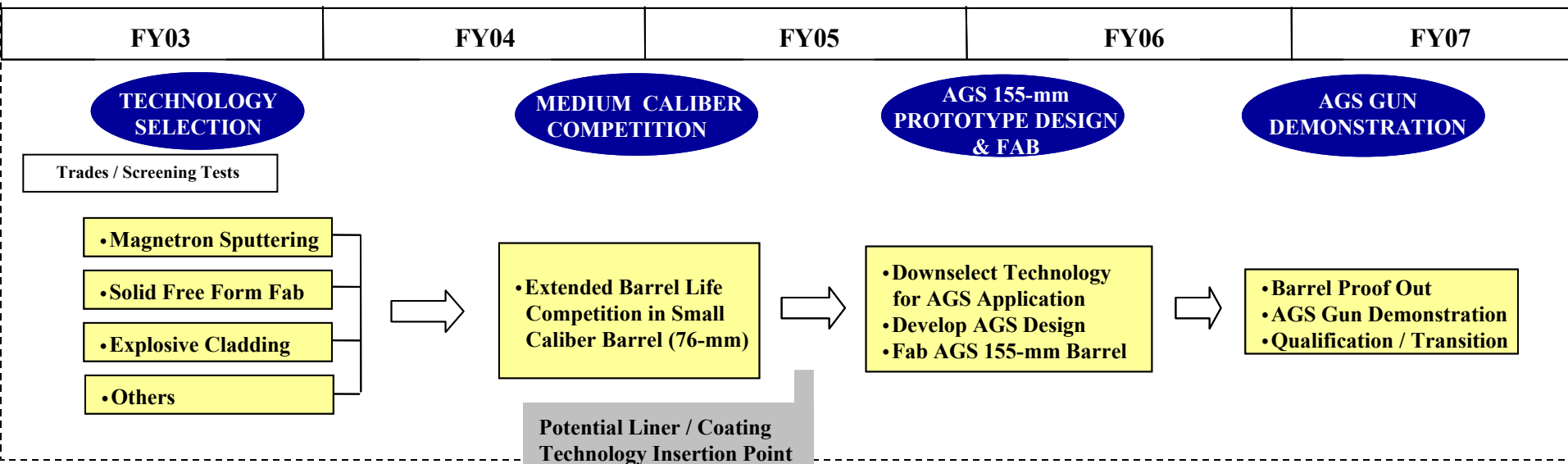
Each technology path will provide increased barrel life and if both successful, will be combined for substantial barrel life improvement



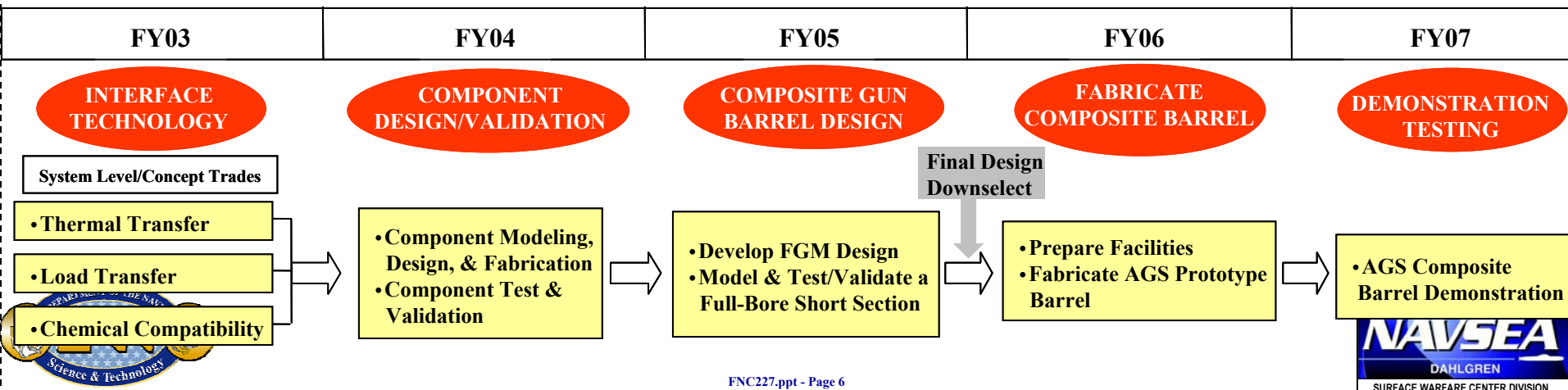


Refractory Lined / Coated Steel Barrel

Technical Approach



Advanced Composite Barrel



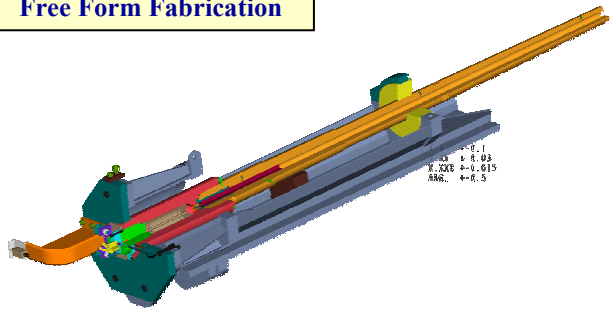


Refractory Barrel Technology

Technology Assessment

- Electroless Nickel-Boron
- Ta Sputtering
- Explosive Cladding
- CED
- EPVD
- Free Form Fabrication

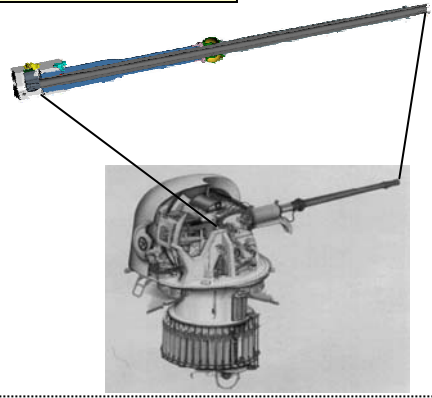
Screening Evaluations



Subscale Competition/Demo

- Explosive Clad Barrel Test
- EPVD Barrel Test
- Chrome Plated Barrel Test

76mm Gun Tests



Vendor Down select

Develop 155mm Refractory Barrel Design

Fabricate 155mm Refractory Barrel

Proof Test 155mm Refractory Barrel

Demo Test 155mm Refractory Barrel



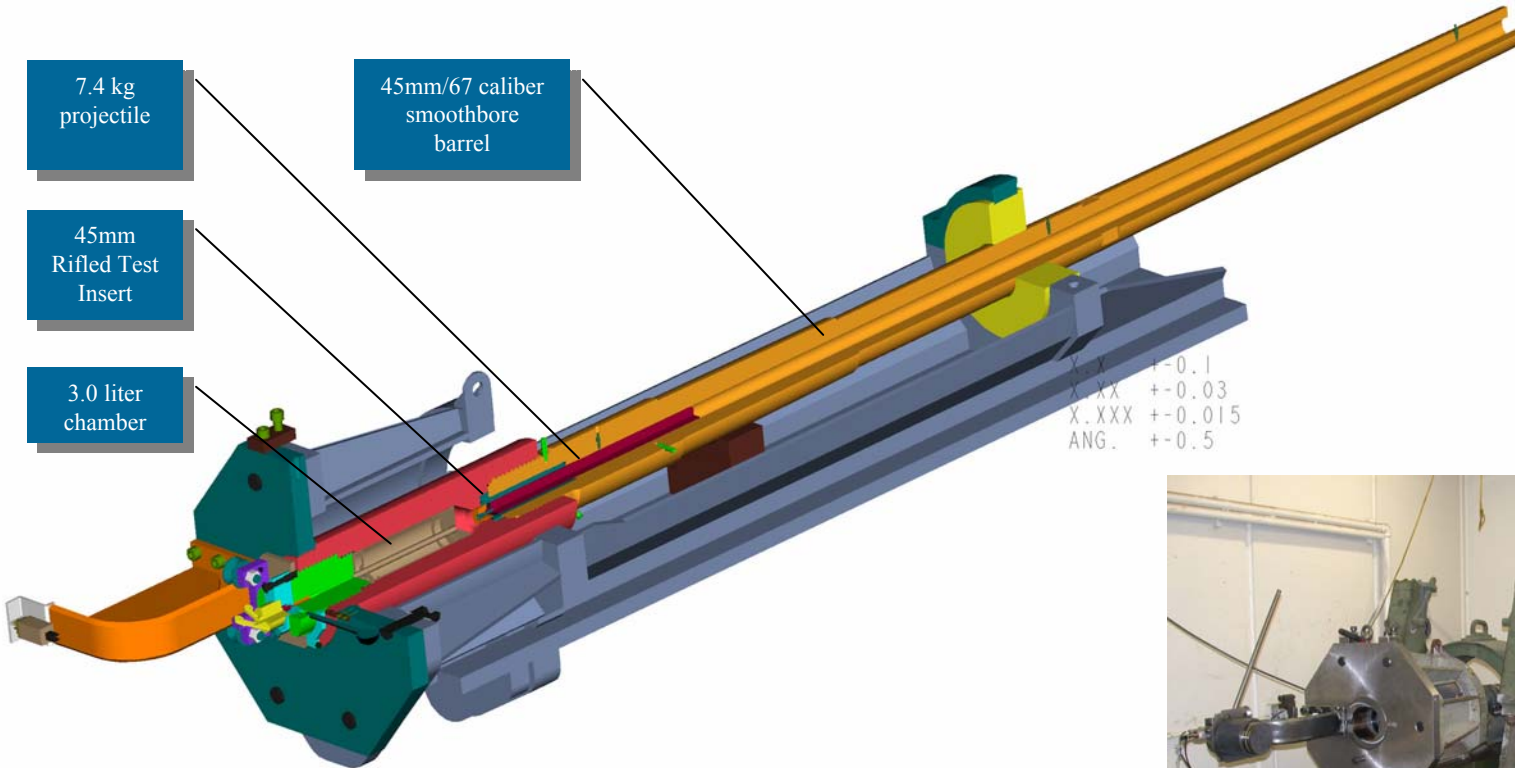


Transition Criteria

- 1 - Compliance with AGS Interface Control Document (ICD)**
- 2 - Equivalent Ballistic Performance to Baseline AGS Barrel**
- 3 - 50% Improvement in Barrel Life Over Baseline AGS Barrel**
- 4 - Reduced Life Cycle Cost Compared to Baseline AGS Barrel**
- 5 - Production and Gun Fire Testing of Full-scale Prototype**



45mm Test Fixture



- Accurately reproduces the thermal, chemical and mechanical environment of a large caliber gun
- 50 shot test sequences used to evaluate coating adhesion and integrity
- Over 700 shots fired to date



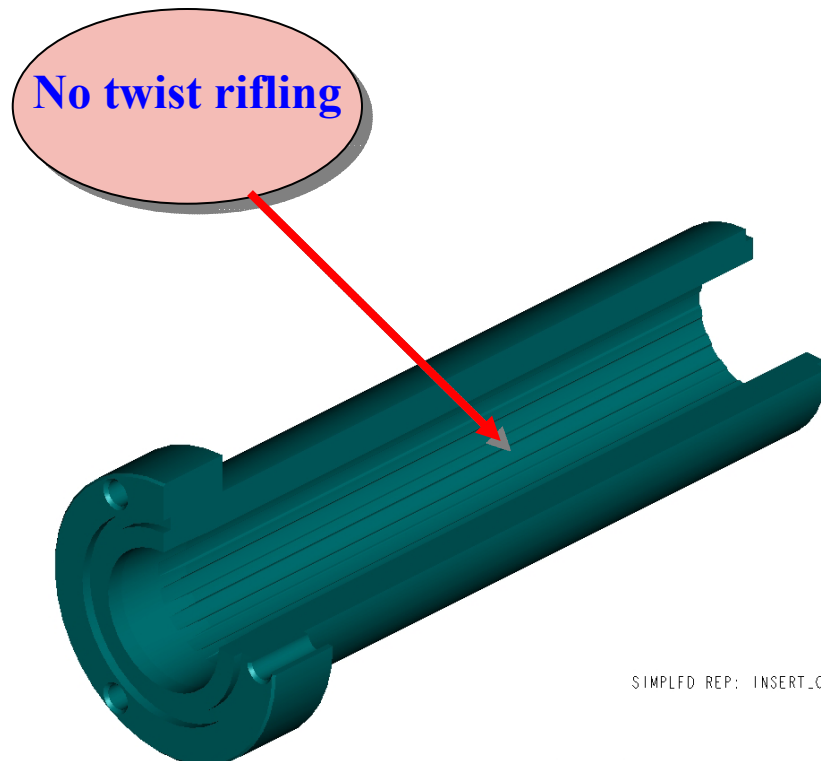
45mm gun in place at UDLP test range

Provides cost effective means of evaluating coatings for large caliber gun application





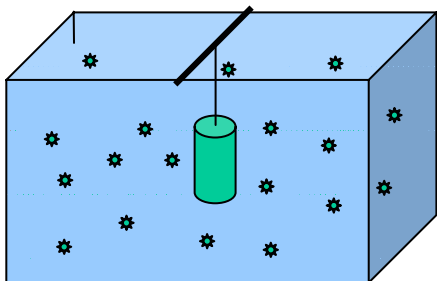
- Test insert used to evaluate the performance of advanced coating materials
- Insert includes shot start region and first few calibers of projectile travel
- Thickness sized to provide a strain level similar to the AGS barrel at maximum service pressure conditions for LRLAP
- Insert does not simulate compressive residual stress from autofrettage in the AGS barrel



SIMPLFD REP: INSERT_ONLY

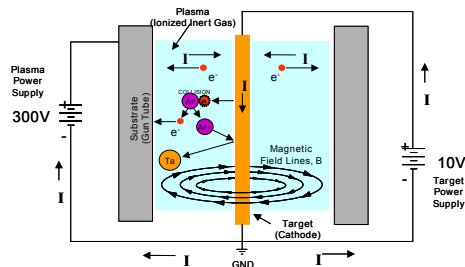


Electroless Nickel-Boron



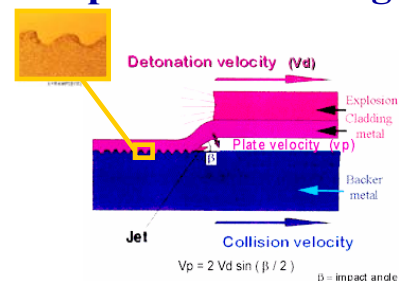
Catalytic plating process produces extremely uniform coating even on complex geometries

Sputtering



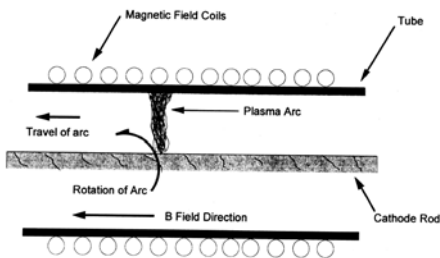
Material is sputtered, from a coaxial target, uniformly over the inside diameter of the barrel

Explosive Cladding



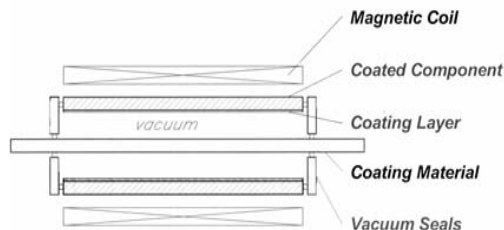
Tube of cladding material is mechanically bonded with the gun barrel in a collision driven by an explosive detonation

Coaxial Energetic Deposition



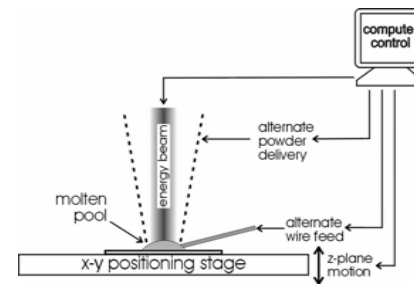
Plasma arc rotates around center conductor and travels along its length depositing material

Electromagnetically Enhanced Physical Vapor Deposition



Electrically controlled magnetic fields enhance the plasma environment of the physical vapor

Solid Free-Form Fabrication

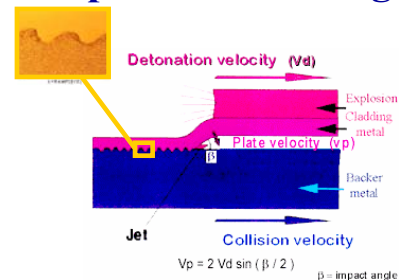


Engineered material is created by alloying of powdered and/or wire-fed metals



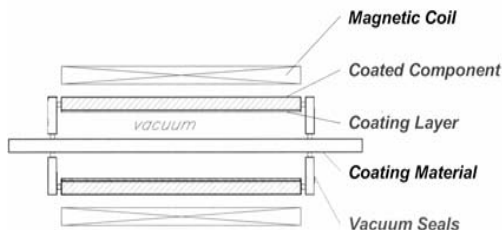


Explosive Cladding



Tube of cladding material is mechanically bonded with the gun barrel in a collision driven by an explosive detonation

Electromagnetically Enhanced Physical Vapor Deposition



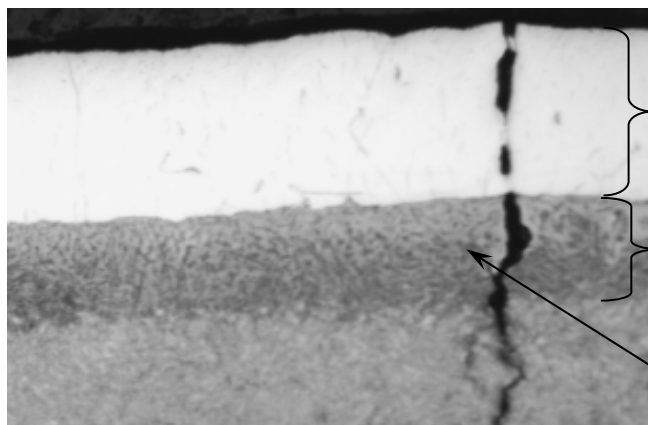
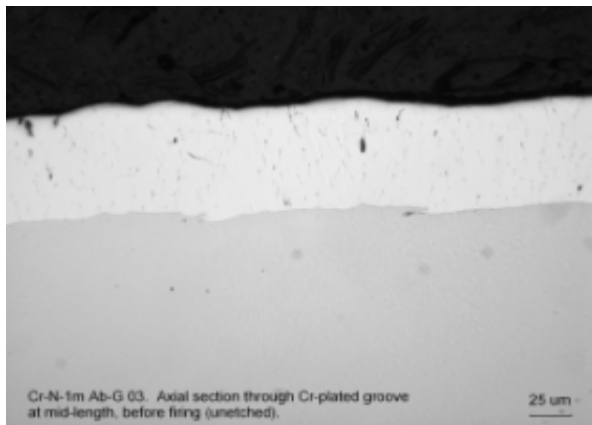
Electrically controlled magnetic fields enhance the plasma environment of the physical vapor

Chrome Plated Baseline



Unfired Sample

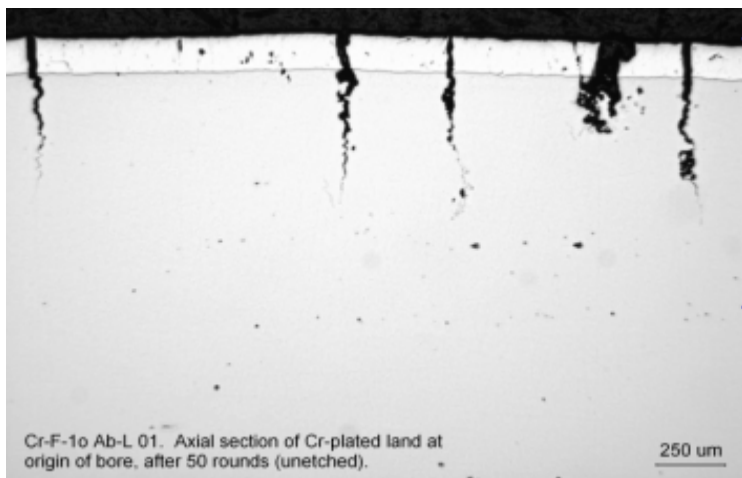
57 Firings



Chrome Plating

Heat Affected Zone

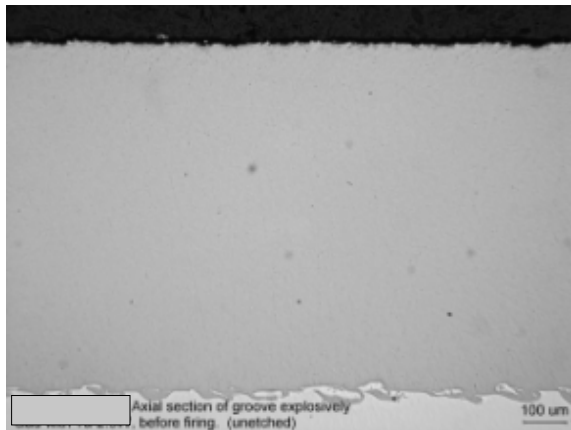
Heat Check Crack



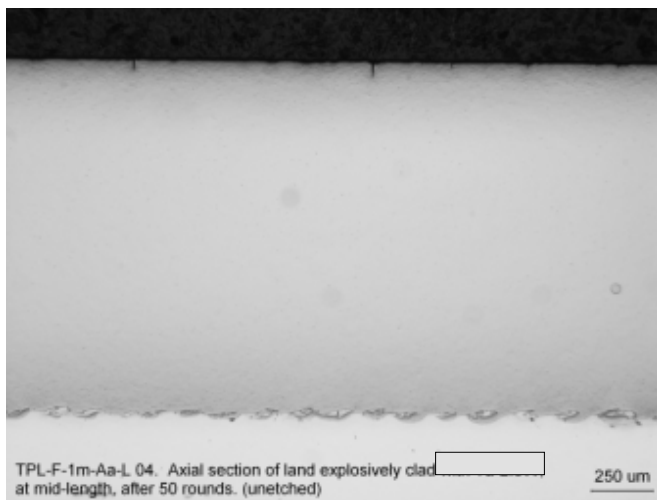
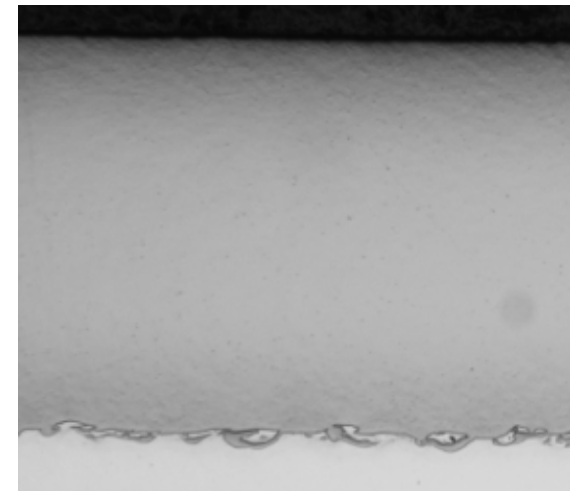
- Chrome plating showed very little evidence of wear, visual appearance compared favorably with 155mm gun barrel assets with approximately fifty shots
- Chrome plated baseline showed damage from heat checking, chemical attack and thermally altered grain structure similar to that characteristic of large caliber gun systems



Unfired Sample



50 Firings



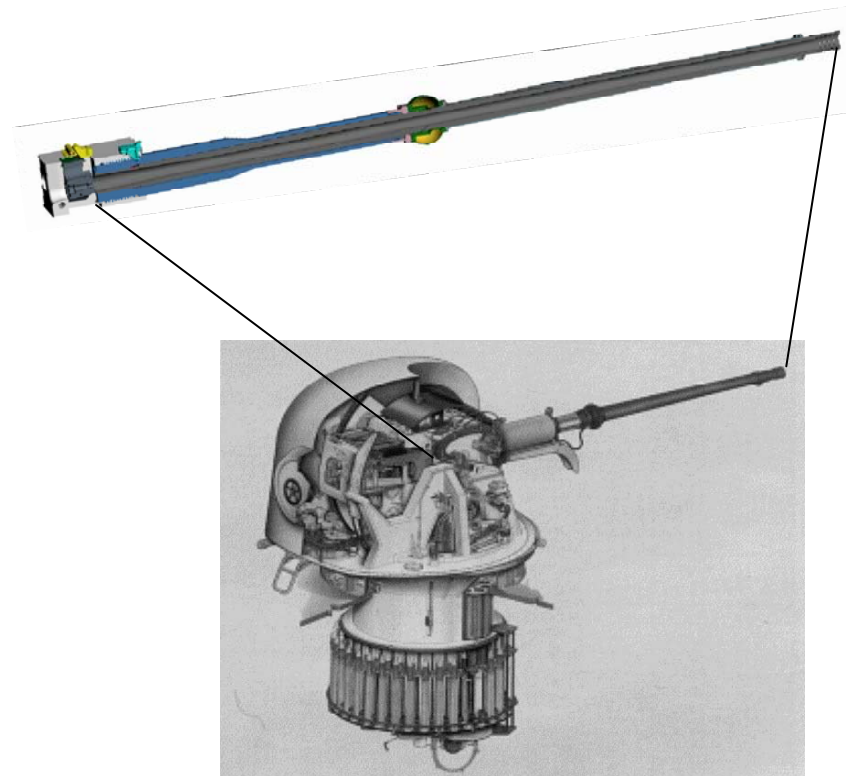
- Refractory metal alloy coating showed minimal effects after 50 firings
- Heat checks were significantly fewer and smaller than the chrome baseline
- The substrate appeared unchanged after 50 firings with no heat affected zone
- Interface between coating and substrate shows evidence of an overly energetic clad



Prototype Barrel Assembly For Mk 75 76mm Gun

Key areas of development

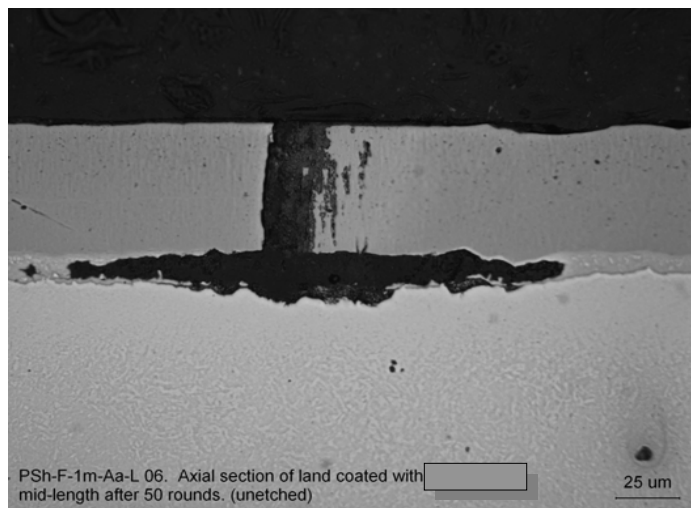
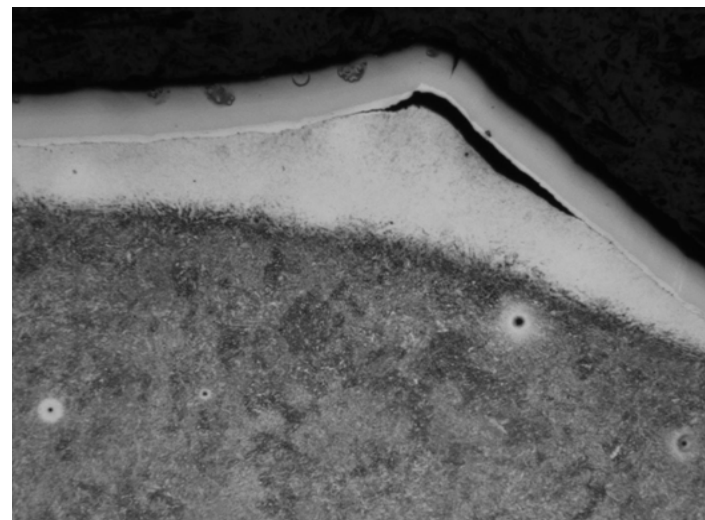
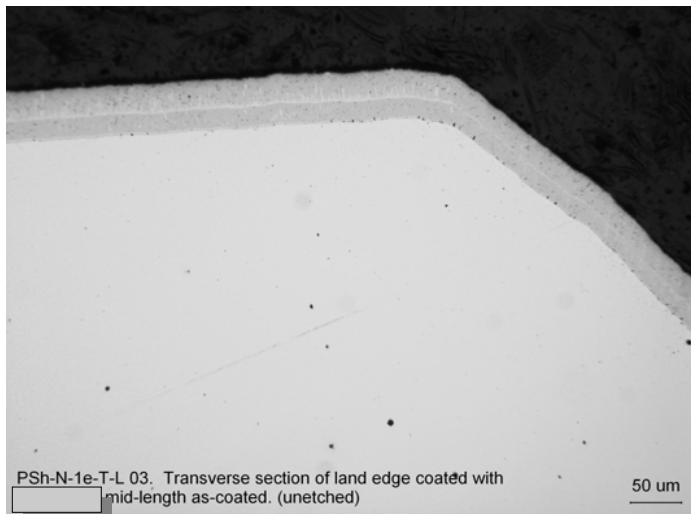
- Cladding the complex geometry of the chamber
- Transitions and overlaps in successively clad layers
- Quantification of residual stresses resulting from the explosive event
- Machining operations in the clad alloy
 - Boring
 - Honing
 - Cutting
 - Grinding





Unfired Sample

50 Firings

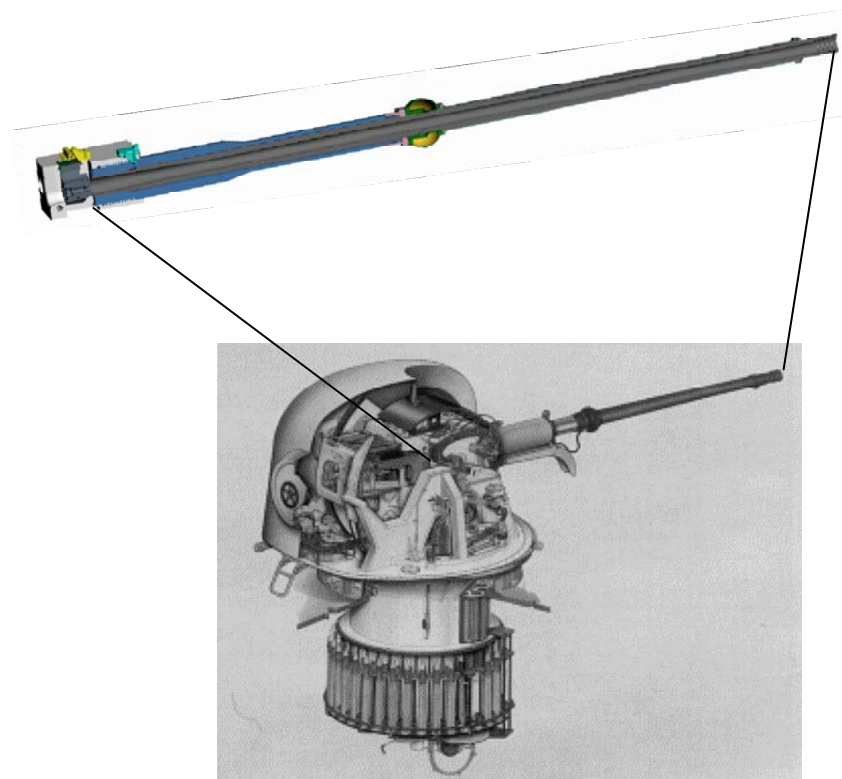


- Coating applied over thin interlayer showed good adhesion
- Less than 10% of material removed after 50 firings
- Interlayer corroded much more rapidly than either refractory metal or steel
- Interlayer separated from steel at point of highest heat input

Prototype Barrel Assembly For Mk 75 76mm Gun

Key areas of development

- Application of an adherent coating that does not use an interlayer
- Application of a uniform coating on a barrel with complex ID and OD geometry





- **Completed screening candidate technologies based on performance in gun firing tests**
- **Selected two for continued development and demonstration in 76mm scale, Explosive Cladding and Electromagnetically Enhanced Physical Vapor Deposition (EPVD)**
- **Completed producibility reviews on both technologies incorporating information into preliminary designs for 76mm prototype barrels and identifying key areas of development**
- **Currently working to demonstrate successful resolution of all key issues for both technologies**





- **Prototype 76mm barrel assemblies scheduled to be complete end of '05 with rapid fire testing conducted early '06**
- **Down-select to single technology for application in full scale 155mm barrel to be built in '06 – '07**
- **Demonstration of technology via proof fire testing and rapid fire testing in 155mm in '07**

