Material Research

Tungsten Carbide

2011
May 25

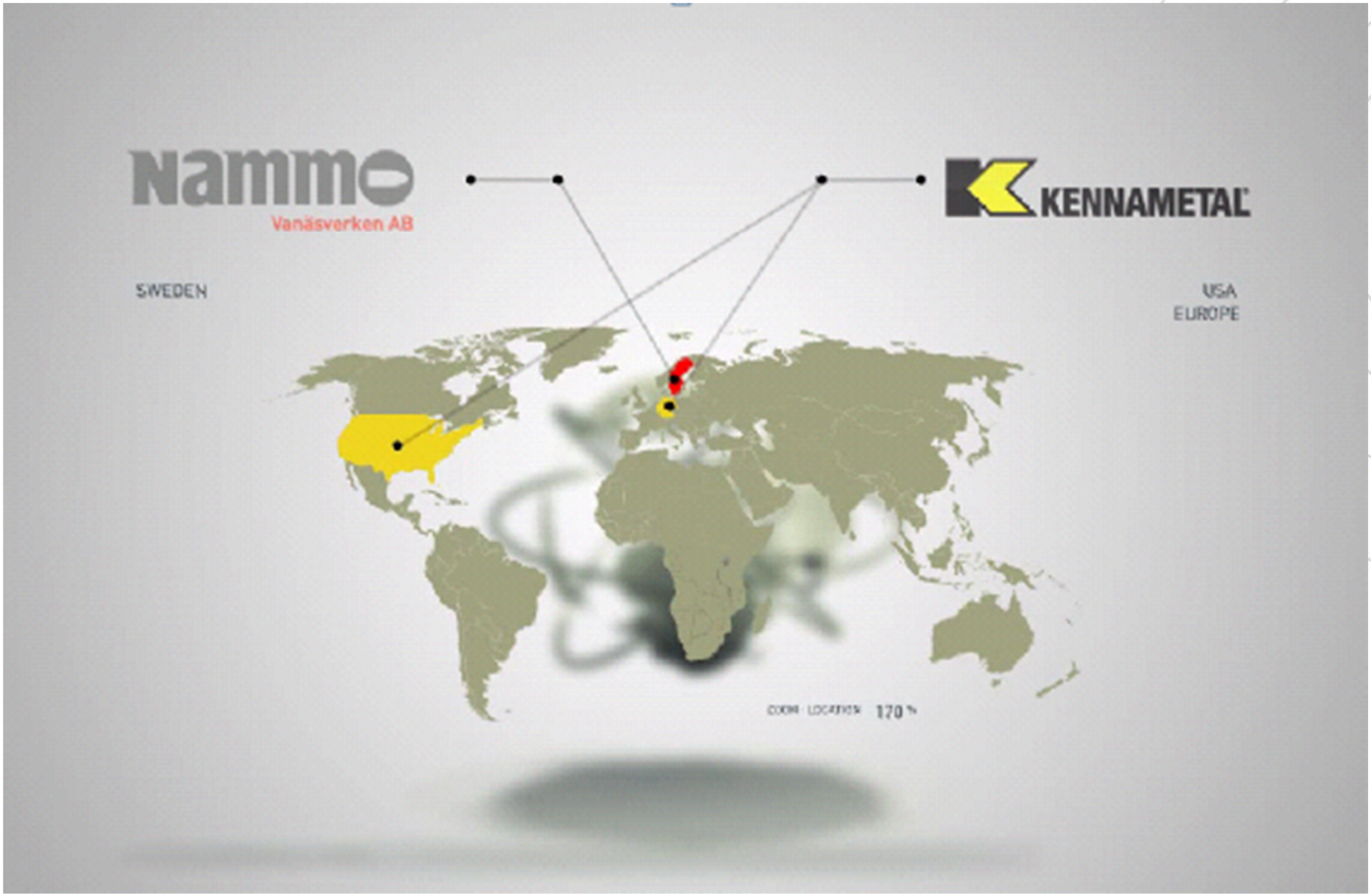
AP
Armor Piercing
SMALL ARMS AMMUNITION

Fredrik Erninge
R&D Manager
Nammo Vanäsverken
Sweden

Jon Bitler
Manager, Material Science
Kennametal Rogers
USA

KENNAMETAL

Nammo



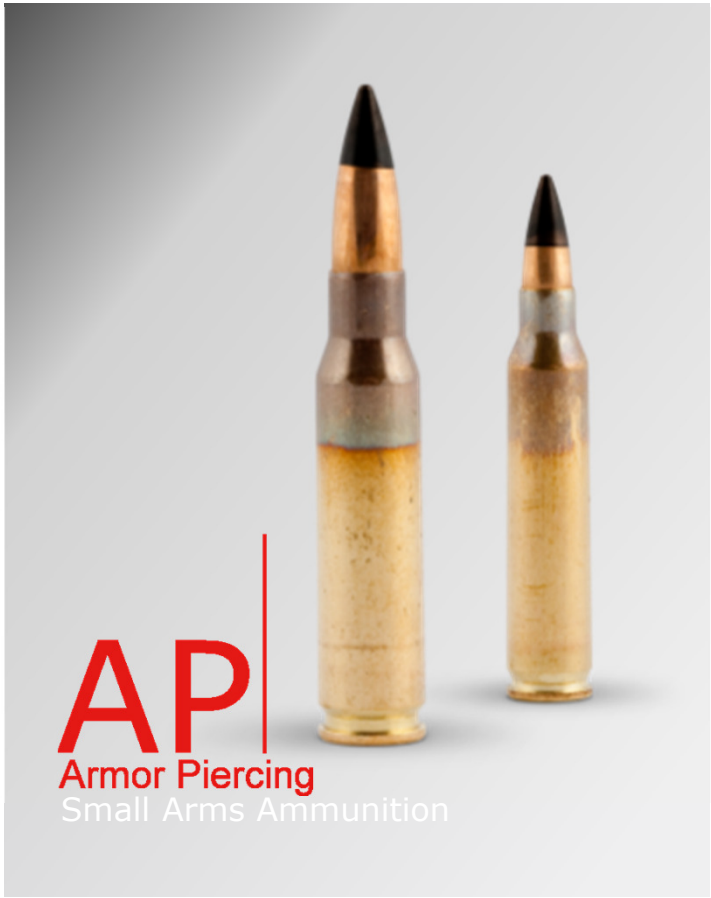
KENNAMETAL

Nammo

SECURING THE FUTURE

Topics

- Nammo Armor Piercing - Background
- Next generation Armor Piercing
- Material Research
  - Kennametal
- Armor Piercing Designing
- Summary



KENNAMETAL

Nammo

SECURING THE FUTURE

M993 & M995 Armor Piercing

- World leading military specified Armor Piercing in caliber 5.56 and 7.62 mm
- Designed by Nammo Vanäsverken 20 years ago
- Kennametal has been sole supplier of the Tungsten Carbide core

AP 5.56 7.62 12.7
Armor Piercing
SMALL ARMS AMMUNITION

- 150 million Armor Piercing cartridges produced
- Qualified as M993 respectively M995 by US Army 1996

KENNAMETAL

Nammo

SECURING THE FUTURE

Next Generation Armor Piercing

- Improved penetration
  - Different impact angels
  - Armor Steel
  - Ultra hard targets (Ceramics)
- Improved ballistic match to ball reference

Nammo

Adapting projectile and projectile core geometry

- Tungsten Carbide core without Cobalt
  - Nammo Green Ammunition Concept

KENNAMETAL

Tungsten Carbide material research

SECURING THE FUTURE

Who is Kennametal?

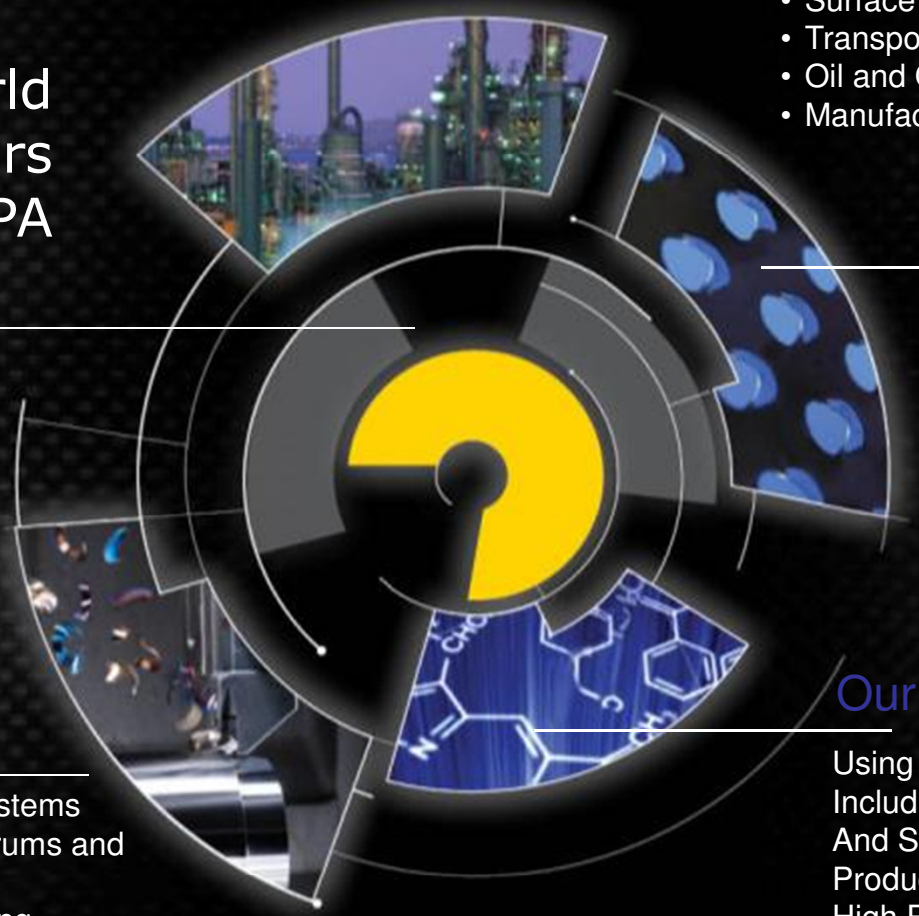
World Headquarters
Latrobe, PA

About Us

Kennametal Delivers Productivity To Customers Seeking Peak Performance In Demanding Environments By Providing Innovative Custom And Standard Wear-resistant Solutions

Our Products

- Energy Exploration Cutting Systems
- Road Rehabilitation, Mining Drums and Cutting Systems
- Machine Tooling: Turning, Milling, Holemaking, Systems
- Specialty and Defense products



Our Customers

- Aero-Structure, Aero-Engine Manufacturing
- Surface and Underground Mining
- Transportation Manufacturers
- Oil and Gas Drilling
- Manufacturing Machining Centers

Our Differentiators

- Proprietary Powder Metal Material Formulas
- Specific Customer Application Expertise, Engineered Solutions
- Patented Pressing, Sintering and HIPing Methods
- Specific Tungsten Processing Methods

Our Processes

Using Advanced Materials Expertise Including Tungsten Carbide, Ceramics, And Super-hard Materials, And Superior Product Development Methods To Deliver High Performance Wear Solutions

SECURING THE FUTURE

KENNAMETAL

Nammo

Defense Products

Small Caliber Cores

- Tungsten Carbide
- Tungsten Heavy Alloy

Medium & Large Caliber Penetrators

- Tungsten Heavy Alloy

Trend

- Increasing demands for Co-free Tungsten Carbide and Tungsten Heavy Alloys in the defense industry

Challenge

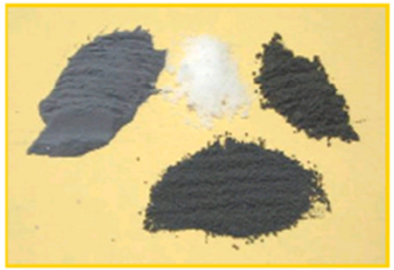
- Replacement of Co by alternative binder metals maintaining the performance of the established Co-containing alloys

SECURING THE FUTURE

KENNAMETAL

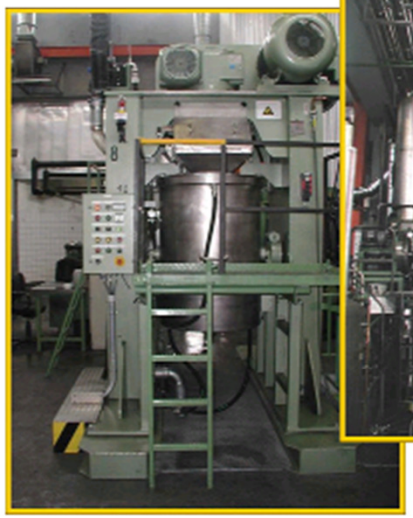
Nammo

Manufacturing Process Tungsten Carbide Core



From Raw materials ...

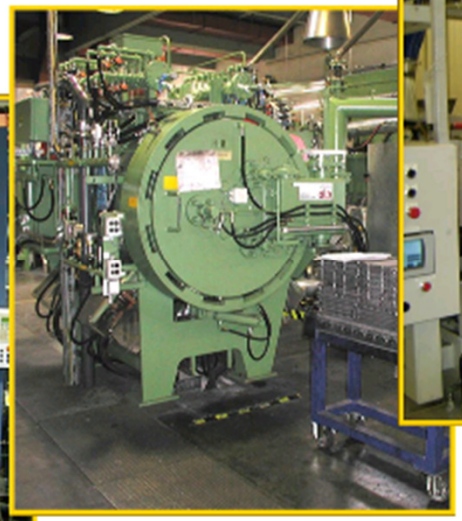
Wet milling



Spray drying

Pressing

Sintering



Grinding & Quality Control

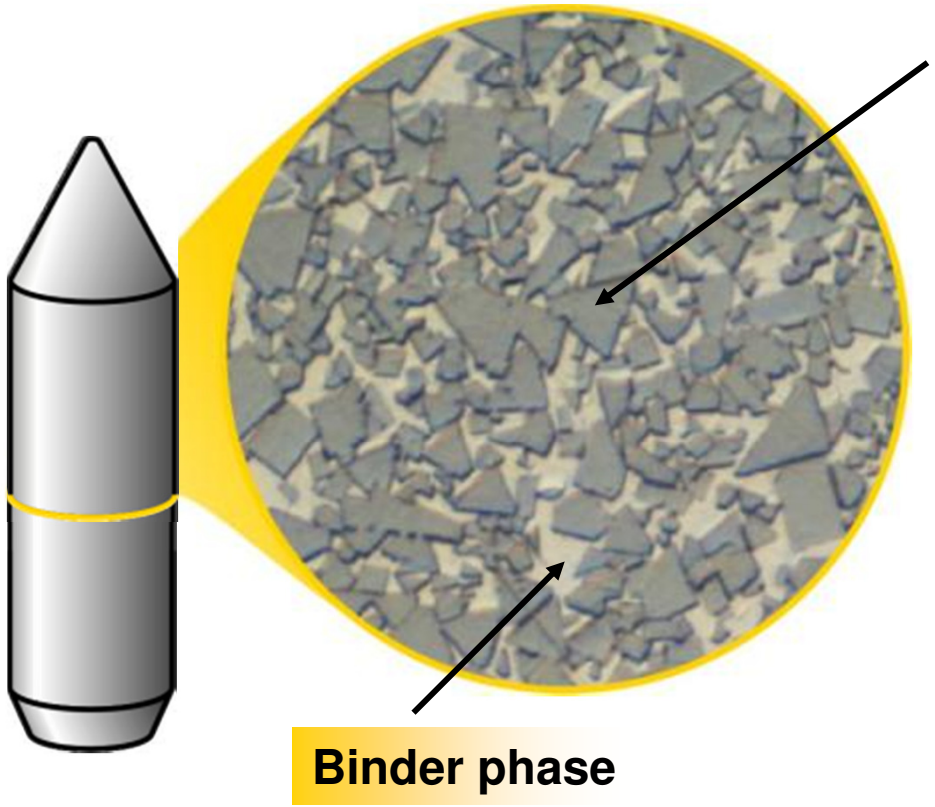
... to Tungsten Carbide Core

KENNAMETAL

Nammo

SECURING THE FUTURE

Microstructure / Material Properties

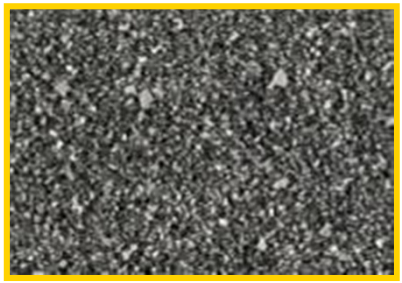


Tungsten carbide (WC)

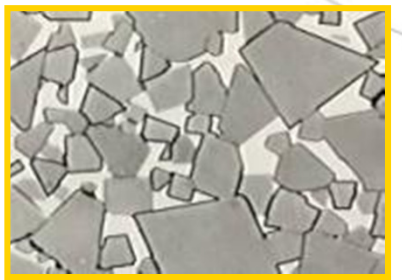
Different WC grain size affects the following properties:

- **Hardness**
- **Fracture Toughness**

fine



coarse



Variation of WC grain size, amount of binder phase, type of binder metal determines the material properties of the tungsten carbide core

KENNAMETAL

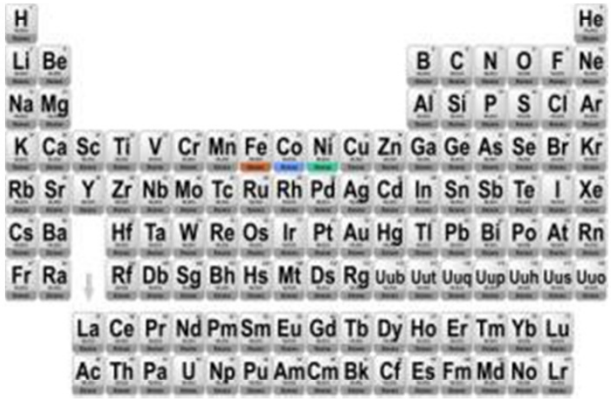
Nammo

SECURING THE FUTURE

Binder phase

- Properties affected by the binder phase:
  - **Hardness**
  - **Fracture Toughness**
  - **Corrosion Resistance**

- Binder metals for hardmetal: Cobalt, Iron, Nickel and combinations



27
Co
58,933
Cobalt

Lattice structure:
hexagonal

Density:
8.9 g/cm³

Melting point:
1493 °C

26
Fe
55,845
Iron

Lattice structure:
body-centered cubic

Density:
7.9 g/cm³

Melting point:
1536 °C

28
Ni
58,693
Nickel

Lattice structure:
face-centered cubic

Density:
8.9 g/cm³

Melting point:
1455 °C

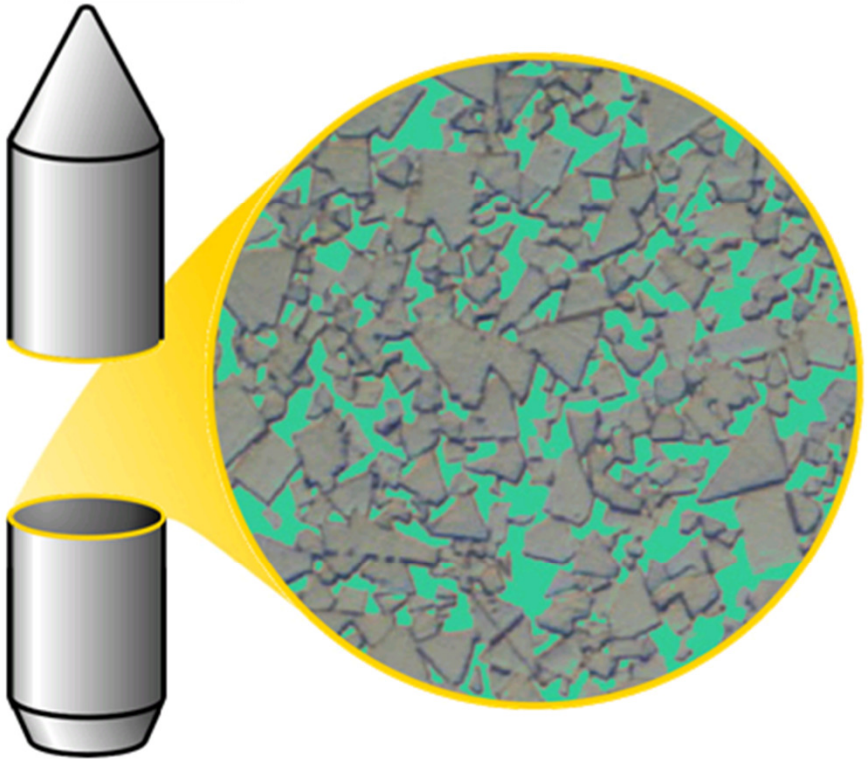
KENNAMETAL

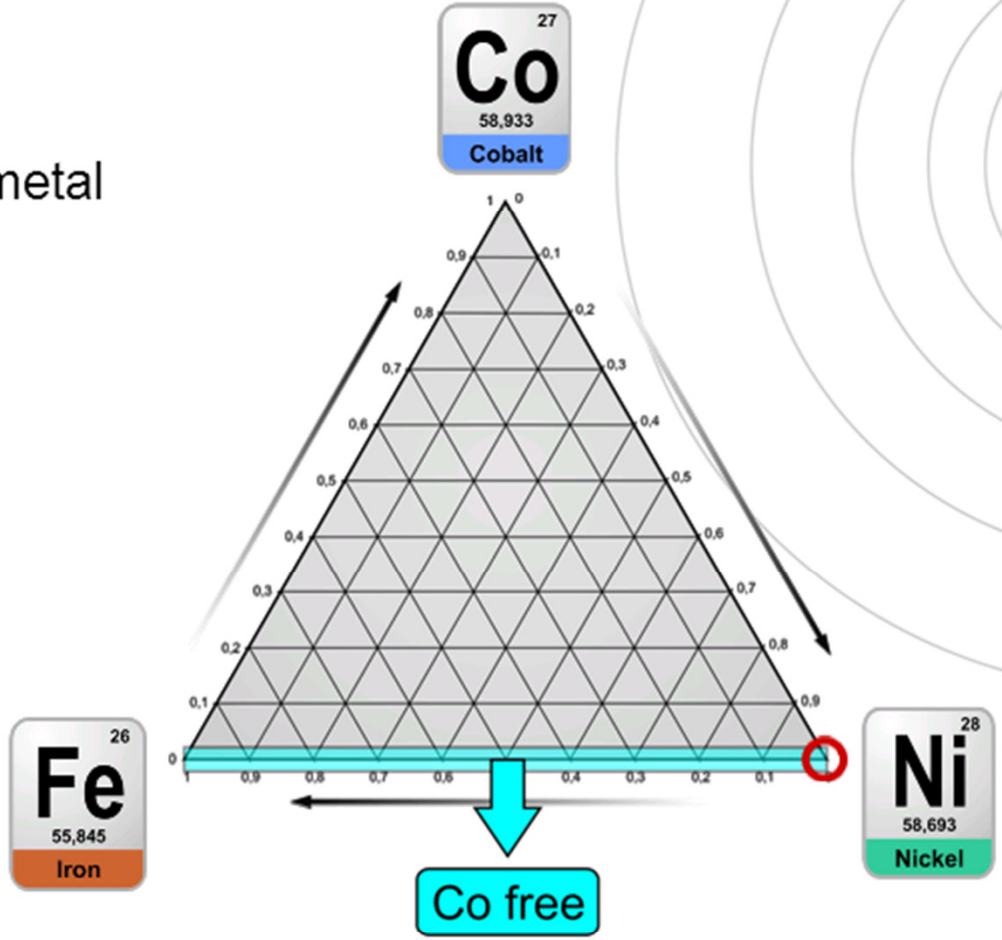
Nammo

SECURING THE FUTURE

Cobalt free Binder

- Cobalt is the most popular binder metal in the hardmetal industry
- Co free means: Iron and/or Nickel



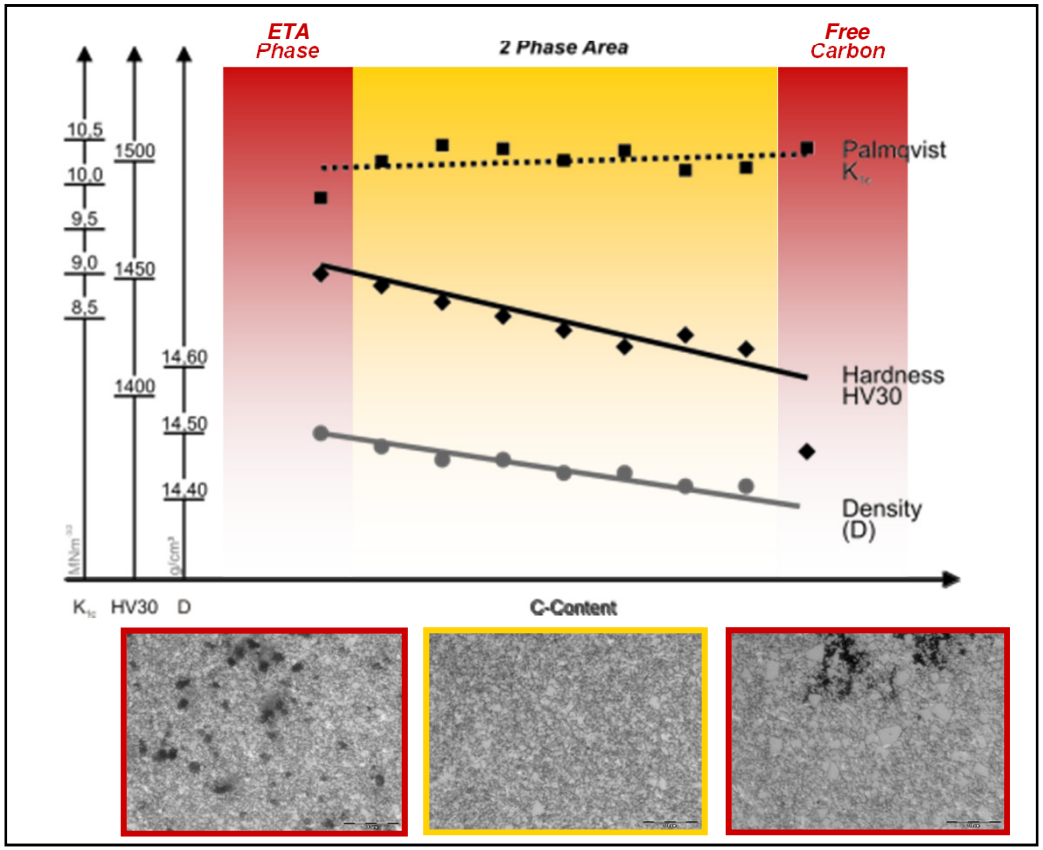


KENNAMETAL

Nammo

SECURING THE FUTURE

2-Phase Area and Properties for WC - 10% Co-free binder hardmetal



Width of Carbon Window:

WC - 10% Co	~	0,20%
WC - **10% Co free binder**	~	**0,30%**

Properties 2-Phase Area:

Density [g/cm²]:	14,42 - 14,48
Hardness HV30:	1420 - 1450
Palmqvist [K_{1C}]:	10,2 - 10,5

Wide carbon window insures consistent mechanical properties

KENNAMETAL

Nammo

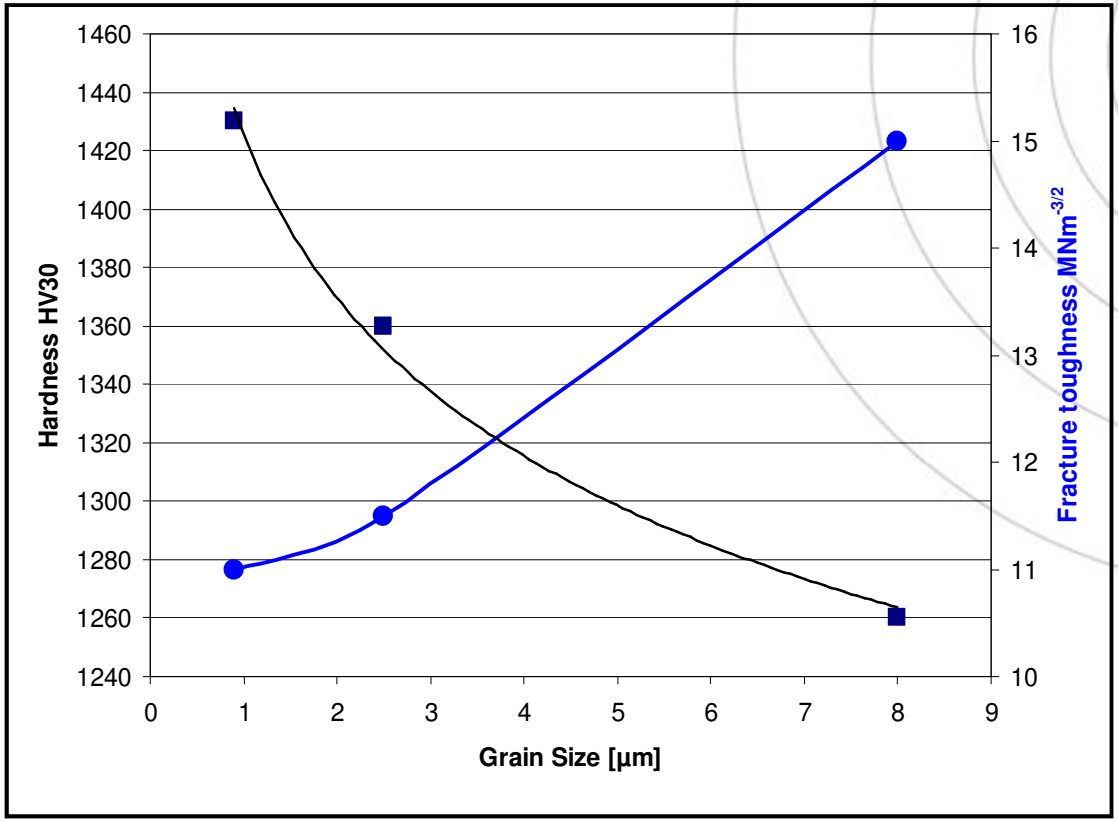
SECURING THE FUTURE

Co-free Tungsten Carbide Cores 7,62 mm

fine

medium

coarse



Mechanical properties can be tailored for specific applications

KENNAMETAL

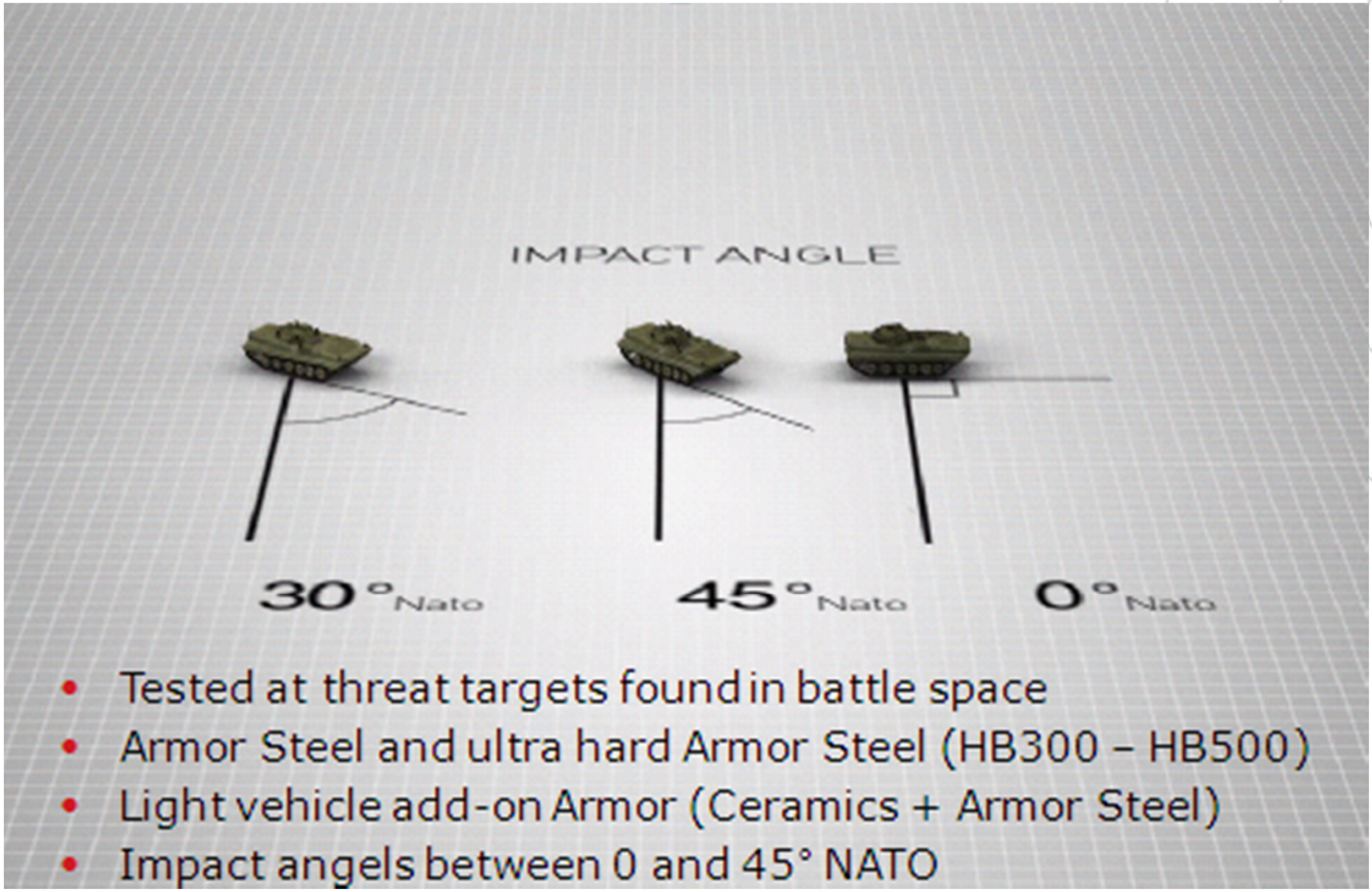
Nammo

SECURING THE FUTURE

Live Firing Penetration Test

- **7.62 mm M993 vs. Cobalt free equivalent**
- **Cobalt free cores with same dimensions as M993 core**
- **Same projectile mass on tested cores/projectiles**
- **Same muzzle velocity**
- **Penetration test program with standard M993 as reference**
- **Recording of v_{50} velocity (50% penetration / 50% stop)**

Live fire penetration test



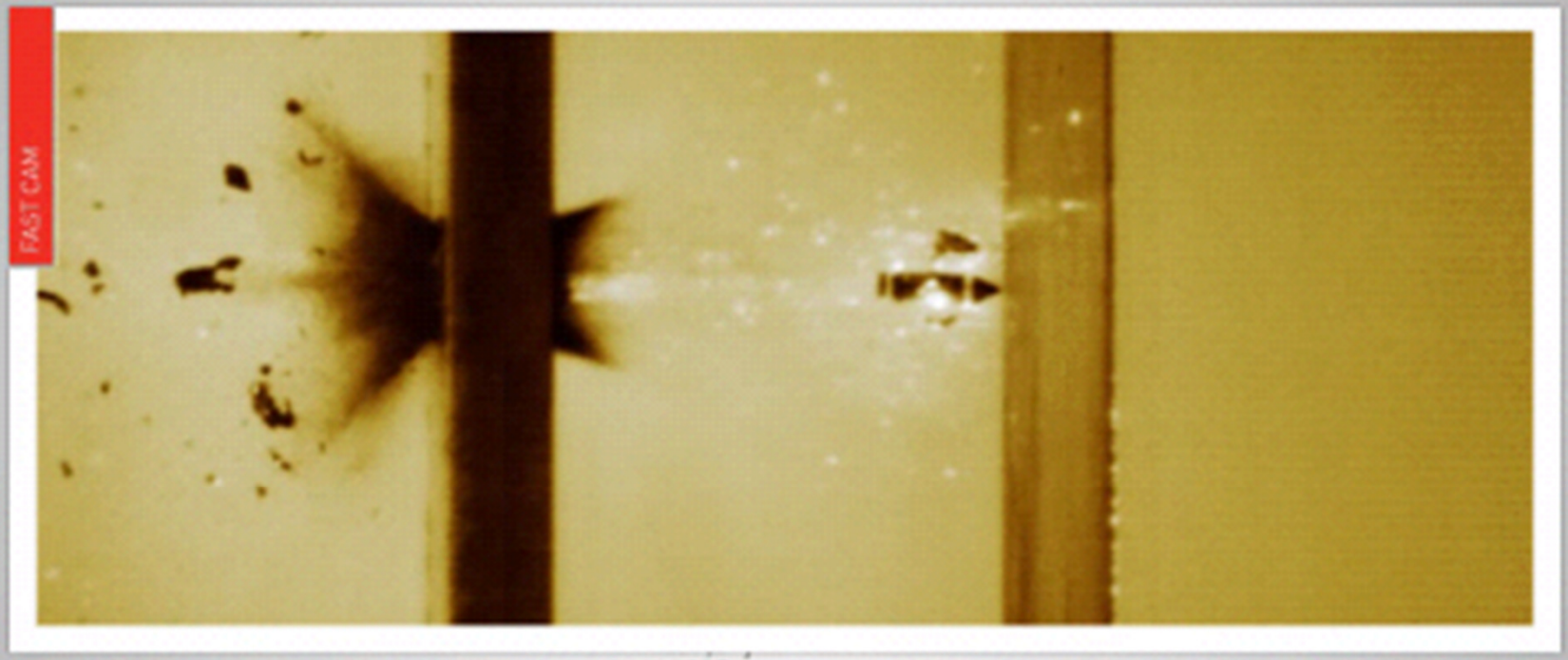
- Tested at threat targets found in battle space
- Armor Steel and ultra hard Armor Steel (HB300 – HB500)
- Light vehicle add-on Armor (Ceramics + Armor Steel)
- Impact angels between 0 and 45° NATO

KENNAMETAL

Nammo

SECURING THE FUTURE

Live fire penetration test



- 18 mm Armor Steel 300 HB
- Target distance 100 m
- Impact angle 0° Nato

KENNAMETAL

Nammo

SECURING THE FUTURE

Conclusion

Cobalt free Tungsten Carbide Cores gives;

- Same high penetration performance in all kind of targets and impact angles
- No compromising of the Nammo AP all round top performance including inclined targets
- Same ballistic performance
- Same cartridge requirements

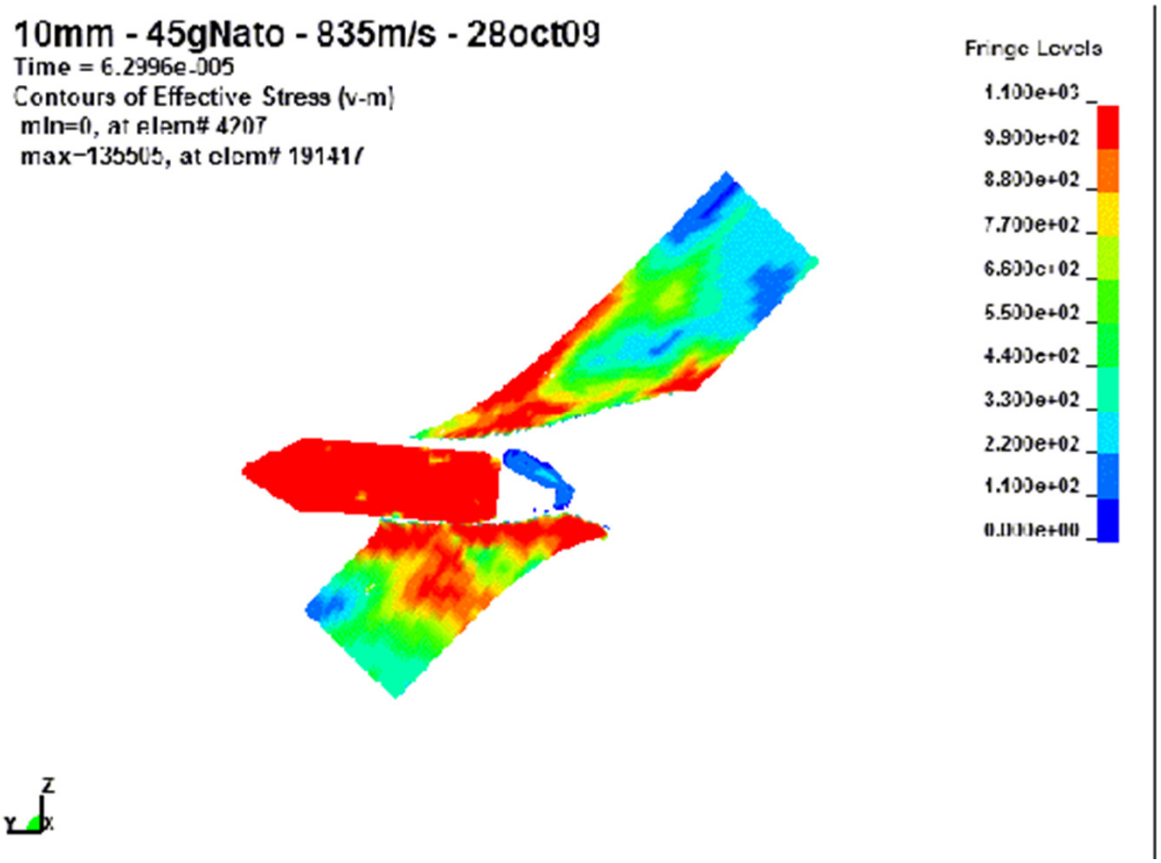
SECURING THE FUTURE

KENNAMETAL

Nammo

Continued AP Development

- Enhanced penetration capabilities by adapting geometry



1. Geometry theoretically optimized by FEM simulations
2. Theory tested in reality
3. Cartridge adapted for ballistic match to ball reference

KENNAMETAL

Nammo

SECURING THE FUTURE

Summary

- Challenges in producing Cobalt Free Tungsten Carbide solved by Kennametal
- Cobalt free Armor Piercing gives the same high penetration performance
- Enables Nammo to expand the Green ammunition concept to the Armor Piercing small arms products
- Enhanced Armor Piercing, Cobalt free, in 5.56 and 7.62 mm available soon

SECURING THE FUTURE

KENNAMETAL

Nammo

AP
Armor Piercing
Small Arms Ammunition

Questions

SECURING THE FUTURE

KENNAMETAL

Nammo

Speaker information

Fredrik Erninge
R&D Manager
+46 505 182 07
Nammo Vanäsverken AB, Sweden
fredrik.erninge@nammo.com

Jon Bitler
Manager, Material Science
(479) 986 4646
Kennametal Rogers, USA
Jon.bitler@kennametal.com

KENNAMETAL

Nammo

SECURING THE FUTURE