LIGHTWEIGHT, HIGH PERFORMANCE MATERIALS FOR 21ST CENTURY COMBAT SYSTEMS

LIGHTER, FASTER, STRONGER

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Alcoa Howmet
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LIGHTWEIGHT, HIGH PERFORMANCE MATERIALS FOR 21ST CENTURY COMBAT SYSTEMS

- The High Performance Material Transition
- Investment Casting Manufacturing Process
- Investment Casting Titanium Properties
- Casting Applications for Combat Systems

LIGHTER, FASTER, STRONGER

- Traditional materials of construction for combat systems has been **steels**
  - Multiple manufacturing paths
  - Readily available
  - Competitively priced
- However, the required insertion and relocation **rate** of weaponry has increased markedly due to technology of counter-measures
  - Fast-in and fast-out is critical

Photo credits: MuseumReplicas, used by permission
Charlottenlund Fort Haubitz, Sooe at da.wikipedia
Sherman Tank, BonesBrigade at en.wikipedia

LIGHTER, FASTER, STRONGER

- Modern warfighter is faced with increasing **loads** of “non-lethal” combat gear
  - Communication equipment
  - Target detection/ acquisition devices
  - Survival gear for hostile environments

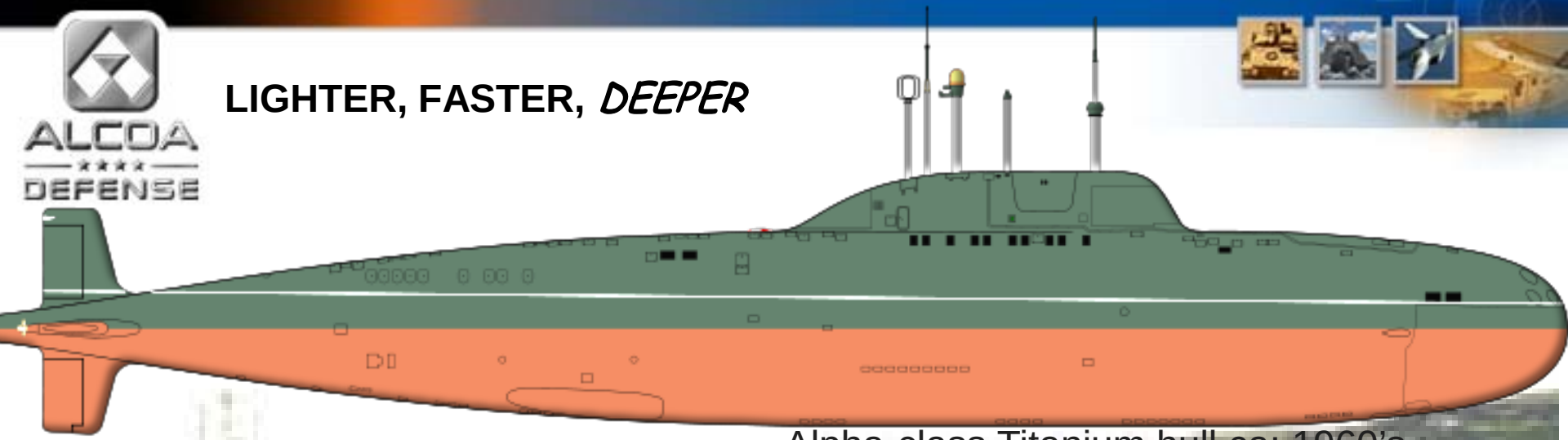
Photo credits: traversing: Marines.mil
kneeling: TheKingsList used by permission

LIGHTER, FASTER, STRONGER

- **Titanium** embodies a unique suite of properties perfectly suited for advanced service applications
  - One-half weight of steel
  - Higher strength/weight ratio
  - Superior corrosion resistance

Photo: NASA

LIGHTER, FASTER, *DEEPER*



Alpha-class Titanium hull ca: 1960's

Photo: lazurit.sci

THE MATURING MATERIAL

- **Titanium manufacturing** has matured significantly in the last five decades, driven primarily by:

Aerospace

- Turbine engine cases and structure
- Turbine engine compressor blades
- Airframe structures
- Fasteners for composite aircraft (B787)
- Landing gears/ wheels and brakes
- *Modern military fighter aircraft typically are 30-45% by weight Titanium*

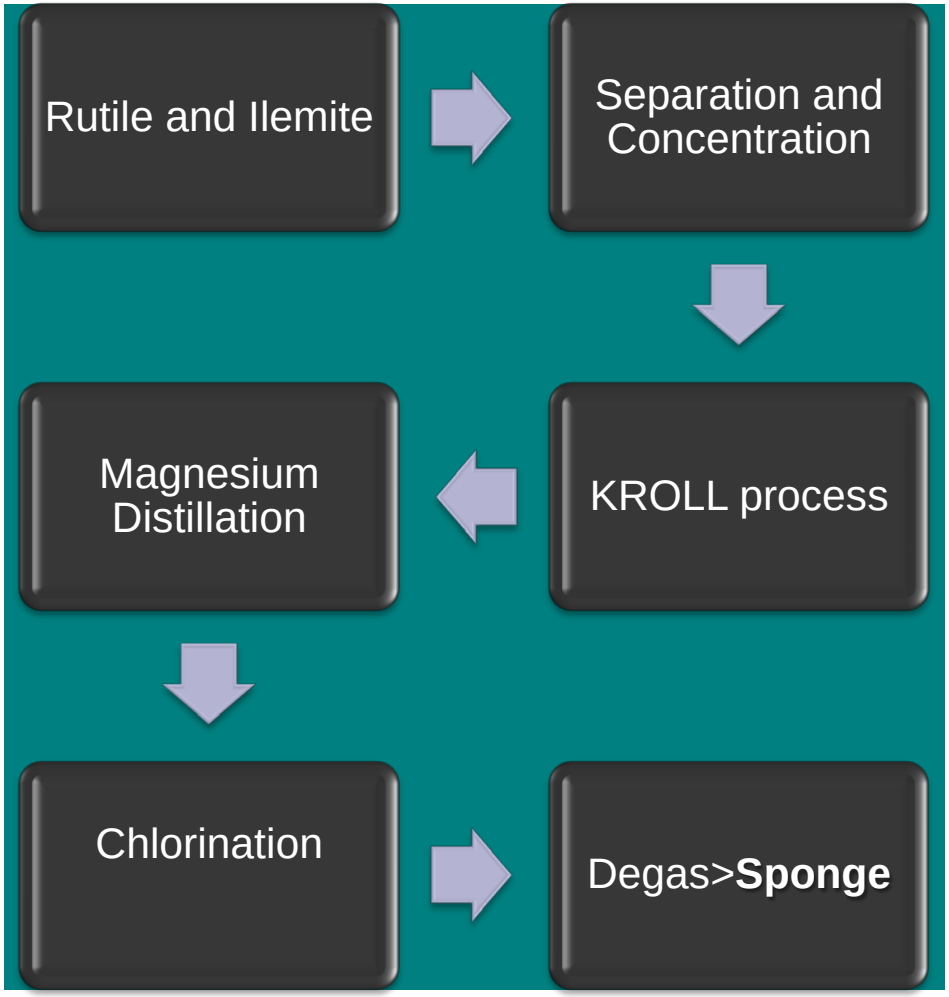
Medical

- Instruments
- Fasteners
- Joint prosthesis
- Orthopedic fixtures –rods, plates, etc

Recreation

- Golf clubs
- Cycling frames
- Motor car racing frames and engine valves
- Motorcycle racing components
- Turbocharger wheels

MULTIPLE MANUFACTURING PATHS



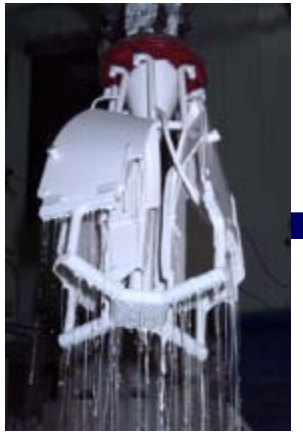
- Titanium sponge and alloying materials (e.g., aluminum, vanadium) are melted by plasma hearth, electron beam and electrode arc – all processes are in hard vacuum or inert atm. due to reactivity with oxygen and solubility of hydrogen at melting temperatures.
- Titanium is solidified as ingots or continuously cast bars.
- Titanium may then be forged, extruded (limited red. in area), rolled, ring rolled or re-melted and investment cast – many common metal working methods

INVESTMENT CASTING
MANUFACTURING PROCESS AND PROPERTIES

Titanium Investment Casting Process

Wax Pattern in Die

Completed Wax Cluster



Mono-shell Dipping

Dewax

Titanium Pour

Shell Removal

Titanium Investment Casting Process

Gating Cut-Off

HIP

Chem Mill

Weld Repair

X-ray Inspection (NDI)

3-Axis Layout (CMM)
Finished Part

Material Properties in MMPDS

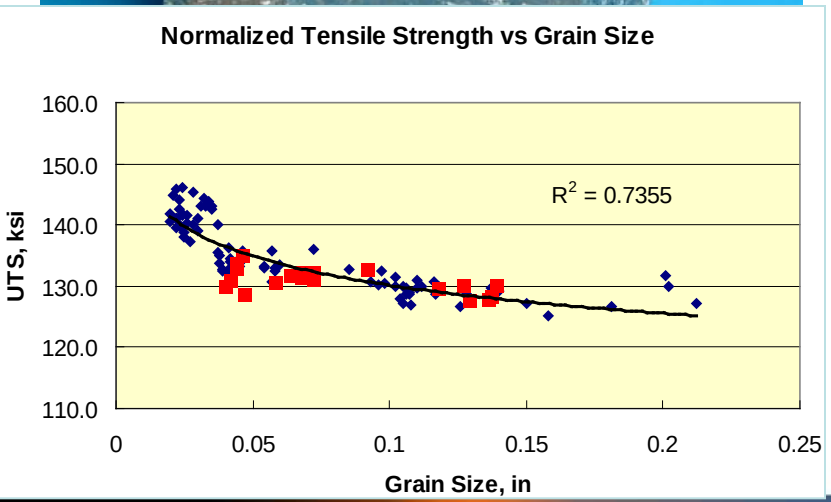


Table 5.4.1.0(g). Design Mechanical and Physical Properties of Ti-6Al-4V Titanium Alloy Casting

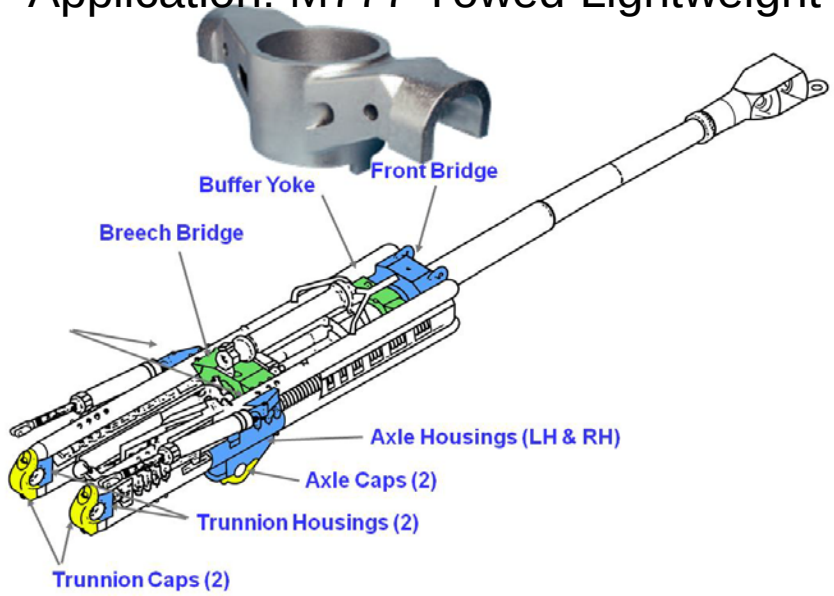
Specification	AMS 4962[a]		AMS 4992					
Form	Investment Casting							
Temper	HIP and Annealed							
Thickness, in.	≤1.000		<0.500		0.500-1.500		1.500-4.000	
Location within casting	Designated area							
Basis	A	B	*A*	*B*	*A*	*B*	*A*	*B*
Mechanical Properties:								
F_{tu}, ksi	125[b]	128	125	129	123	127	120	124
F_{ty}, ksi	119	122	111	116	112	116	110	115
F_{cy}, ksi	...	...	117	122	119	123	117	124
F_{su}, ksi	...	...	86	89	85	87	85	87
F_{bru}[b], ksi:								
(e/D = 1.5)	...	...	201	207	196	202	192	199
(e/D = 2.0)	...	...	252	260	246	254	242	250
F_{bry}[b], ksi:								
(e/D = 1.5)	...	...	172	180	174	180	172	182
(e/D = 2.0)	...	...	207	216	210	217	209	220
e, percent (S-Basis)	5	...	5	...	4	...	3	...
RA, percent (S-Basis)	...	...			19	...	12	...
E, 10^3 ksi	16.9							
E_c, 10^3 ksi	17.4							
G, 10^3 ksi	...							
μ	...							
Physical Properties:								
ω, lb/in.^{3}	0.160							
C, Btu/(lb)(°F)	See Figure 5.4.1.0(b)							
K, Btu/[(hr)(ft^2)(°F)/ft]	...							
α, 10^{-6} in./in./°F	See Figure 5.4.1.0(b)							

a Inactive for new design.
b S-Basis. The *rounded* T_{99} value is 126 ksi.
c Bearing values are "dry pin" values per Section 1.4.7.1.

INVESTMENT CASTING

APPLICATIONS FOR COMBAT SYSTEMS

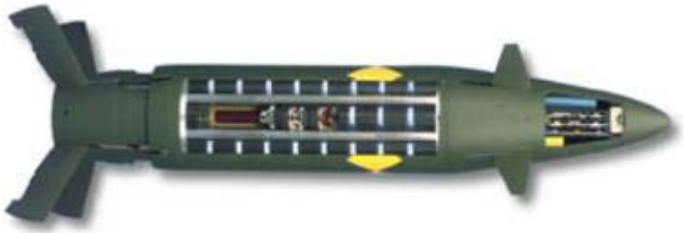
Application: M777 Towed Lightweight Howitzer

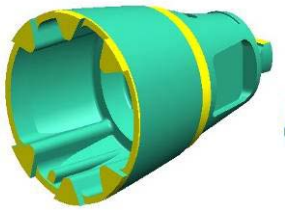


Investment castings used to reduced weight from 19,000 to **under 8,900 lbs**

Photo: lifting: marines.mil Cpl. Jennifer Poole
firing: army.mil

Application: Munitions Missile Cone

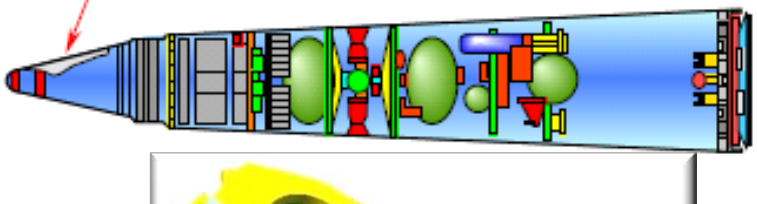


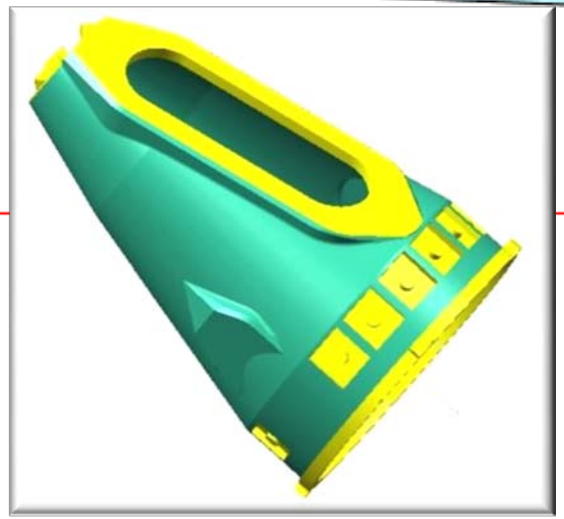


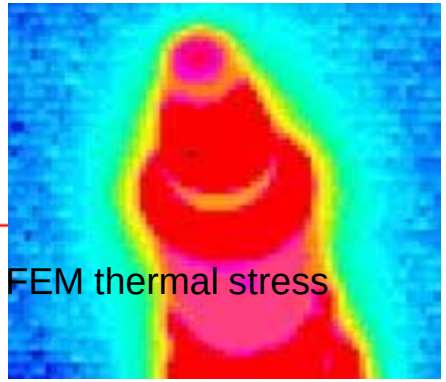
Alcoa Advantage:

- Lightweight, titanium casting provides unsurpassed structural integrity and assures guidance system performance
- Durable to virtually all environmental conditions
- Casting allows high-volume manufacturing

Application: High-Altitude Missile Cone





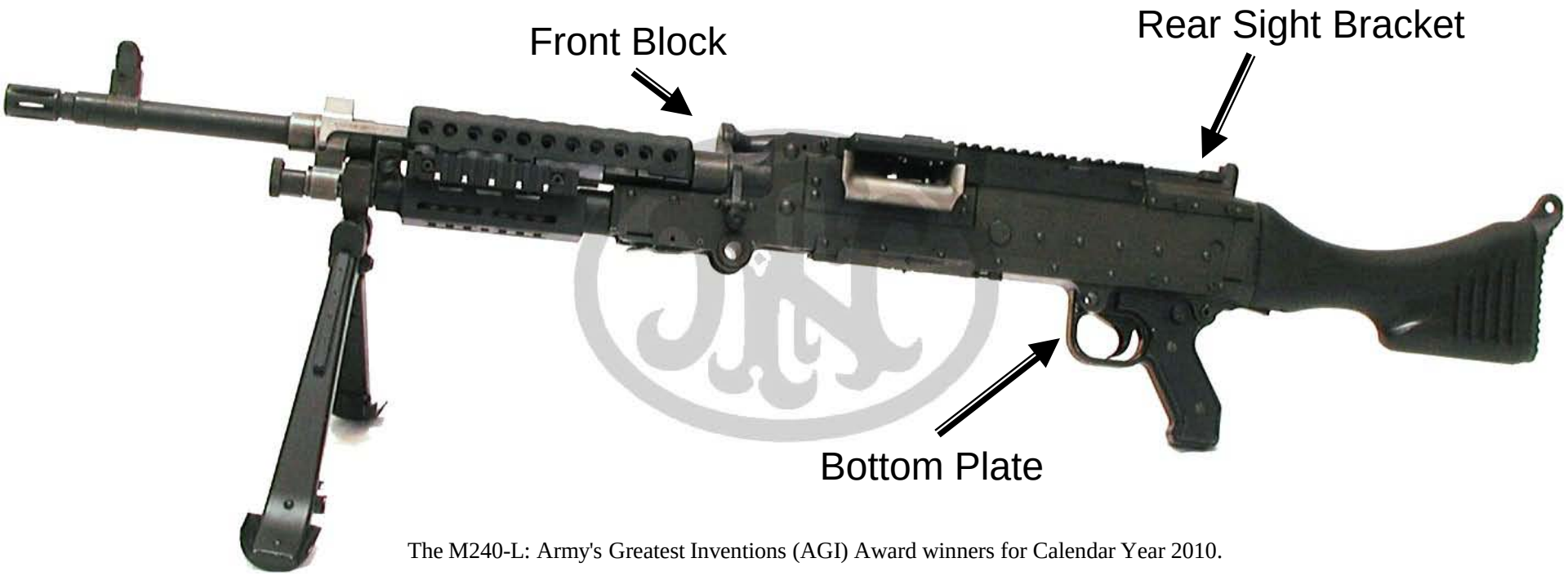


Alcoa Advantage:

- Lightweight, titanium casting provides compatible coefficient of thermal expansion with infrared window
- Durable to virtually all environmental conditions
- Casting allows high-volume manufacturing

Application: Machine Gun

Replacing steel castings with titanium castings results in an upgraded weapon that is 35% lighter

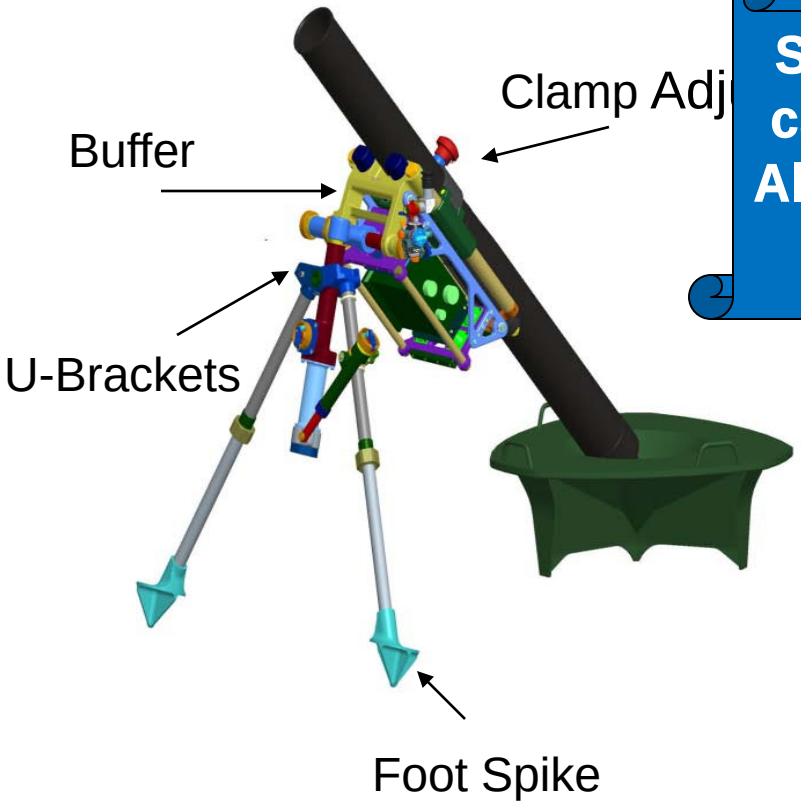


The M240-L: Army's Greatest Inventions (AGI) Award winners for Calendar Year 2010.

Photo:PEOsoldier.armylive.dodlive.mil

Application: Mortar Bi-Pod

Light-weight ***and*** field durability are drivers for using titanium materials



See actual castings in Alcoa Booth 329

81mm & 120 mm Mortar Bi-Pods

SUMMARY

- ✓ The modern warfighter requires lighter, faster and stronger materials to excel in ever-changing environs
- ✓ Titanium investment castings have matured significantly over the past few decades driven by demand of aerospace and other critical to performance markets
- ✓ Titanium investment castings are increasingly employed throughout air-land-sea defense applications providing equivalent or enhanced performance compared to traditional materials at one-half the weight

Thank You!

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