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Ti for Military Ground Vehicles: Are Hopes Dashed?

International Titanium Association
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Outline

- Advantages of titanium for armor
- Why the lack of titanium applications in ground combat vehicles
- Current applications
- Future defense challenges
- General difficulty in adopting new materials
- Improved fuel economy to reduce convoys and related casualties
- Future vehicles – new and upgrade programs
- New technologies
- Opportunities

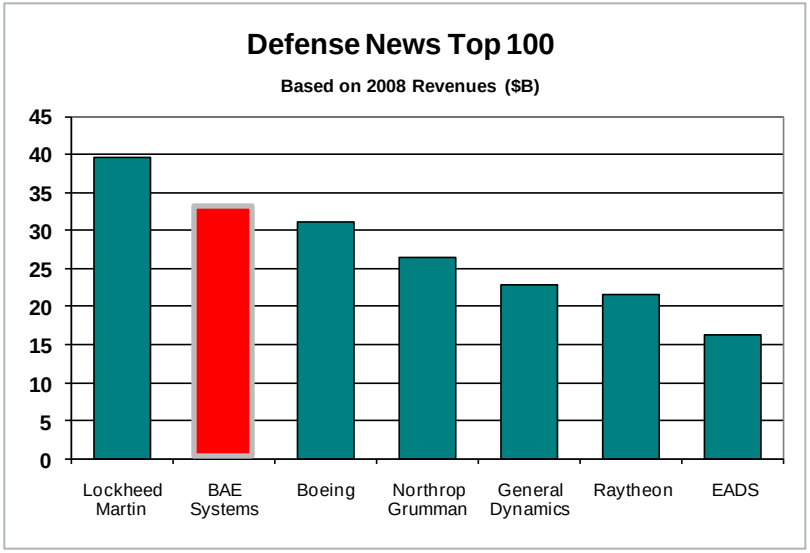
One of the world's largest defense companies

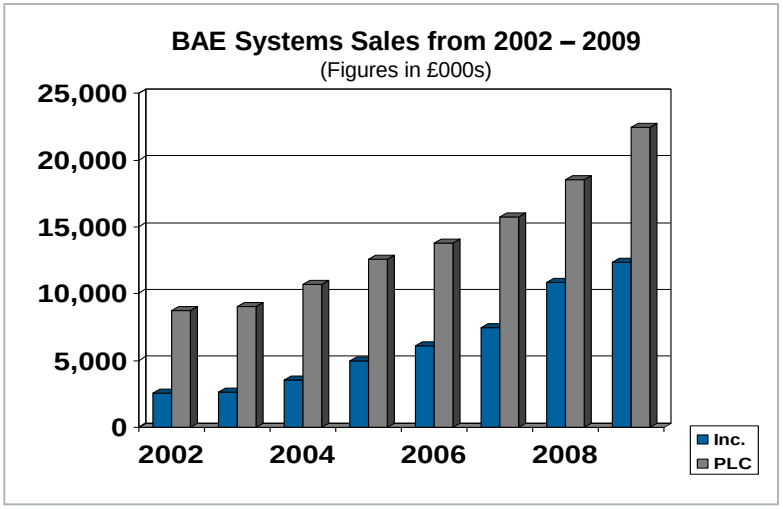
BAE Systems plc

- 107,000 employees
- 2009 sales of £22.4B ($35.1B**)
- 2009 order book of $73.4B**
- Second largest global defense company
- Top 10 U.S. prime contractor
- Seven home nations
- Presence in more than 100 nations

BAE Systems, Inc.

- 52,000 employees (44,000 in the U.S.)
- 2009 sales of £12.4B ($19.4B**)
- Major operations in 38 states, the UK, Sweden, Israel, Germany, Mexico, Switzerland, and South Africa
- A U.S. company chartered in Delaware
- Special security agreement with US Gov't





** US$ equivalent calculated using the 2009 average exchange rate of $/£ = 1.566, denoting sales and orders throughout the year

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Products: Land and Armaments – Ground Combat Vehicles

Supporting the Warfighter – current to future

Core Competencies:

- *Combat vehicle survivability*
- *Modeling and simulation*
- *Systems integration*
- *Rapid prototyping*
- *Reliability testing*
- *Lean manufacturing*
- *Field support*

Combat Systems

Recovery Vehicle

Personnel Carrier Family

Future Force

Self Propelled Artillery Family of Vehicles

Future Combat Vehicle

Amphibious Family of Vehicles

Advanced Tactical Vehicle

Survivable Wheeled Vehicles

High Energy Laser Technology Demonstrator

Current Force

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Properties of Steel, Aluminum, and Titanium Armor

	RHA Steel MIL-DTL-12560	Aluminum 5083 MIL-DTL-46027	Ti-6Al-4V MIL-DTL-46077
Tensile Strength (MPa)	1,170	350	970
Density (g/cm^3)	7.86	2.70	4.50
Specific Strength* ($MPa-cm^3/g$)	150	130	220
Mass Efficiency (E_m)**	1	1.0-1.2	1.5

* Specific strength—tensile strength divided by density.

** Mass Efficiency (E_m)—the weight per unit area of RHA required to defeat a given ballistic threat divided by the weight per unit area of the subject material.

Low-Cost Titanium Armors for Combat Vehicles
Jonathan S. Montgomery, Martin G.H. Wells, Brij Roopchand, and James W. Ogilvy
JOM 49 (5) 1997, JOM

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Tracked vehicles


Bradley Fighting Vehicle


CV90


Hercules


Warrior


AAV


Armored Medical Evacuation Vehicle


Challenger II


Bv206S


BvS10


Bulldog


M113 Family of Vehicles


ACV 300


Trojan


Terrier


Titan


FAASV


MLRS (CHASSIS)


M9 ACE

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Artillery systems


Paladin PIM


Archer


M777


FH-77


AS90


Light Gun


M109 Family of Vehicles


HIMARS (CHASSIS)

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Wheeled vehicles


FMTV


JLTV (GTS)


JLTV (USCS)


RG-35


Armored Commercial Vehicles


RG-33 4x4


RG-33 6x6 MMPV


Up-Armored Humvee


Caiman MRAP


RG-12


RG-31 Mk5


Panther


RG-31 Mk6

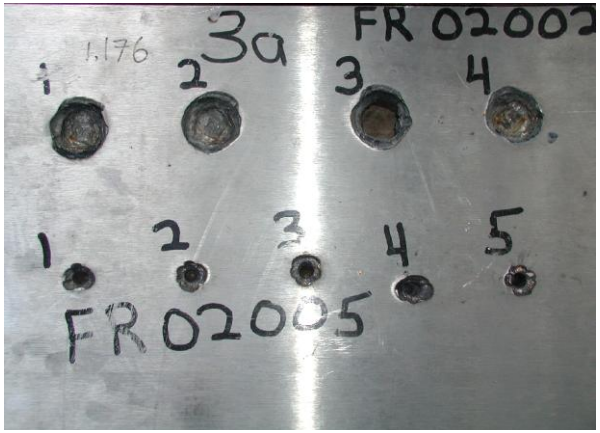

Tactica


RG-31 Ambulance


RG-32 M

Bradley Infantry Fighting Vehicle

- Commander's Hatch
- Development began in 1990 (over 20 years ago)
  - ~150 lb Ti-6Al-4V forging
  - Specification developed for optimizing ballistic properties
  - Ballistic testing required on every 50 hatches
  - Over 2000 produced, no failures
  - Single melt option recently tested and added to specification
- **Roof armor**
  - 5/8 inch plate, unwelded
  - Developed specification – not MIL-DTL-46077
  - Composition optional
  - O content <0.30
  - Ballistic qualification



M777 Lightweight Towed Howitzer

- BAE Systems UK Global Combat Systems
- All titanium (with primary exception of barrel)
- Welded Ti-6Al-4V sheet, and castings
- 777 systems delivered
  - In service in Afghanistan since 2006
- Replaces 17,000 pound M198
  - Less than 10,000 pounds
- Permits single rotor helo transport

R&D vehicles using titanium

- AGS-Light , Air Droppable Tank
  - Ti hatches, armor plate
- Crusader Self Propelled Howitzer
  - Gun mount
- Composite Armored Vehicle
  - Selective armored areas
- Pegasus 8x8 Wheeled Demonstrator
  - Primary hull structure
- NLOS Lightweight Self Propelled Howitzer
  - Several gun components
- ARES Space Frame Demonstrator
  - Lower hull, space frame

Never made it to production

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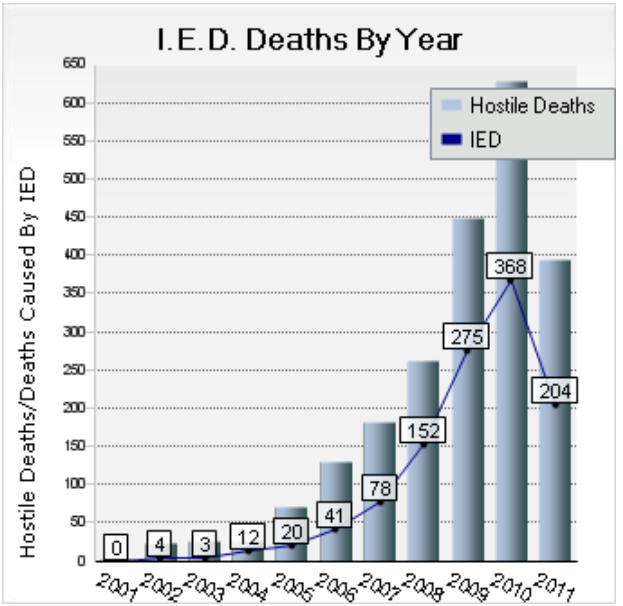
Combat Vehicle Market - Forces

- Declining defense budget
- Increasing national deficit
- Affordability
  - See recent GCV competition
- Exit of Iraq, Afghanistan in 2012-13
- The asymmetrical threat is not going away fast enough
- Plenty of new programs on the drawing board



http://icasualties.org/Iraq/index.aspx

Each vehicle will require significant armor upgrades

Competition from other Advanced Materials

- Combat Vehicle materials are currently MIL-SPEC steel and aluminum armor materials
- Non-armor materials (suspension, powertrain, structure) are commercial steel or aluminum alloys
- Adopting new materials for military vehicle market follows development for aerospace or commercial sector
- Ceramics, organic composites, metal matrix composites, etc.
  - On paper, excellent performance with light weight
  - Often proprietary – desire multiple sources
  - Lack of industrial or military specification
  - Downstream processing not understood: cutting, machining, joining, coatings, etc.
  - Effort needed to develop the above is not insignificant

Titanium is already there!

Improved fuel economy

Credit: USMC - Lance Cpl. Kelly R. Chase

- Cost of fuel in theatre
  - $40.00 per gallon average

    (CNN report, August 17, 2011)
- 1 out of 8 casualties in Iraq were associated with Convoys
  - Not all convoys carried fuel exclusively
- Improved mileage due to reduced weight –BAE Systems Study
  - Roughly 1 MPG for tracked combat infantry fighting vehicle
  - Infantry Fighting Vehicle study indicated 1.7% of fuel savings for each 1000 pounds of weight reduction
  - Replacing majority of steel armor with Ti could readily achieve about 4000 pound weight reduction
    - 6.8% fuel economy improvement
  - $19,000 saved per vehicle lifetime in fuel costs
  - Reduced weight also significantly reduces wear on suspension components

Potential Future Ground Applications

- Ground Combat Vehicle
  - Delayed by protest
- Joint Light Tactical Vehicle
  - Still under competition for EMD phase
- Marine Personnel Carrier
  - In development
- Bradley Infantry Fighting Vehicle
  - Survivability upgrades hitting upper weight limit
- Armored Personnel Carrier Replacement
- Paladin Integrated Management
  - Self propelled next generation howitzer
- Expeditionary Fighting Vehicle
  - Marines seeking replacement
- Amphibious Assault Vehicle
  - Survivability upgrades planned

Many opportunities for titanium






New technologies discussed at ITA-2011

- Solid state powder metallurgy processes maturing for sheet and plate
  - Near Net Shape Processing
  - Roll compaction
  - HIP
  - PIF
- Non-Kroll manufacturing processes developing
  - Hunter
  - Hydrogenated Dehydrogenated Powder
  - FFC Cambridge
- Continuous cast billet

Opportunities and Challenges – Ground Combat Vehicles

- Despite declining defense budget, as many new vehicle programs or upgrades are on the horizon as ever
- Increased armor protection at lightest weight is a requirement across combat and tactical platforms
- Argument that titanium is ‘expensive’ compared to incumbent materials- needs to be evaluated relative to life cycle cost
  - Several $M vehicle could have as much as 10,000 pounds of Ti for armor or structure which represents less than 10% of the acquisition cost
  - Enables armor protection, mobility, fuel economy, reduced maintenance
- New technologies for lower cost production will help

U.S. Combat Systems Commitment

We Protect Those Who Protect Us

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