Metallic Materials & Processes

Enabling Lightweight System Initiatives

Alcoa – Howmet

Presentation at NDIA
GARM SYMPOSIUM
27 APRIL 2005

Purpose

- **Establish that Metallic Materials and processes are key enablers for achieving development and production objectives for Lightweight systems**
- **Illustrate that Lightweight Initiatives are enabled by:**
  - **Materials technology**
  - **Innovative processes**
  - **A total systems approach**
  - **Rigorous cost value analysis**
- **Confirm that a balanced approach to design, materials, processes, and cost will enable solutions**

Objectives

- **Demonstrate that advances in Titanium alloys and processes have resulted in**
  - **Meeting Lightweight Systems objectives and**
  - **Offering direct applications for achievement of key challenges in armament and protection systems**
- **Illustrate that "new" aluminum alloys offer mechanical properties and other characteristics which will meet design/performance challenges**

Challenges

- Lightweight materials with application specific properties
- Forming high precision complex geometric shapes/contours repeatedly
- Reducing part count – improving manufacturability
- Achieving wrought properties with cast materials
- Introducing “new” materials and processes via concurrent engineering
- Lead-time reduction

Enablers

- "New" alloys responsive to application needs
- Quality control of complex processes
- Stereolithograhy enabled schedule and cost reductions
- Castings yielding near wrought properties
- Demonstrated capability to form complex parts at near net shape – reducing part count, lead time, cost, etc.
- Expanded metals industry links to applications engineering

Applications

- Weapon structures and mechanisms
- Muzzle brakes
- Projectile components
- Warheads
- Structural elements
- Propulsion modules
- Protection systems (armor)

Realizing the Benefits

- **Lightweight Systems Initiatives are critical to the development and realization of enhanced legacy systems and supporting Transformation goals.**
- **Advanced Metallic Materials and Processes have been and are being applied successfully to meet requirements and enable superior Combat operational capability resulting from light weight.**

Alcoa Capabilities

- Aluminum Sheet & Plate
- Aluminum Extrusions
- Titanium, Aluminum & Superalloy Investment Castings
- Aluminum Sand Castings
- Titanium, Aluminum & Superalloy Forgings
- Advanced Titanium, Aluminum & Superalloys
- Enclosures
- Prime Services
- Machining
- High Temperature & Wear Resistant Coatings
- High Technology Fasteners
- Design

Howmet Castings – Overview

- **Leading Manufacturer of Titanium, Aluminum and Superalloy Precision Investment Castings**
  - **Military & Commercial Engines and Airframes**
  - **Lightweight Armament**
  - **Missiles and Munitions**
- **Total Solution Provider**
  - **Machining, Coating (high temp and wear resistant), Supply Chain Management and Design Services**
- **Supplier of Superalloy and Titanium Ingots, Ceramic Cores and Crucibles, and Advanced Tooling**
- **Headquartered in Cleveland, Ohio**
  - **Part of Alcoa Investment Cast and Forged Products**

Examples of Titanium & Aluminum Castings

Titanium Armament

- **Market need for light-weight artillery**
  - **Greater transportability/ rapid deployment**
- **Cast titanium offers:**
  - **Light weight and high strength**
  - **Lower cost than fabrications**
  - **Reduced manufacturing time**
  - **Potentially better performance than fabrications**

M777 Howmet Titanium - In The News

- *Machine Design* November 2003
- *Modern Casting* December 2003
- *Engineered Casting Solutions* Winter 2004
- *Marine Corps Gazette* June 2004
- *Materials World* June 2004

Engineered Casting Solutions – 2004


ENGINEERED CASTING SOLUTIONS

Military Makeover
the Investment Casting Way

The introduction of thin-walled titanium castings improved the manufacturability, affordability and quality of the LW155 Howitzer.

Christopher Hatch, U.S. Marines, Picatinny, New Jersey
Robert Nestor, U.S. Army Industrial Ecology Center Casting Emission Reduction Program, Picatinny, New Jersey

The successful implementation of thin-walled titanium investment castings has been crucial in achieving full-rate production requirements of the howitzer while maintaining quality.

The Transformation

The Lightweight Howitzer Program

Co-Author: **Robert Nestor**
US Army Industrial Ecology Center, Casting Emission Reduction Program

"The successful implementation of **thin-walled** titanium castings has been **crucial** in achieving **full-rate production** requirements of the howitzer while **maintaining quality**."

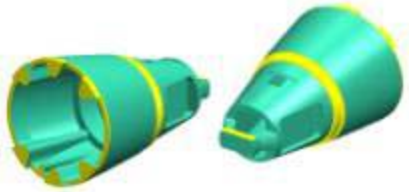
M777 Part Count Reduction*

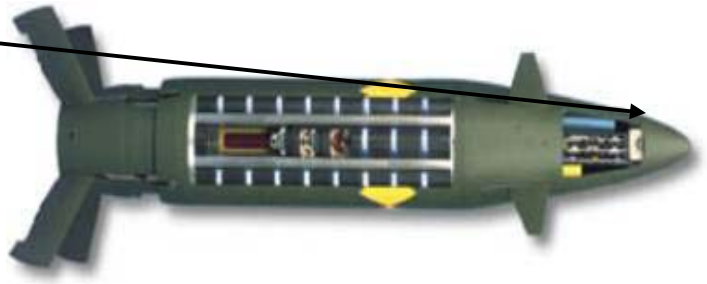
Titanium Structure	Fabrication	Casting	Reduction
Cradle	324	172	47%
Body	215	11	95%
Saddle	116	5	96%
Stabilizers	70	2	97%
Spades	120	2	98%
Trails	98	2	98%
Elevating Yoke	19	1	95%
Buffer Yoke	11	1	91%
Total	973	196	80%

*http://www.machinedesign.com/ASP/strArticleID/56460/strSite/MDSite/viewSelectedArticle.asp

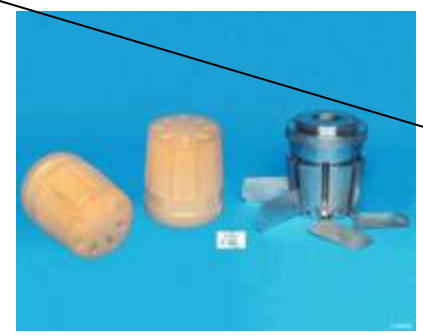
Projectile Castings

Nose Cone



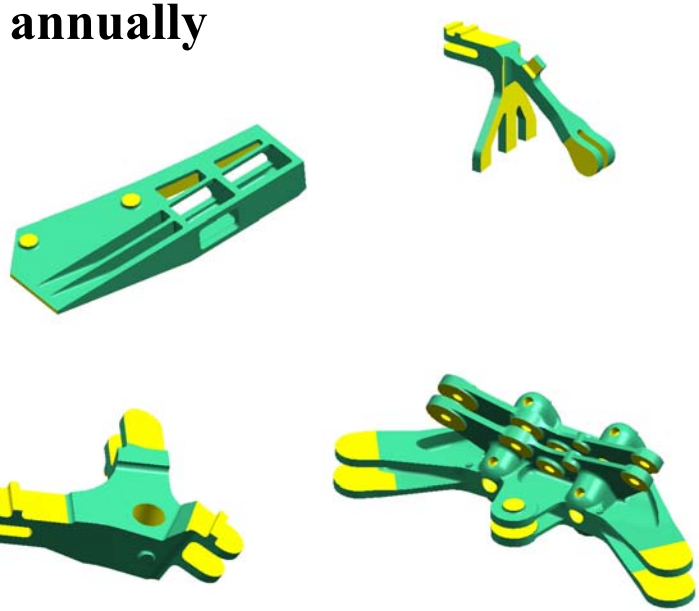


Base

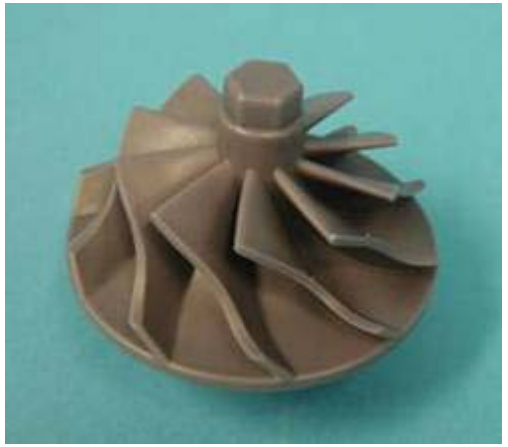


Examples of Other Titanium Parts

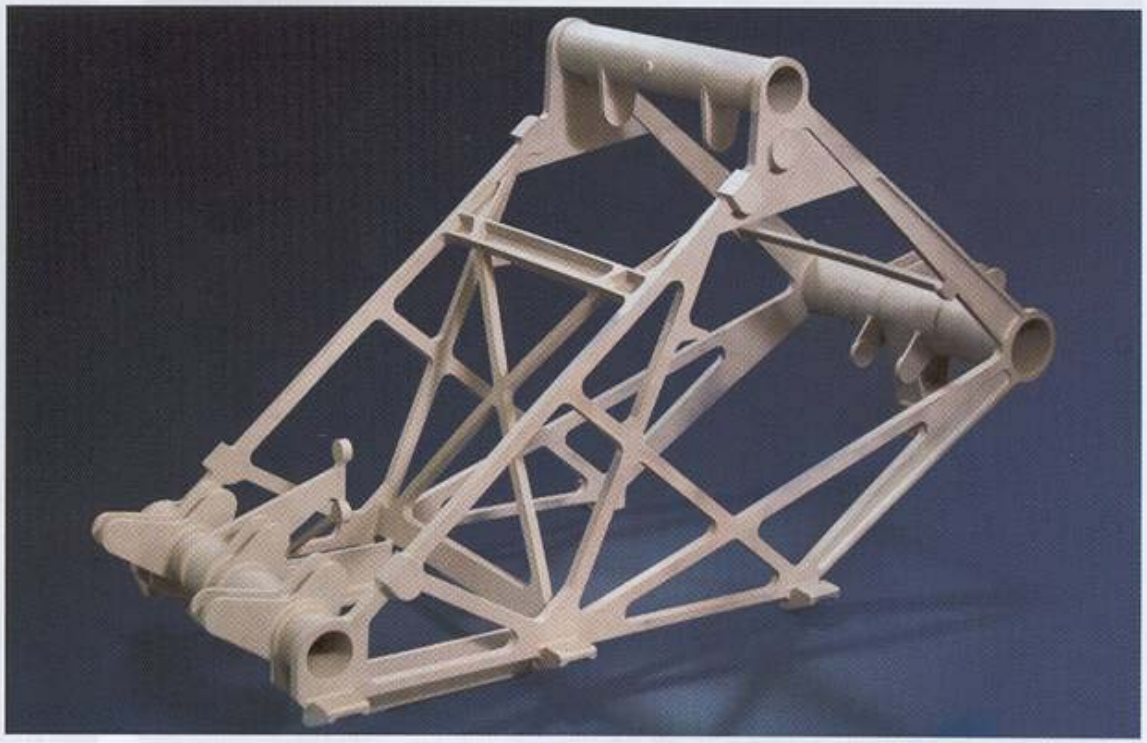
- HTC currently ships >$2M of brackets, mounts and clevises annually



- HTC will ship >$7M in turbocharger wheels for the commercial transportation market this year (~117,000 units)



Examples of Aluminum Castings



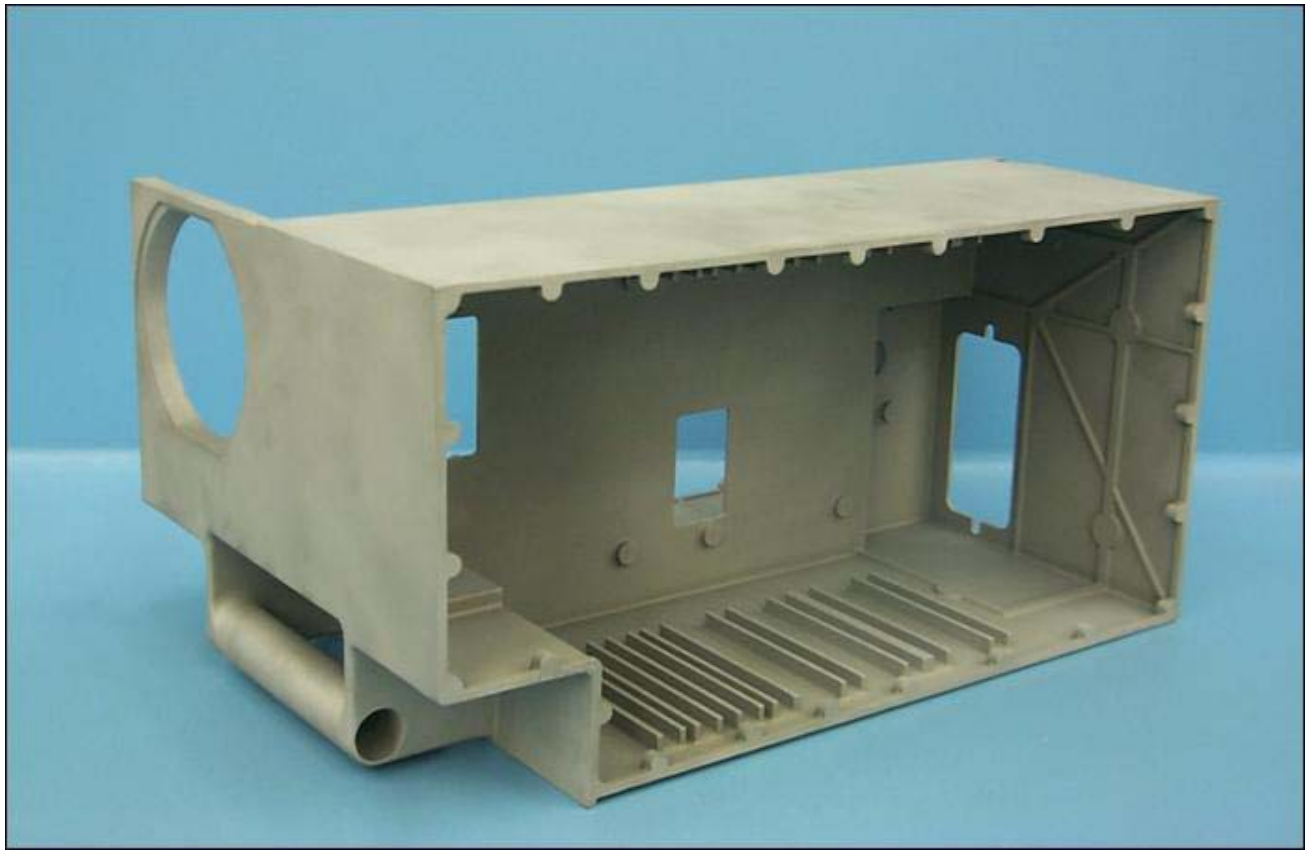
Howmet's Bethlehem Casting Component
Eliminates 50 Man-hours of Assembly

Dimensions: 36" x 24" x 14"

Large Structural Aluminum Parts

Dimensions: 48” x 20 dia”

Electronic Enclosures



Investment Casting Process

Rapid Prototype can be used instead of tooling


Die Construction


Wax Injection


Wax Assembly


Shell Build


Dewax

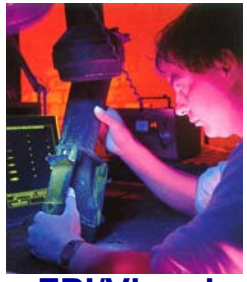

Casting


Shell Removal


Cut-off


Heat Treat


Finishing


FPI/Visual


X-Ray Inspection

Casting Capabilities – Aluminum/Titanium

Process	Material	Pour Capacity	Working Envelope
Aluminum	200 and 300 series aluminum	750 lbs	48” x 75”
Small Titanium	Ti 6-4, Ti 6-2-4-2, Ti 5553	200 lbs	<32” diameter
Large Titanium	Ti 6-4, Ti 6-2-4-2, Ti 5553	1,600 lbs	<62” diameter

Advancements in Investment Casting

- **Exciting "New" Alloys**
  - **Cast titanium with forged properties**
  - **High strength aluminum casting alloy under development**
- **Automation/Robotics Enabling Efficient High Volume Production**
  - **Satisfying demands for commercial transportation vehicles**
- **Ability to produce very small and large 3D single piece castings**
  - **Titanium parts up to 62" in diameter**
  - **Aluminum parts up to 70" in length**
- **Lead times down from 16 weeks to 4-6 weeks**
- **Development hardware available in a few weeks utilizing SLA and electronic technologies**

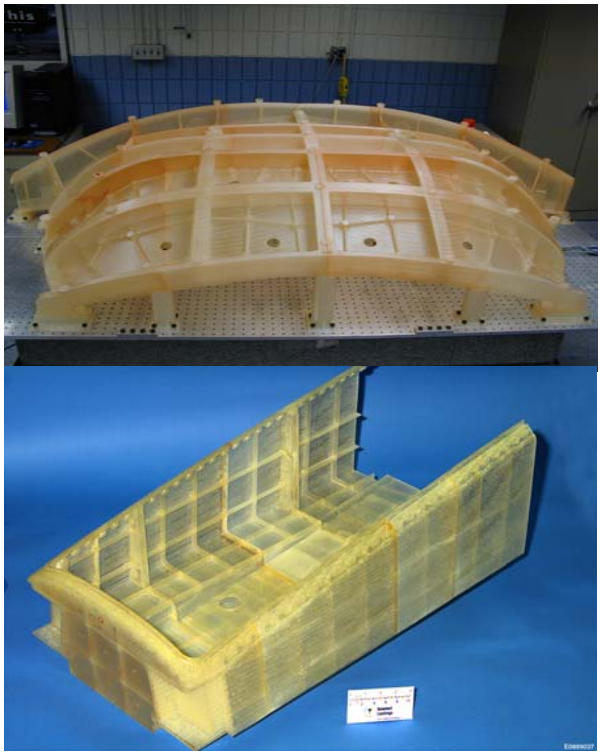
Cast Material Properties

Titanium				
Alloy	Treatment	σ_{uts} (ksi)	σ_y (ksi)	% el.
Ti 6-4	HIP+Anneal	130	120	6
Ti 6-2-4-2	HIP+Anneal	125	115	8
Ti 5553	Stabilized	168	153	9

Aluminum				
Alloy	Treatment	σ_{uts} (ksi)	σ_y (ksi)	% el.
A356	T6	32-45	28-34	3-5
D357	T6	45-50	36-40	2-3
C355	T6	41-50	31-40	2-3
A201	T7	60	50	3-5

Development Capabilities

- Pre-Production Use of Electronic Data
  - Solidification Modeling
  - Concurrent Engineering
  - Wax Tooling
  - Inspection
- Rapid Prototyping
  - SLAs
  - Complex Pattern Fabrications
  - 1-2 Week Lead-times
  - Electronic Files are Critical



Evolution of Alcoa Design Activities

Audi Space Frame → A3I → ALSI

ALSI Objective

To integrate Alcoa's *proven* capabilities into the design of *new* and *legacy* military ground vehicles:

- Design methodology
- Depth of material expertise
- Breadth of manufacturing capabilities

ALSI Goal

To partner with military ground vehicle OEM's to provide the Army with *cost-effective weight reduction* through the implementation of Alcoa/OEM solutions.

GOAL: 25%-50% reduction in weight
(system dependent)

Conclusions

- **Advanced Metallic Materials have enabled achievement of key lightweight system initiatives and are in the process of supporting others**
- **Capabilities are evolving and focused to meet needs of armament and protection community by addressing**
  - **Materials technology – to achieve desired properties**
  - **Processing technology – to ensure effective integration in complex configurations at an affordable cost**
  - **Design expertise – to assist OEM's in meeting their lightweighting goals in a cost-effective manner**