O'FALLON CASTING
NONFERROUS INVESTMENT CASTINGS
600 Cannonball Lane
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Cost Factors of Aluminum Investment Castings

Bruce Willson

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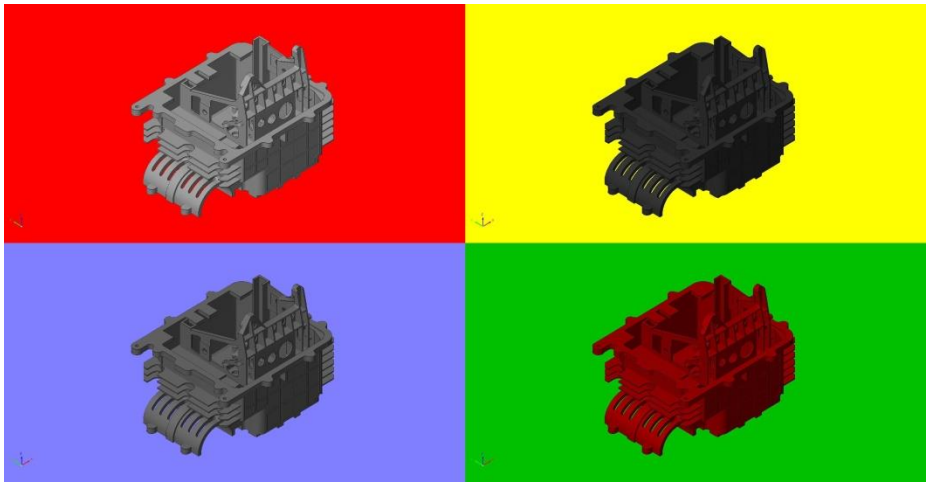
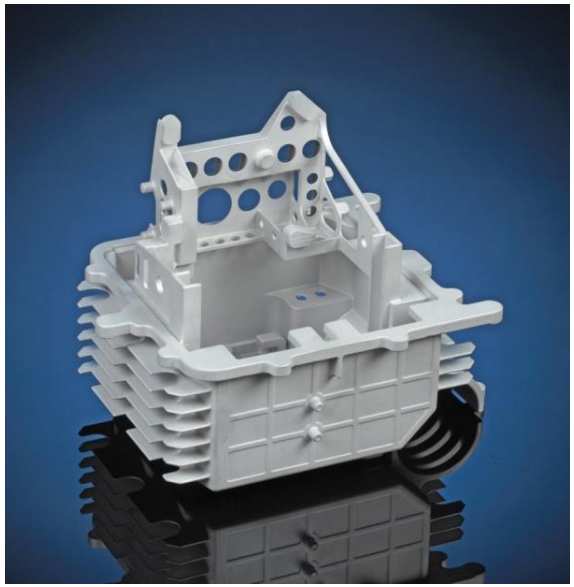
Castings present a cost effective solution for the manufacture of Near Net complex shapes that reduce Part Count of an assembly and improve the affordability, manufacturability and reliability of the end product



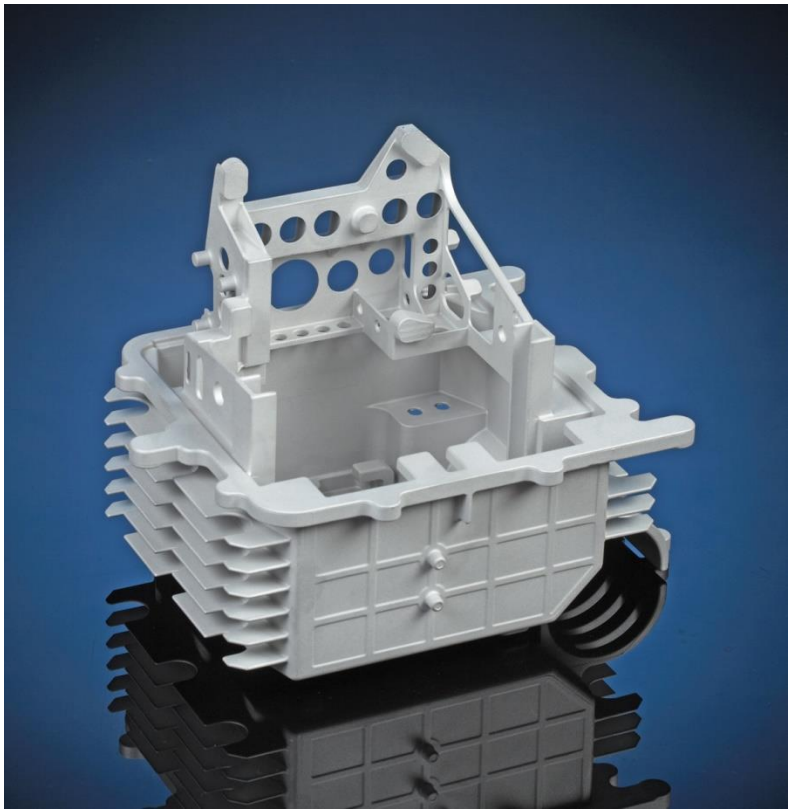
Cost Factors of Aluminum Investment Castings

- Castings present an opportunity to Enhance VALUE
  - 70 – 95% of a Product Cost is a function of Design Decisions
  - Castings are a Custom Product
  - Casting Design & Procurement requires some specialized expertise



Cost Factors of Aluminum Investment Castings

- Cost Factors relative to the VALUE they represent



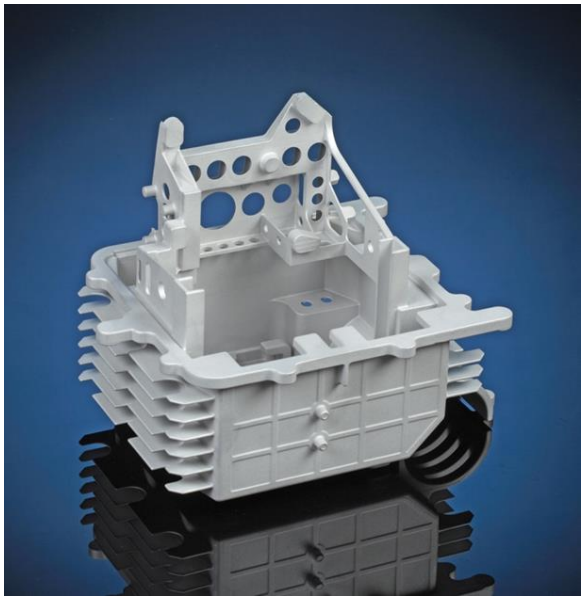
AFS/MCDP – 2013 Casting of the Year

Shoe Box

Cost Factors of Aluminum Investment Castings

- Context
  - What is an Investment Casting
  - Strengths & Weaknesses of Investment Casting

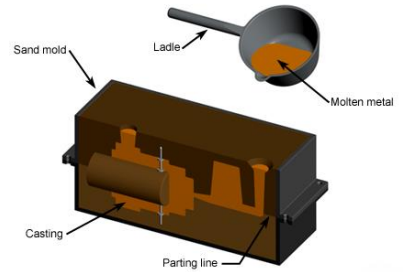
- Discuss various Cost Factors
  - Nonrecurring Tooling expense
  - Premium Tolerances
  - Inspection Requirements
  - Pieces per Sprue
  - Scrap – Yields - Rework

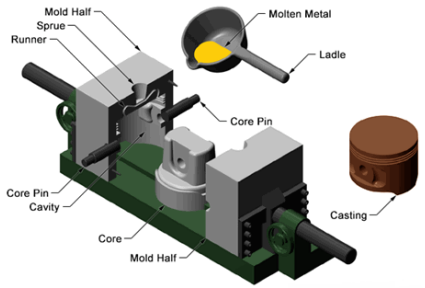


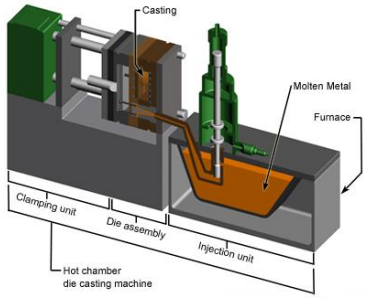
- Lessons Learned
  - Increase the Value of your Casting Purchases

Foundry Processes

- **Sand Casting Processes**
  - Green Sand
  - Chemically Bonded Sand
    - Gas Catalyzed / Coldbox Systems
    - Shell Process
    - Nobake / Airset Systems
  - Unbonded Sand
    - Lost Foam
    - V-Process
- **Permanent Mold Processes**
  - Die Casting
  - Permanent Mold Casting (Gravity Diecasting)
  - Low-Pressure / Vacuum Permanent Mold Casting
- **Ceramic & Plaster Processes**
  - Investment Casting
  - Ceramic Molding
  - Plaster Molding

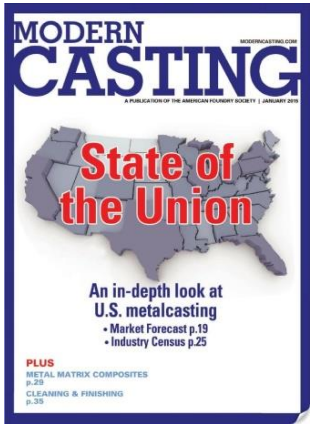






Cost Factors of Aluminum Investment Castings

- **Modern Casting – January 2015**
  - 800 US Foundries cast Aluminum Alloys
  - Aluminum the 3rd most commonly cast metal



- **Investment Casting Institute – IC Sales %**
  - Superalloy 56.9%
  - Steel 25.2%
  - Titanium 10.3%
  - Aluminum 5.4%
  - Copper 2.3%

Cost Factors of Aluminum Investment Castings

- **Primary Value provided by Investment Casting is twofold**
  - Near Net Shape
    - Reduce Secondary Machining
  - Part Count Reduction
    - One Piece structures that reduce Assembly Operations

- **Aluminum IC is primarily about Part Count Reduction**
  - Aluminum is readily castable & machinable
  - Greater density of competing processes
    - Die Casting
    - Machined “Hog Outs”
  - Increased dependency on customer skill to design for IC

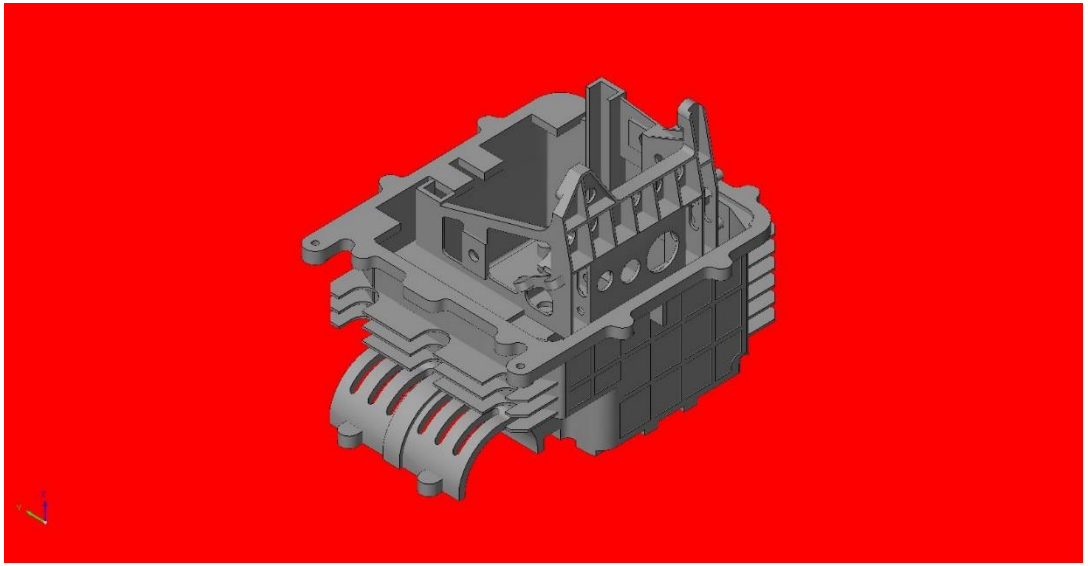
Cost Factors of Aluminum Investment Castings

- **Definition:** Investment Casting is a foundry process by which a cast metal part is produced from a ceramic (investment) mold that has been formed by a disposable (wax or plastic) pattern.
- Prior to World War II Investment Casting was largely used for the manufacture of Jewelry & Art
- Investment Casting became industrialized to produce Near-Net-Shape cobalt based components for aircraft in the 1930's

"Perseus with the Head of Medusa"
Benvenuto Cellini
Bronze, 1545

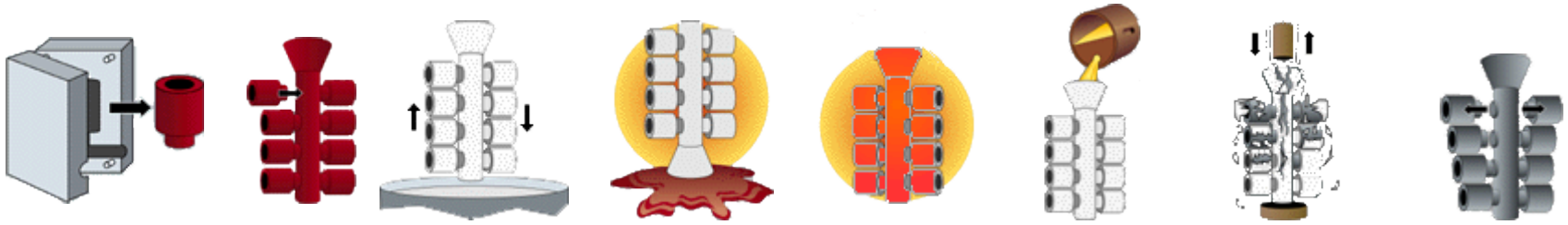
Cost Factors of Aluminum Investment Castings

The Investment Casting Process



Investment Casting Process

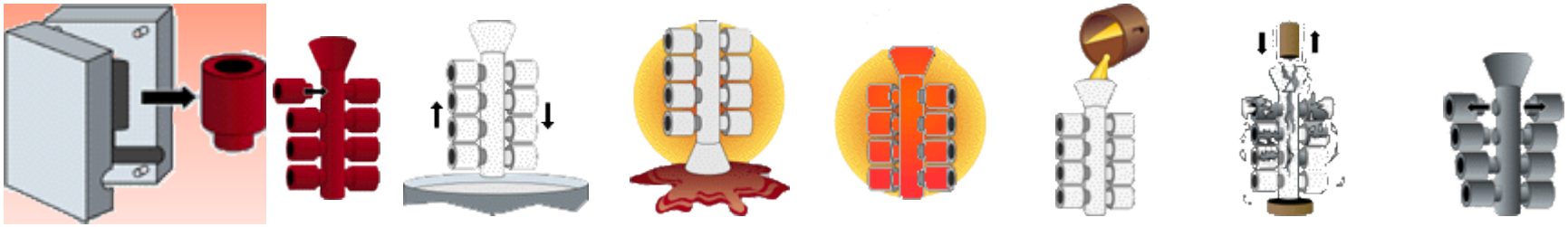
- Eight basic steps to Manufacture an Investment Casting



http://www.investmentcasting.org/video.asp

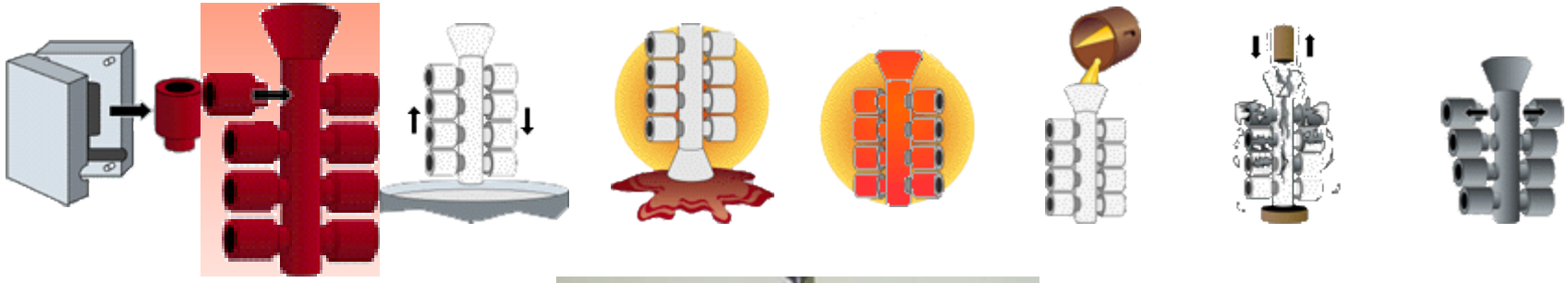
Investment Casting Process

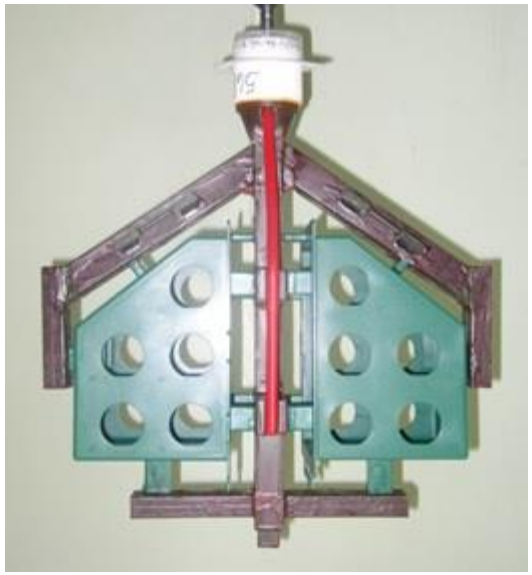
- Step 1: Produce a disposable (wax) pattern from mold



Investment Casting Process

- Step 2: Assemble multiple patterns to gating system

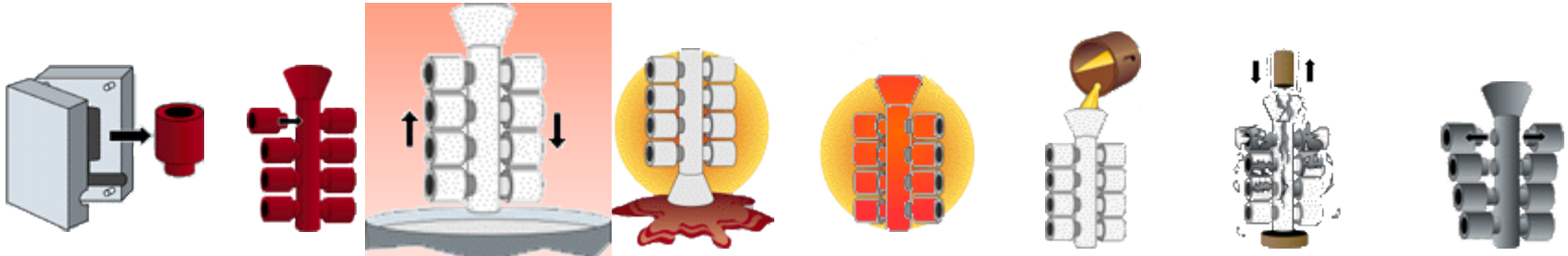




Wax Pattern Assembly

Investment Casting Process

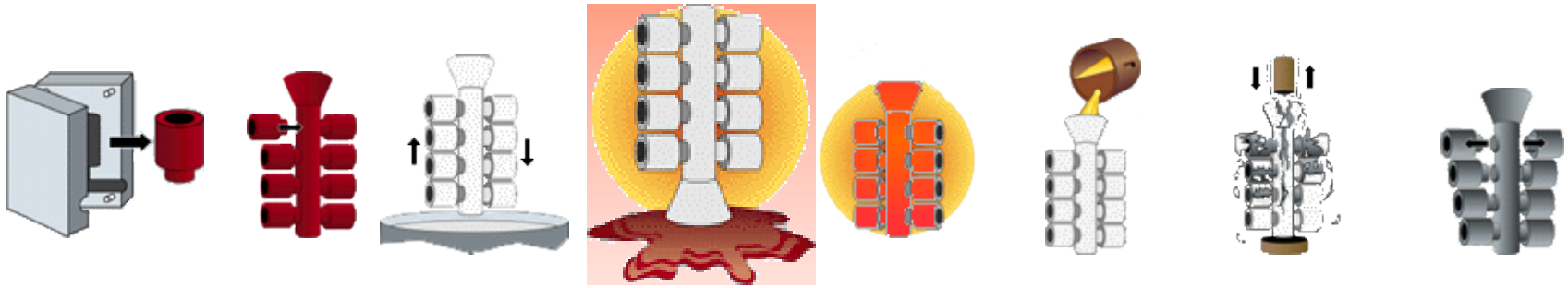
- Step 3: Form Ceramic Shell around Wax Assembly



Layer of Ceramic Shell being applied by robot

Investment Casting Process

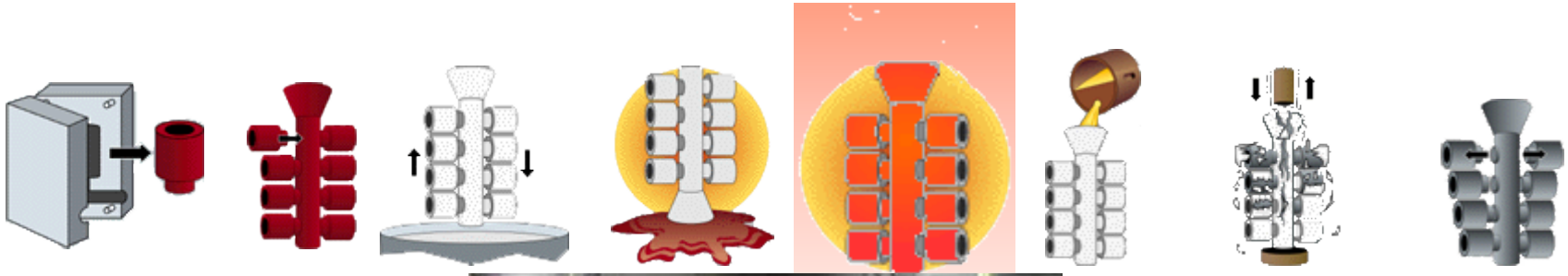
- Step 4: De-Wax Ceramic Shell



Steam Boilerclave to de-wax shell

Investment Casting Process

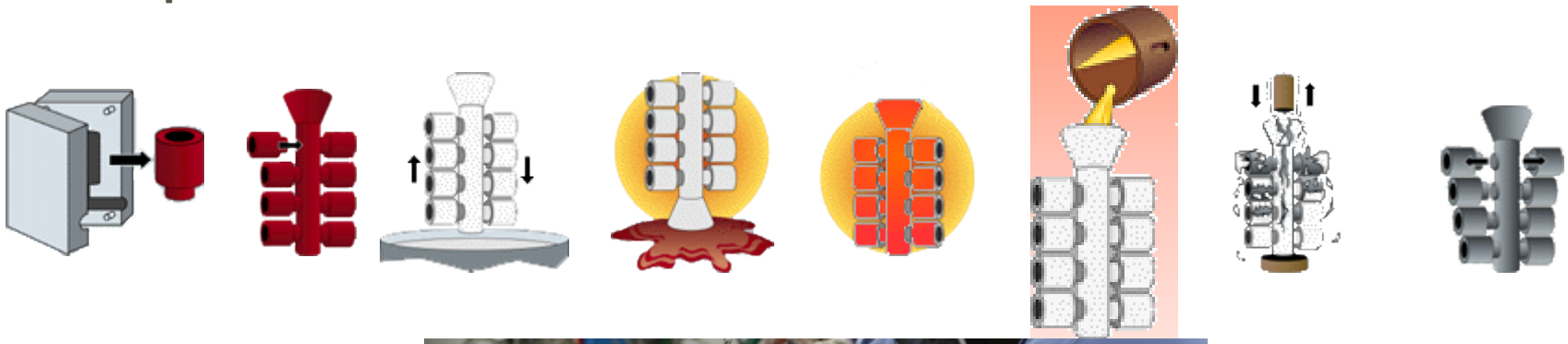
- Step 5: Fire the Ceramic Shell



Ceramic Shells being Fired

Investment Casting Process

- Step 6: Cast metal into fired Ceramic Shell



Casting Ceramic Shell with Ladle

Investment Casting Process

- Step 7: Remove Ceramic Shell from solidified metal

Removing Ceramic with Water Blast

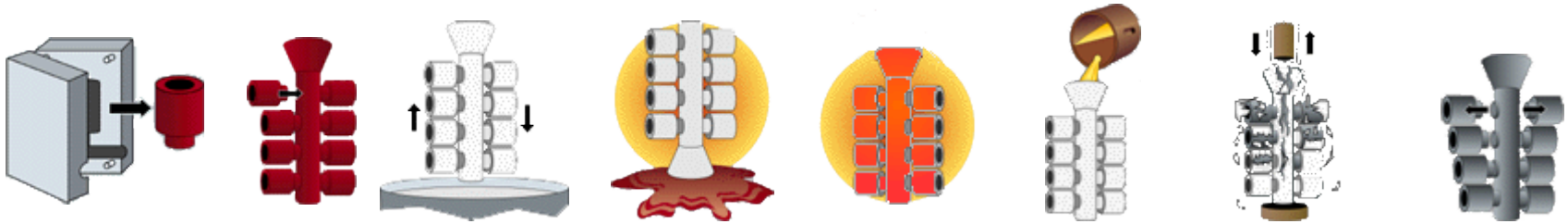
Investment Casting Process

- Step 8: Separate Castings from runner system

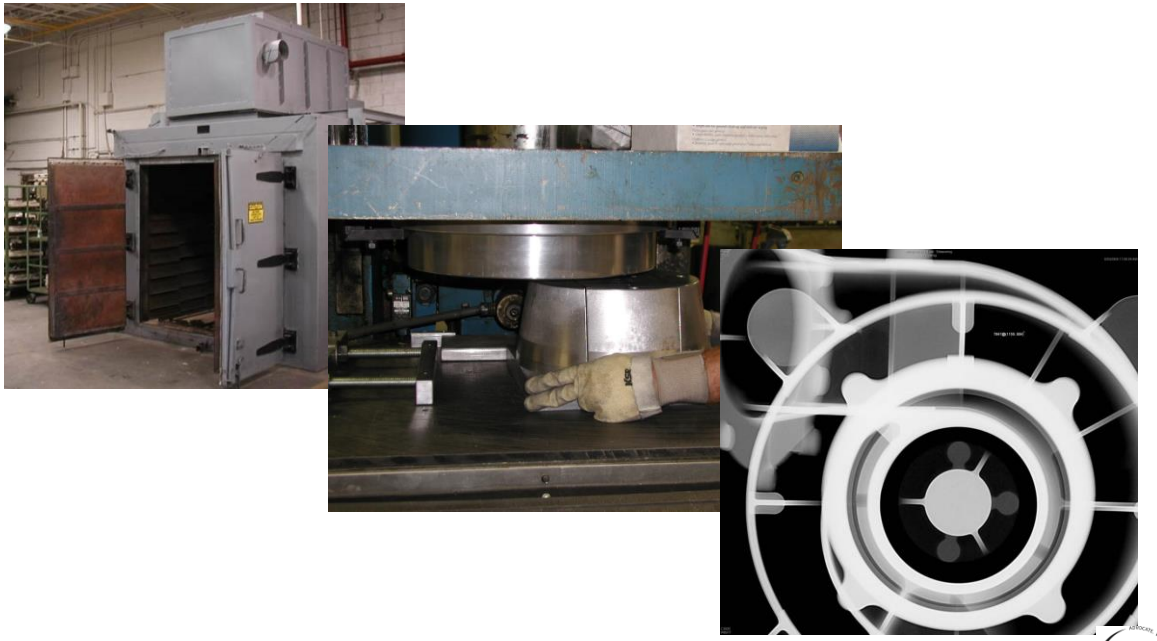
Cut-off operation with band saw

Investment Casting Process

- With Aluminum castings there are additional operations:

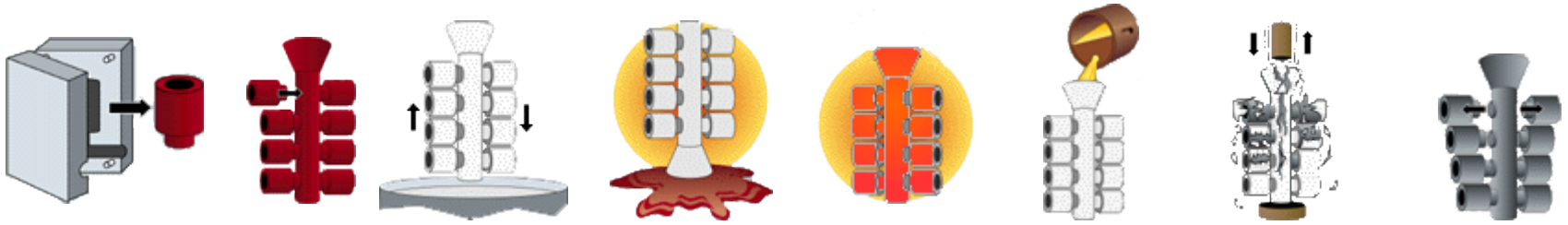


- Heat Treatment
  - Solution Anneal
  - Artificial Aging
- Straightening
- Final Inspection
  - Dimensional
  - NDT



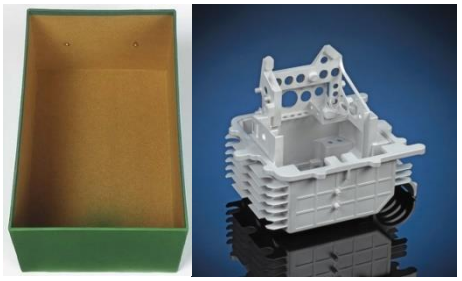
Investment Casting Process

- Eight basic steps to Manufacture an Investment Casting



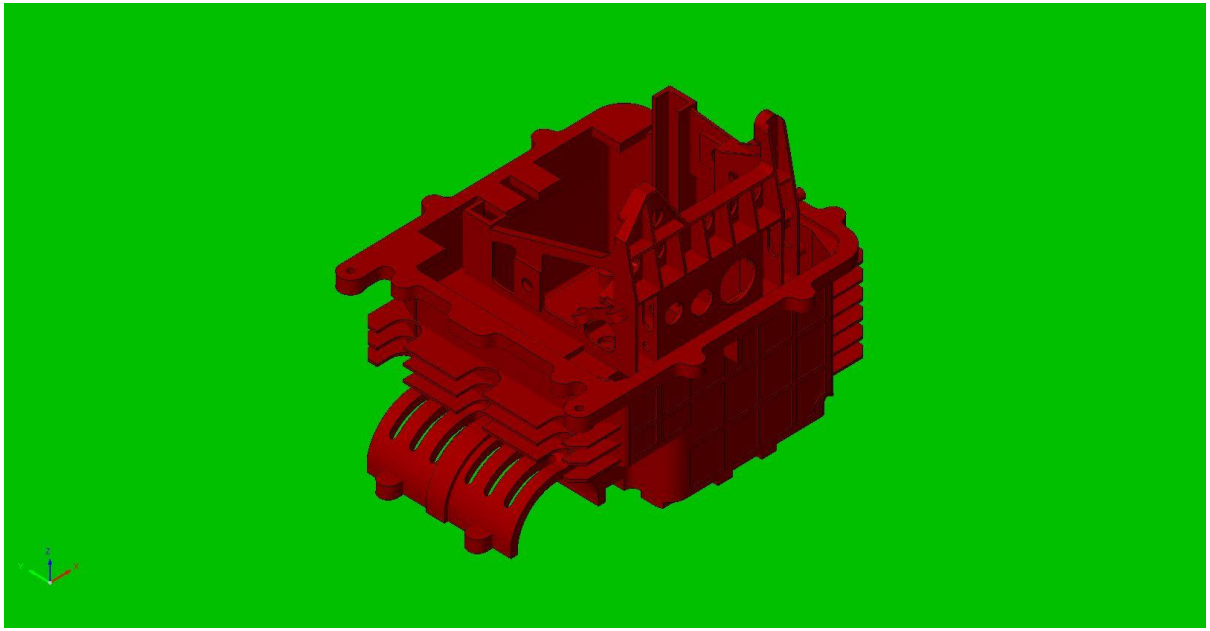
For the majority of process steps Investment Castings are handled as SPRUES and not as individual PARTS.

Process is less sensitive to part configuration



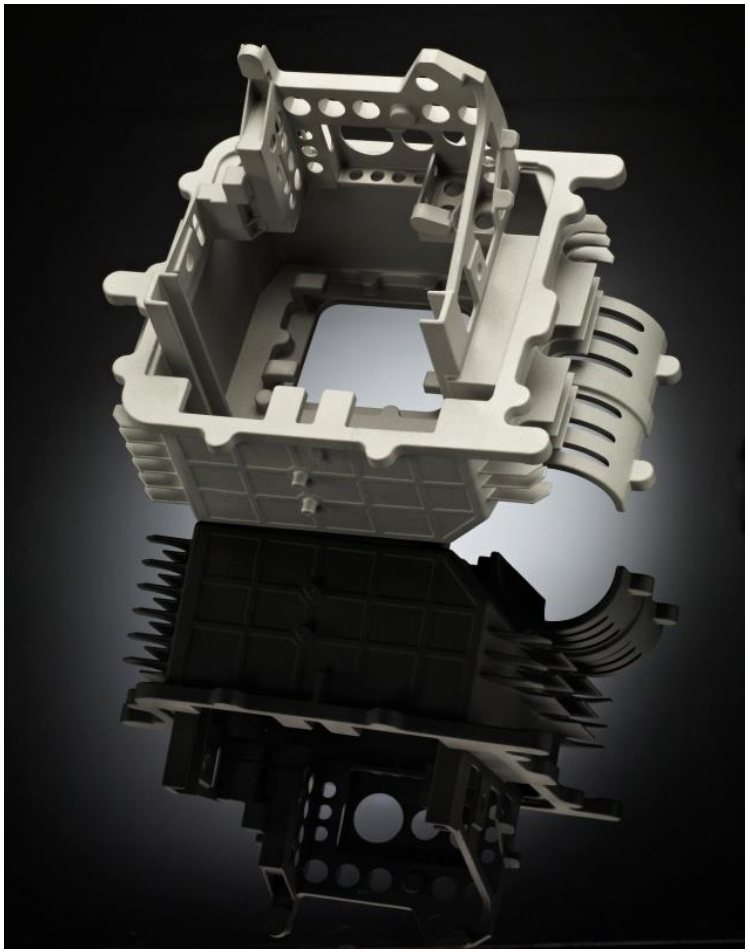
Cost Factors of Aluminum Investment Castings

Characteristics of Investment Casting



Investment Casting Strengths

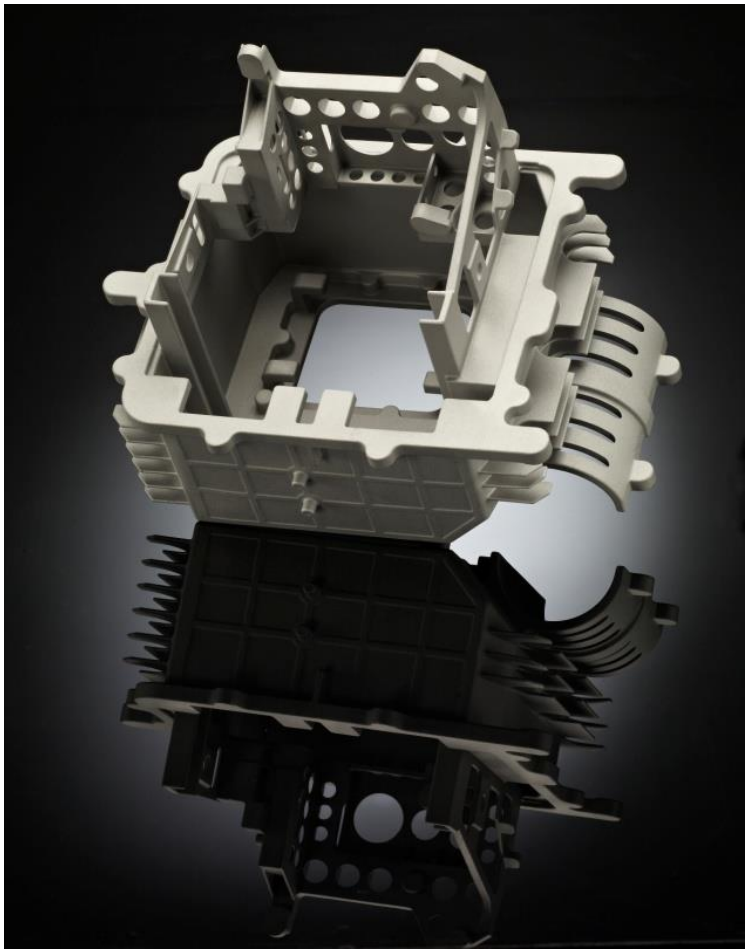
- **Complexity at Incremental Cost**
  - Combine multiple pieces into one
  - Reproduce fine detail
    - Contours and rounded surfaces
    - Undercuts
- **Near Net Shape**
  - Minimal stock allowance
  - Minimize secondary operations
- **Design Freedom**
  - No draft angle
  - Internal configuration
- **Low Initial Investment**
  - Moderate tooling costs



American Foundry Society
2013 – “Casting of the Year”

Investment Casting Weaknesses

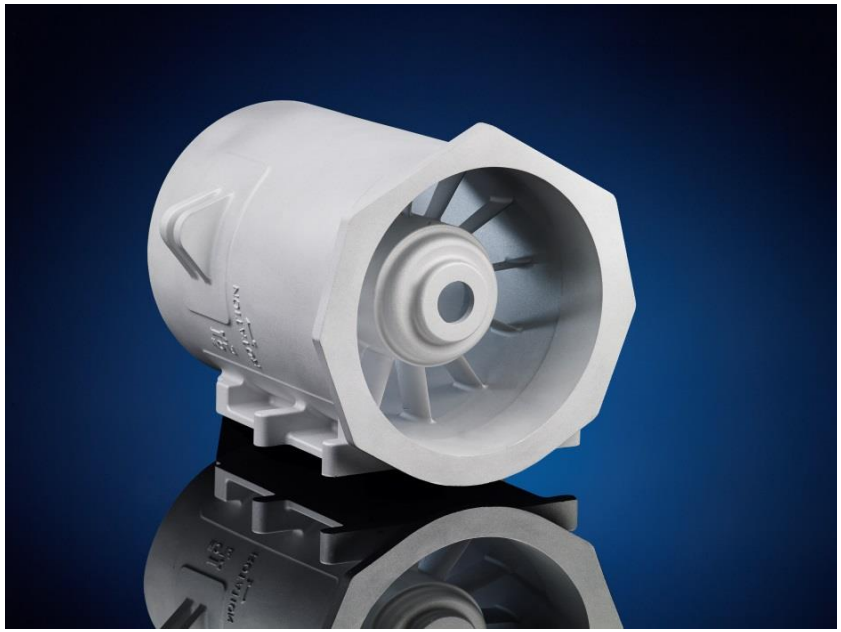
- **Multiple Process Steps**
  - More Labor Intensive Process
  - Higher per Unit Cost
- **Long Cycle Time**
  - Approximately 3-weeks from pattern injection to shipping



American Foundry Society
2013 – “Casting of the Year”

Characteristics of a Potential Investment Casting

- Alloy Machinability
  - Near Net Shape
  - Reduced Secondary Machining
- Eliminate Assembly & Fabrication
  - Reduction of Part Count
- Light Weight
  - Optimum wall .070 - .120”
- Cosmetic Appearance
  - 60 – 200 RMS
- Precision Tolerances
  - ±.005 inch per inch

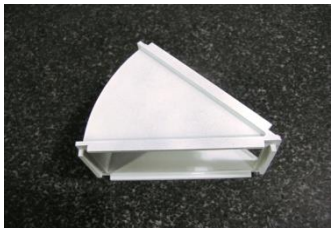


2014 – AFS/MCDP Casting of the Year Honorable Mention

Typical Nonferrous Applications

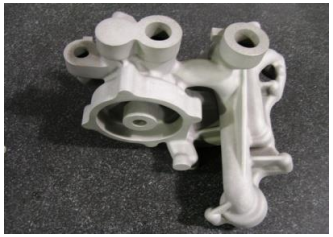
- *Electronic Boxes & Chassis*
  - *Part Count Reduction*

- *Microwave Bends*
  - *Tolerance*



- *Optics Housings*
  - *Thin wall to reduce weight*

- *Fluid Flow*
  - *Near Net Shape*



Cost Factors of Aluminum Investment Castings

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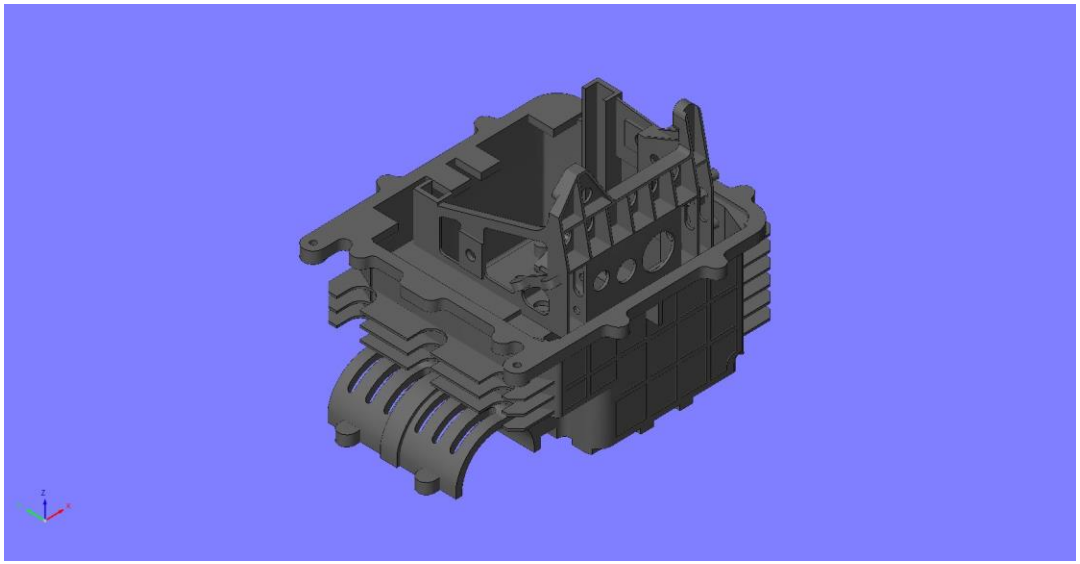


Cost Factors of Aluminum Investment Castings

- Typical Nonrecurring Investment Casting Tooling Costs
  - Wax Injection Pattern Mold
    - Aluminum
    - Manual, Semi-Automated, Automated
    - Single or Multi-cavity
  - Straightening Fixture
    - Hand
    - Compression (press) Fixture
  - Inspection
    - Tool Point – 6 Point Nest
    - Functional Gaging
  - Other
    - Cutoff Fixture
    - Gate Grind Fixture
    - First Article Inspection
    - Set-Up Charges

AFS/MCDP 2015 Casting of the Year Nominee

Cost Factors of Aluminum Investment Castings

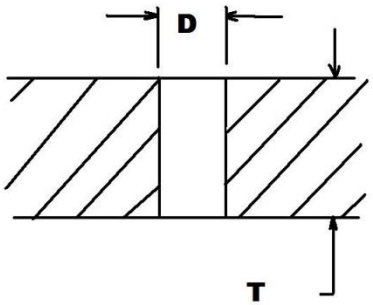
- Typical Direct Manufacturing Cost – Aluminum IC
  - 34% Material
    - Pattern Wax
    - Ceramic Shell
    - Metal
  - 66% Labor & Labor Overhead
    - Wages
    - Benefits

Cost Factors of Aluminum Investment Castings

- **Parts per Sprue**
  - Largely a Function of the Size of part
    - Gate into “Heavy” areas of configuration
  - More Pieces per Sprue = Lower the Unit Cost
    - Cast in Sprues – not as parts

Cost Factors of Aluminum Investment Castings

- Configuration
  - Generally less a cost driver if designed within industry guidelines
    - If the features allow for a robust ceramic shell to be built
      - Holes
      - Blind Holes
      - Slots
      - Undercuts



  - Extraordinary features may require additional effort
    - Soluble Wax Cores
    - Preformed Ceramic Cores

Cost Factors of Aluminum Investment Castings

- Yields - Scrap & Rework
  - Castings are a yielded process
    - Predictable yields are essential
      - Price
      - Delivery
  - Can be related to the Manufacturability
    - Example - Insufficient Fillet Radii

- Symptoms
  - Chronic missed deliveries
  - Short ship quantities
  - Price increases

- Work with foundry to improve Yields
  - Drawing Changes

Cost Factors of Aluminum Investment Castings

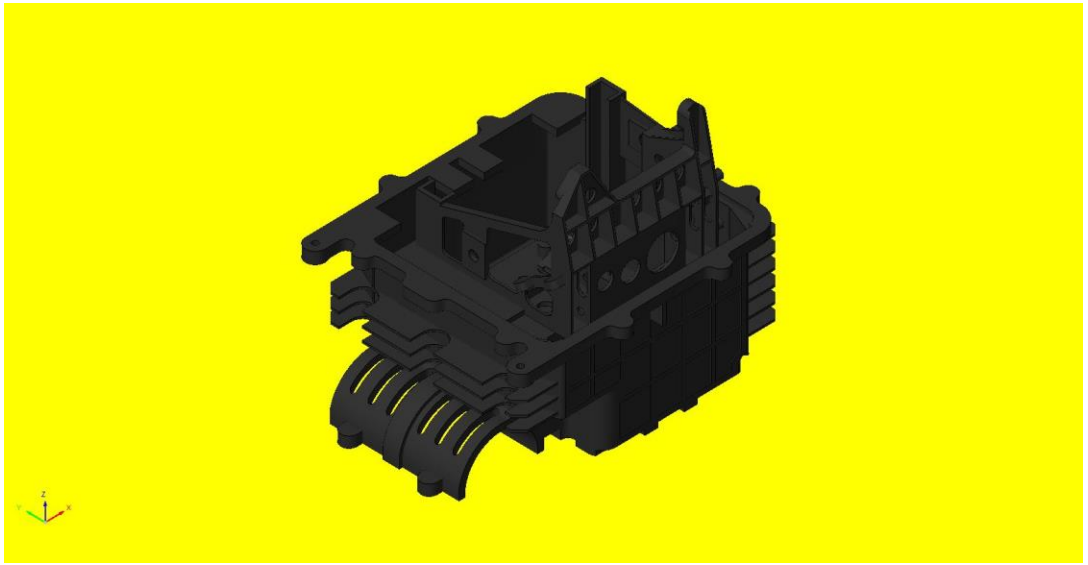
- Straightening
  - Most casting features are fixed in place by tooling
  - Flatness, Perpendicularity, Roundness, etc.
    - Geometry can be affected by configuration and processing
    - Straightening may be required to restore geometry
  - Premium tolerances can increase Straightening Effort

Cost Factors of Aluminum Investment Castings

- Inspection Requirements
  - Radiography
    - 14” x 17” film plus chemicals & processing
    - Digital Radiography for acceptance of product
  - Physical Property Testing requirements
    - Separate Test Bars
      - Most economical
      - Most consistent

Cost Factors of Aluminum Investment Castings

Lessons Learned

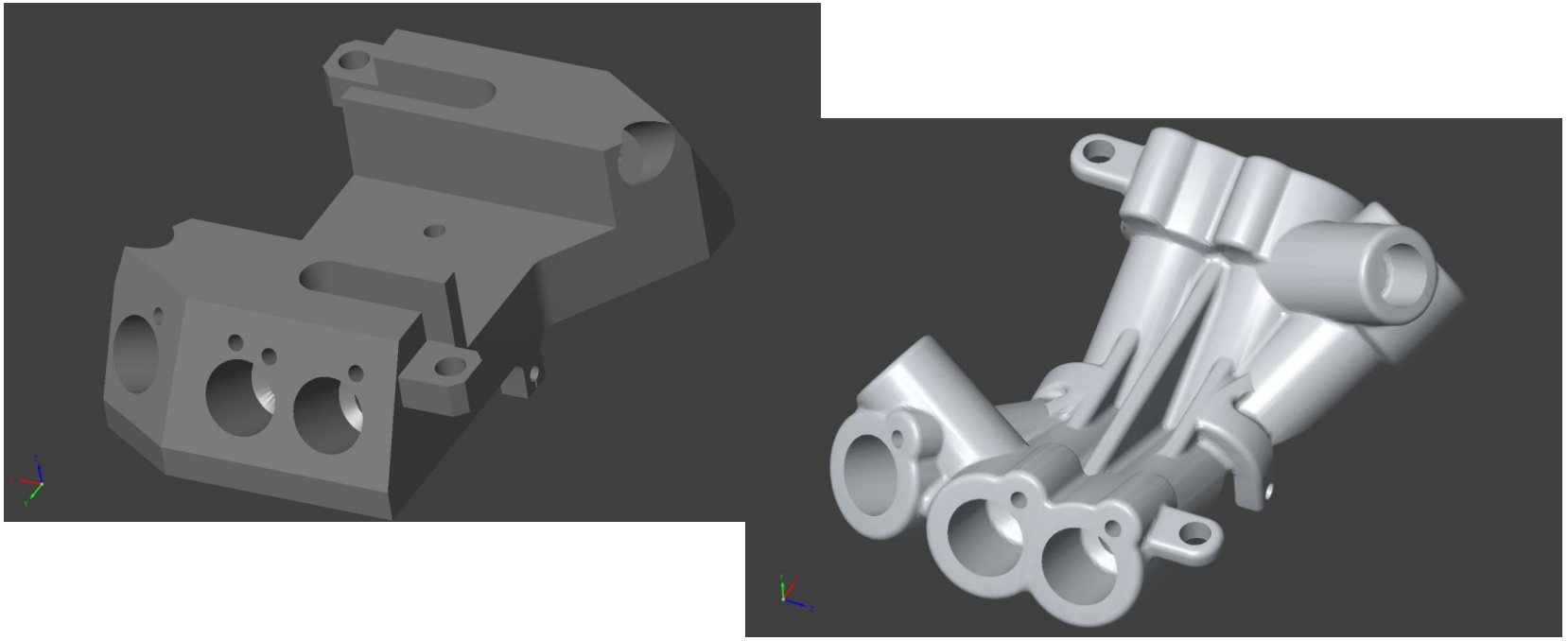


Cost Factors of Aluminum Investment Castings

- Share early market projections with suppliers
  - Annual Volume
  - Longevity
  - Allow suppliers to propose volume appropriate tooling
    - Minimizes Part Labor Content
    - Minimizes Part-to-Part Variation
    - Minimize Tool Wear

Cost Factors of Aluminum Investment Castings

- Casting Design & Purchasing requires specialized expertise
  - Grow Internal Expertise
  - Design for Manufacturability
    - Nature & Capabilities of Process
    - Solicit feedback from the Supply Base



Cost Factors of Aluminum Investment Castings

- Increase part Value - Design for Higher Levels of Complexity
  - Complexity cost is largely reflected in tooling cost & pattern injection
    - Once the pattern is formed, complexity less of a cost driver.
  - Part Count Reduction
    - Combine multiple piece structure into 1-Piece casting
    - Reduce the number of transactions
    - Reduce assembly time & expense
    - Reduce failure modes

Cost Factors of Aluminum Investment Castings

- Embrace Concurrent Engineering
  - Early Supplier Involvement with design
    - Opportunity to Reduce Part Count of Assemblies
    - Avoid incurring unnecessary “Designed-In” costs

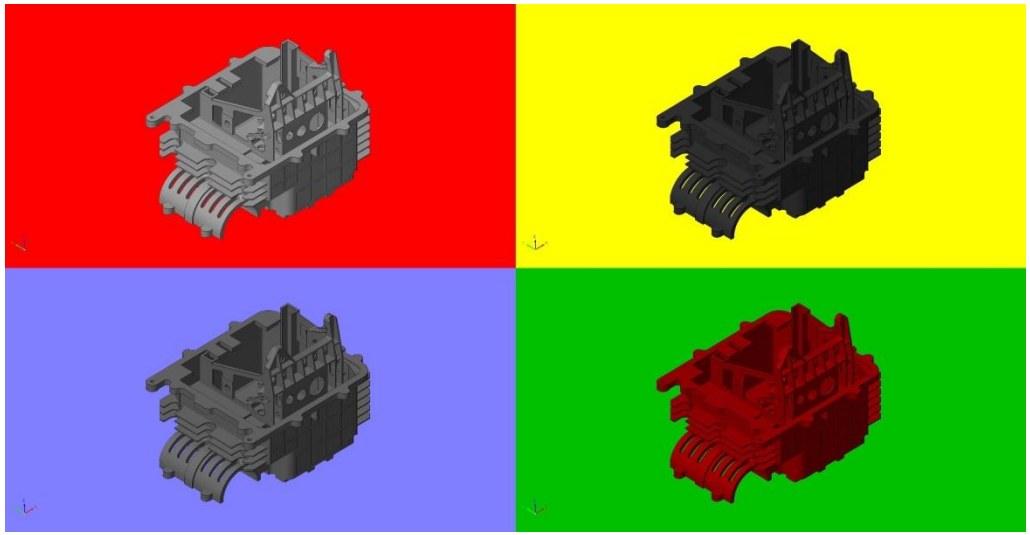
- Vendor & Industry Provided Educational Opportunities
  - Concurrent Engineering Service
  - IC-101
  - IC-201

Cost Factors of Aluminum Investment Castings

Castings present a cost effective solution for the manufacture of Near Net complex shapes that reduce Part Count of an assembly and improve the affordability, manufacturability and reliability of the end product.

Questions?

Thank You!



Contact

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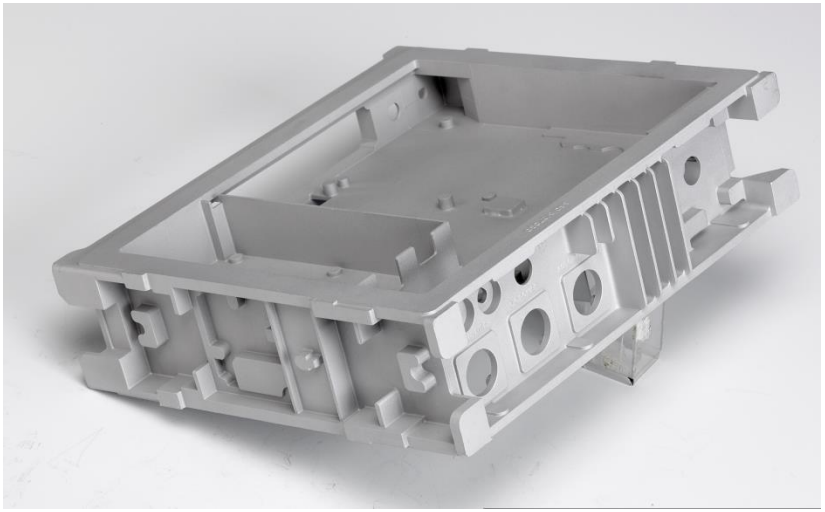

YouTube: http://www.youtube.com/watch?v=UEiuYo9L0Jk
http://www.youtube.com/watch?v=IbNqipic0g4