

- Manufacturing for Fuel Economy
- August 12, 2008

OUR BELIEFS

Respect

Collaboration

Excellence

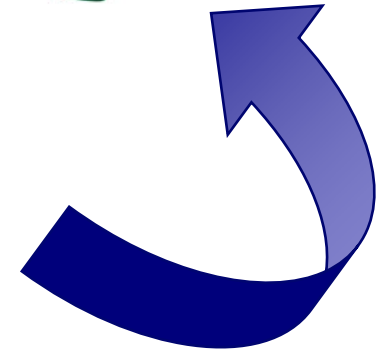
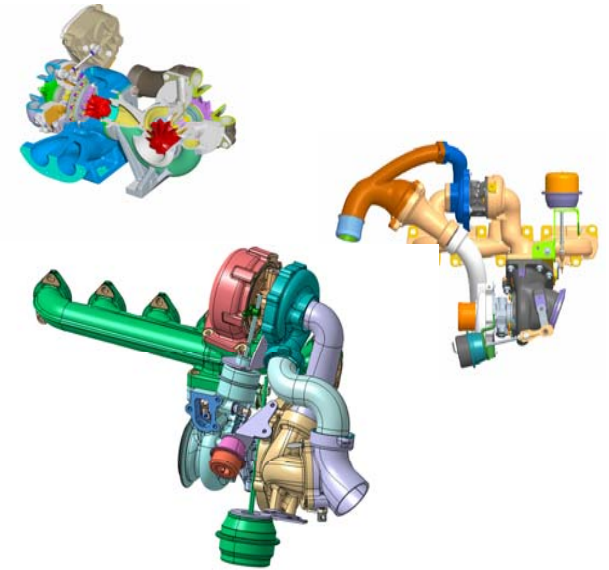
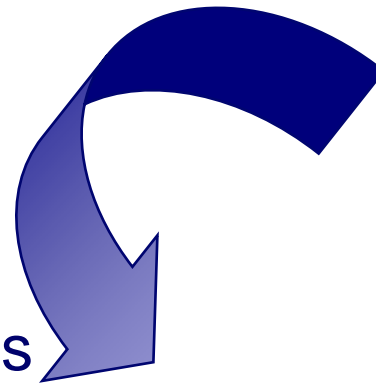
Integrity

Community

 **BorgWarner**

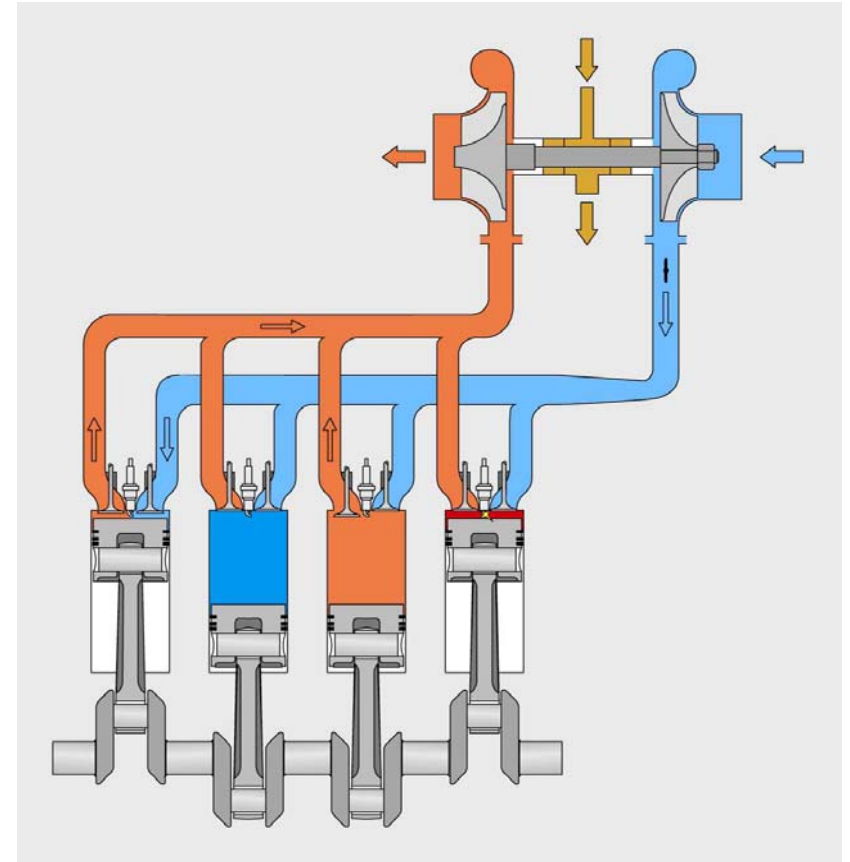
Agenda

1. Technical Need/Benefits
2. Market Outlook
3. History/Experience
4. Manufacturing Challenges



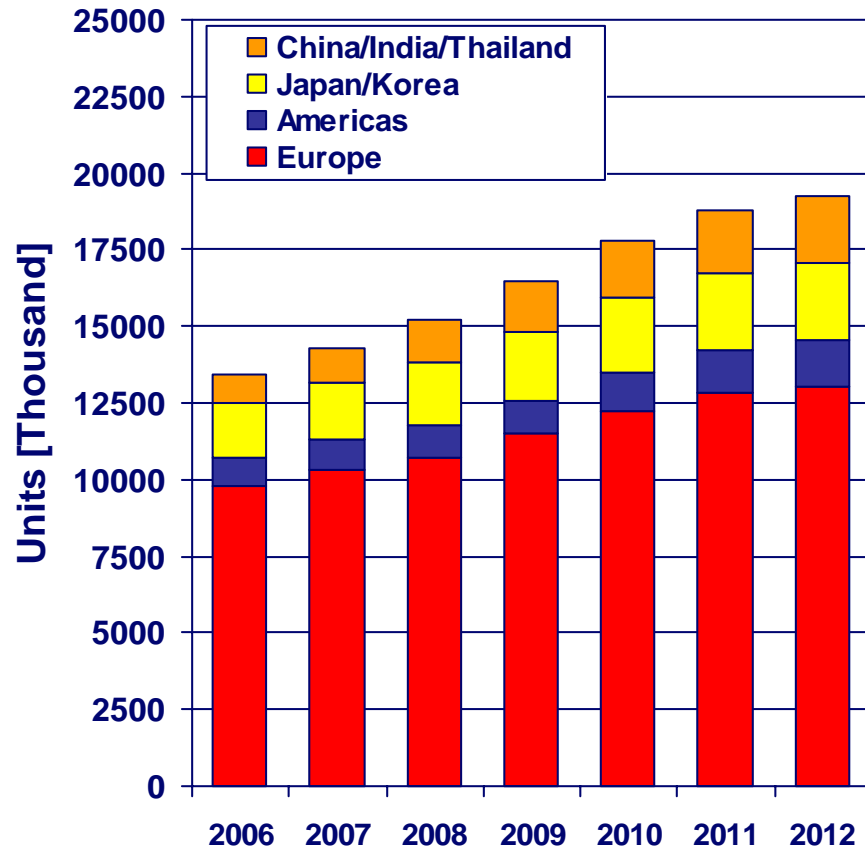
Why Turbocharging

- **Advantages of Exhaust Gas Turbocharging**
- Fuel Consumption is Lower, Utilizes Wasted Exhaust Gas
- Engine Displacement can be Smaller, Friction and Thermal Losses are Less, Higher Power to Weight Ratio
- Small Engine Installation Space Required & Reduces Weight
- Improves Engine's Torque at Low Engine Speed

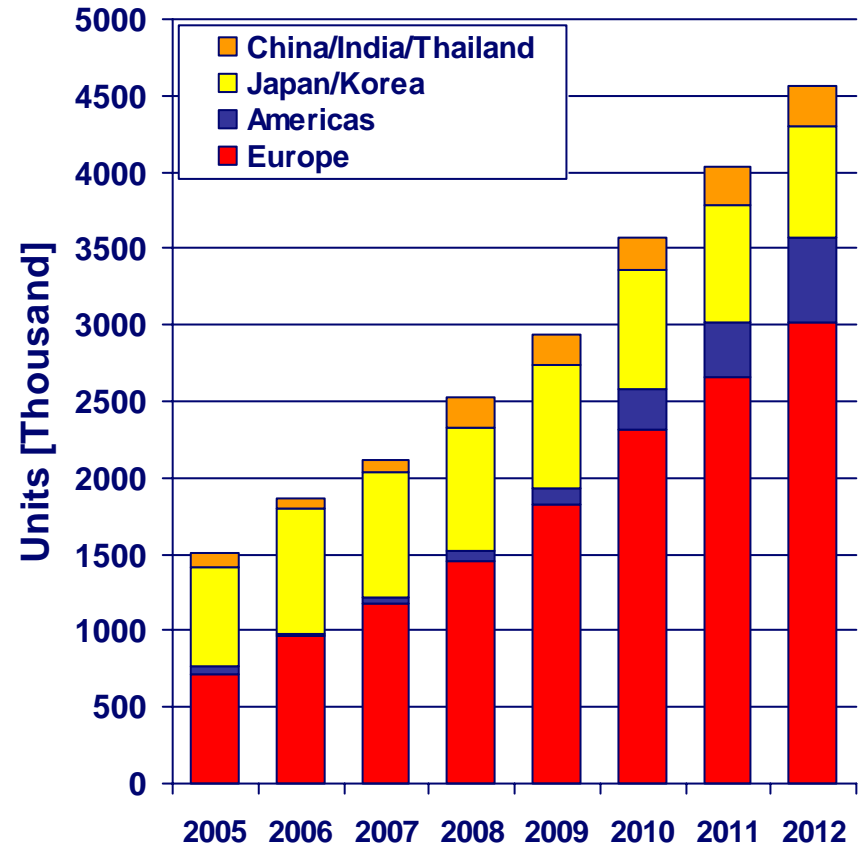


Turbocharger Growth by Market*

Diesel Engines



Gasoline Engines

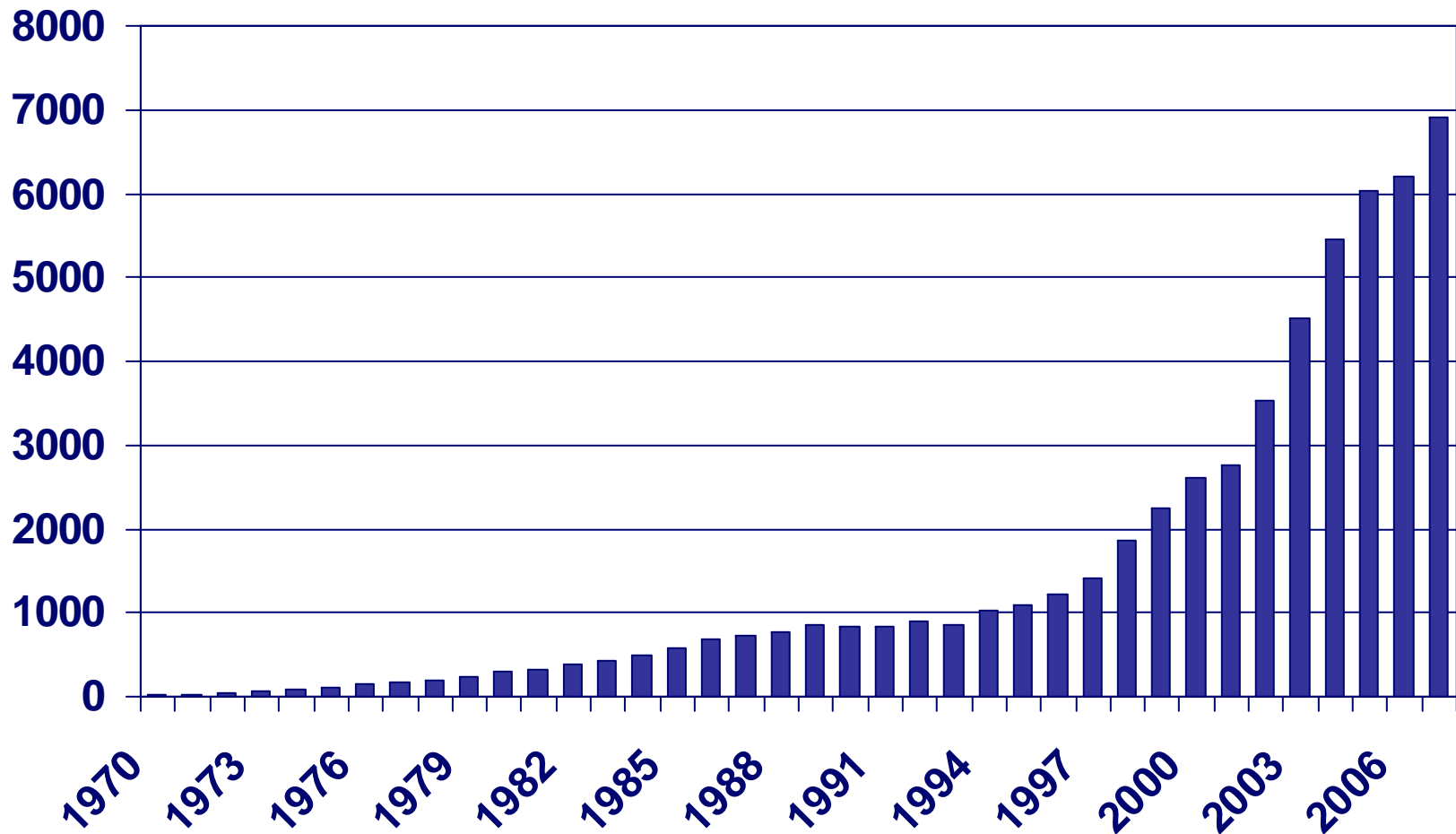


- *Includes North American light truck applications
- *OE demand only
- *R2S is counted as 2 turbos

Sources: CSM, JD Power, own estimations

AM:lrp presentation_2007/0908

BorgWarner Turbocharger Production Output 1970-2007



BorgWarner Turbo & Emission Systems History

1949: First Turbo Produced

1954: NA Production Begins

1960: European Production Begins

1975: Production Expansion Globally Begins (Europe, SA)

1992: Production of Small Gasoline Pass Car Turbo

1997: BW Acquires AG Kühnle, Kopp & Kausch (Germany)

1999: BW Acquires Schwitzer and integrates to become BWTS

2000: VTG in Production for Passenger Car

2002: R2S in Production for Marine Application

2003-Present: Continued Global Production Expansion In Europe, Asia, NA, SA



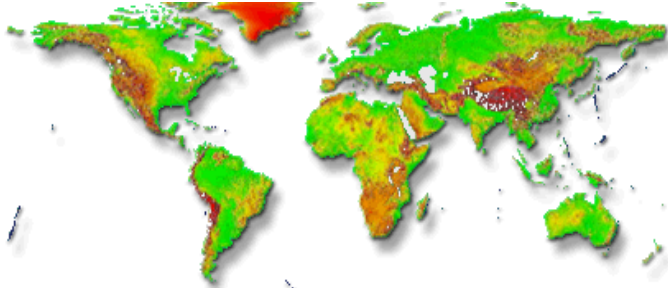
Firm Foundation of Experience

Challenges of Meeting Future Boosting Needs

- **Higher Efficiencies** (Fuel Consumption)
- **Improved Transient Behaviour** (Emissions, Driveability)
- **Higher Boost Pressure** (Power Density)
- **Higher Temperature Capabilities** (Fuel Consumption, DPF, EGR)
- **Minimize Oil Leakages/Consumption** (Emissions)
- **Durability**
- **Cost Reduction**



Outside Influences – Watch Out



Geographic Location
Altitude and Surrounding Environment



Oil Quality
Oil Pressure
Vibration
Exhaust & Clean Air Cleanliness
Temperatures

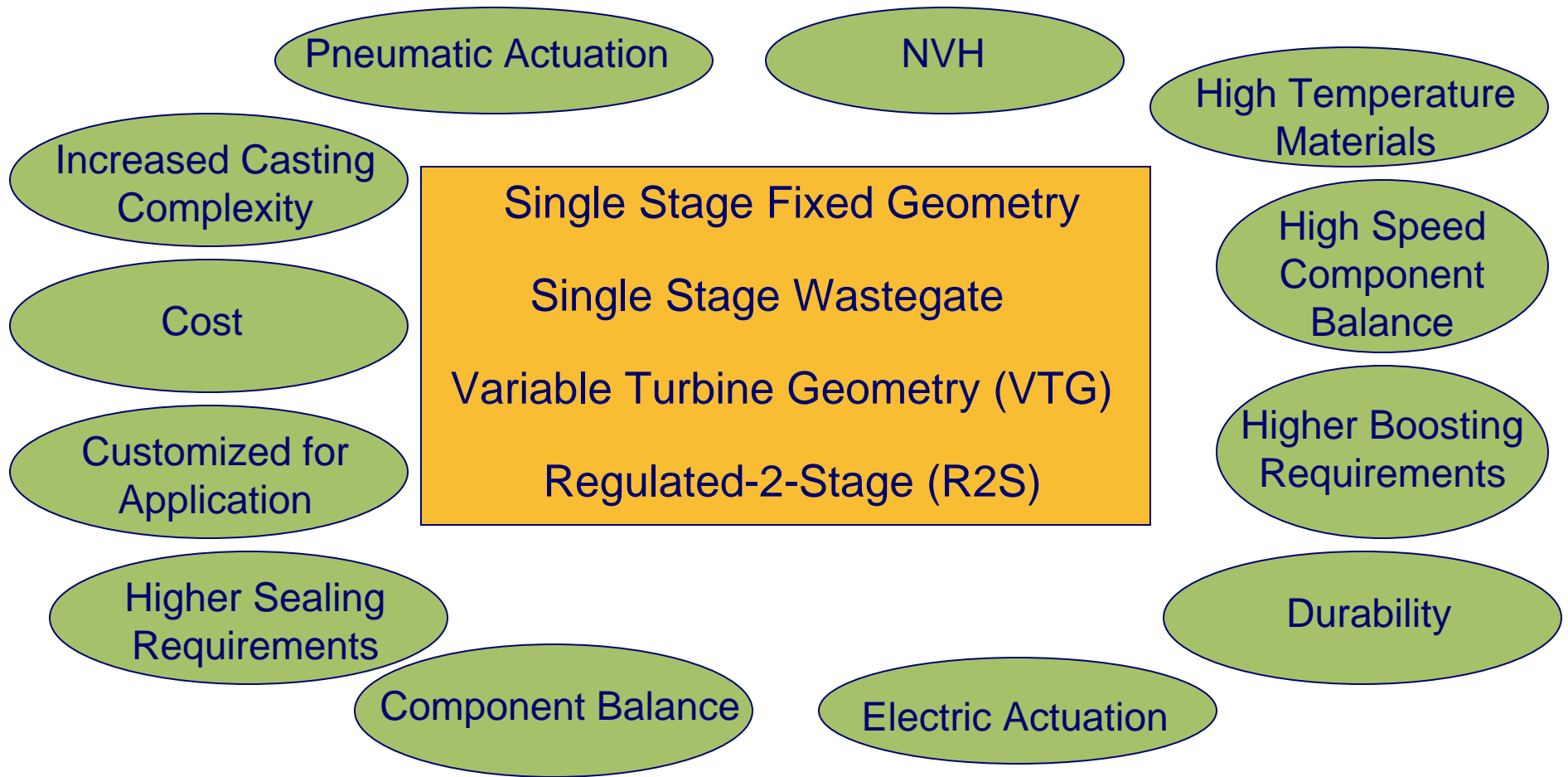


Duty Cycle
Application
Life vs. Cost



BorgWarner's Knows the Right Questions to Ensure Success

Product Evolution



Integrating Manufacturing into the Development Process is Critical

Variable Turbine Geometry (VTG)



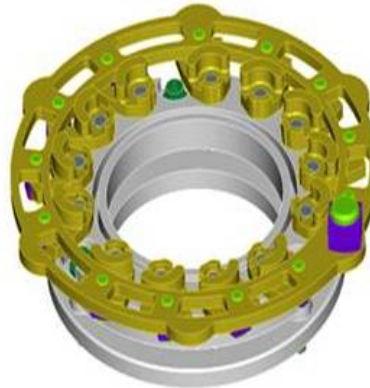
Variable Turbine Geometry (VTG)

Design Challenges

VTG Benefits & Challenges

Challenges –

- Dimensional Stability
- Corrosion
- Vibration
- Fatigue
- Torque Multiplication
- Electronic Actuation



VTG Corrosion Test – STILL FUNCTIONAL

Robust Design Analysis & Rigorous Testing Required:

- Complex Closed System Stack Up
- Thermal & Structural Analyses
- CFD and CHT Analyses
- Wear and Galvanic Potential Material Level Testing
- Fatigue, Creep, and Thermal Cycle Component Level Testing
- Gas Stand and Flow Bench Performance Mapping/Testing
- Firing Engine Durability Testing
- Vehicle Durability Testing



VTG Soot Test – STILL FUNCTIONAL

BorgWarner Offers Industry Leading Experience in VTG Design & Validation!

Manufacturing Challenges

VTG Benefits & Challenges

- Highly Developed Tolerances & Stacks
- Innovative Use of Super Alloys
- Sophisticated Raw Material Processing
- Complex Component Processing/Machining
- Advanced Assembly Automation:
- Extensive Quality/Inspection Systems



BorgWarner Offers Industry Leading Experience in VTG Manufacturing!

Regulated 2 Stage (R2S)



Regulated 2-stage Turbocharging (R2S) for Light Vehicles

Manufacturing Challenges

Shaft & Turbine Wheel

- **Complex Clearance Tolerances & Stacks:**
 - Wheel to housing clearances
 - Shaft to bearing clearances
 - Shaft to housing clearances

- **Sophisticated Raw Material Processing:**
 - Nickel-based Material Investment Casting
 - Shaft-Blanking Processes

- **Complex Component Processing/Machining:**
 - High-Speed Grinding
 - Proprietary Hardening and Annealing
 - Multi-Plane Low and High Speed Balancing

- **Advanced Assembly Automation:**
 - Modular Assembly Stations with Robotic Positioning

- **Extensive Quality/Inspection Systems:**

BorgWarner leverages years of experience in Turbine S&W manufacturing.

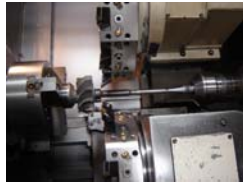
Shaft & Wheel Process



Welding



Additional Operations



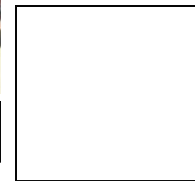
Rough Turn



Additional Operations



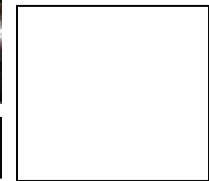
Finish Grind



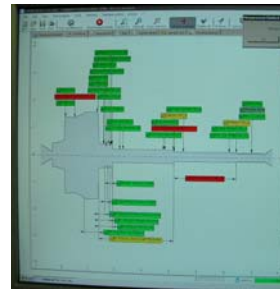
Additional Operations



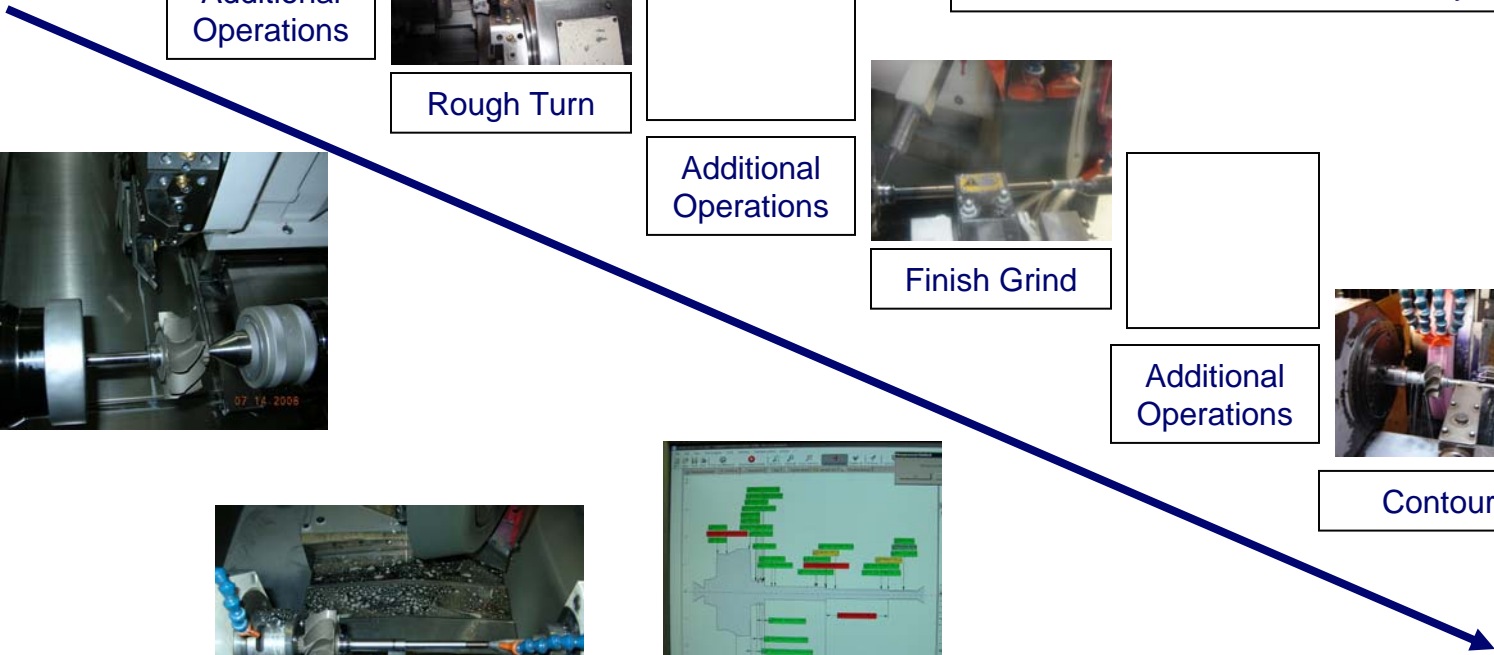
Contour



Additional Operations



- Managing Manufacturing Tradeoffs
- Weld Strength vs Residual Stress
 - Surface hardness vs Residual Stress
 - Groove Surface Finish & Tolerance vs Sealing
 - Surface Finish vs Efficiency



Or



Bringing it Together

