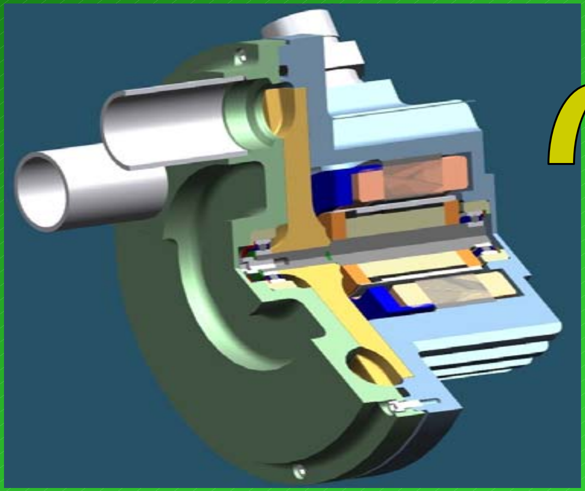
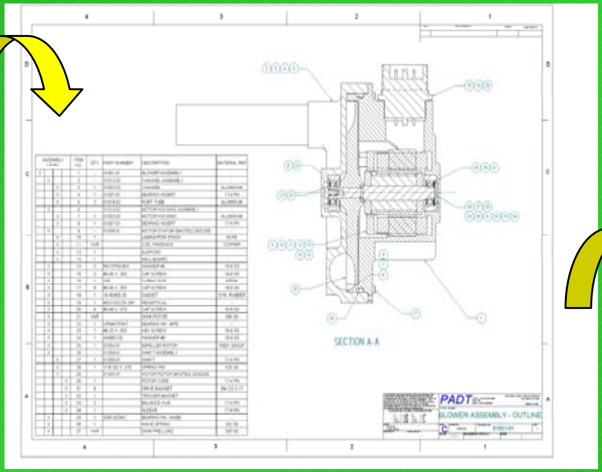
Design Process Example

Hydrogen Regenerative Blower





James R. Peters

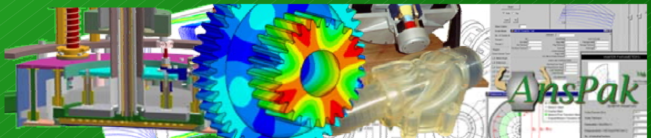
New Design Paradigms

Workshop 2002

June 25 – 27 2002

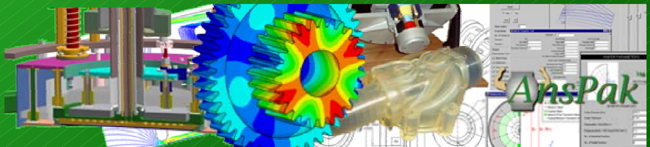
Presentation Outline

- Background on PADT
- PADT's core businesses - foundation for improving design and development process.
- PADT's design/development process outlined
- Example of Hydrogen Regenerative Blower and other related products
- Key elements of our current process which have produced greatest improvements in speed and quality.
- Critical areas of research necessary to radically improve the design development process.



PADT Background

- Incorporated in March, 1994
- *Goal*: To Utilize CAE Technologies to Provide Engineering Services in a Timely and Affordable Manner
- Now 42 Employees (average 10+ years experience)
  - Located in Tempe, Arizona (ASU Research Park)
  - 15,000 Sq. Ft. Facility
  - 2/3 Office
  - 1/3 Shop & Lab
  - Branch Office in Los Angeles, CA
- Perspective from a small business



PADT's Core Businesses

Engineering Services

Design
Analysis
Electrical Engineering
Software Development
Testing Services

Aerospace
Automotive
Semiconductor / MEMS
Consumer Products
Medical
Government Research
Internal PADT

Rapid Manufacturing

Stereolithography
Fused Deposition
Selective Laser Sintering
3D Printing
Injection Molding
Rubber Molding
Vacuum Forming
Model Shop

Aerospace
Automotive
Semiconductor
Consumer Products
Medical
Government Research
Internal PADT

Systems R&D

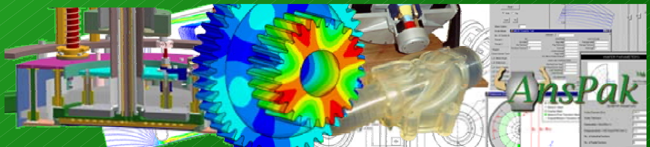
Power and Vacuum Systems:
Air & Fuel Handling
Custom Blowers
Custom Turbines
Turnkey Systems
SBIR Contracts

Aerospace
Automotive
Medical
Consumer Products
Government Research
Internal PADT

Software
Sales / Support / Training

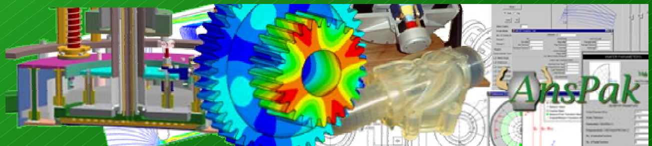
ANSYS
ADAMS
Sinda/G
Custom Software
Stratasys

Aerospace
Automotive
Semiconductor / MEMS
Consumer Products
Medical
Government Research
Internal PADT

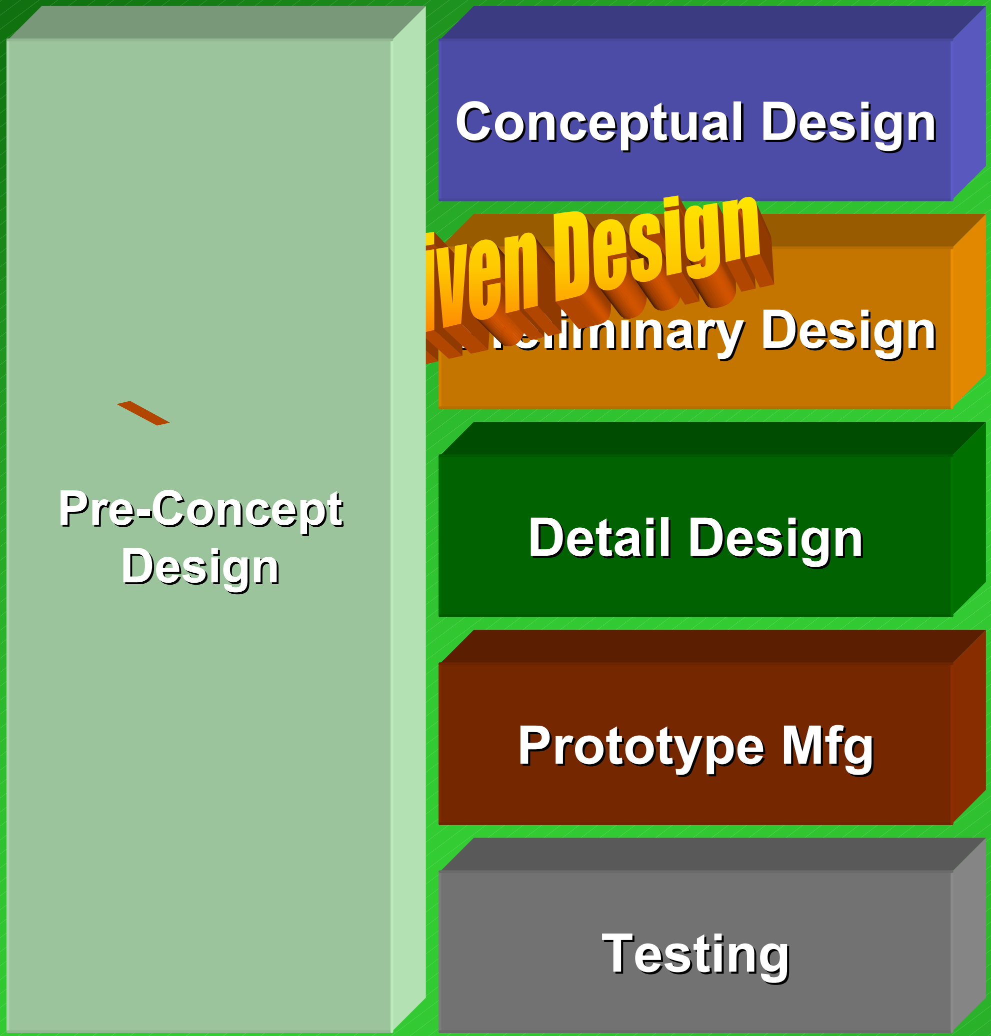


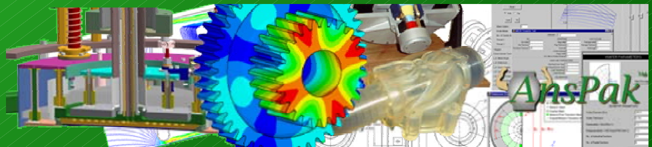
PADT's Core Businesses

- Business units sharpen skills by having diverse customer base – operating in a "I need it yesterday" environment.
- Resources are shared across business units.
- Each business unit provides a unique contribution to the evolving design process.
- Capabilities and experience enhanced by SBIR programs.
- Reputation is only as good as last job.

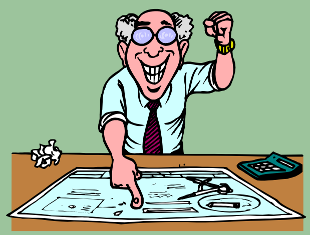


Design / Development Process



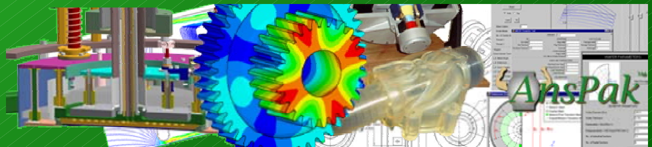


Design / Development Process



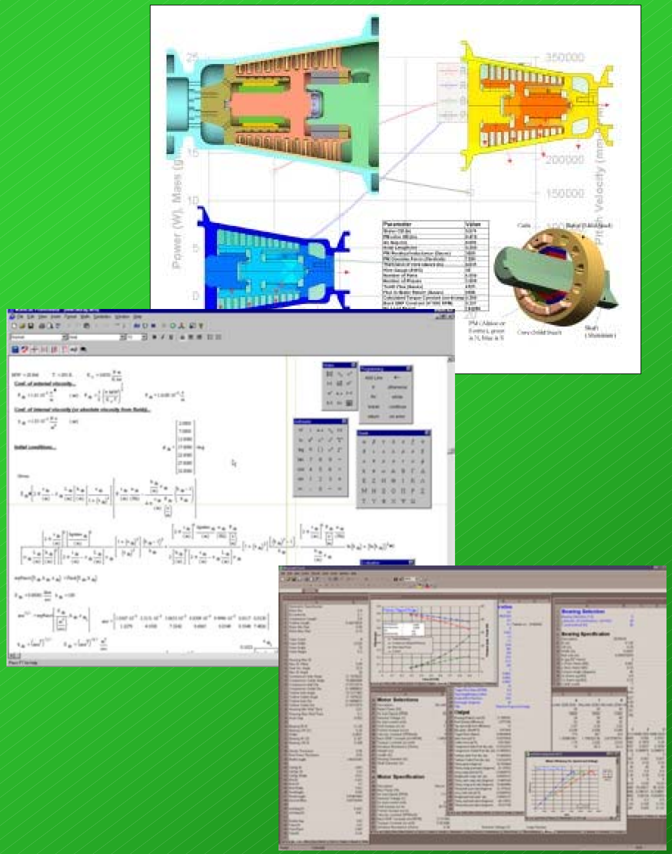
Pre-Concept Design

- Done at risk by PADT (pre-contract)
- Stage to further refine requirements and establish detailed statement of work.
- Potential concepts presented to customer.
- Allows PADT to better understand customers processes and expectations.
- Establishes creditability in experience and abilities to meet objectives.

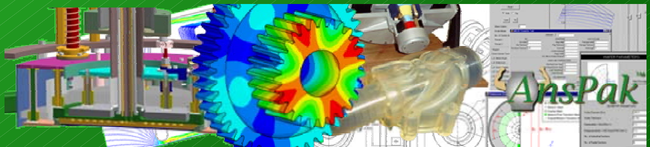


Design / Development Process

Conceptual Design



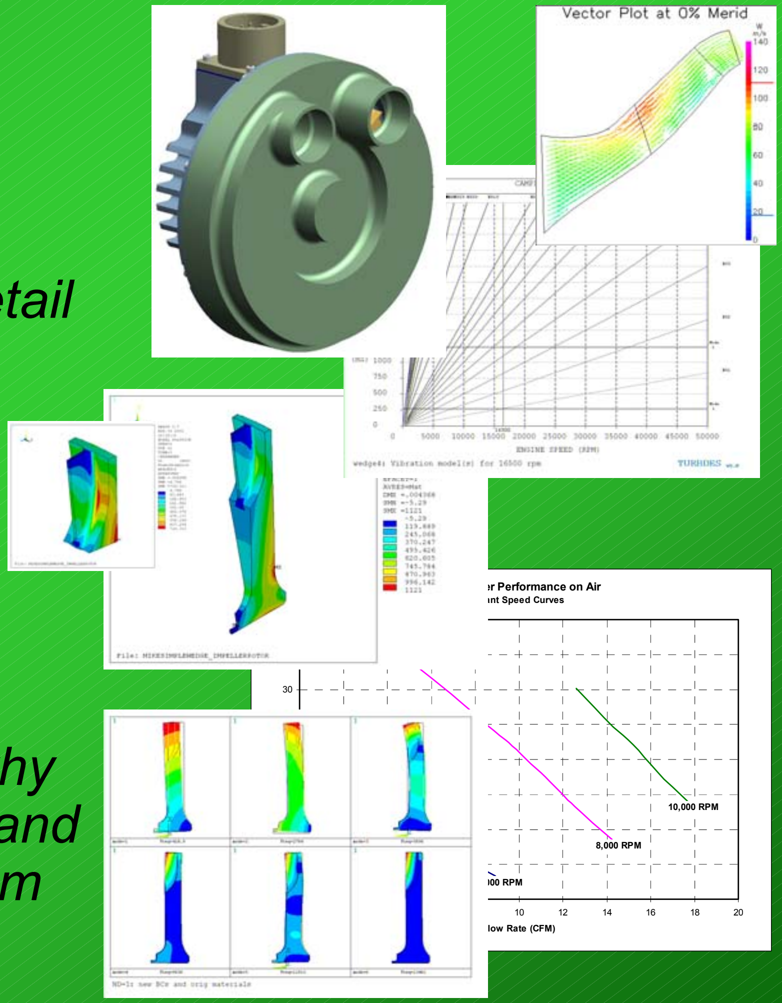
- Multidisciplinary team with outside experts
- Sketches, Whiteboard drawings - at most 2D CAD for our class of products
- Spreadsheet level analyses
- Simple FEA as necessary
- Discussions with vendors – early and often
- ***Most*** important stage of design – success or failure is determined at this stage
- Come out knowing *geometry layout, materials, manufacturing plan, assembly procedure, NRE costs*

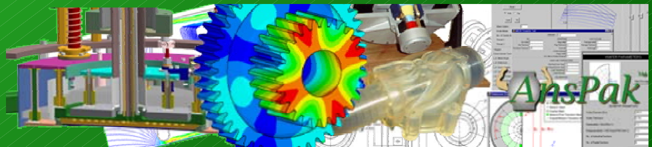


Design / Development Process

Preliminary Design

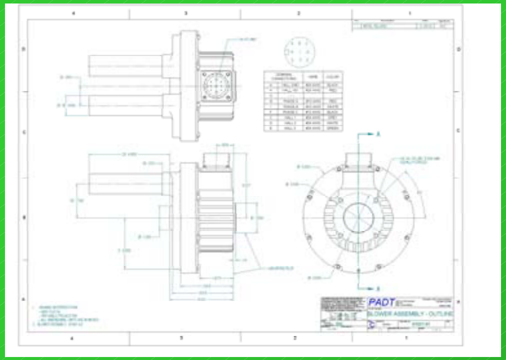
- Build assembly with 3D solids – *No Detail Drawings at this stage!*
- Address press fits, tolerances and wall thickness
- High end spreadsheet
- High end FEA as necessary
- Discussions with vendors – continued
- Come out knowing *assembly layout, why every feature in the assembly is there and its purpose, all analyses indicate system will perform as designed.*



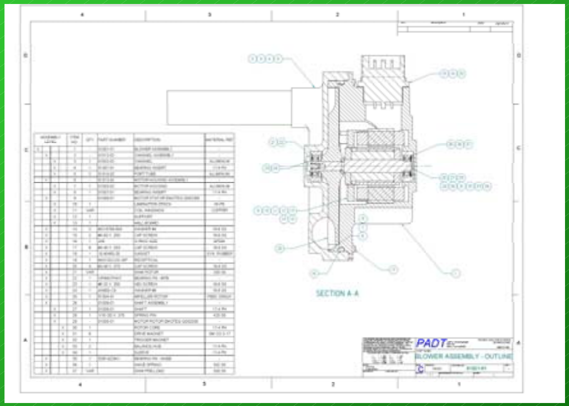


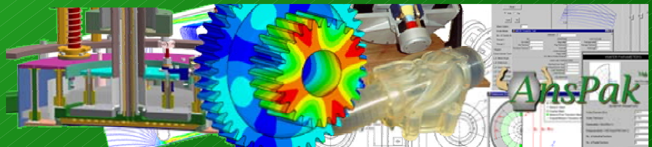
Design / Development Process

Detail Design



- Draw detailed drawings – add notes for manufacturing and assembly.
- Heavy Vendor interaction for supplied components.
- No FEA this stage.
- Electronic Solid Models used directly in manufacturing – most cases.
- Documentation of design.
- Come out ready for prototype manufacturing and testing.

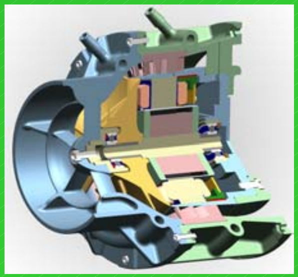


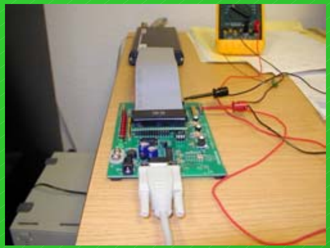


Design / Development Process

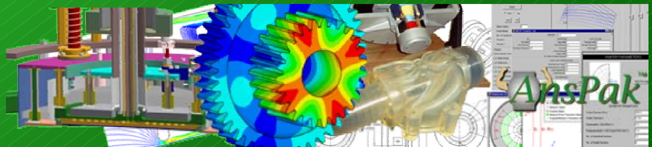
Prototype Mfg

- Use rapid manufacturing to test and verify system fit and performance quickly and economically.
- Modified parts quickly produced and tested.
- Strong vendor communication minimizes components not living up to stated claims.
- Trouble areas can be studied and re-analyzed in real time.
- Come out knowing system will work, can concentrate on cost reduction for production.



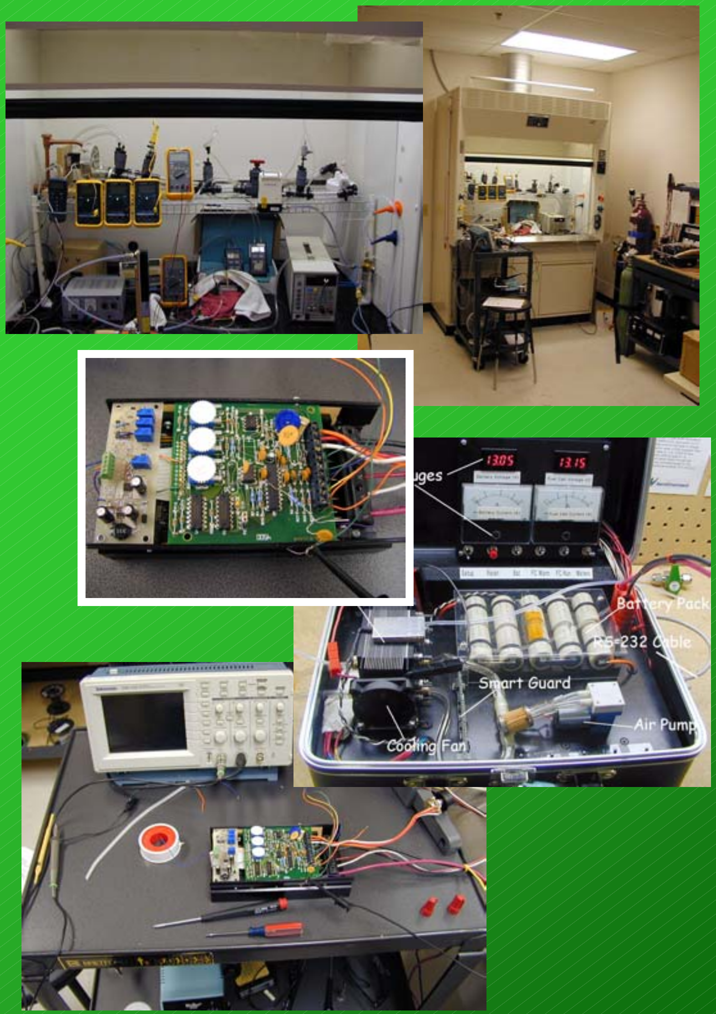


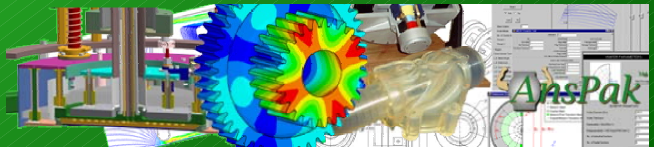


Design / Development Process

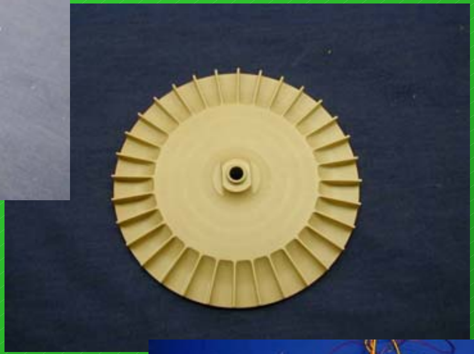
Testing

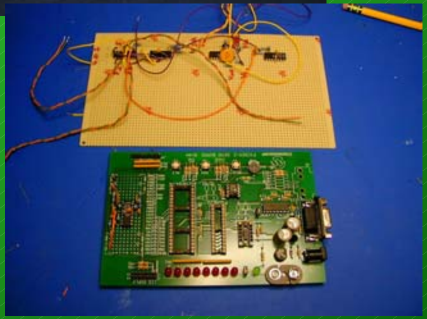
- Concurrent with prototype development
- Being able to conduct in-house critical
- Designer/Analyst also in lab
- Verification FEA as necessary



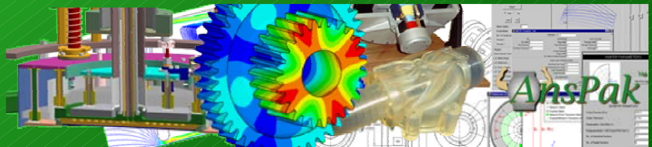


Hydrogen Regenerative Blower



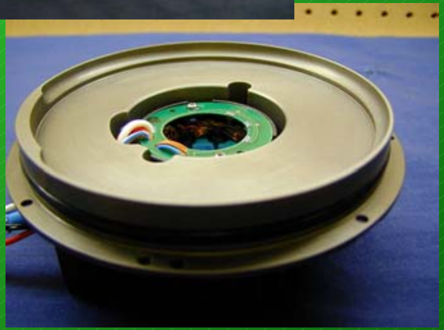


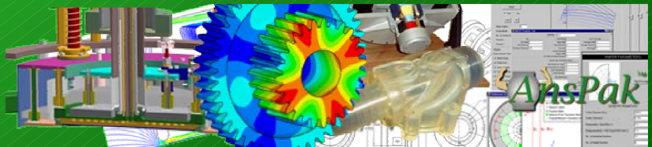
- Provided Initial Specification:
  - Performance Goal
  - Design Envelope
  - Life Requirement
  - Cost Goal
  - NRE
  - Efficiency
  - Materials
- Pre-Concept Design Stage
  - Further refined requirements (Priorities)
  - Presented early trade studies
  - Set expectations and narrowed concepts



Hydrogen Regenerative Blower

- Concept Design Stage Analyses
  - Aerodynamic Efficiency
  - Size and Weight
  - Rotordynamics/Bearing Design
  - Thermal Management
  - Motor/Controls Design
  - Cost/Manufacturability
  - Commercialization/Marketing
- Aerodynamic Performance Drove Development Costs
- High Efficiency Motor/Controller Critical to Meeting Design Goals.

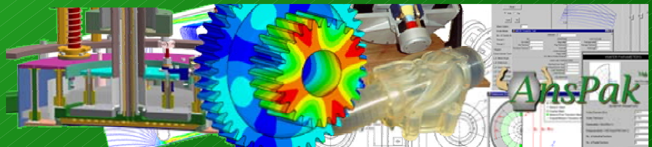




Hydrogen Regenerative Blower

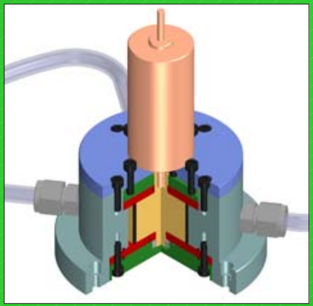
Application	Distributed Power, Automotive
Flow	20 SCFM max
Pressure	3.0 psig (on air), 1.0 psig (reformate)
MTBO	~ 5000 hr, bearing rep.
Weight	5 lbm
RPM	~ 15000
Efficiency	25% - 30%, DCin to Fluid

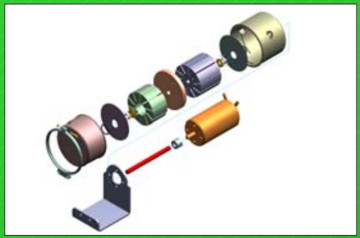
- **Quiet (60 dBa), light, low production cost**
- **Aluminum Construction (prototypes)**
- **5.5” dia. x 3.5” long**
- **5000 Endurance test is underway**
- **Brushless DC Motor, wound from 12 V**
- **Follow on Funding from DOE will improve aerodynamics**

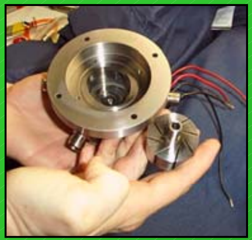


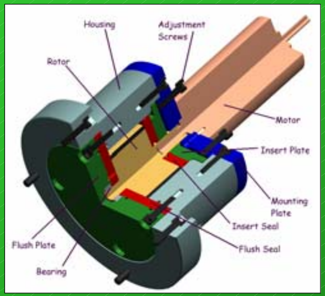
Vane Compressor Example

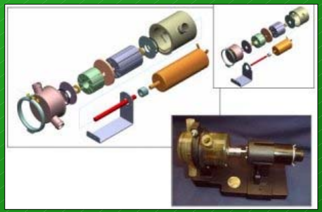
- US Army SBIR Project
  - Phase I & II
- Fuel Cell Air Handler
- Spreadsheet Performance Model
  - Motor, Bearings, Vanes, Shroud Shape
- SolidEdge Assembly Model
- Customer gives performance needs
  - Modify spreadsheet to meet needs
  - Update solid model
  - Cleanup drawings and go to Mfg
- Featured in Jan. 2000, Mechanical Engineering Magazine

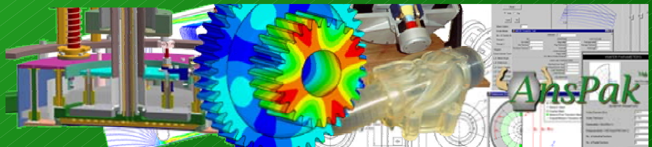








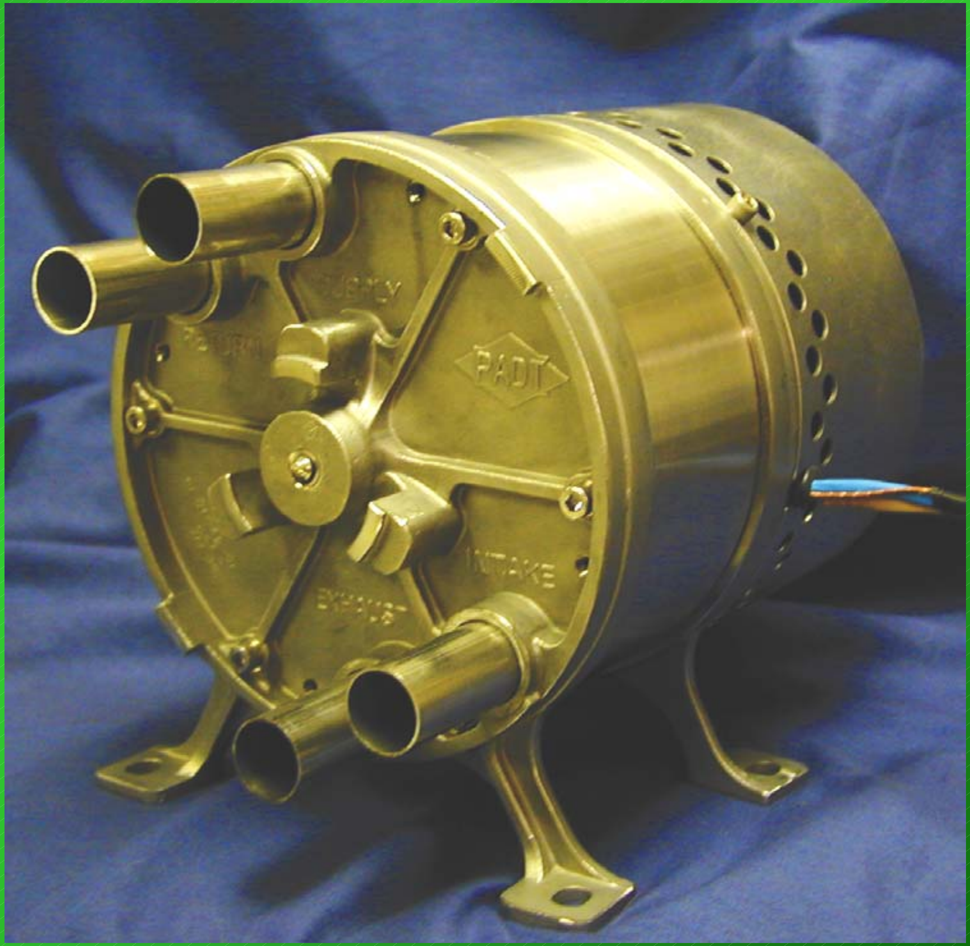


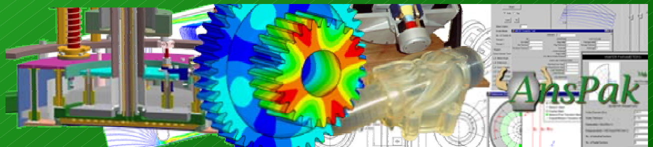


Compressor/Expander Development

Application	Distributed Power
Flow	20 SCFM max
Pressure	~ 15 psig
MTBO	20,000 hr, bearing rep.
Weight	40-80 lbm
RPM	1000
Efficiency	80%, DCin to Fluid

- **Funded by the US ARMY**
- **Reduces system cost**
- **Very High Efficiency with good turndown**
- **7.5” dia x 7”-10” long (length depends on flow)**
- **SS304 Construction**
- **Brushless DC Motor**

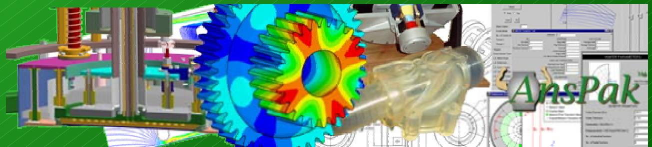




Assessment of the UNIROTOR'S Impact

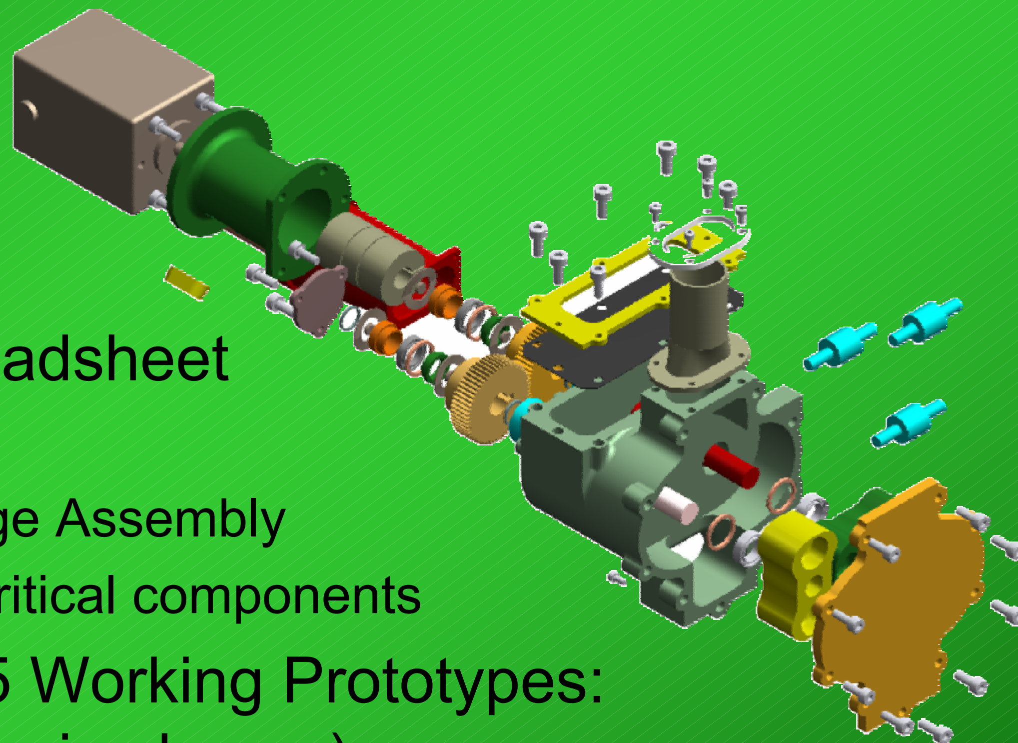
- Analysis indicates that the UNIROTOR increases Fuel Cell system output by ~18%
- Could be one of the enabling technologies for distributed generation
- Consumes about ½ the power that competing stand alone compressors consume

- Weighs about the same as competing technologies
- Designed for fuel cell systems (clean and water tolerant) unlike other options
- Best suited for FC applications between 1 kW and 20 kW of net power



Air Handler Example

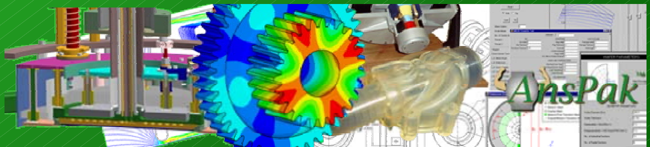
- Custom Air Handler for Fuel Cell
  - No lubricant
  - Quite
  - Efficient
  - Small



- Performance Spreadsheet drove Geometry
  - Linked to SolidEdge Assembly
  - ANSYS used on critical components
- From Concept to 5 Working Prototypes: 12 Weeks (5 weeks in shop…)

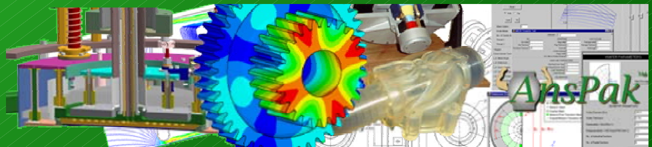
Key Elements of our Current Process

- *Analysis driven design*!
  - Have proper tools
  - Have knowledge about how to use/customize tools
  - Know how to pick to right tool
- *Designing for manufacturing and assembly from start*.
- Having highly skilled self-motivated staff.
- Having rapid manufacturing capability in-house.
- Having electrical engineering capability in-house.
- Successful research and development through SBIR programs has been ***critical!***



Key Elements of our Current Process

- Being willing to exchange profit for experience in new business areas.
- Keeping core design teams small.
- Being constantly exposed to many companies in different industries.
- Keeping focused on the big picture – systems approach.
- Co-location of all business units.



Critical Areas of Research Necessary to Radically Improve Design/Development Process

- *Advancements in Rapid Prototype Manufacturing* to be able to economically obtain fully dense metallic parts.

- High-End Multiphysics analyses becoming very common – Analysis requirements always expand to the available computational capabilities available. *Still need orders of magnitude increase in computational power.*

- Use internet model to create *intranet based design station*. Cataloging of company processes, procedures and analysis models for rapid access.

- Use of Artificial Intelligence Algorithms to "*Knowledge Capture*" past failures and successes in product development.