HYDROGEN TRANSMISSION AND DISTRIBUTION WORKSHOP

NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO

COMPRESSION TECHNOLOGY AND NEEDS

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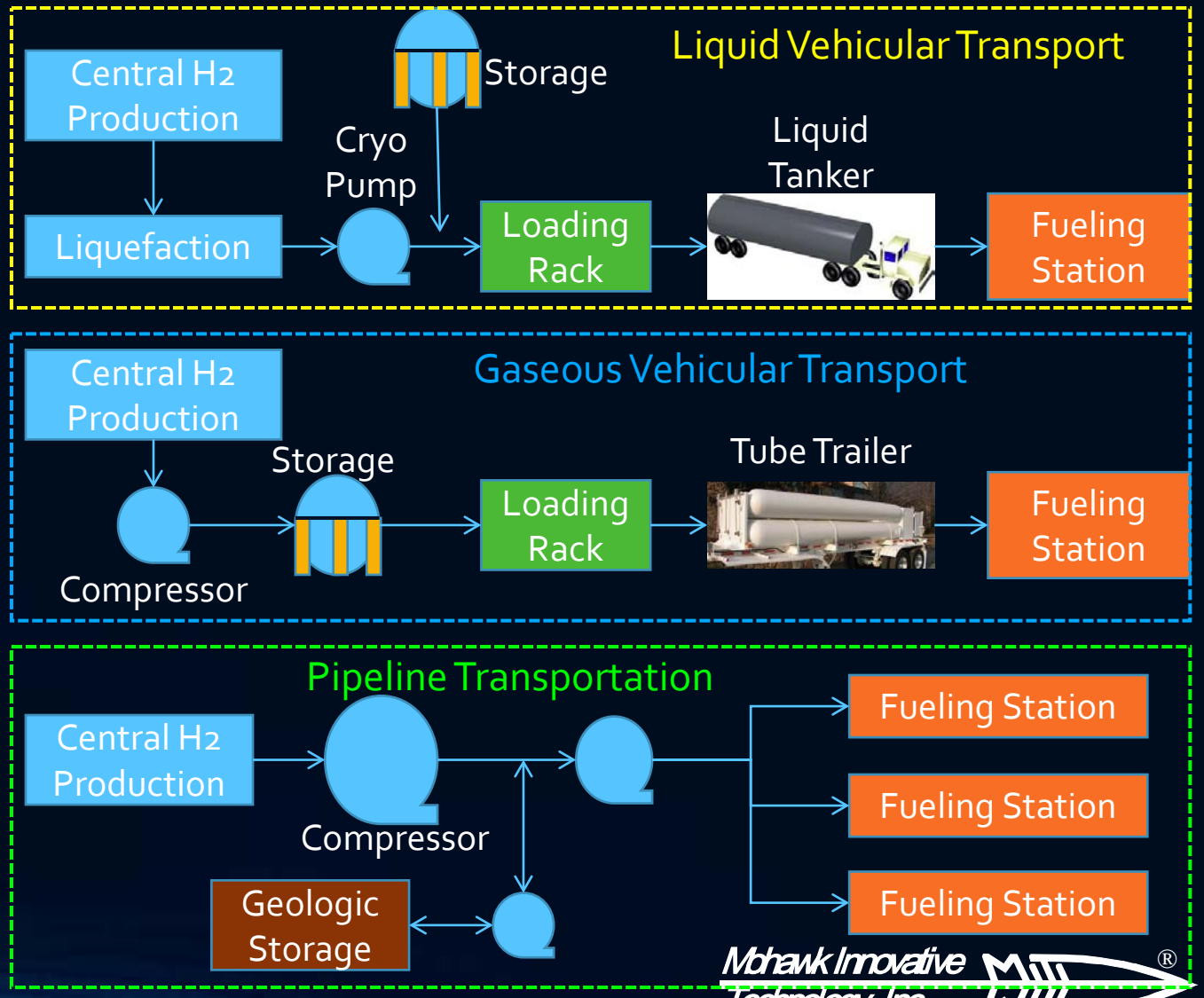
Content of my Presentation

- Overall pipeline delivery steps, production to file up
- Different types of compressors
- Pipeline compressor development steps and accomplishments
- Need for Forecourt Compression system
- Other major components: drive, sealing, pipeline, valves, site for testing, gear-box, materials, cost
- Summary of needs

Hydrogen Delivery From Production to Point-of-Use

- Centralized Production
- Delivery to Fueling Station
  - Liquid Vehicular Transport
  - Gaseous Vehicular Transport
  - Pipeline Transportation
  - Others
- Fueling Station
  - Liquid - Cryogenic Pump
  - Gaseous – Compressor & Storage



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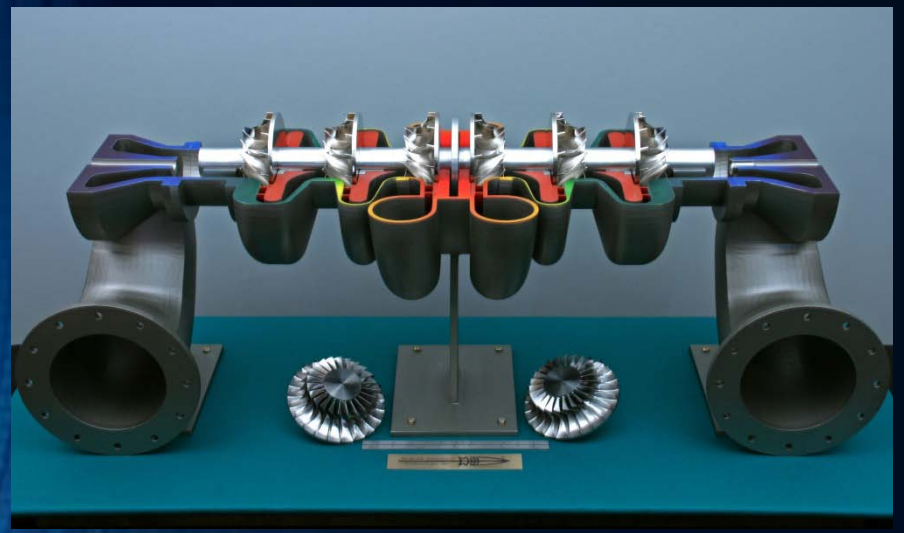
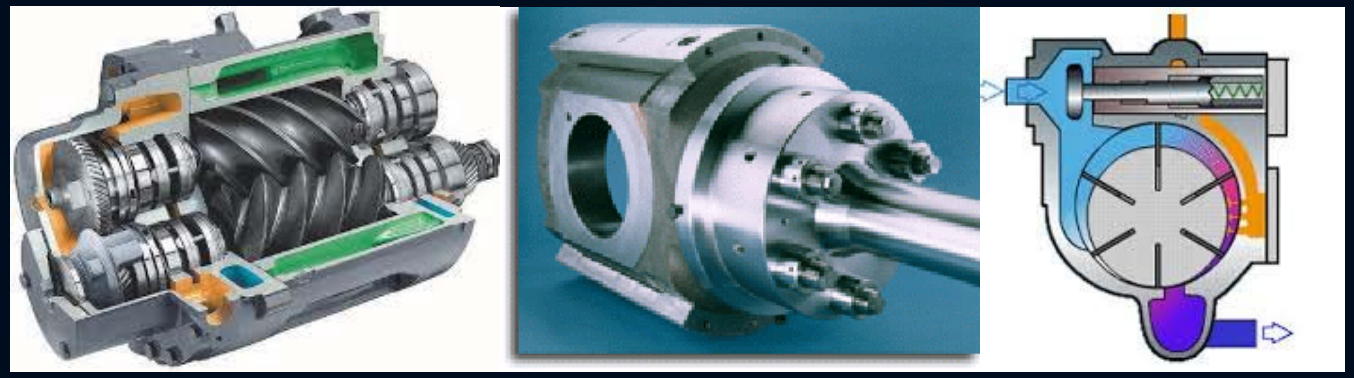
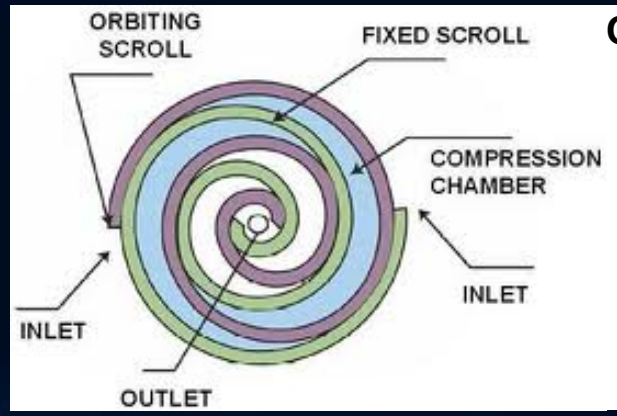
Possible GH2 High Volume "Low Pressure" Compressor Types

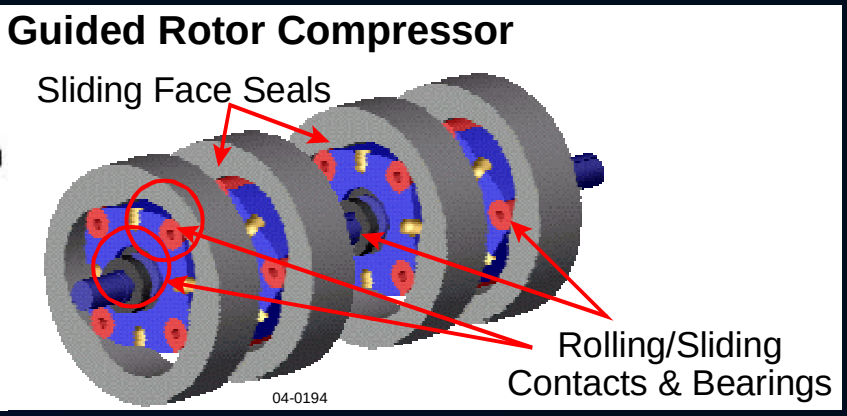


Centrifugal Compressor
- One Moving Part
- High Reliability
- Oil-Free, No Contaminants
- Minimal Contact/Sliding Parts
- High Efficiency and High Flow



Contacting Surfaces, Numerous Parts, Lubrication





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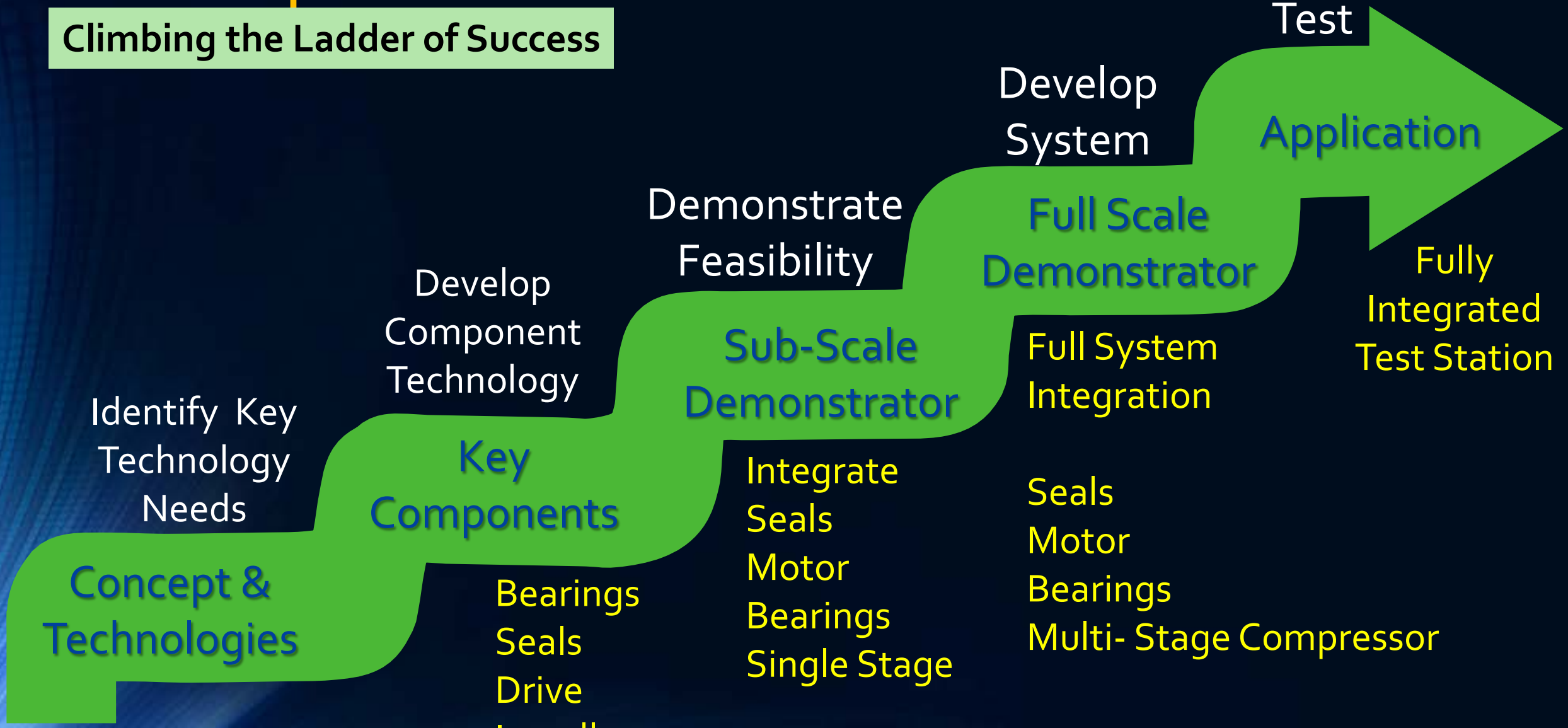
Development Plan

Climbing the Ladder of Success



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MiTi Pipeline H2 Compressor Development Steps and Accomplishments

- Oil-Free Multi-Stage Dual Entry
- Centrifugal Compressor Design
- Ultra-High Operating Speed
- Supercritical Operation
- Gen. IV Foil Bearings & Seals
- Single Stage Testing in Helium
- 1300 to 1500 psi Pressure Rise
- ½ x10^{+9} H2 gr-/day & 9 MW Drive

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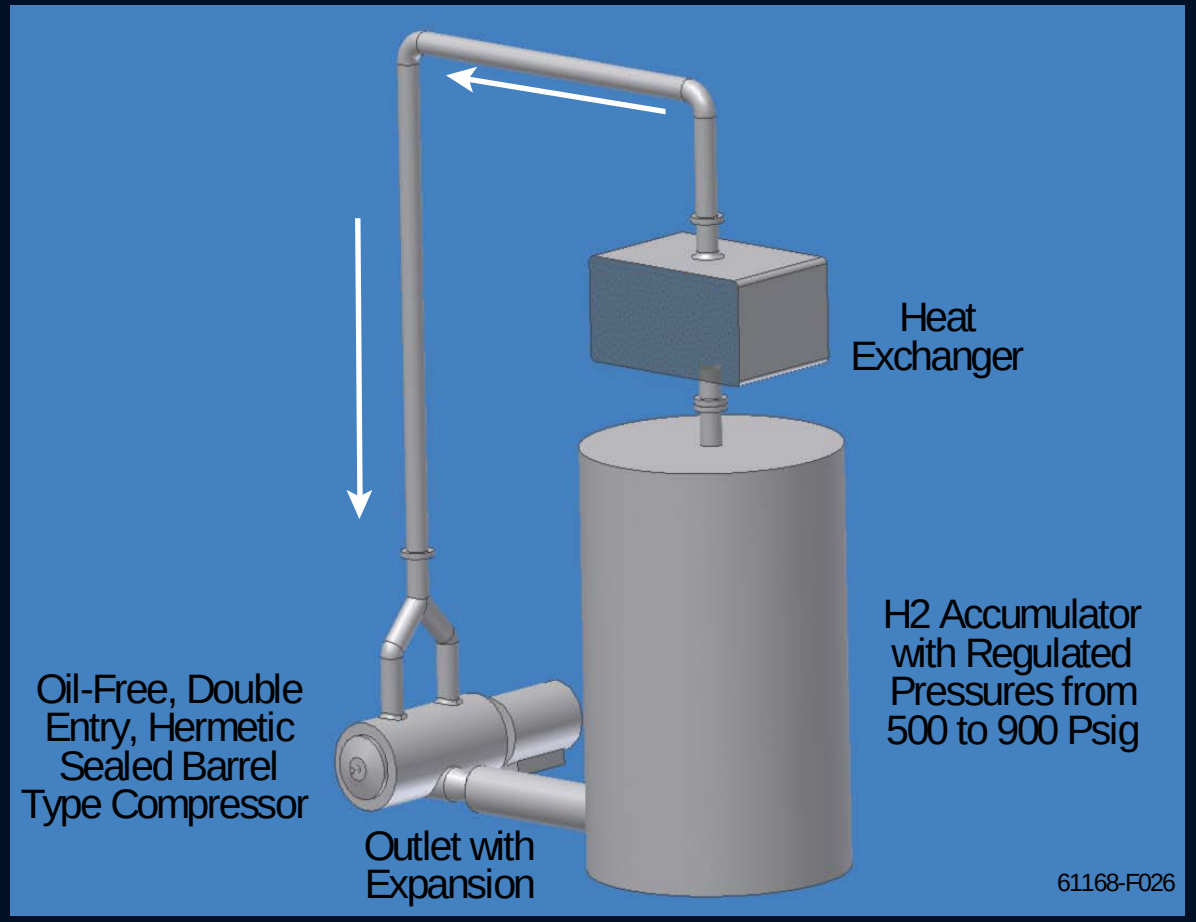
Issues Left to be Resolved for High Volume

- Oil-Free High Power & Speed Drives
- System Level Performance Validate Facility
  - Multi-Stage Compressor Train
  - High-Speed & Power Transmission Coupling
  - Static & Dynamic Sealing
  - Validate Life/Reliability/Maintenance
- Materials
  - Validation in High Pressure H2
  - Foil Bearing/Seals Performance in H2
- Economics & Manufacturing



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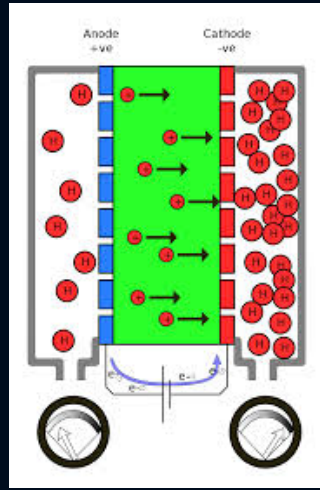
Low Volume "High Pressure" Compressor Types

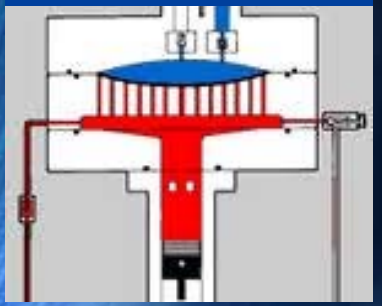
Compressor Type	P Inlet (Bar)	P Outlet (Bar)	Flow Capacity (kg/hr)	Limitations/Issues
Reciprocating	2.4 - 20.7	310 – 448	8-251	Contamination, Maintenance, Reliability, Cost
Diaphragm	20.7	414 - 448	33-164	Maintenance, Reliability, Material Compatibility
Intensifier	20.7-431	414 – 862	9-30	Contamination, Maintenance, Reliability
Ionic	25	1000	27-323	High cost, New Technology, Unknown Reliability
Electrochemical	0	207 - 827	0.5-2	Still at R&D stage, Low Flows
MiTi Viscous Hydrofoil Concept	20.7	103 - 896	10-100	Material Hydrogen Compatibility

Reciprocating

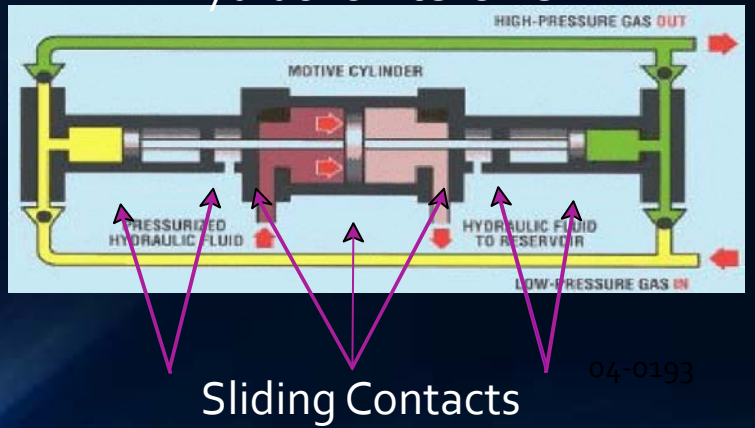
Ionic



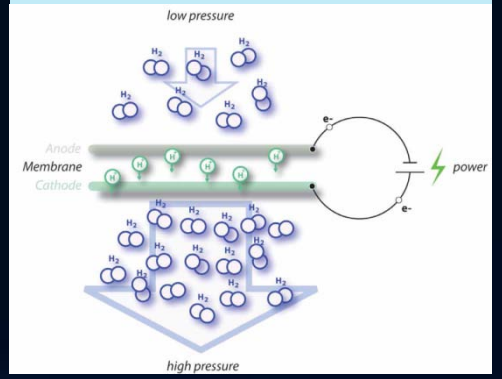
Diaphragm

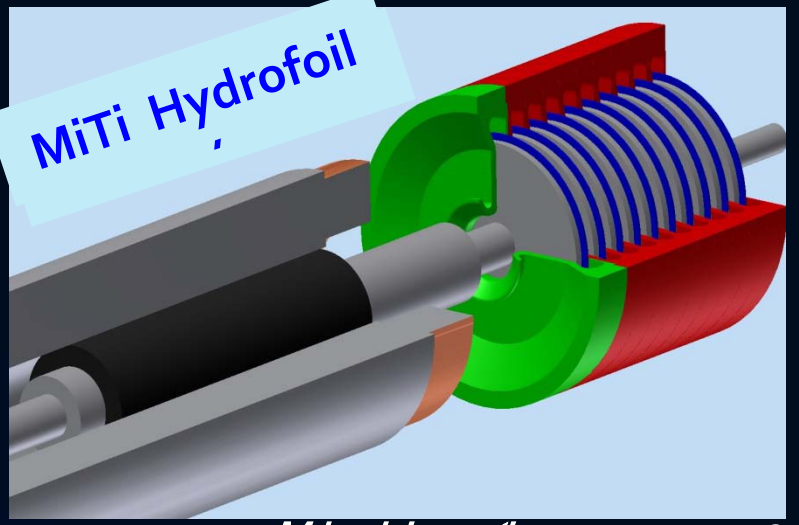


Hydraulic Intensifier



Electro-Chemical





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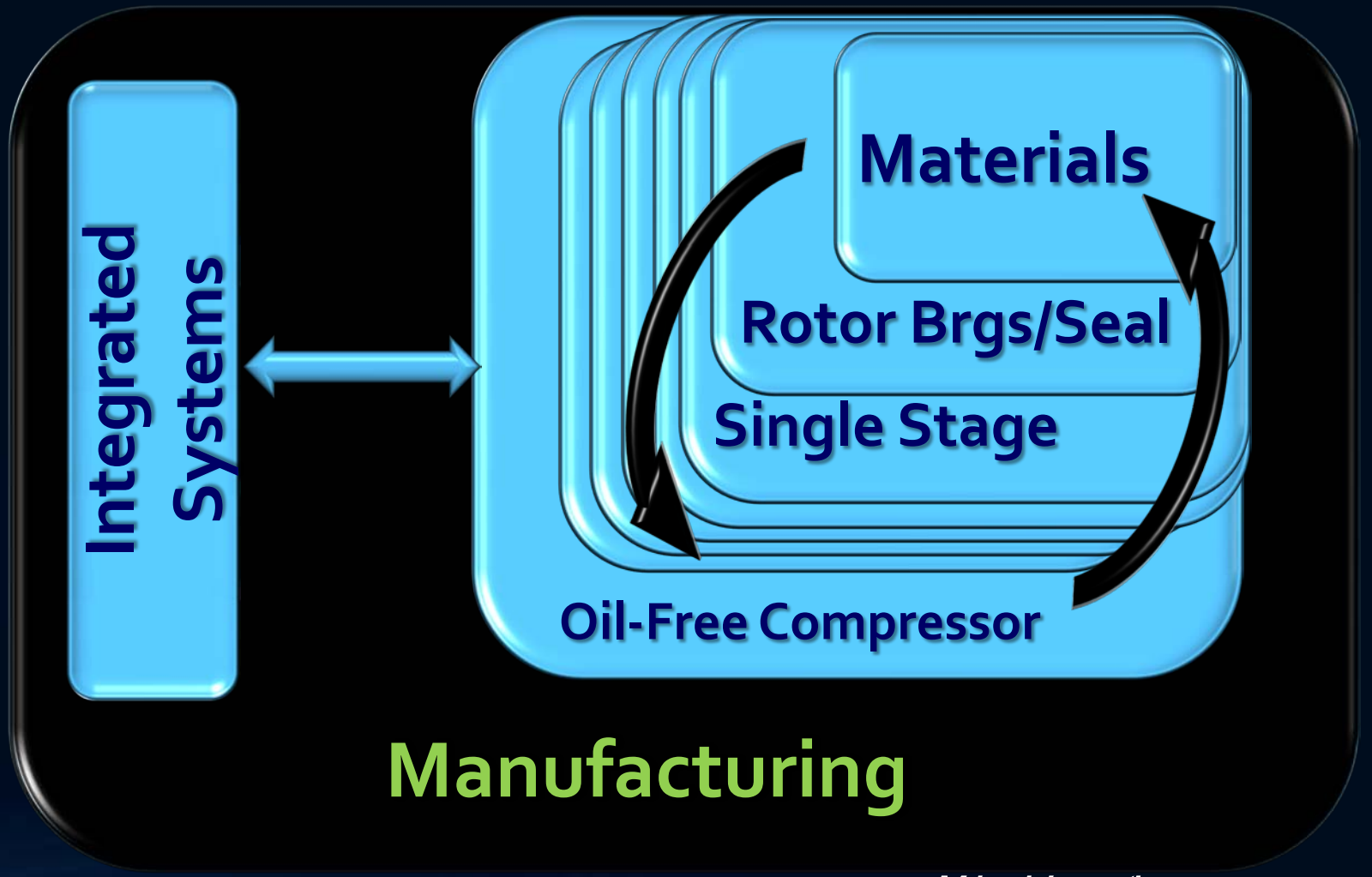
Miniaturization Technology & Design Methodology

Requires Miniaturization Factor by 3 Orders of Magnitude (6-9 MW to x kW)

Key Technology Miniaturization:

- ► Design Rule (t•P)
- ► Parametricalization
- ► Time + 3D Modeling
- ► Process-Technology



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Forecourt Compressor Requirements

- High Pressure (From 20 to 875 Bar)
- High Efficiency (≥ 73% Isentropic)
- Low Capital Cost ($240,000 Uninstalled)
- High Reliability (Single Unit Operations)
- Low Maintenance Needs and Costs (≤ $4800/year)
- **Contaminant & Oil Free**

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Miniaturization Technology Development

Miniaturized manufacturing tools are key to the development and fabrication of miniaturized system components.

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Miniaturization Technology Developments

Design Rule for Miniaturization, $M \sim \int (t \times P)$

Miniaturization Factor < 0.12

N ~ 0.5×10^6 rpm, P ~ 1 kW

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Additional Forecourt Compression System Needs

- Drive System & Possibly Gear Box
- Static and Dynamic Sealing
- Valves
- Hydrogen Compatible Materials
- Site and Facility for Testing
- Manufacturing Process and Specialized Tooling

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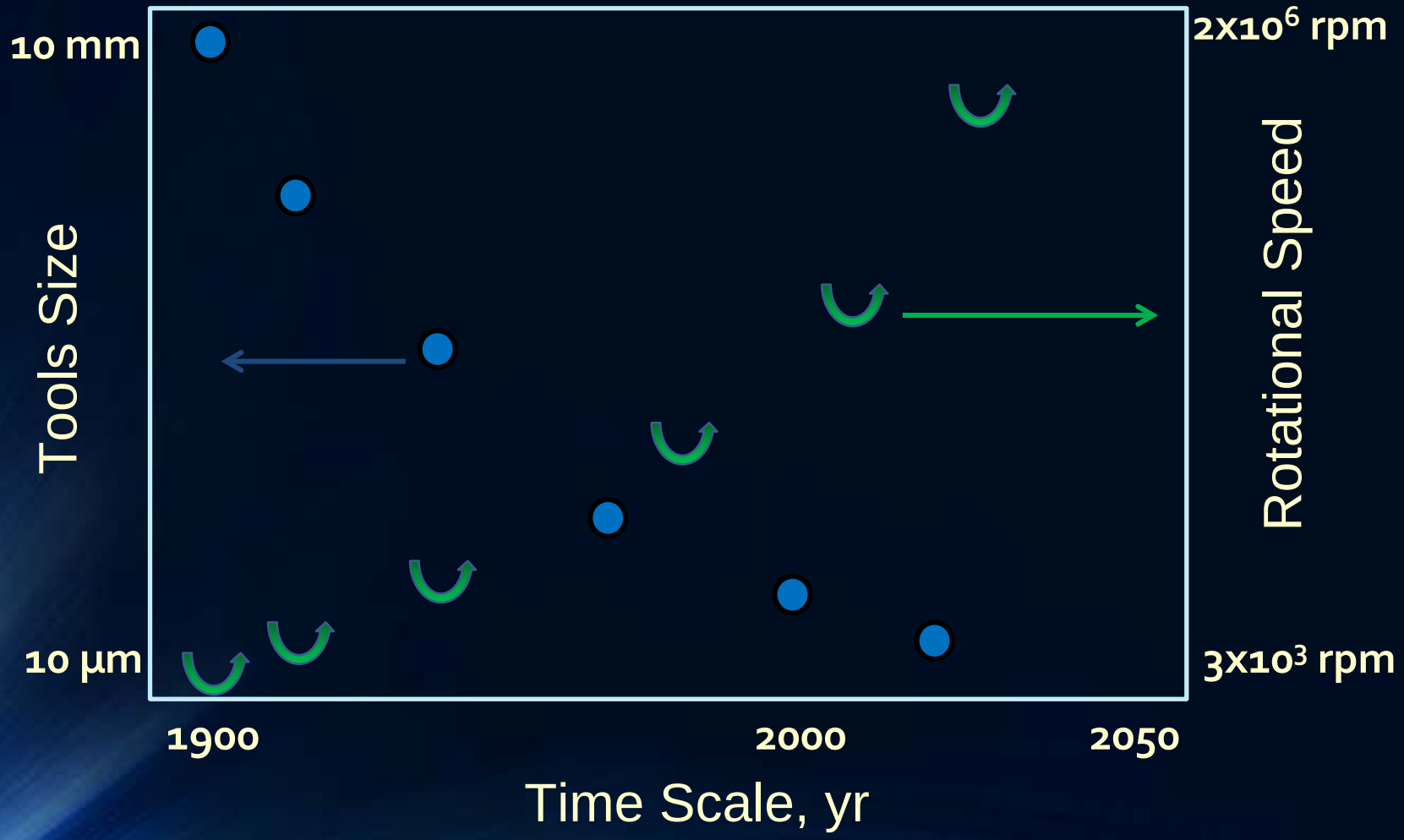
Miniaturized Manufacturing Tools & Spindles Status --

Development of high speed spindles lags the development of tools, 10 µm range requires 1 Mrpm spindle, which HYTBD



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Miniaturization Technology Development

In Order to Properly Miniaturize Critical System and its Components:

- Parametricalization method is essential for the time dependent 3-D miniaturized system.
- Miniaturized manufacturing tools are key to the economical development and fabrication of miniaturized system components.

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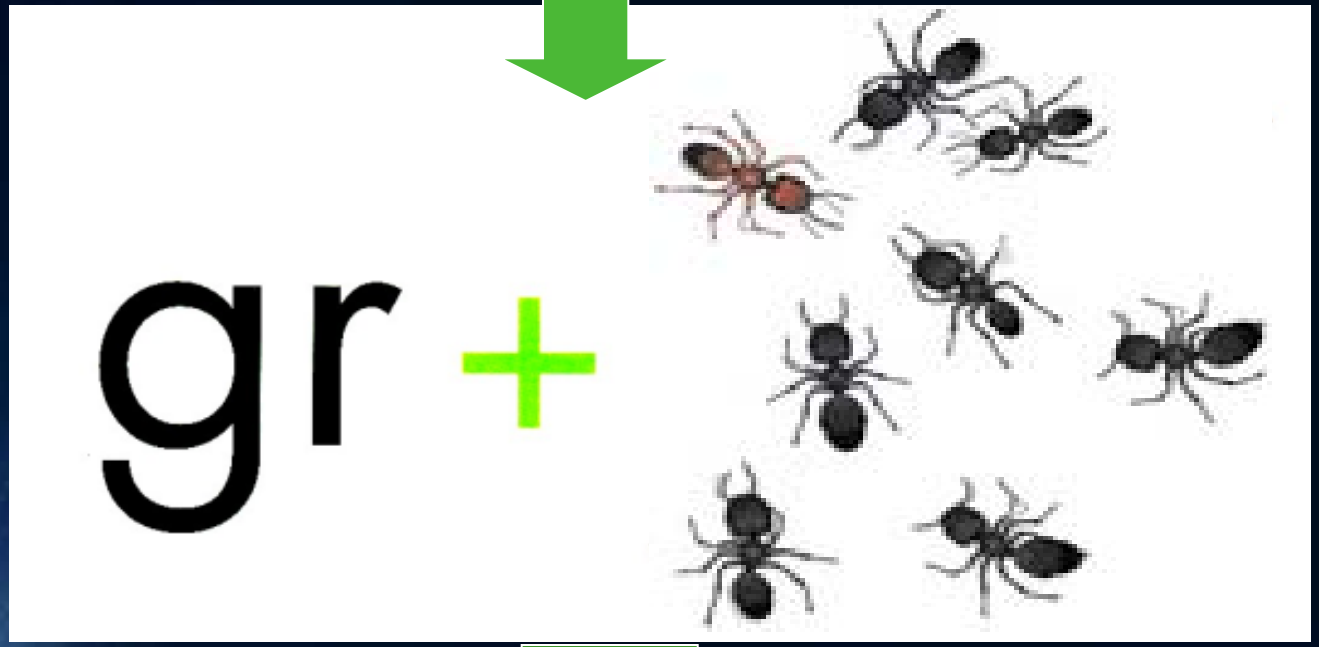
Summary of Needs

- Efficient Compression of Low Molecular Weight Gas
- Establish Creative Design & Design Rules
- Miniaturization Technology Developments
  - Power
  - Thermal Management
  - Miniaturized Manufacturing Tools

Establish Creative Design & Design Rules

SBIR Little



Huge Potential Impact

Single Stage Centrifugal Compressor Testing in Helium

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Thank you for your attention

is grateful to the DOE for its support of our small company and the advancement of centrifugal compressor technology.

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