… FROM CONCEPT TO PRODUCTION

Quantum Hydrogen Storage Systems

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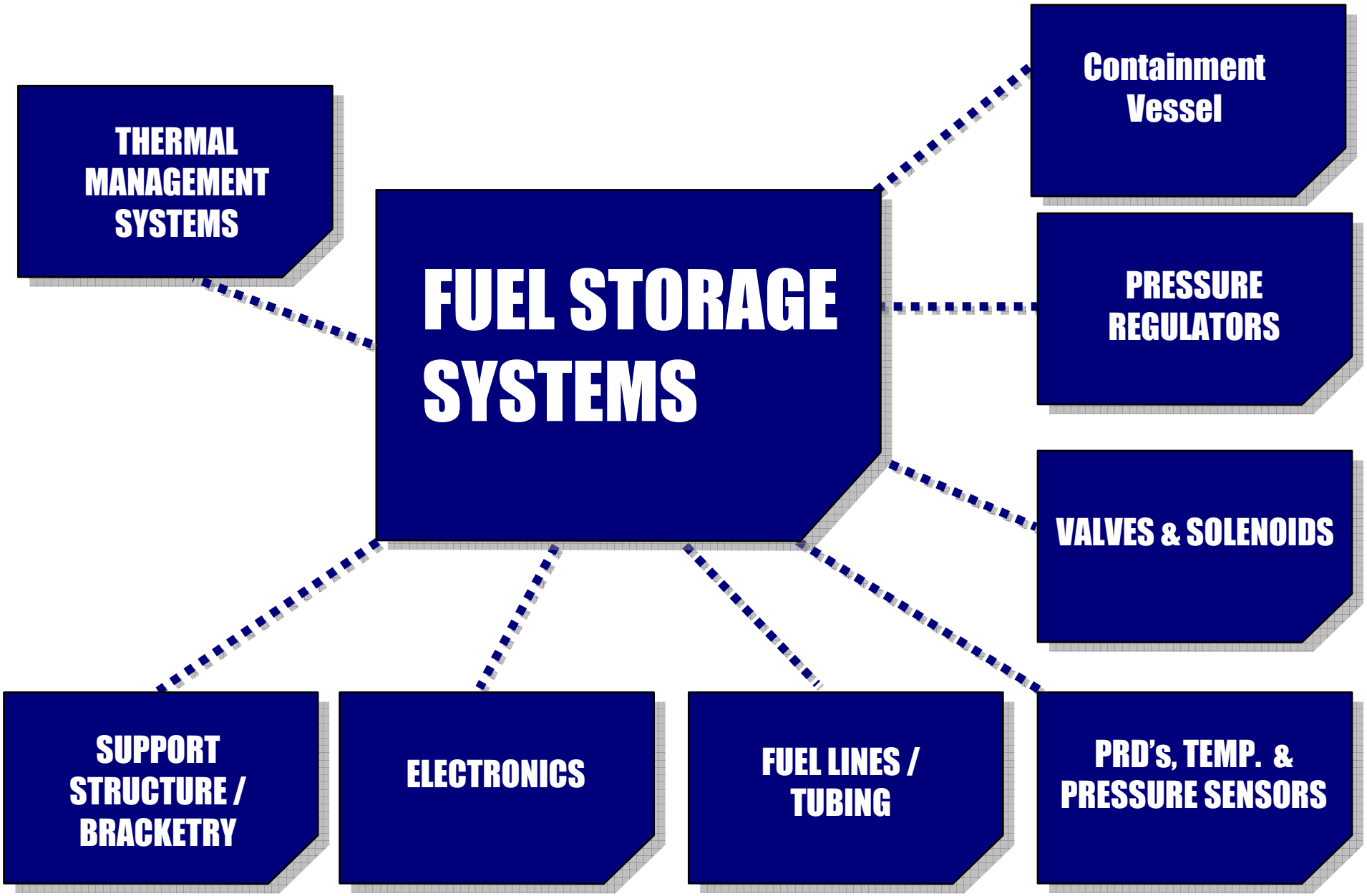
Hydrogen Storage – It's More Than a Tank

Hydrogen storage systems on H_2 vehicles must:

- Contain
- Control
- Regulate
- Monitor
- Distribute
- Meter
- Refill
- Survive

Integrated Fuel Storage Systems



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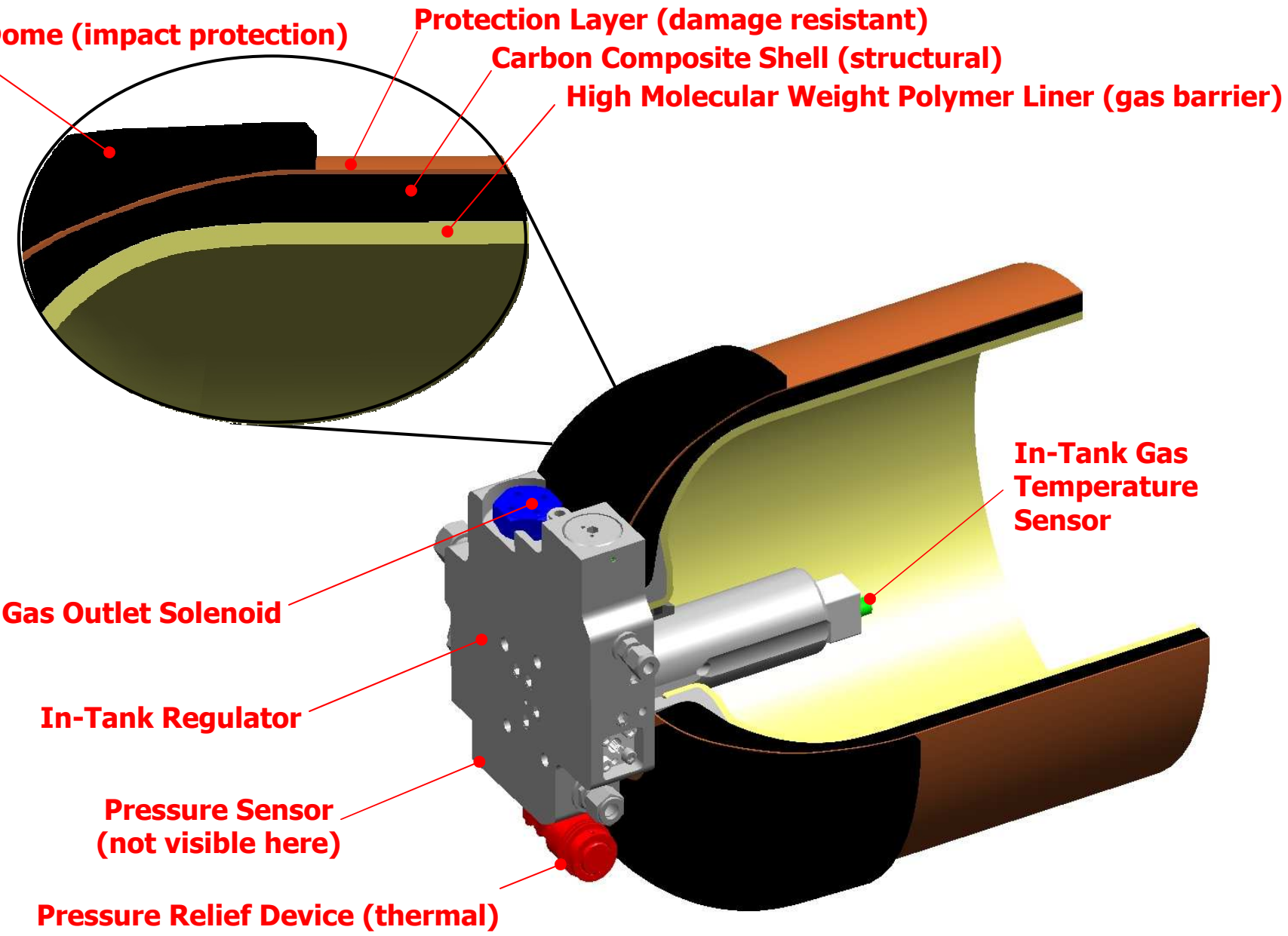
Quantum TriShield™ Storage Tank



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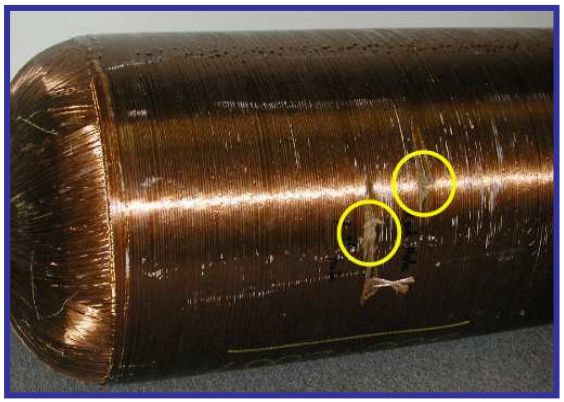
Tank Validation

Storage Pressure	Standards Compliance
3,600 psi (25 MPa)	NGV2-2000 (modified) DOT FMVSS 304 (modified)
5,000 psi (35 MPa)	E.I.H.P. / German Pressure Vessel Code DBV P.18 NGV2-2000 (modified) FMVSS 304 (modified) KHK (Japan)
10,000 psi (70 MPa)	E.I.H.P. / German Pressure Vessel Code DBV P.18 FMVSS 304 (modified) KHK (Japan)

Validation Tests

- Hydrostatic Burst
- Extreme Temperature Cycle
- Ambient Cycle
- Acid Environment
- Bonfire
- Gunfire Penetration
- Flaw Tolerance
- Accelerated Stress
- Drop Test
- Permeation
- Hydrogen Cycle
- Softening Temperature
- Tensile Properties
- Resin Shear
- Boss End Material

Validation Testing



Gunfire Testing

Environmental Testing

Hydrogen Cycling

Burst Testing

Bonfire Testing

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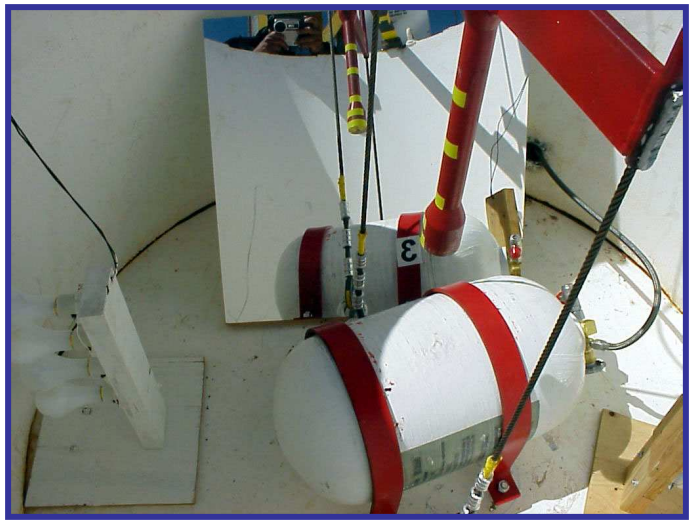
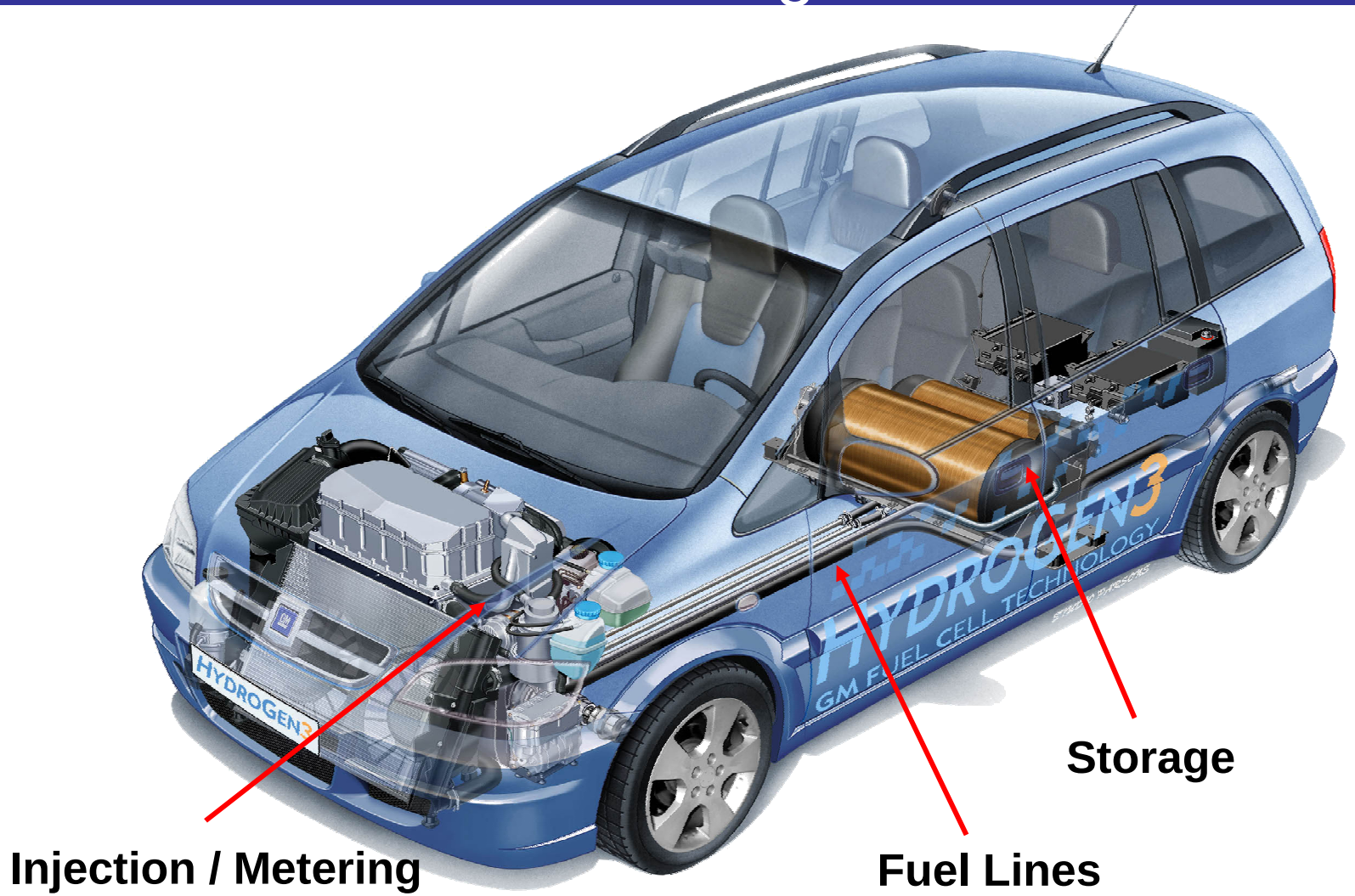
Severe Abuse Testing



OEM Production Level Integration



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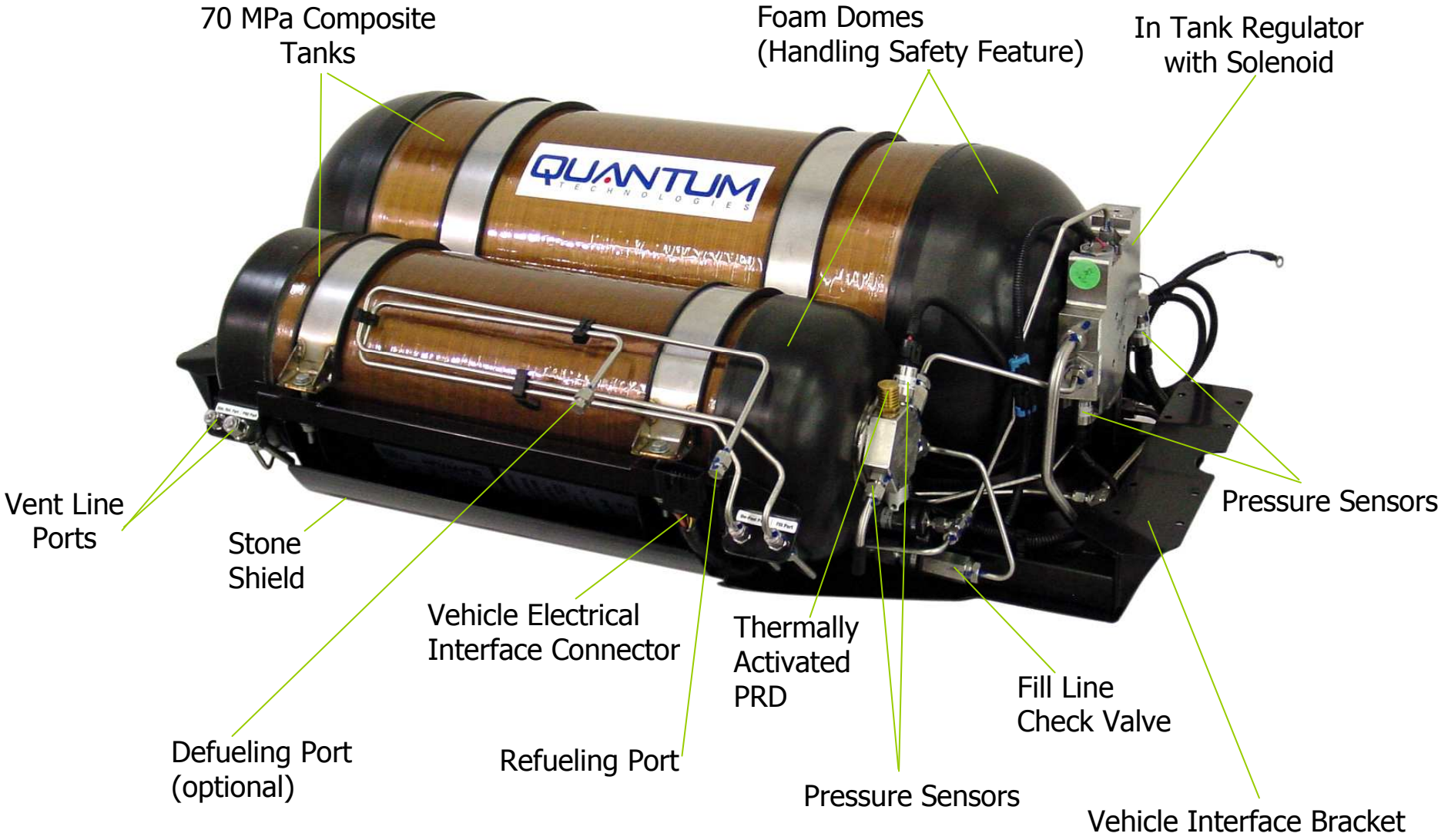
70 MPa Hydrogen Fuel Storage System



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General Motors HydroGen3

70 MPa Hydrogen Storage Engineering

Suzuki WagonR

70 MPa Hydrogen Storage Systems

General Motors Hy-Wire

35 MPa Hydrogen Storage Systems

GM Sequel

70 MPa Hydrogen Storage Systems

DOE Storage Targets

Parameter	Quantum Current*	2005	2010	2015
Usable Specific Energy (kW hr / kg)	1.3	1.5	2	3
Usable Energy Density (kW hr / L)	0.8	1.2	1.5	2.7
Cost ($ / kW hr)	$10-$17	$6	$4	$2
Cycle Life (Cycles, 1/4 tank to full)	15,000	500	1,000	1,500
Refueling Rate (kg H_2 / min)	2.0	0.5	1.5	2.0

* Single 160L 70 MPa tank, 500k production volume, optimized carbon, health monitored storage system.

Compressed Hydrogen Storage System Costs

Approximately 65% of System Costs are Carbon Fiber

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Achieving DOE Targets with Advanced Manufacturing

Path for Compressed Hydrogen Technology -

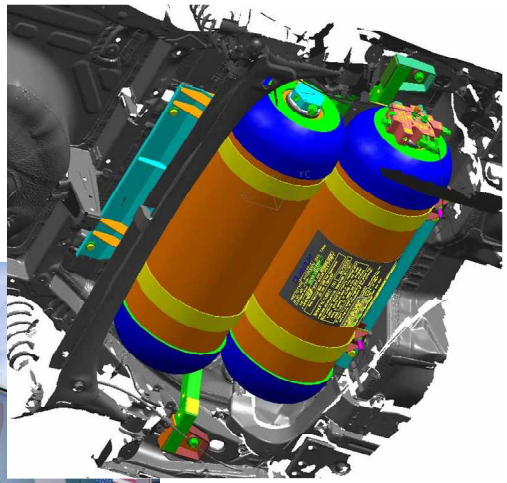
- •Storage Centric Vehicle Design
- •Single Longitudinal 160L 70MPa Storage Module
- •On Tank Automatic Valve
- •External Low Cost Pressure Regulation Components
- •Health Monitored Tank (1.8 SP Burst Ratio)
- •Integrated Filament Winding w/ Fiber Placement
- •Revision of Codes & Standards enabling Fiber Placement
- •Chilled Hydrogen Supply for Fast Fill

Achieving DOE Targets with Advanced Manufacturing

Estimated Performance -	
Usable Specific Energy (kW hr / kg)	> 2.0
Usable Energy Density (kW hr / L)	0.9
Cost ($ / kW hr)	< $10
Cycle Life (Cycles, 1/4 tank to full)	15,000
Refueling Rate (kg H_2 / min)	> 2.0

In Summary

- 35 MPa and 70 MPa storage systems in use on H_2 vehicles today
  - Extensive testing and validation completed
  - In use experience growing
  - Compressed H_2 storage vessels are “the strongest part” of the vehicle
- Refueling infrastructure being implemented to support compressed H_2 systems
- Challenges remain
  - Cost
  - Packaging on vehicles (range)



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