Ultra-lightweight LH2 Storage for LH2 Powered Aircraft and Other Vehicles

March 2024

3rd Annual H2-Aero Symposium
With the SAE AeroTech Conference
March 13-14, 2024
Charlotte, North Carolina, USA

GTL

Creating Transformational Technologies

Hydrogen Economic Barrier

Hydrogen (H_2) can make air transportation clean and more economical

but conventional Hydrogen Storage Tanks Are <u>Too Heavy</u>

State of the art is
5-7% Hydrogen fraction

Need ~35% Hydrogen fraction
for parity with kerosene

GTL

Validated Ultralight Cryotank Breakthrough

75% mass reduction

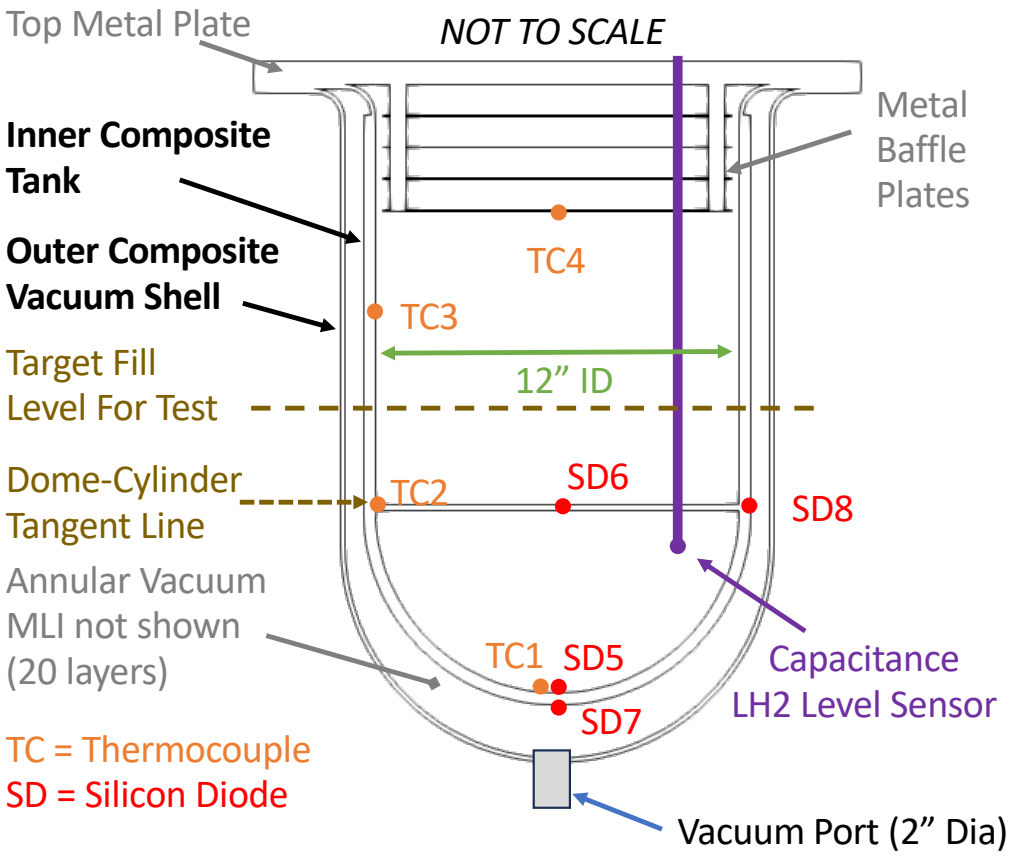
compared to state-of-the-art cryotanks

Gravimetric index (propellant fraction) > 55% for liquid H_2 vacuum insulated tanks

Provides 10X More H2 Fuel than conventional storage technology

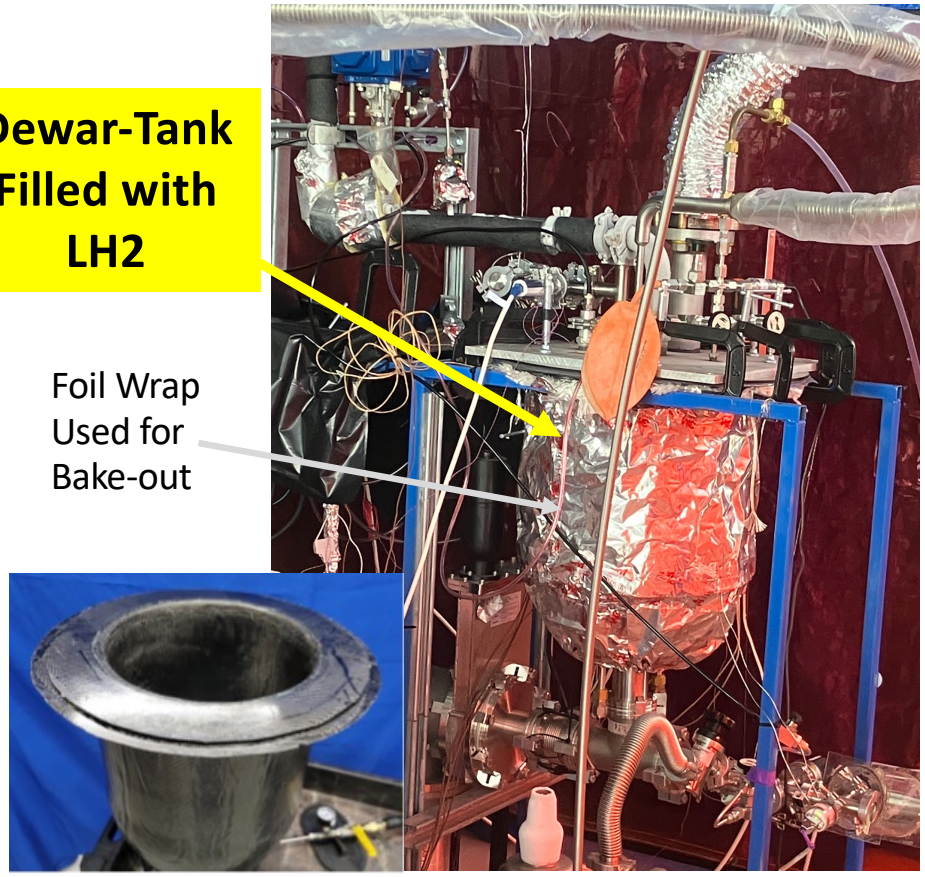
GTL

Subscale Composite Vacuum Jacketed LH2 Tank



Dewar-Tank Filled with LH2

Foil Wrap Used for Bake-out



Successful Operation of Composite Vacuum Jacketed LH2 Dewar-Tank

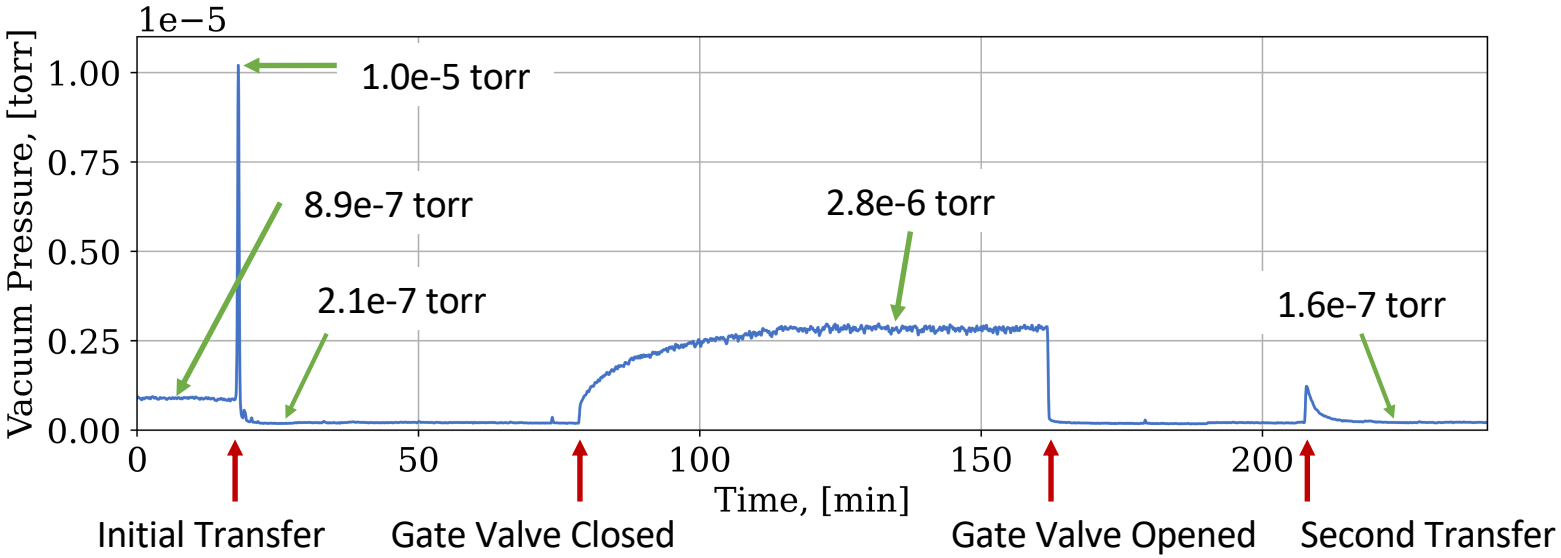
GTL

Vacuum Pressure During LH2 Test

Isolated vacuum jacket held 2.8e-6 torr for about 50 min with LH2

> 100X Better than requirement

This vacuum pressure indicates the total molecular permeation rate (inner, outer and seals) would be less than 9.46e-6 mbar-L/s-m2 (6e-9 sccs/in2) <performing additional tests to verify>

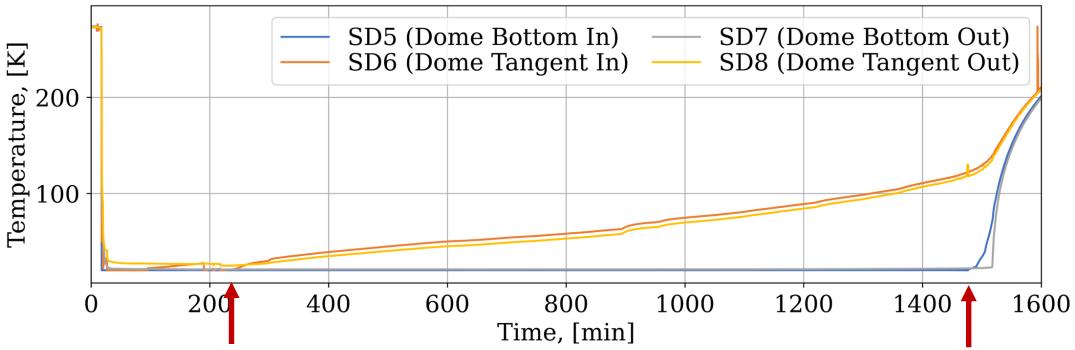


Verified Composite Dewar-Tank is Leak Tight with LH2

LH2 Boiloff Rate and Hold Time

~2.8W heat load into subscale => ~1% boiloff/day for full scale

Subscale Unit
Held LH2 for ~21 Hours



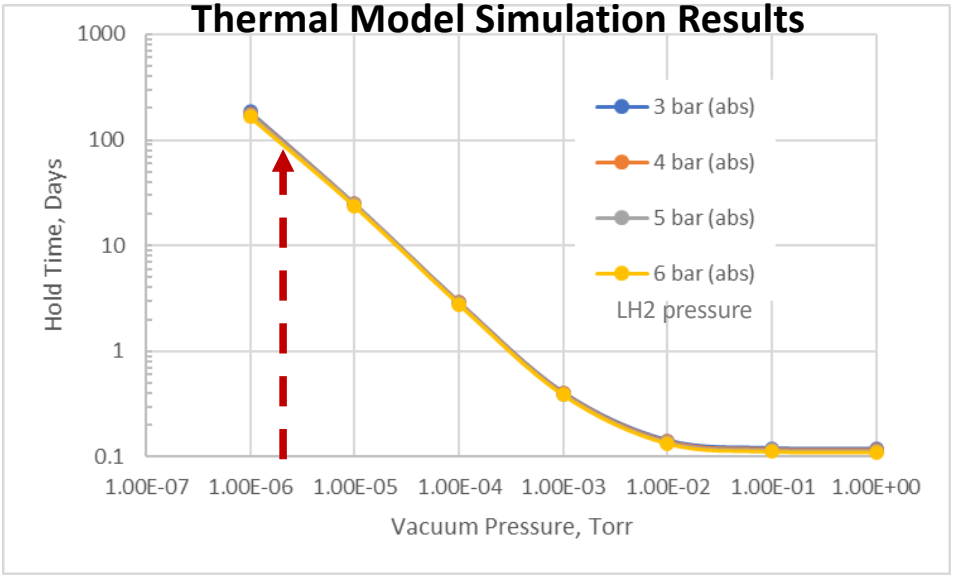
LH2 at tangent

No LH2 Remaining

Subscale Dewar-Tank took 1,259 min (~21 hrs) to boiloff 7 liters
Average boiloff rate ~ 0.33 L/hr or ~6.3e-6 kg/s

Average 2.8 W of heat load (92% from top plate)

Full Scale Unit
Thermal Model Simulation Results

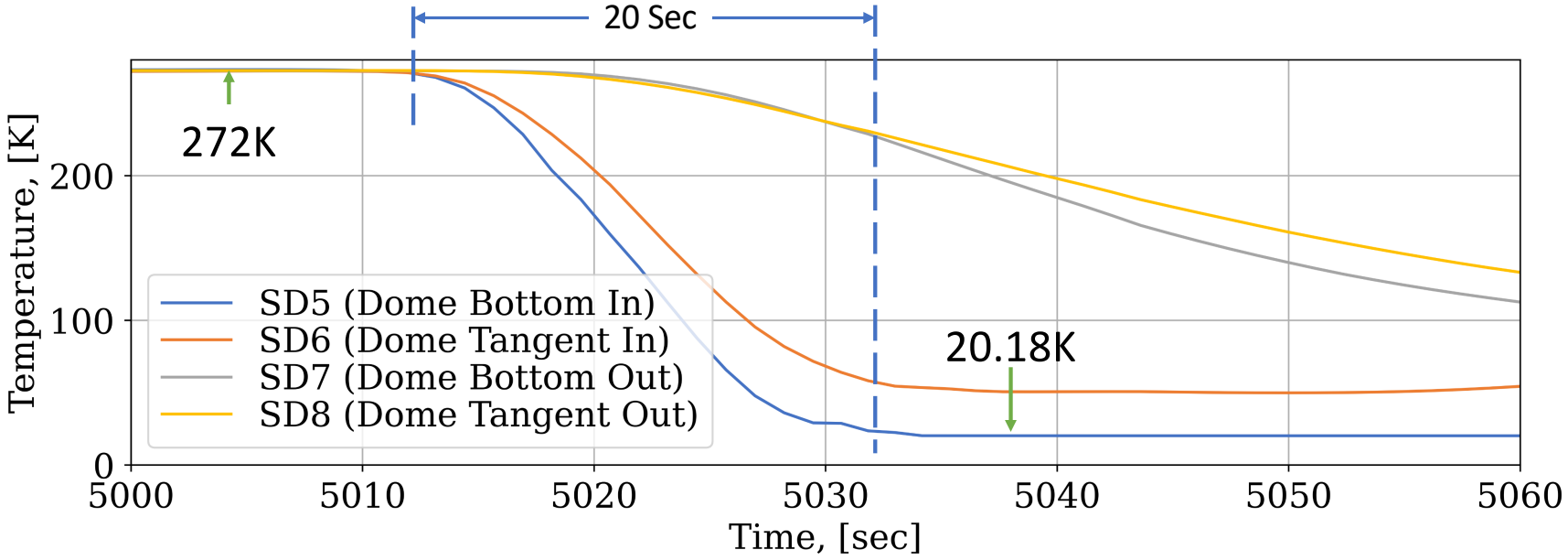


Anticipate ~90 days for 19kg LH2 Dewar-Tank to boil dry
Approximately 1% per day boiloff

Verified Capability to Hold LH2 for Long Duration

Subscale Composite Tank Chill Down with LH2

<20 seconds to go from Ambient Temperature to Holding LH2



Aircraft composite LH2 tanks can be filled in a few minutes

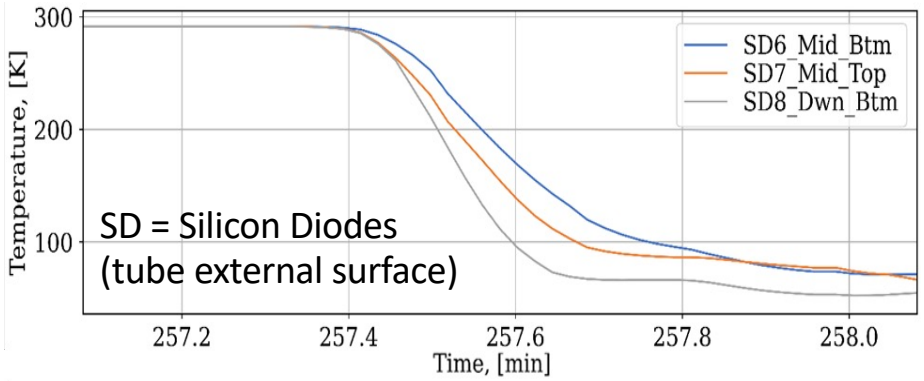
just like current aircraft operations

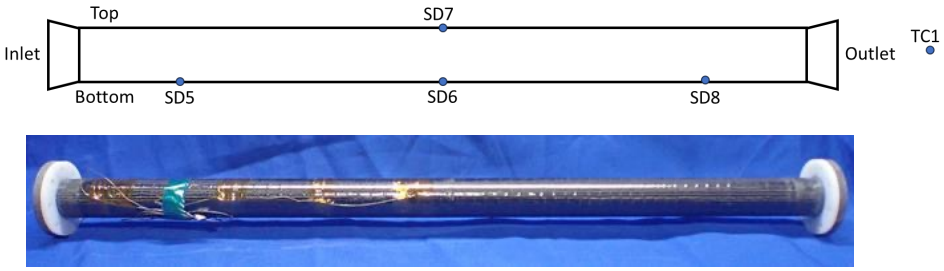
GTL

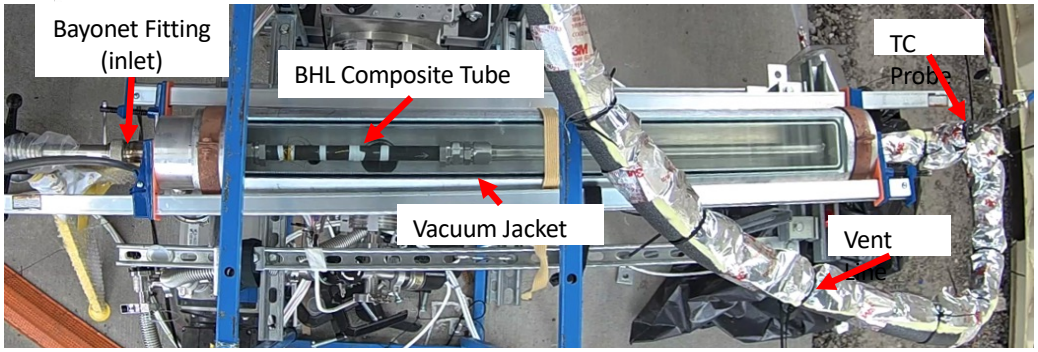
Composite Tube Rapid Chill Down with LH2

Less than 1 second for composite tube to achieve full LH2 flow

- Tube exterior surface reached steady state in <30 sec
- LH2 flow rate ~3.8 g/s
- Flow quality through composite tube 0.6% to 1.1% gas after 1 sec
- LH2 supply was saturated at 9 psig (22.13K)
- 1” dia by 14” long composite tube



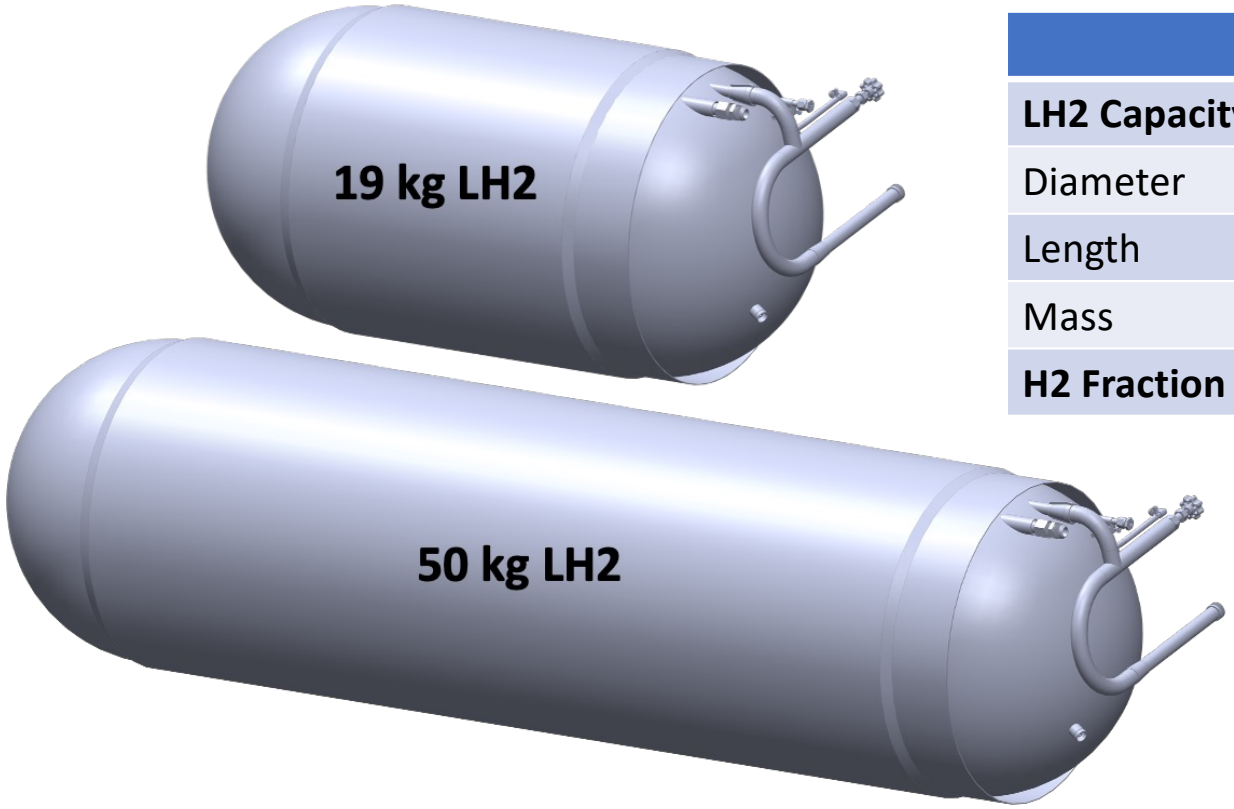




Minimizes boiloff during LH2 transfer (potential zero boiloff fills)

GTL

Flight Composite LH2 Dewar-Tanks



	Prototype	Stretched
LH2 Capacity	**42 lb (19 kg)†**	**110 lb (50 kg)**
Diameter	28” (0.71 m)	28” (0.71 m)
Length	53” (1.34 m)	106” (2.7 m)
Mass	33 lb (15 kg)	66 lb (30 kg)
H2 Fraction	**55.6%**	**62.5%**

† LH2 at 4 bar with 5% ullage

Min Burst Pressure	360 psi (24.8 bar)
Max Design Operating Pressure	143 psi (9.9 bar)
Nominal Vacuum Pressure	< 1e-4 Torr
Average Boiloff Rate	1% per day

Also developing 48” dia and 63” dia versions

Small LH2 Dewar-Tank scheduled to fly on manned helicopter in 2024

And on space mission in 2025

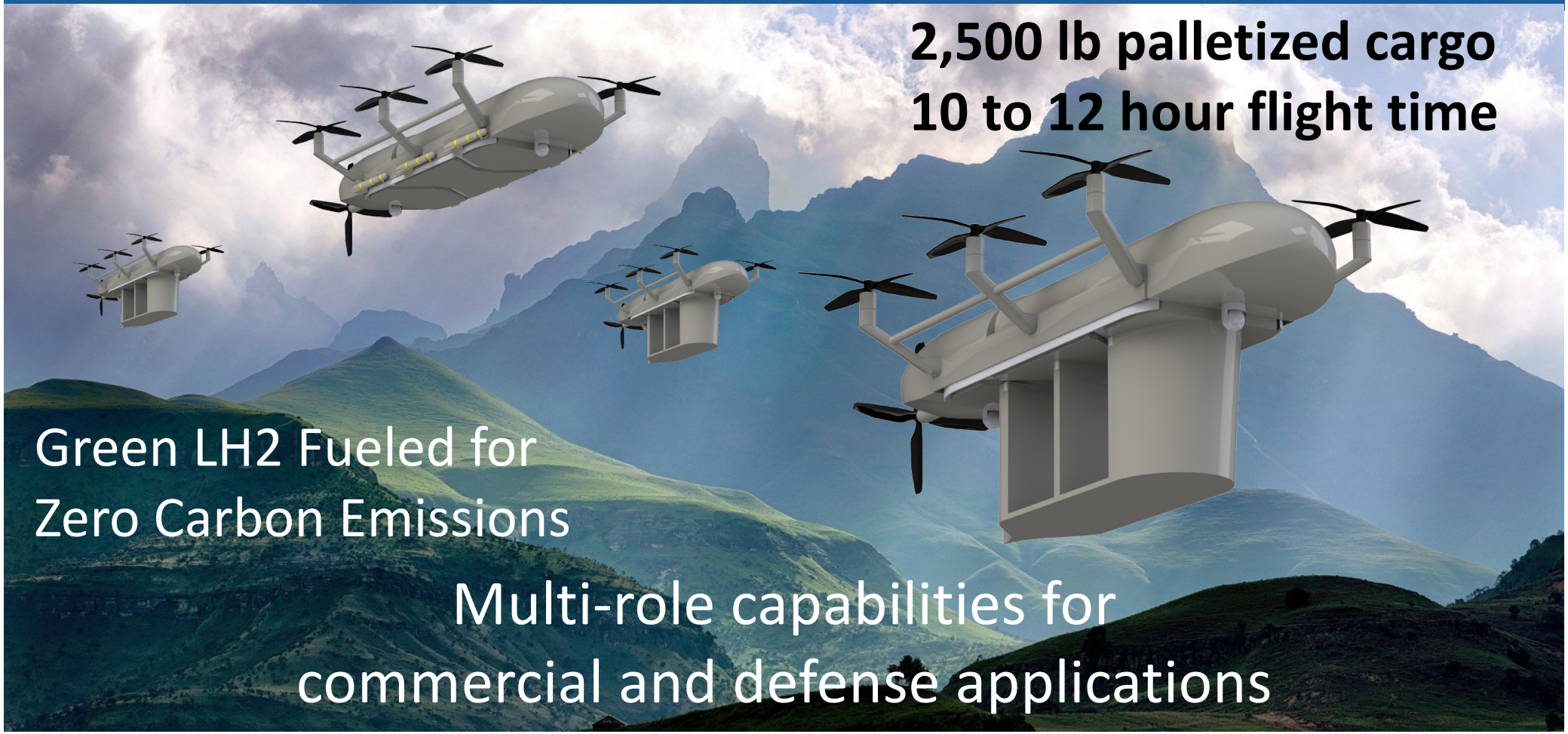
GTL

Long Endurance Drone Technology Demonstrator

- Composite LH2 Dewar-tank and fuel cell system drone
- Goal is persistent hover for 48 hrs
  (> 4X world record hover)
- Prototype under IR&D Development
- Flight demonstration planned for 2024

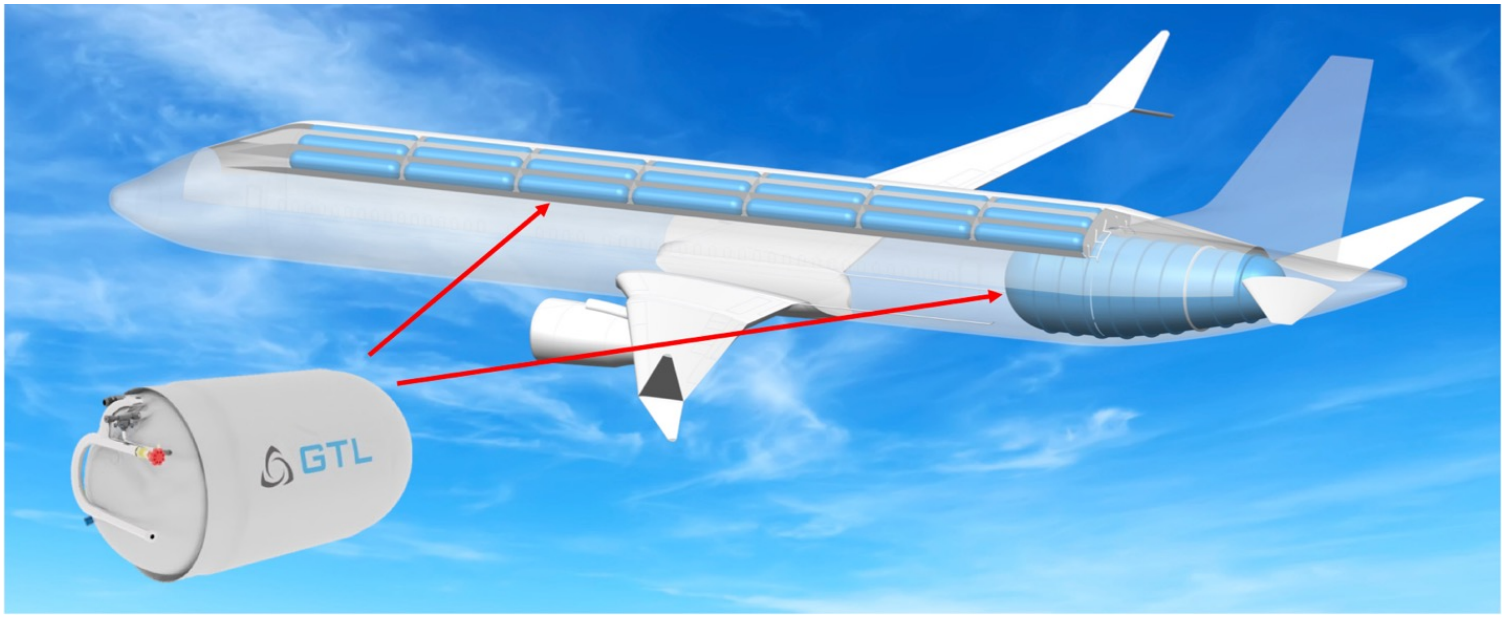
GTL

Wrangler™ LH2 Heavy Lift Drone



GTL

Conceptual Retrofit of 737 Max 8 for LH2



- Retrofit design maintains same payload mass, payload volume, number of passengers, flight range, and flight speed as the original kerosene fueled aircraft.

- Retrofit reduces aircraft weight by 25,000 lb to 32,000 lb using GTL's Composite Dewar-Tanks with LH2 instead of kerosene, which is 13% to 17% of reference aircraft maximum takeoff weight.

GTL

- For more information contact:

Paul Gloyer
President / Partner
o: (931) 455-7333
paul.gloyer@gtlcompany.com

Tim Lewis
Vice-president / Partner
o: (931) 455-7333
tim.lewis@gtlcompany.com

GTL