SUPERSONIC HYDROGEN TUBE VEHICLE
Mach 2.8 with Low Energy

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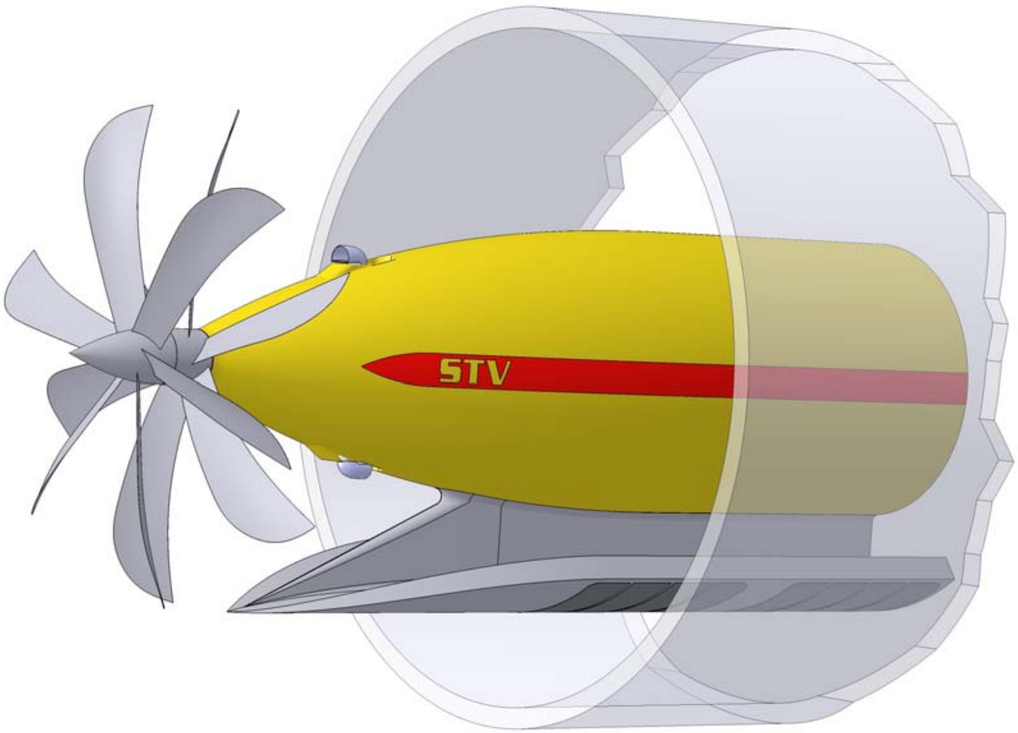

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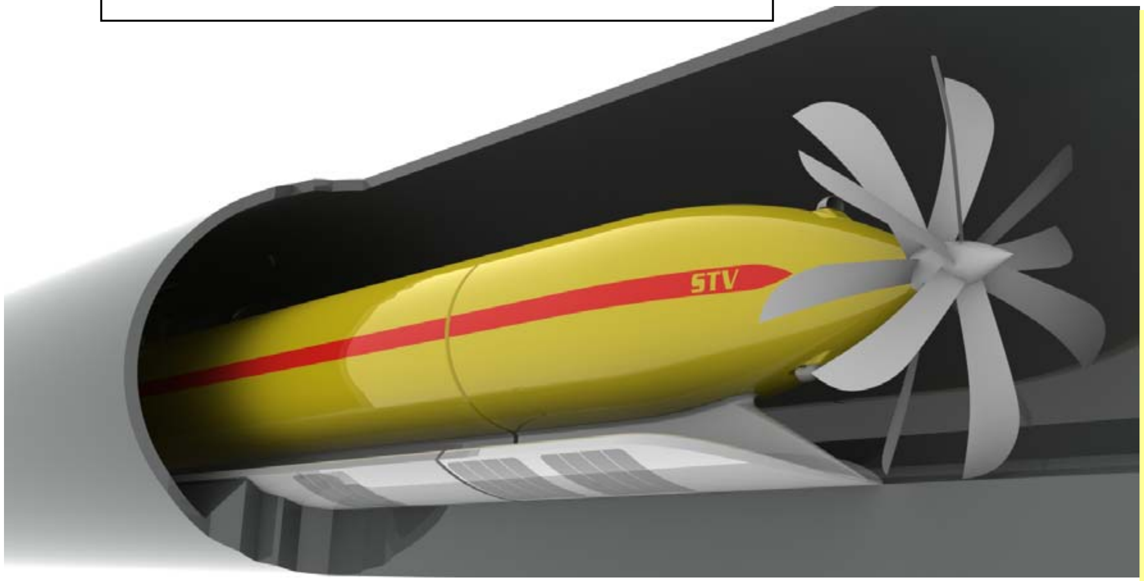
Vehicle Projects Inc has a unique history (since 1998) of developing large fuelcell vehicles

Fuelcell mine locomotive, a non-hybrid

127 t, 1.6 MW (max) fuelcell-hybrid shunting locomotive

SUPERSONIC TUBE VEHICLE: ***Concept***

Operation of a vehicle in a hydrogen atmosphere



Features

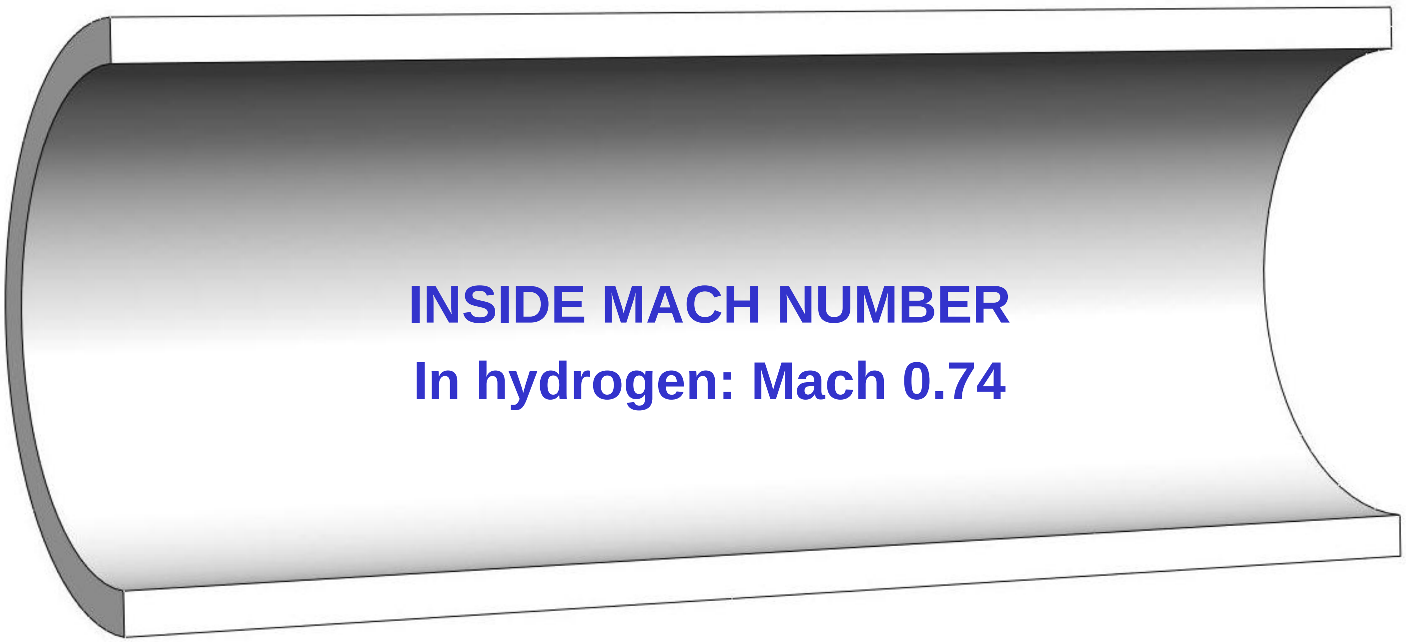
- Propfan propulsion
- Gas-bearing levitation
- Gas pressure ~ 1 bar
- Fuelcell powered
- Train-airplane cross

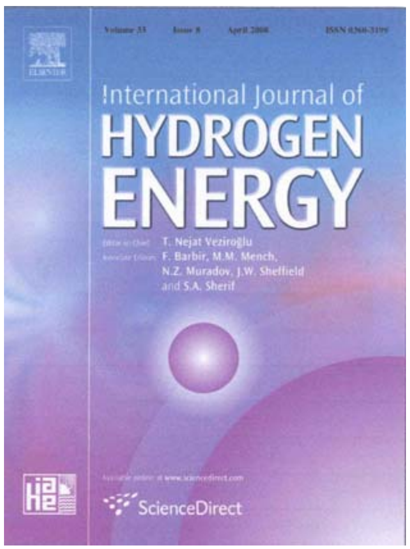
- **Onset of transonic flow increased by 3.8**
- **Parasitic drag reduced by 15**
- **A hydrogen atmosphere requires a tube or pipeline**
- **Solves the problem of hydrogen storage**

TWO MACH NUMBERS

OUTSIDE MACH NUMBER

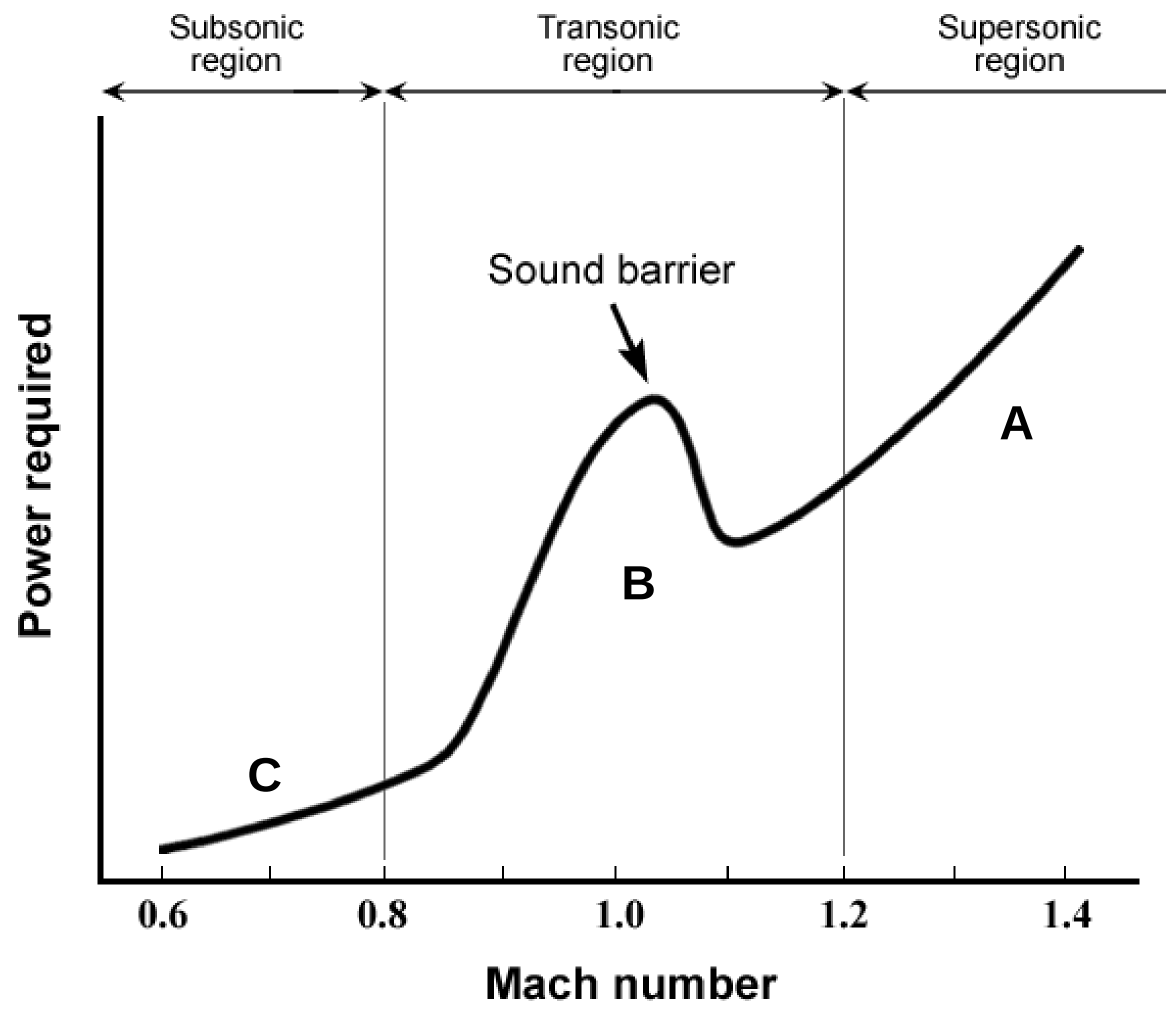
In air: Mach 2.8





- **Hydrogen tube vehicle for supersonic transport: Analysis of the concept**. *Int. J. Hydrogen Energy*. 33 (2008) 1995-2006
- **Hydrogen tube vehicle for supersonic transport: 2. Speed and energy**. *Int. J. Hydrogen Energy*. 35 (2010) 5745-5753

TRANSONIC LIMIT ON SPEED



ESTIMATION OF SPEED LIMIT

- Speed is limited by shock waves at prop blade tips
- Cruise speed of An-70 is 800 km/h at 10 050 m
- Speed of STV is 800 km/h x ratio of speeds of sound = 3500 km/h
- Mach 0.74 inside tube, Mach 2.8 outside

PRACTICAL CRUISE SPEEDS

Mode	Speed (km/h)
Supersonic Tube Vehicle	**3500 (Mach 2.8 in air)**
Airplane	**910**
Maglev (Shanghai)	**500**
High-Speed Train	**350**
Coach	**150**

Drag Equations

$$D_p = \tfrac{1}{2}\, C_p\, S\, \rho\, V^2$$ **Parasitic drag**

$$D_i = C_i\, W^2 / (\tfrac{1}{2}\, b^2\, \rho\, V^2)$$ **Induced drag**

D	Drag (induced drag ½ total for airplane)
C	Drag coefficient
S	Frontal area
ρ	Gas density (density of ~ 1/15 of air)
V	Velocity
W	Airplane weight
b	Wingspan

$E = Fd = Dd$

$P = TV = DV$

Conclusion: At given speed, drag of STV about 1/30 of airplane

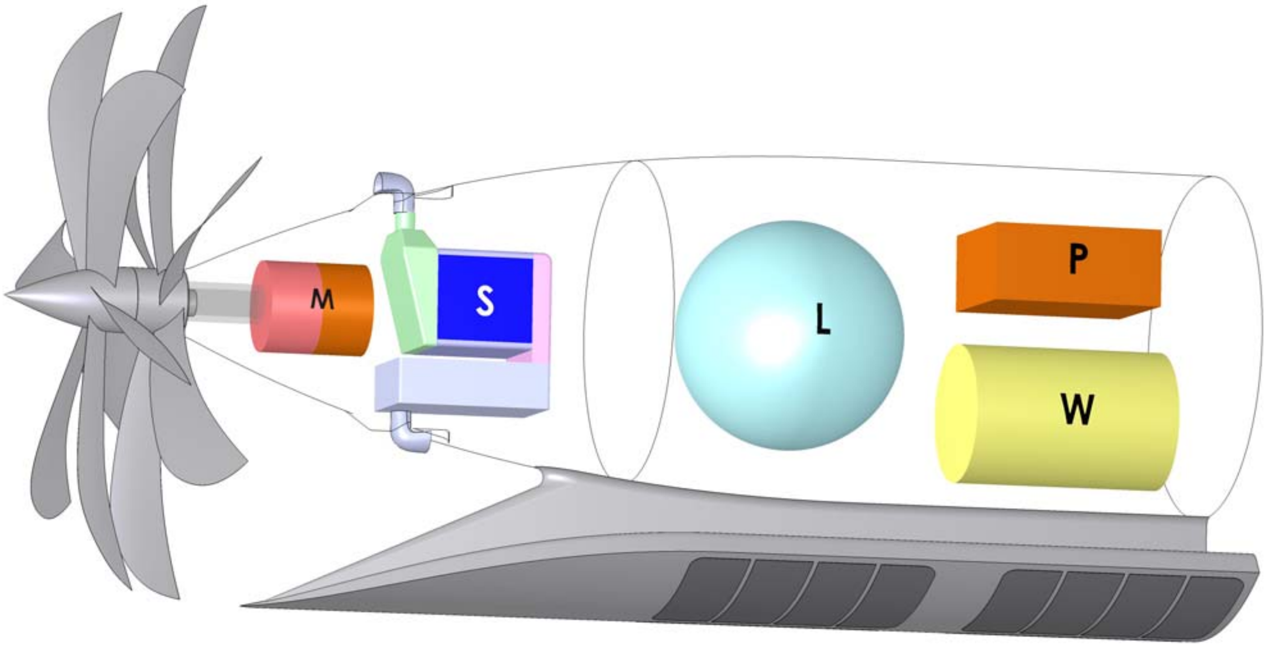
NORMALIZED ENERGY CONSUMPTION

Mode	E_{Nd} (kJ/seat-km)	V_0 (km/h)
Airplane	1530	870
Coach	254	110
Maglev	227	430
Train	184	300
STV	130	1500

RESULTS FOR STV

- **Capable of 3500 km/h (Mach 2.8)** – compare 910 km/h for Boeing 747
- **Concurrent low energy consumption** – at Mach 2.8, less than half the energy per passenger of Boeing 747 at Mach 0.81

BASIC TEST OF FEASIBILITY



- S = Fuelcell stacks (to scale of fuselage)
- L = Liquid oxygen (to scale)
- W = Water holding tanks (to scale)

(M = Propulsion motors; P = Power electronics)

CHALLENGES

Large:

- Gas-bearing levitation
- Infrastructure cost

Moderate:

- Safety
- Severe jetlag

CONCLUSIONS

- STV would be 3.3 x faster than current commercial airplanes
- Normalized energy consumption would be much lower
- The concept has been shown to be physically feasible
- Major challenges: gas-bearing levitation and infrastructure cost
- My work is to lay the theoretical foundations