

Developments for High-Speed Transportation: suggestions, points of interest and open fields

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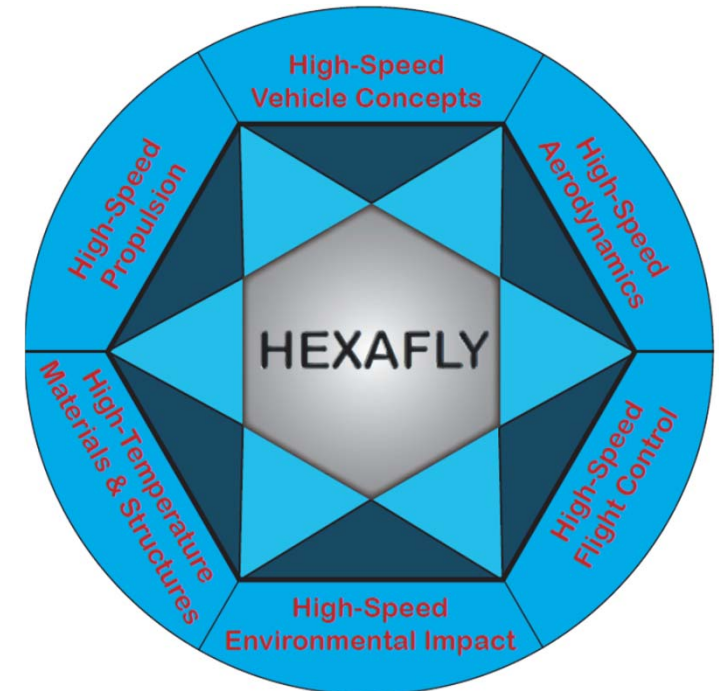
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Where are we now?

Time to test by Flight!

Emerging technologies and breakthrough methodologies to be flight tested grouped along **6 major axes**:

1. *High-Speed Vehicle Concepts*
2. *High-Speed Aerodynamics*
3. *High-Speed Propulsion*
4. *High-Temperature Materials and Structures*
5. *High-Speed Flight Control*
6. *High-Speed Environmental Impact*



R&D of Interest

1. *High-Speed Vehicle Concepts*

1. *Starting from basic principles*

- *diverting from Cayley's principles*
- *Aero-Propulsive-Thermo-Structural approach*

2. *Integrated design: propulsion – airframe*

3. *Light-Weight structures able to cope with high-temperature*

4. *Not constraining HST-design by classical constraints:*

- *Killing physically sound concepts*
- *Legal, infrastructure (airport, fueling, operation), internal layout rather as guidelines than imposed constraints*

5. *Thermal-Energy Management: coping with heat and on-board cooling*

Question: elements imposed or trade-off

- *Cryogenic fuels?*
- *Speed?*
- *PAX?*

R&D of Interest

2. *High-Speed Aerodynamics*

1. *Covering large range of speeds: subsonic, transonic, supersonic*

- *Assuring high L/D, minimal CoP shift...*
- *T/O and landing*

2. *Minimizing drag*

- *Pressure drag*
- *Viscous drag: transition onset, extent and delay → beneficial for heat transfer*

3. *Modelling of various aspects: CFD, engineering tools*

- *Turbulence: compressibility, transition...*
- *Nose-to-Tail Computations: positive T-D*
- *Validation with experiments*

Question: availability

- *Available WT models?*
- *Available Windtunnels?*

R&D of Interest

3. *High-Speed Propulsion*

1. *Covering large range of speeds: subsonic, transonic, supersonic*

- *Thermodynamic Cycles (e.g. using cryogenic fuel as lowest heat sink?)*
- *Assuring low sfc*
- *TBCC preferred solution (RBCC quite fuel demanding)*
- *Intake design: moveable geometries, BL suction*
- *Combustor: shape, cooling, injector layout...*
- *Nozzle: integrated, SERN, TVC...*

2. *Modelling of various aspects: CFD, engineering tools*

- *Combustion: turbulent, supersonic, fast-reaction mechanism*
- *Emissions predictions: NO_x, UHC, H₂O, CO₂...*

Question: availability

- *Available propulsion models?*
- *Available Propulsion benches?*

R&D of Interest

4. *High-Temperature Materials and Structures*

1. *High-temperature and light-weight materials: CMC, TMC, UHTC... both for internal and external flowpaths*

- *Oxidizing resistant*
- *Characterization at HT*
- *Thermo-mechanical fatigue characterization for CMC,...*
- *Lifetime prediction tools*
- *Environmental compatible: rain, hail, ... high-temperature...*
- *EBC: Environmental Barrier Coating*

2. *Integrated light-weight structures*

- *Multi-bubble architectures: propulsion bays, cabins, tanks...*
- *Integrated TPS vs Cryogenic tanks: passive or active*
- *Integration and manufacturing of panels, fixation, joints, seals*
- *NDI, HMI, easy replacement,...*
- *Cooling Techniques: regenerative, transpiration*

Question: availability

- *Available material databases at HT?*
- *Available thermo-mechanical material characterization benches?*

R&D of Interest

5. High-Speed Flight Control

1. **Covering large range of speeds: subsonic, transonic, supersonic**
 - Assuring high L/D, minimal CoP shift...
 - All moveable control surfaces
 - Interference with light-weight structure, e.g. PIO
2. **Automated GNC – HMS Coupling**
 - Automatic Guidance Navigation and Control Coupled to Health Monitoring System
 - Onboard Real-Time Trajectory Reshaping
 - FDI: fault Detection and Isolation
 - Synthetic Cockpit: minimal number of windows
3. **IFM: In –Flight Measurement Techniques (linked with HMS and FDI)**
 - FADS: Flush ADS
 - FOS: Fiber Optical Sensors (lower harness weight) for strain, temperature...
 - ...

Question: availability

- Available Experience



Available Flight Control on remotely controlled aircraft?

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R&D of Interest

6. *High-Speed Environmental Impact*

1. *Emission at various altitudes: T/O & landing, climbing, cruise*

- *NO_x, H₂O, CO₂, UHC on ozone layer and stratosphere (beyond 30km)*
- *Environmental Paradigm*

2. *Sonic Boom (→ hot topic in the US and Japan)*

- *Shape design*
- *N or S shaped sonic boom: rattling vs pressure differences*
- *Predictions: cruise, caustic, turbulence, wind...*
- *...*

3. *Noise*

- *High-Speed Jet noise*
- *T/O & Landing*
- *Cabin noise (through BL?, SWBLI...)*

Question: availability

- *Available sonic boom data and tools for acoustic propagation?*
- *Available climate models?*

R&D of Interest

7. Additional Points

1. Updating Cost models:

- *Linked to HST aircraft development and operational costs*
- *Recurring & non-recurring costs*

2. Airport Infrastructure & Operations

- *Operational: preparation (chill-down, heat-up), time-slots...*
- *PAX-loading & unloading*
- *Fuel production and distribution*

3. Human Biology

- *Time-zone difference: different sort of jet-lag → bio-rhythm*
- *Acceptable accelerations*

4. On-board systems:

- *On-board energy generating system: closed cycle*
- *Parametric weight estimation for all components*

5. Air Traffic Management

- *Stratospheric flights*
- *Crossing tropospheric routes*
- *Gliding approaches*

R&D of Interest

7. *Additional Points*

6. *Safety aspects:*

- *Linked to HST aircraft development and operational costs*
- *Recurring & non-recurring costs*

7. *Business case scenario*

- *Updating routes and potential from 2035 till 2050*
- *PAX-interest and market capture*
- *sensitivity analysis for 300PAX aircraft.*
- *Potential synergies: critical cargo, access to space...*