Disruptive Technology: Hypersonic Propulsion

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Dr. William U. Borger

Director

Propulsion Directorate

Air Force Research Laboratory

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Outline

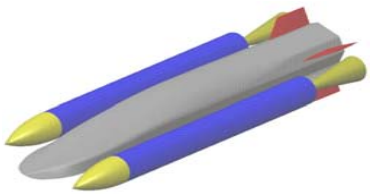
- The value of speed
- What does it take
- Summary

Potential Air Breathing Hypersonic Applications

Source: SAB, Why and Whither of Hypersonic Research in USAF, Dec 2000

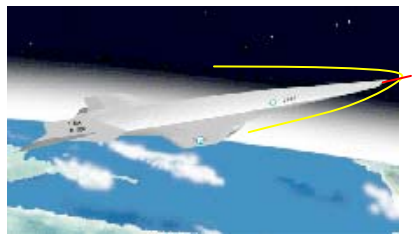
Weapons (missiles)

- Time Critical Mobile targets
- Hard and Deeply Buried Targets
- Suppression of Enemy Air Defense
- Ballistic Missile Defense / Theater Ballistic Missile Defense



Aircraft

- Global Strike/Recce



Space Operations

- Routine launch
- Replace & maintain key satellites

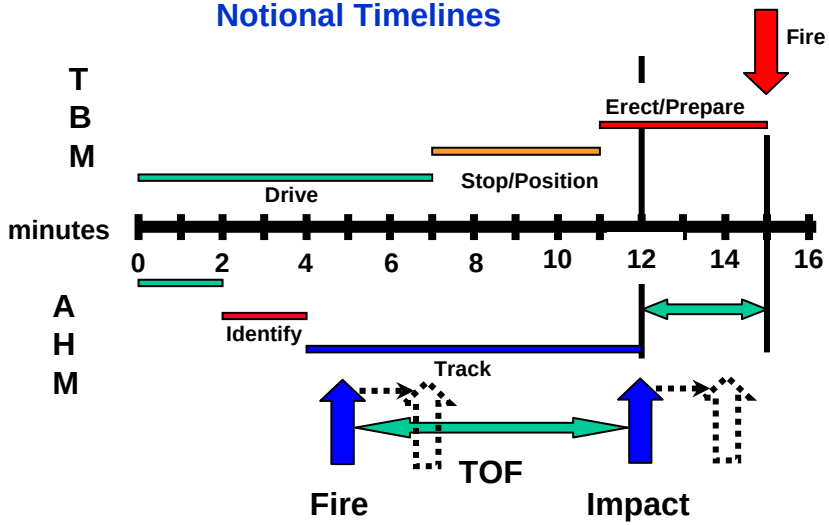
SAB: Scientific Advisory Board

SAB TR 00-03, Cleared for Open Distribution

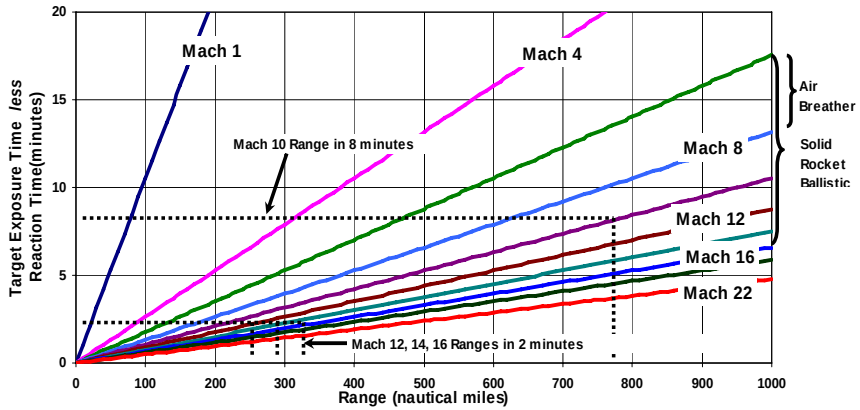
Air Breathing Hypersonic Missile

Source: SAB, Why and Whither of Hypersonic Research in USAF, Dec 2000

Notional Timelines



Relies on robust ISR



SAB TR 00-03, Cleared for Open Distribution

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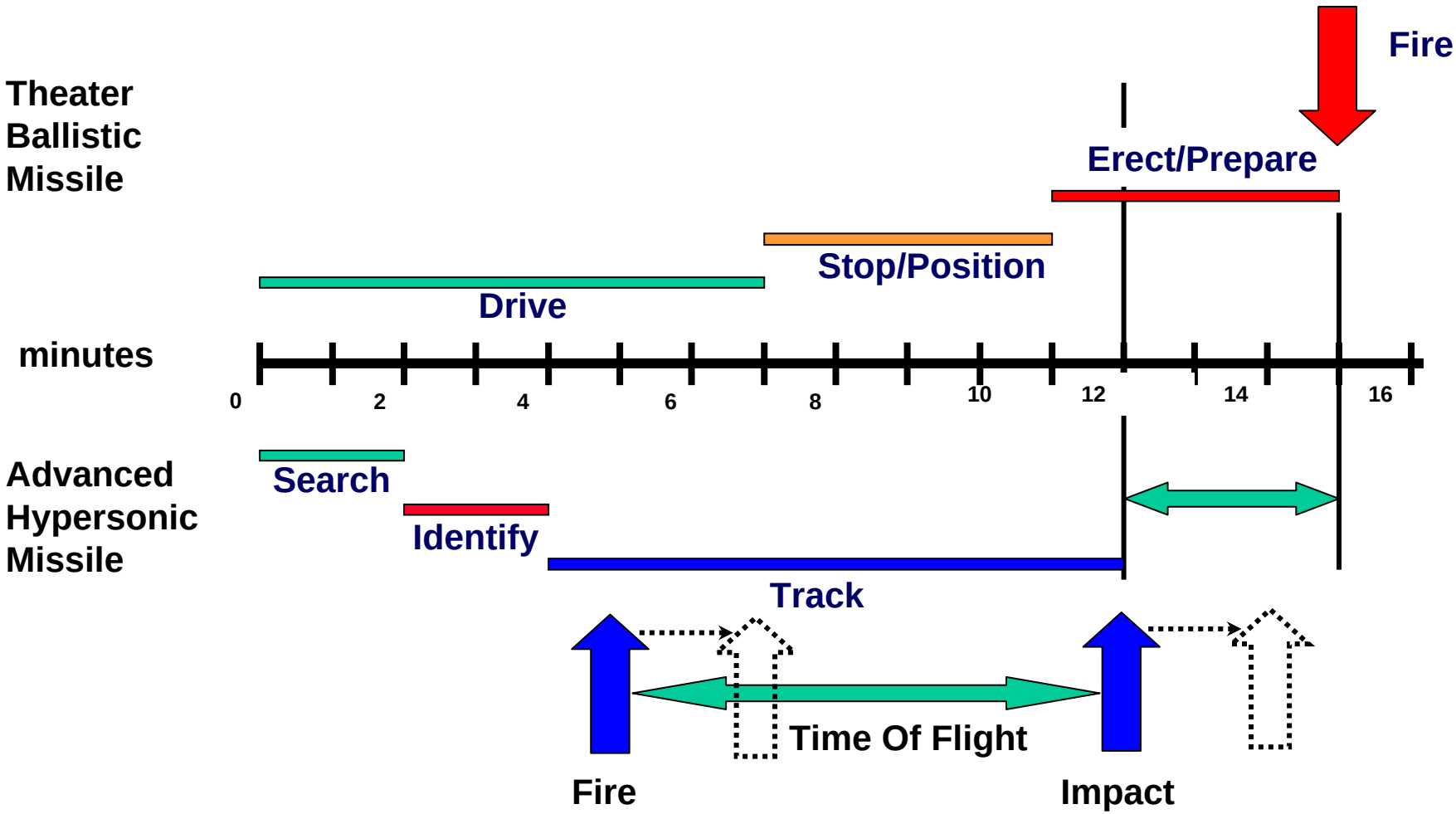

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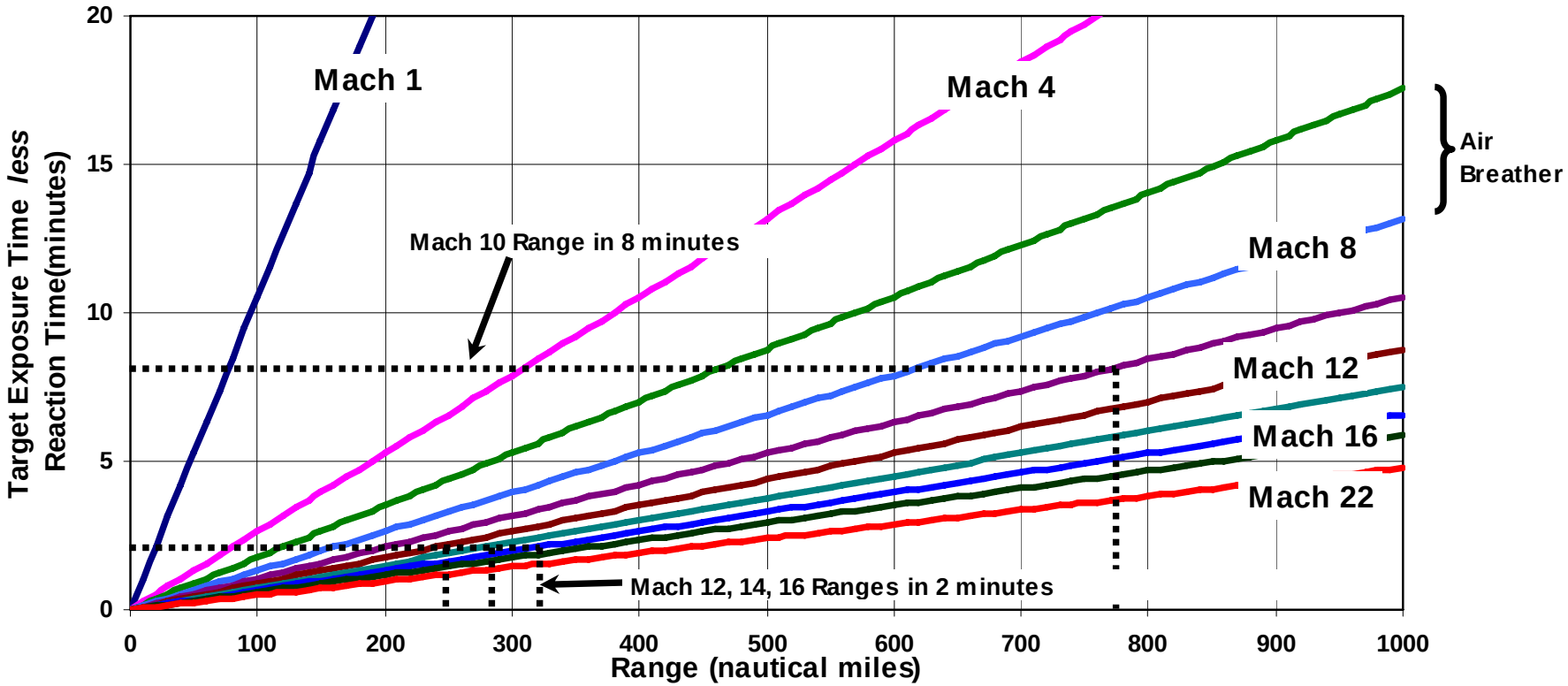
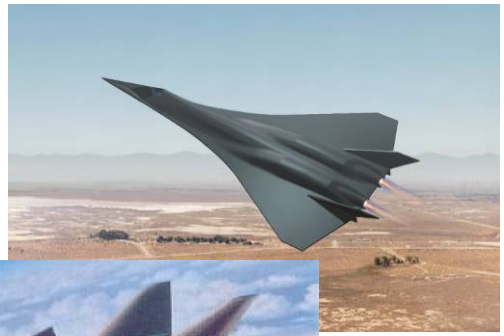


Aircraft: Mach 5-7 Strike/Recce Vehicles

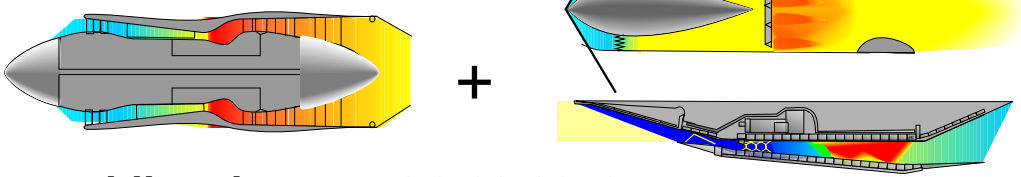


Pros:

- Limited infrastructure impact
- Very fast response times
- Increased speed helps survivability
- Storable fuels - capable of standing alert

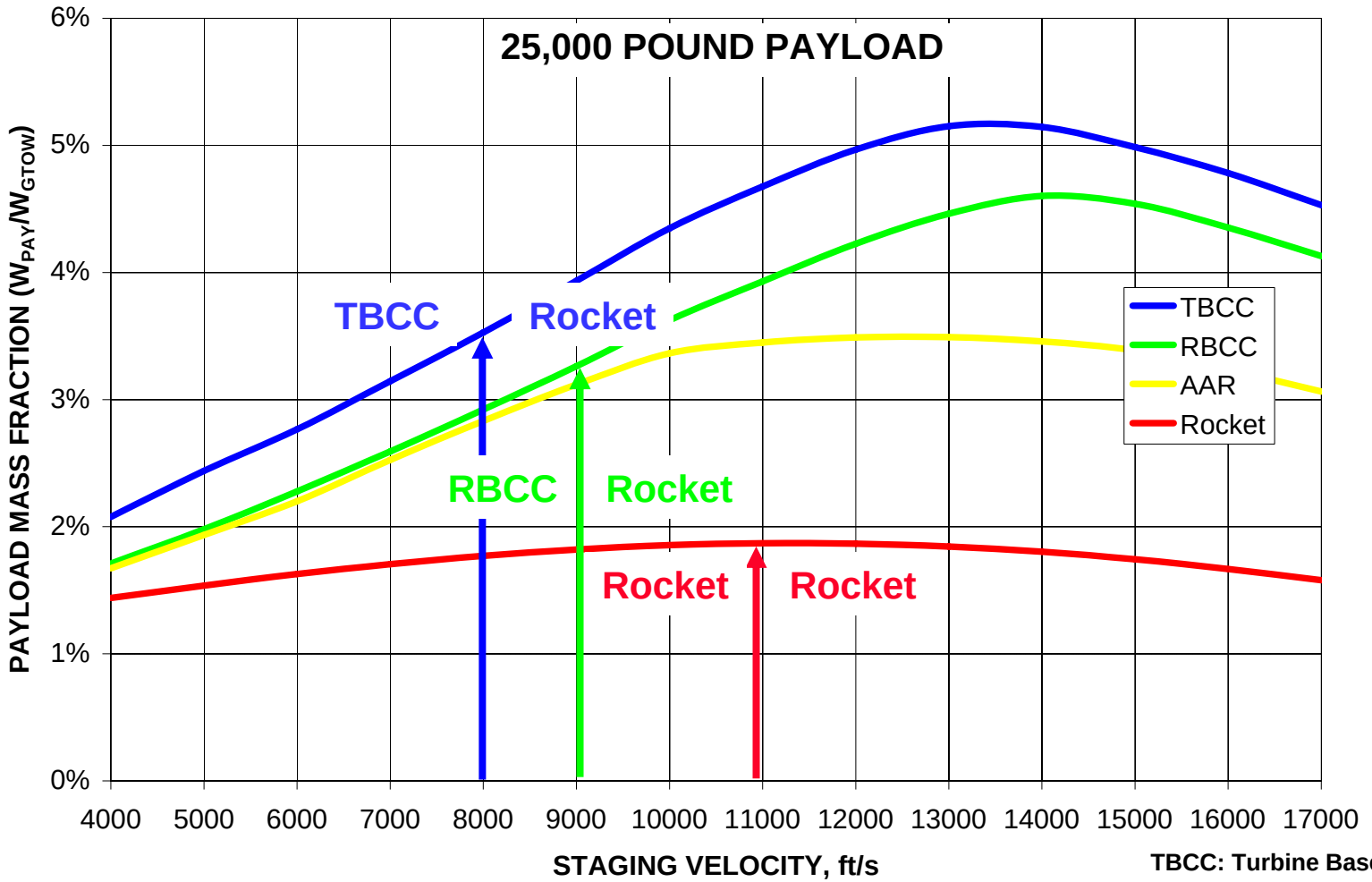
Cons:

- High production costs
- Some R&D needed: combined cycle engines, materials, and cooling
- Increased cost for maintenance, logistics



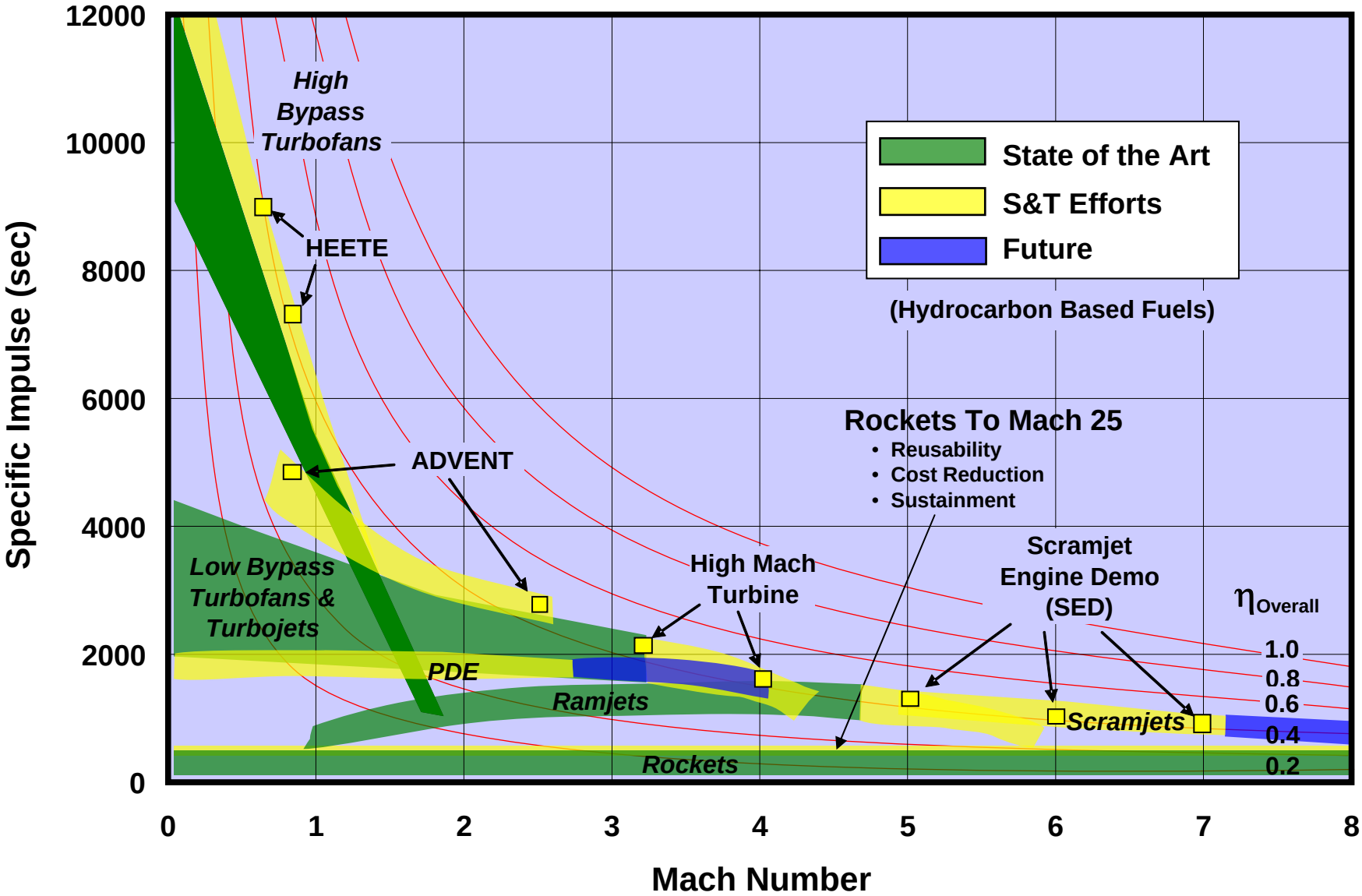
Typically Turbojet and Ramjet or Scramjet

Mach 8 Air-Breathing Propulsion Doubles Payload Fraction to LEO



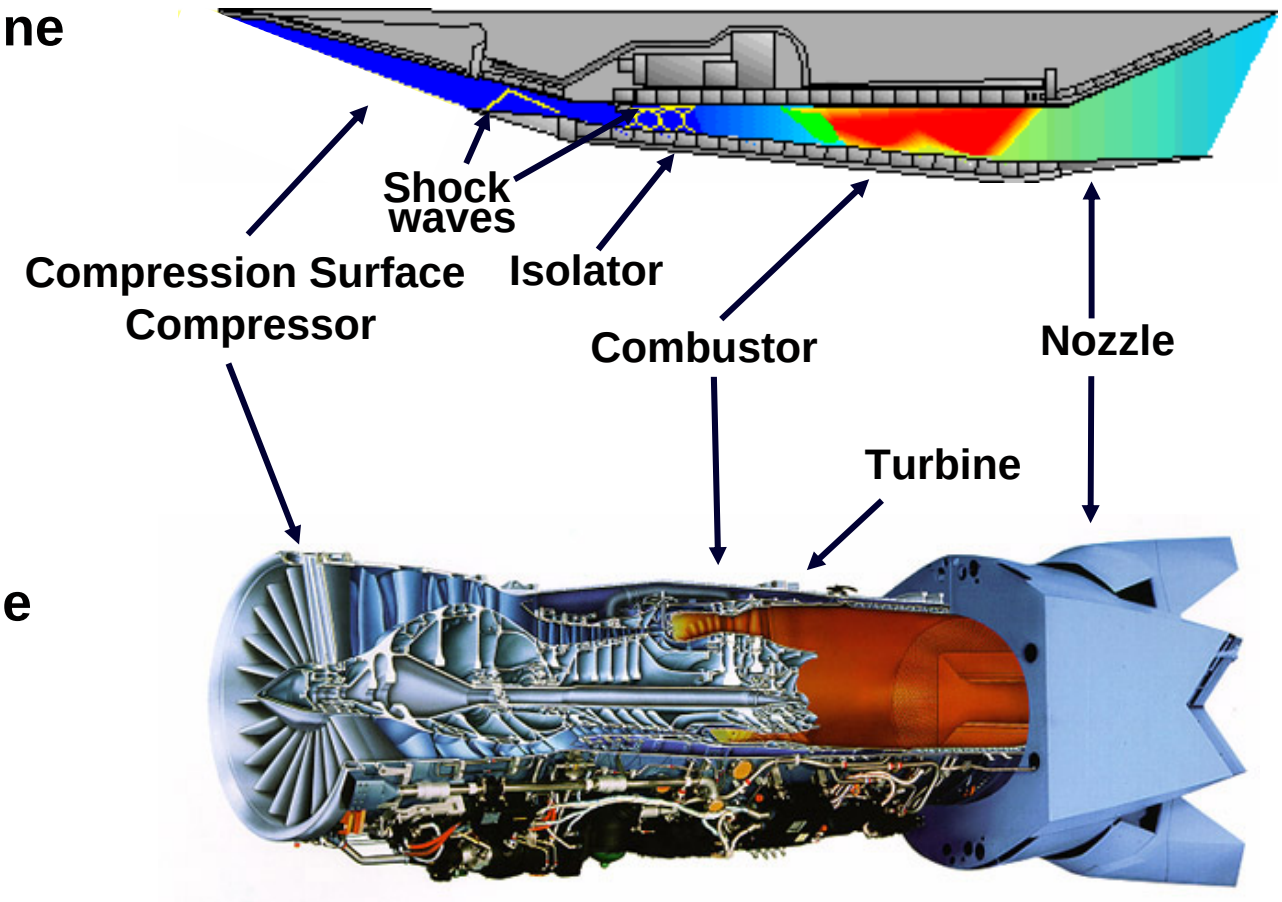
TBCC: Turbine Based Combined Cycle
RBCC: Rocket Based Combined Cycle
AAR: Air Augmented Rocket

Aerospace Propulsion Domain
Improving Fuel Efficiency Across Flight Spectrum



Scramjet Propulsion

Scramjet Engine



Turbine Engine

AFRL's Hypersonic Technology Development Approach

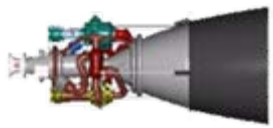
Stair-step approach builds upon prior successes.

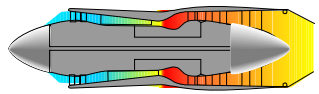
Multiple Roles
(Robust, Responsive)

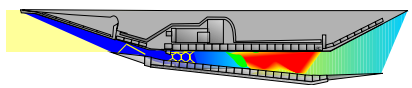
Expendable Space Lift
(On Demand)

Hypersonic Missiles
(Time-Critical Targets)

Large Scramjets and CCEs



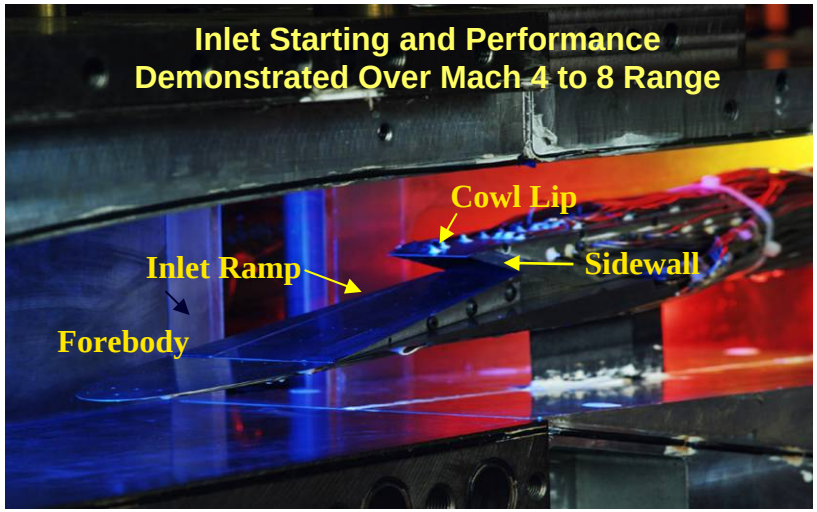


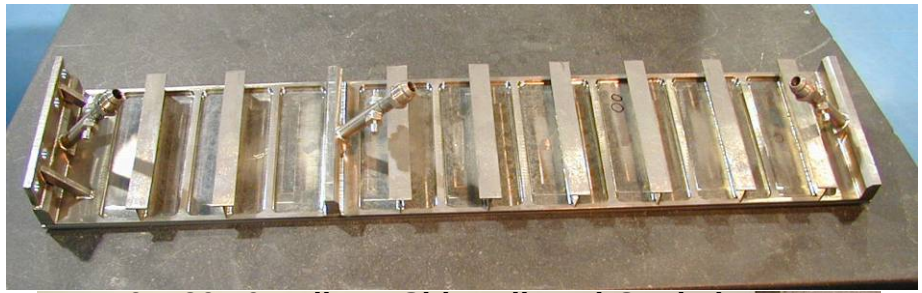


Medium Scramjets

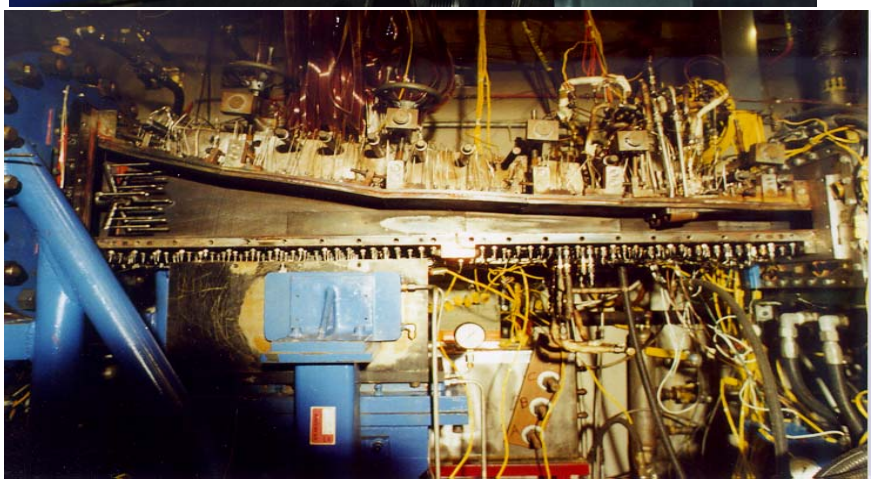
Small Scramjets

HyTech: HYDROCARBON SCRAMJET COMPONENT TECHNICAL CHALLENGES HAVE BEEN MET





6”X30” & Full 75” Sidewall Fuel-Cooled
Heat Exchanger Demonstrated
Structural Durability



Combustor Operability and Performance
Demonstrated Over Mach 4 to Mach 8 Range

Freejet Test of Integrated Heavyweight Engine
Demonstrated Performance & Operability

Cleared for public release: ASC 03-2959

Ground Demonstration Engine 1 Status: Testing at GASL Completed

- Testing initiated Sep 02, completed Jun 03, 60 tests
- Mach 4.5: Performance comparable to heavyweight PTE tests
- Mach 6.5: Performance exceeded heavyweight PTE tests
- Engine fuel cooled structure in excellent condition

First Demo of Flight Weight Hydrocarbon-Fueled/Cooled Scramjet Engine!

Ground Testing Carries Scramjet Development Only So Far

High-speed flight simulation on the ground is tough

- Limited facilities world-wide
- Even in the very best facilities compromises are made
  - Model size and structure
  - Inlet air purity … composition, T-P-M profiles, etc
- Testing at fixed Mach number … no flight transients
- Still have to deduce installed performance … for an engine-airframe that must be well integrated
- Hydrocarbon fuels and active structural cooling exacerbate the test challenges
  - Complex fuel thermodynamics and chemistry

Flight-test required to demonstrate scramjet viability

X-51A Scramjet Engine Demonstrator (SED)

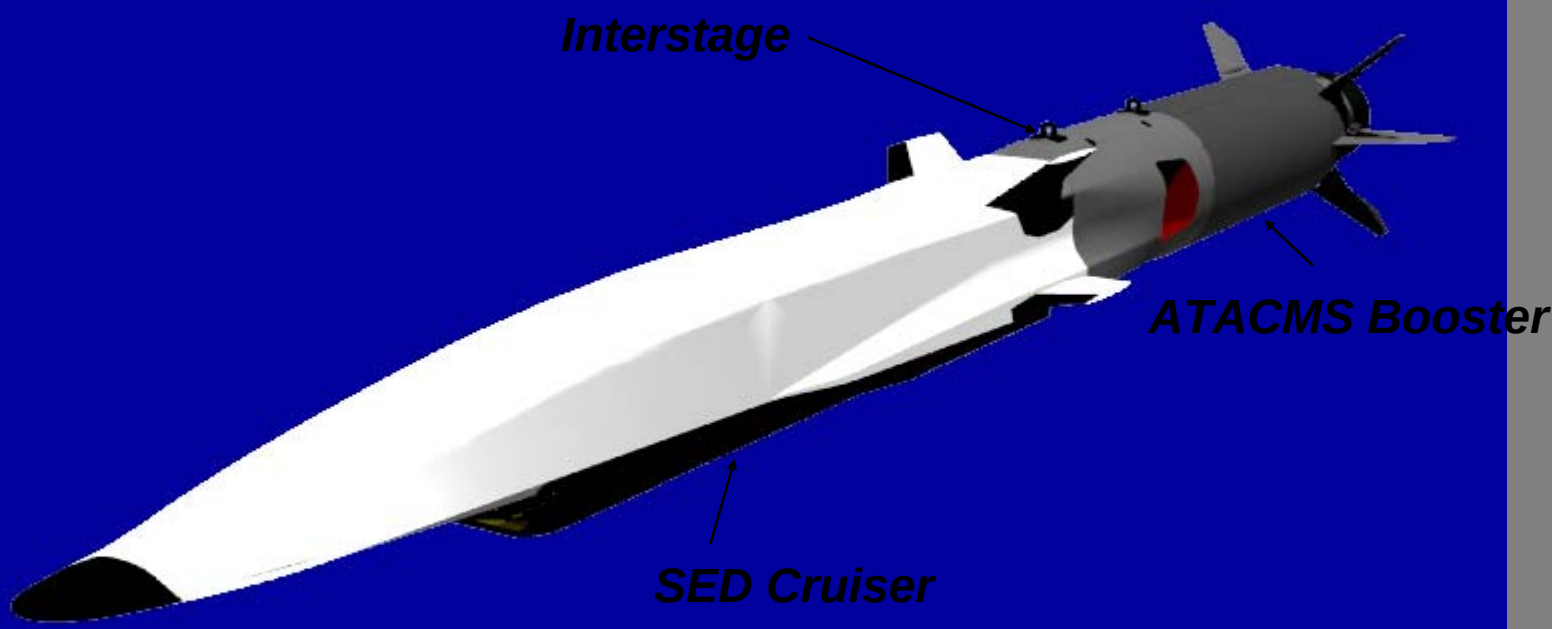
- Joint AFRL-DARPA flight demo of AFRL's hydrocarbon-fueled scramjet & waverider airframe technologies
- Uses modified ATACMS booster
- Scramjet take-over at Mach 4.5
- Cruise at Mach 6.5 to 7.0
- Four flights (FY09 1st flight)

X-51A SED Configuration

Potential Weapon Characteristics

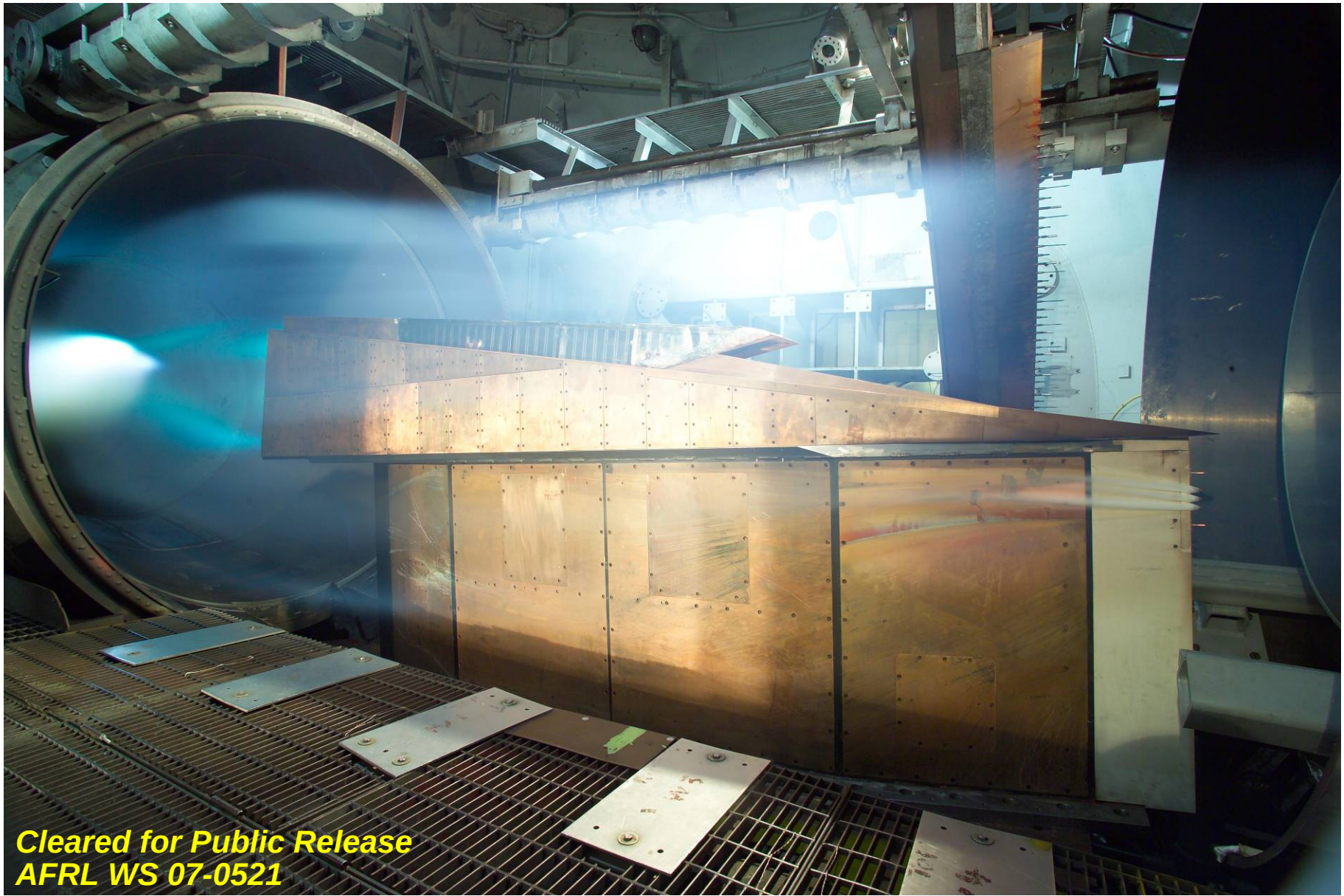
- Tandem or side-by-side booster
- 2300 lb launch weight
- Range: 600 nm/10 min
- 300 lb payload (penetrator, smart submunitions, or explosive)

X-51A Configuration



- *Utilizes one HyTech scramjet engine derivative flowpath*
- *Composite leading edges and Boeing proprietary TPS*
- *Utilizes off-the-shelf booster technology; booster will be modified slightly to optimize air launch*

SJX61-1 Testing at LaRC



Cleared for Public Release
AFRL WS 07-0521

X-51 SED Flight Test Operations

EAFB - Flight Ramp
A/C Pre-Takeoff Events
- **SED Build Up**
- **Load Mission OFP Tape**
- **Load Encryption Keys**
- **Load SED On A/C**

Pt. Mugu Test Range
- Ingress
- Determine - In Zone
- Apply Power
- BIT/GPS Acquisition
- Intent to Launch

Launch
- Internal Power
- Release/Eject Air Vehicle
- Safe Separation
- Booster Ignition

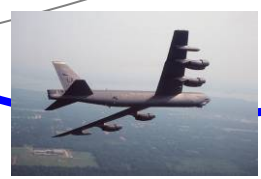
Climb

Separation

Boost

Unpowered Descent

Impact

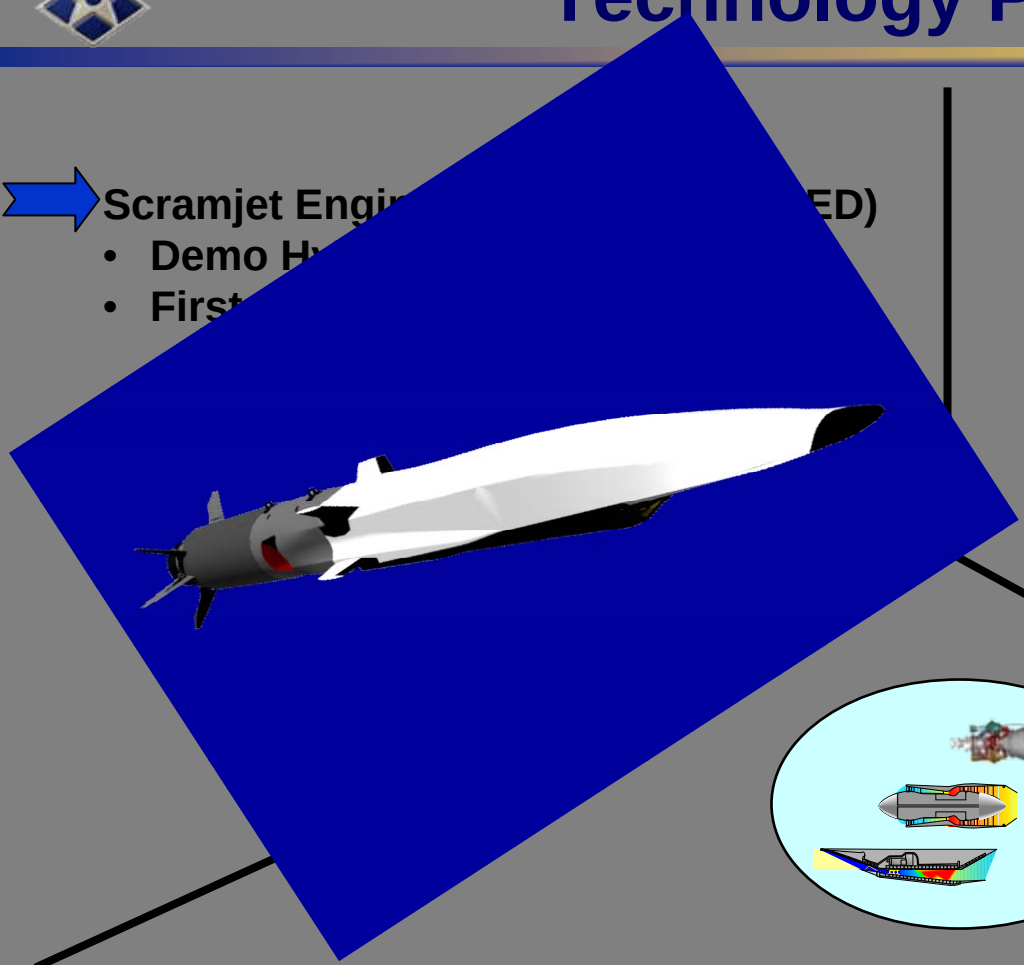


Return to EAFB

AFRL Hypersonic Propulsion Technology Programs

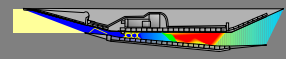
Scramjet Engi ED)

- **Demo H**
- **First**



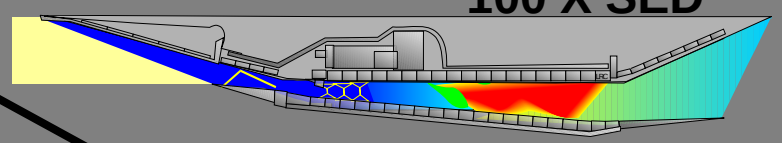
Robust Scramjet

- **10X – 100X scale**
- **Increased durability**
- **Improved operability**



10 X SED

100 X SED

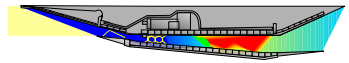


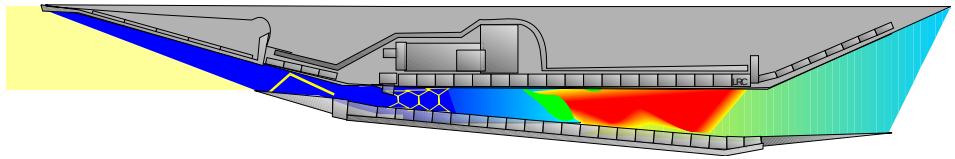
Combined Cycle Engine Components

- **Merge scramjet with turbine and rocket engines for wide range of flight speeds**
- **Key to air breathing access to space**

Robust Scramjet Program

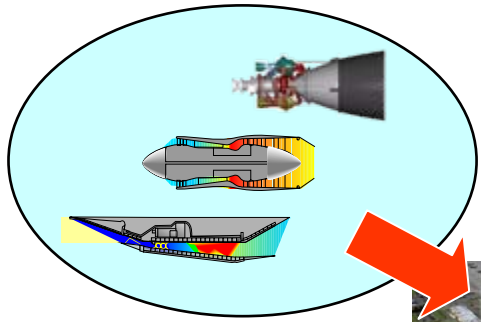
- Addresses scaling issues for 10X and 100X flowpaths
  - Examines improvements to fuel penetration and mixing, as well as general combustion kinetics
- Improves overall scramjet operability
  - Reduce takeover to Mach 3.5
  - Extend upper Mach to 8 to 12
- Identifies new structural concepts to extend durability and reusability
  - 50 cycles near-term
  - 250 cycles far-term

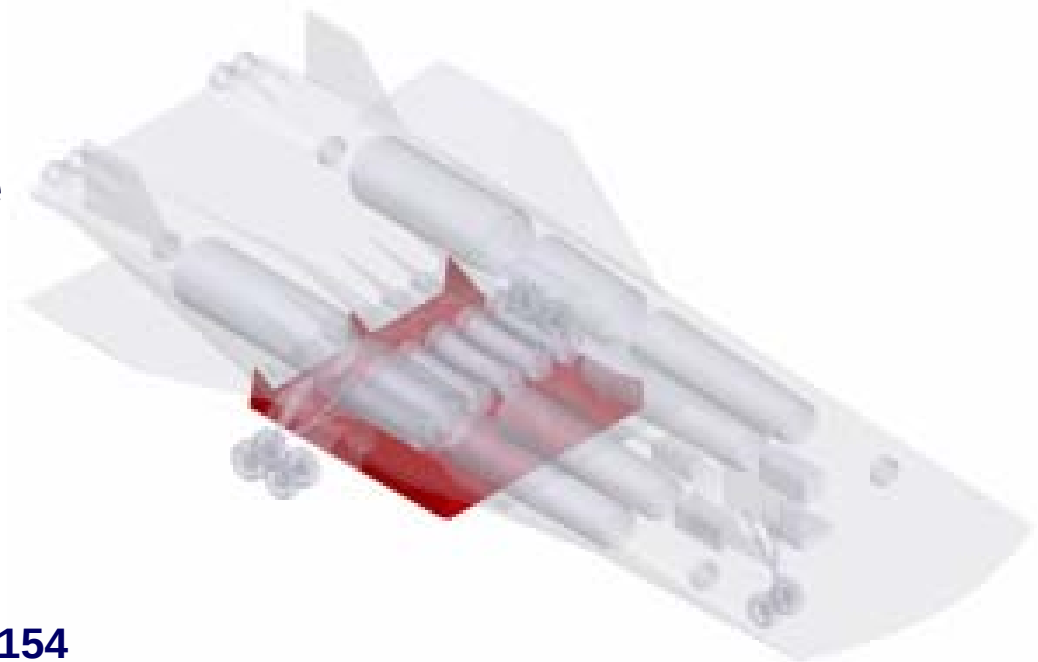




Combined-Cycle Engine Component Development

- Studies since 2002 show concept feasibility and no show stoppers
- Combines ramjet/scramjet engines with turbine and rocket engine cycles
- Rocket-Based Combined Cycle (RBCC) easiest integration
- Studies show promising results for over-under arrangements Turbine-Based Combined-Cycle (TBCC)
- Component development to begin October 2005





Summary

- Hypersonics is a disruptive technology
  - Near term: hypersonic cruise missile could be used to defeat time critical targets
  - Far term: CCEs could enable operationally responsive spacelift with “aircraft-like” operations
- AFRL’s hypersonic propulsion technology development is on track to mature the enabling technologies

Propulsion is the Pacing Technology in Aviation

Wright Brothers Redesigned Engine Provided Enabling Power-to-Weight Ratio

Jet Engine Revolutionized the Shape and Speed of Aerospace Vehicles

High Bypass Turbofans Enabled Jumbo Jets

Scramjets Will Enable Sustained Hypersonic Flight and Routine Access to Space