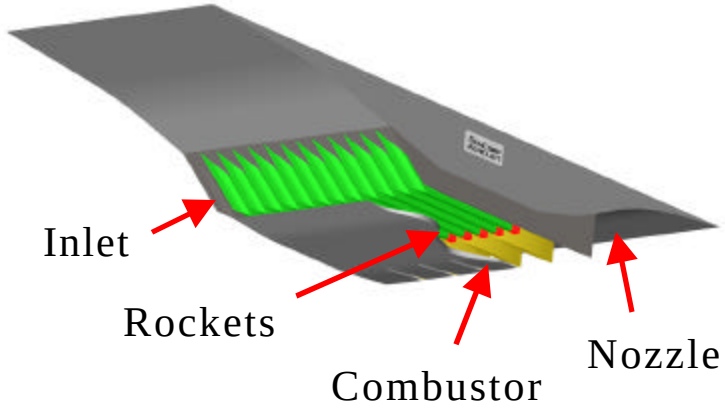
# Advanced Air Breather System

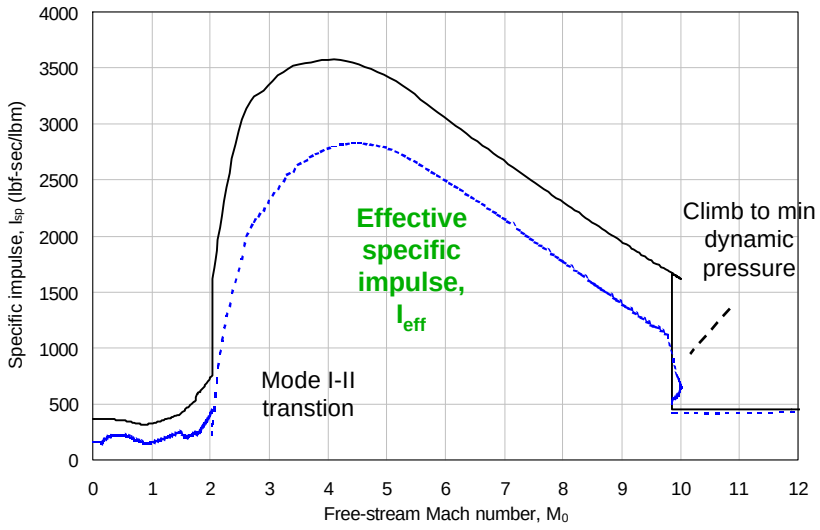
Space Propulsion Technology
Assessment Workshop

April 2001

# Summary Description
# Advanced Air Breather System
# (RBCC Example)

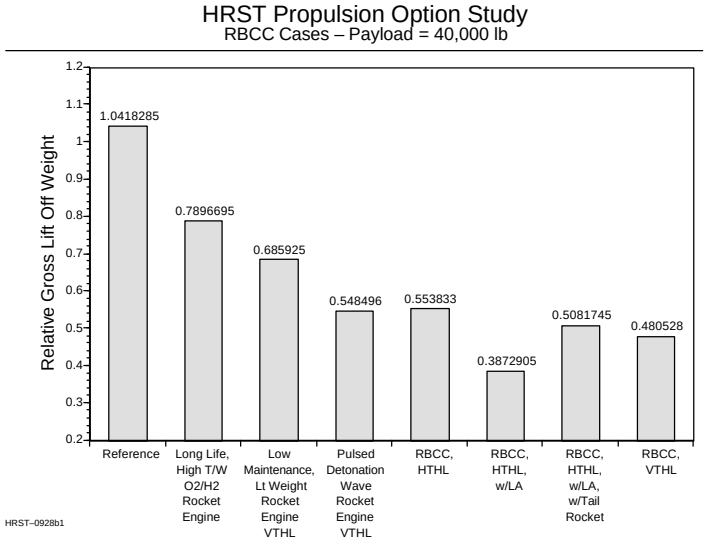
- Combined cycle with $H_2/O_2$ rockets integrated into ramjet/scramjet flowpath
- $O_2$/HC systems are also possible for Gen 3 using air breathers
- Multi-mode operation
  - Air-augmented rocket (AAR), Mach 0 to 2.5, rocket thrust augmented by burning entrained air in combustor - high take-off thrust
  - Ramjet, Mach 2.5-6. Also used for cruise back to landing site
  - Scramjet, Mach 6 to 10-14
  - Scramjet/rocket, during pull-up to low q
  - Ascent rocket, rocket plume expands into combustor to provide high expansion, inlet closed

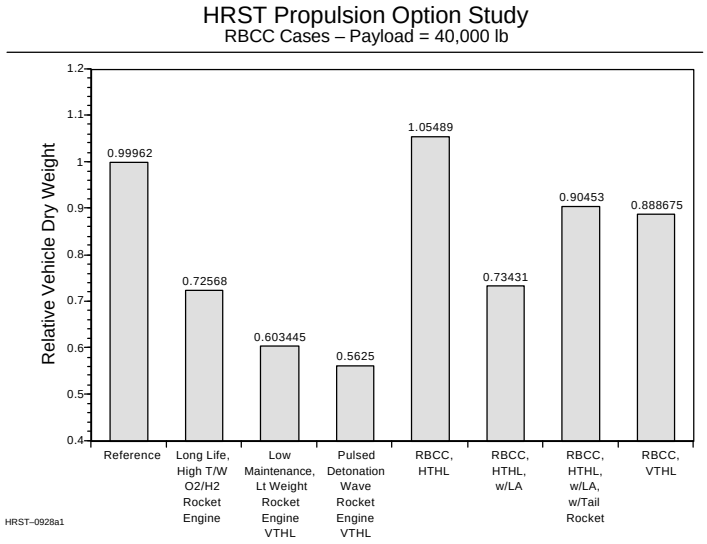


# Potential Benefits
# Advanced Air Breather System

- SSTO RLV weight and weight margin allowances
  - Non-propulsive vehicle dry weight fraction higher than all rocket
    - Vehicle dry weight comparable
    - Gross lift-off weight much lower
  - Propellant volumes less than rocket
- Reduced TOGW makes HTHL feasible
  - Airplane-like operations for lower LCC
- Lower gross thrust requirement versus rocket vehicle
  - Reduces loads on vehicle
- Robust operating margins for life and reliability
  - Rocket Pc 1500-2000 psi
  - Emergency power level >125% feasible for safe abort
  - Multiple struts and powerheads with cross-manifolding for failure tolerance



# Potential Benefits
# Advanced Air Breather System

- RBCC technology is real
  - Significant recent testing performed
  - Excellent results

- For RBCCs early thrust/weights about 10 to 15
  - Mature, advanced materials thrust/weight about 25 to 40
  - Use of very advanced materials could produce thrust/weights around 45 to 55

- Air breather systems trade reduced oxidizer loads versus added delta-V for drag and the weight necessary to reduce the oxidized load
  - Higher L/D - lower drag losses but poorer payload/dry vehicle weight
  - Lower L/D - higher drag losses but better payload/dry vehicle weight

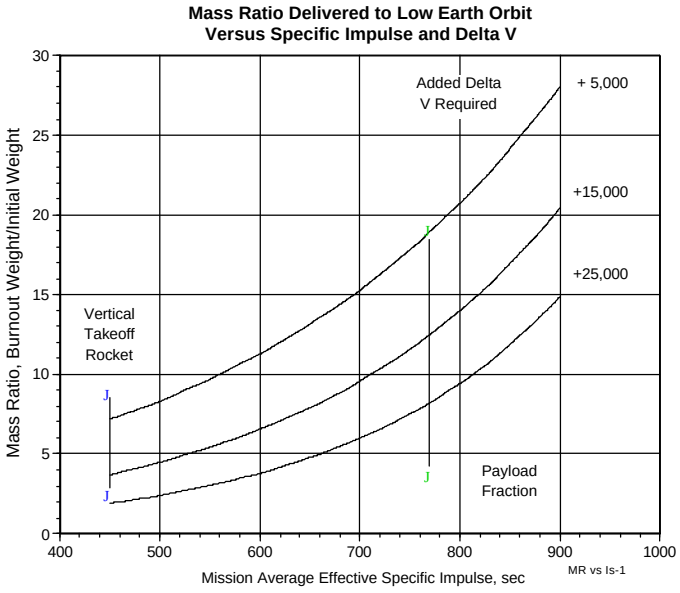
- Large trade space in mission average specific impulse, added delta-V needed (drag losses), burnout weight to initial weight, and payload fraction is opened up by use of RBCC air breathers

- Air breathers beyond RBCC open up even larger trade space

**Integrated Flowpath Test Program**

| Operating Mode | Aerojet | | Rocketdyne | |
|---|---|---|---|---|
| | No. Of Runs | Test Time (Sec) | No. Of Runs | Test Time (Sec) |
| Sea-Level Static | 31 | 173 | 21 | 237 |
| Air-Augmented Rocket | 12 | 97 | 15 | 288 |
| AAR/RAM Transition | 12 | 97 | 32 | 465 |
| - AAR/RAM Traj Sim | 0 | 0 | 11 | 340 |
| RAM | 28 (14*) | 342 (246*) | 21 | 325 |
| RAM/SCRAM Transition | 0 | 0 | 3 | 75 |
| - RAM/SCRAM Traj Sim | 0 | 0 | 2 | 50 |
| SCRAM | 8* | 112* | 6 | 30 |
| SCRAM/Rocket Transition | 21* | 279* | 6 | 30 |
| Rocket-Only | 16 | 129 | 10 | 72 |

* Direct-Connect Tests



# Current TRLs
# Advanced Air Breather System

- Overall propulsion system — TRL 4
- Integrated flowpath performance — TRL 5
  - Hundreds of tests performed, covering all modes — (TRL 4 for HC)
- Cooled flowpath structure — TRL 3
  - Critical technology: lightweight, high temperature materials
  - Thermal strain, high pressure $H_2$ containment, life issues
  - Hot gas seals between flowpath components
- Rocket thrust chambers — TRL 6+
  - Multiple, small, embedded units
  - Fabrication technology demonstrated
- Powerhead components — TRL 6+
  - Moderate pressures, apply existing rocket SOA
  - Critical technology: ox rich preburner
- Valves and EMA's — TRL 6
- Integrated health monitoring — TRL 3
- Control system and software — TRL 3

# Cost to Mature Technology
# Advanced Air Breather System

| | |
|---|---|
| $100K | |
| $500K | |
| $1M | |
| $5M | |
| $10M | |
| $30M | |
| $50M | |
| $100M |  |
| $500M | |

| | |
|---|---|
| 6 Mo | |
| 1 Yr | |
| 18 Mo | |
| 2 Yr | |
| 3 Yr | |
| 4 Yr | |
| 5 Yr |  |
| 5 Yr+ | |