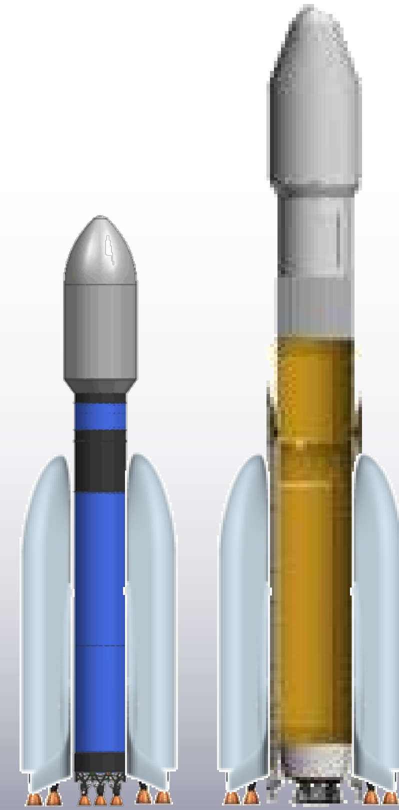
AFRL

THE AIR FORCE RESEARCH LABORATORY

LEAD | DISCOVER | DEVELOP | DELIVER

AFRL Perspective Responsive & Reusable Boost System (RBS)



ASEB-NRC Briefing

17 February 2012

Bruce Thieman
Jess Sponable
Air Force Research Laboratory

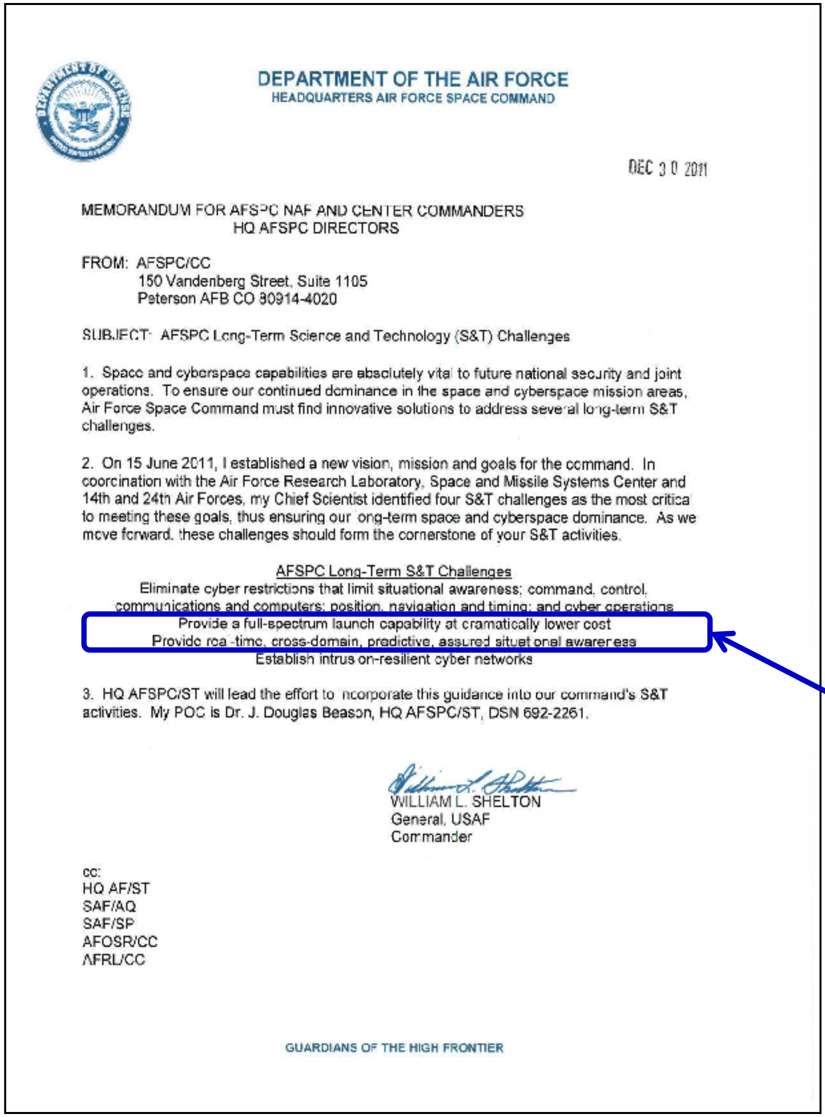
Integrity ★ Service ★ Excellence

AFRL Briefings to NRC on RBS

- **AFRL Perspective on Reusable Booster Technology**
  - 1/2 hour
- **RBS Program**
  - 1 hour (40 min brief and 20 min discussion)
- **Hydrocarbon Boost Technology Program**

  (Tomorrow)
  - 1 hour (40 min brief and 20 min discussion)

Emerging Themes/Needs



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SPACE COMMAND

DEC 3 0 2011

MEMORANDUM FOR AFSPC NAF AND CENTER COMMANDERS
HQ AFSPC DIRECTORS

FROM: AFSPC/CC
150 Vandenberg Street, Suite 1105
Peterson AFB CO 80914-4020

SUBJECT: AFSPC Long-Term Science and Technology (S&T) Challenges

1. Space and cyberspace capabilities are absolutely vital to future national security and joint operations. To ensure our continued dominance in the space and cyberspace mission areas, Air Force Space Command must find innovative solutions to address several long-term S&T challenges.

2. On 15 June 2011, I established a new vision, mission and goals for the command. In coordination with the Air Force Research Laboratory, Space and Missile Systems Center and 14th and 24th Air Forces, my Chief Scientist identified four S&T challenges as the most critical to meeting these goals, thus ensuring our long-term space and cyberspace dominance. As we move forward, these challenges should form the cornerstone of your S&T activities.

AFSPC Long-Term S&T Challenges
Eliminate cyber restrictions that limit situational awareness; command, control, communications and computers; position, navigation and timing; and cyber operations
Provide a full-spectrum launch capability at dramatically lower cost
Provide real-time, cross-domain, predictive, assured situational awareness
Establish intrusion-resilient cyber networks

3. HQ AFSPC/ST will lead the effort to incorporate this guidance into our command's S&T activities. My POC is Dr. J. Douglas Beason, HQ AFSPC/ST, DSN 692-2261.

WILLIAM L. SHELTON
General, USAF
Commander

cc:
HQ AF/ST
SAF/AQ
SAF/SP
AFOSR/CC
AFRL/CC

GUARDIANS OF THE HIGH FRONTIER

- **3X cost reduction for RBS, 10X achieved via full reusability**
- **Payloads**
  - Pico, Nano, +
  - 10-15K (CPGS, Small Medium, etc.)
  - EELV Replacement to 17-64K lbs
- **Global ISR/Strike**
- **Sortie Payloads**
- **Disaggregated Payloads (AFSPC/CC)**
- **Hypersonic testing/testbed**
- **Commercial providers**
- **Point to Point Transport?**
- **Many potential users: AFSPC, GSC, ACC (ASC), STRATCOM, AMC, NCA, OSD, NRO, NASA, etc.**

AFSPC
LONG TERM S&T CHALLENGES

Provide a full spectrum launch capability at dramatically lower cost

Provide real-time cross-domain, predictive, assured situational awareness

A Decade of Studies Recommend:
Initial Steps → Reusable Boost System

- **Predicted launch savings at 50 to 67%**
  - Reduces expendable hardware by a factor of three (Key element is reusable engines)
  - Avoid Shuttle-like manpower-intensive support
- **Recent analysis:**
  - AFRL Responsive Space Advanced Technology Study (2003)
  - Operationally Responsive Spacelift AOA (2004)
  - USECAF Vector 1 Launch Study (2005)
  - Aerospace Future Launch Study (2006)
  - AF SAB Future Launch Vehicles Study (2010)
  - SMC Spacelift Development Plan (draft 2010)
  - EELV/RBS Total Cost of Ownership (

AFRL S&T Goals

- ***66% cost reduction***
- ***24 hr turn-around***
- ***2-8 hr call up***

Consistent Study Results

Reusable technology can reduce launch costs – ELV cost reductions not driven by technology but rather by lean acquisition processes, high production rate & launch range streamlining

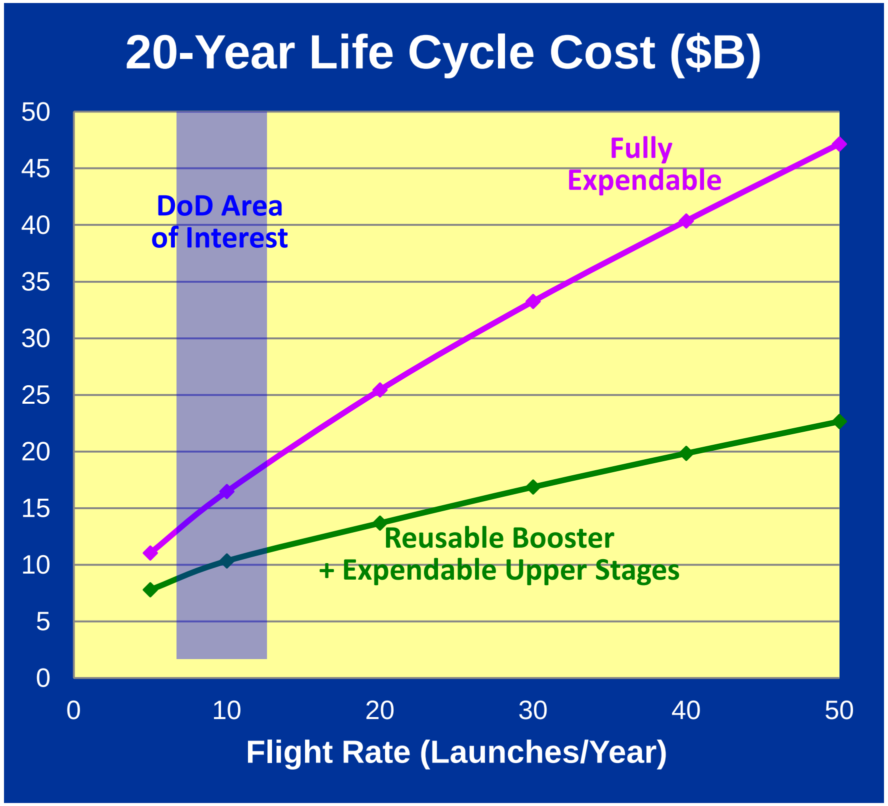
S&T Focus to Achieve the Goal

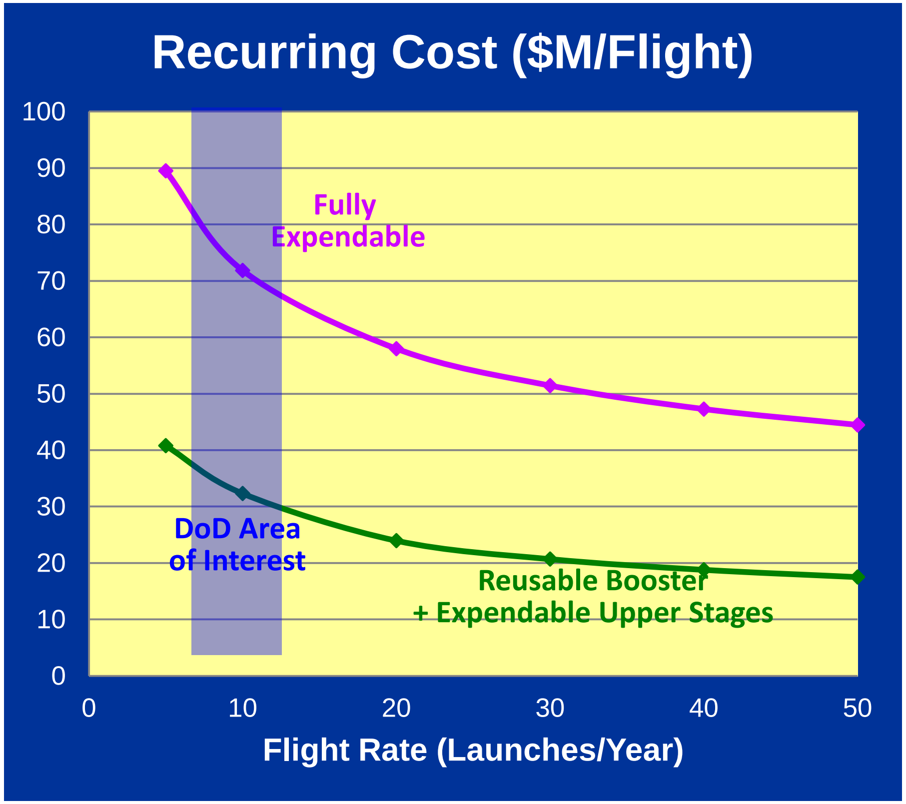
- **Objective: Reduce Cost 50 to 67% for Spacelift**
  - **60% of launch vehicle**
  - **40% of ground ops**
  - **10% of range ops**
  - **40% of mission assurance**

- **Launch Vehicle**
  - **Reuse Booster Stage**
    - 200 reuse booster
    - **50 reuse engine**
  - **More Efficient Engine for Booster and Upper Stage**
- **Design for maintainability, clean pad ops, 15 person contact/shift, 24 hour turn time, 2-8 hr callup**
- **Autonomous Flight Operations and Automated Flight Safety System**
- **Eliminate IOT&E/DT&E for every booster thru reusability & aircraft like ops**

Vehicle Options& Flight Rate Comparison

Exemplar, from extensive parametric analyses





LEO Capacity = 15 klbs; Reusable Fleet Size = 4 up to 20 flts/yr, then 1 more per each additional 10 flts/yr

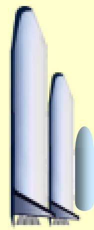
(Values assume all-new developments - Costs in FY2004 Dollars)

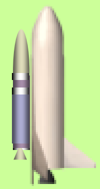
Reusable Booster: Lowest LCC and Recurring Cost at All Likely Flight Rates

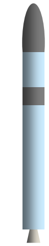
Reusable vs. Expendable Comparison

(This example based on 15 klb to LEO capability)

	RLV	RBS (Reusable Booster System)	ELV
Expended H/W (klb)	0	12	33
Reused H/W (klb)	196	61	0







Avoids 64% of ELV's expendable hardware

Avoids 69% of RLV's reusable hardware

Fully-Reusable RLVs

- Are big because orbiter must go to/from orbit (80% of orbited mass is the orbiter)
- Drives higher development and production costs

RBS

- Balance ELV-RLV Production and Development costs, resulting in lower LCC for most cases

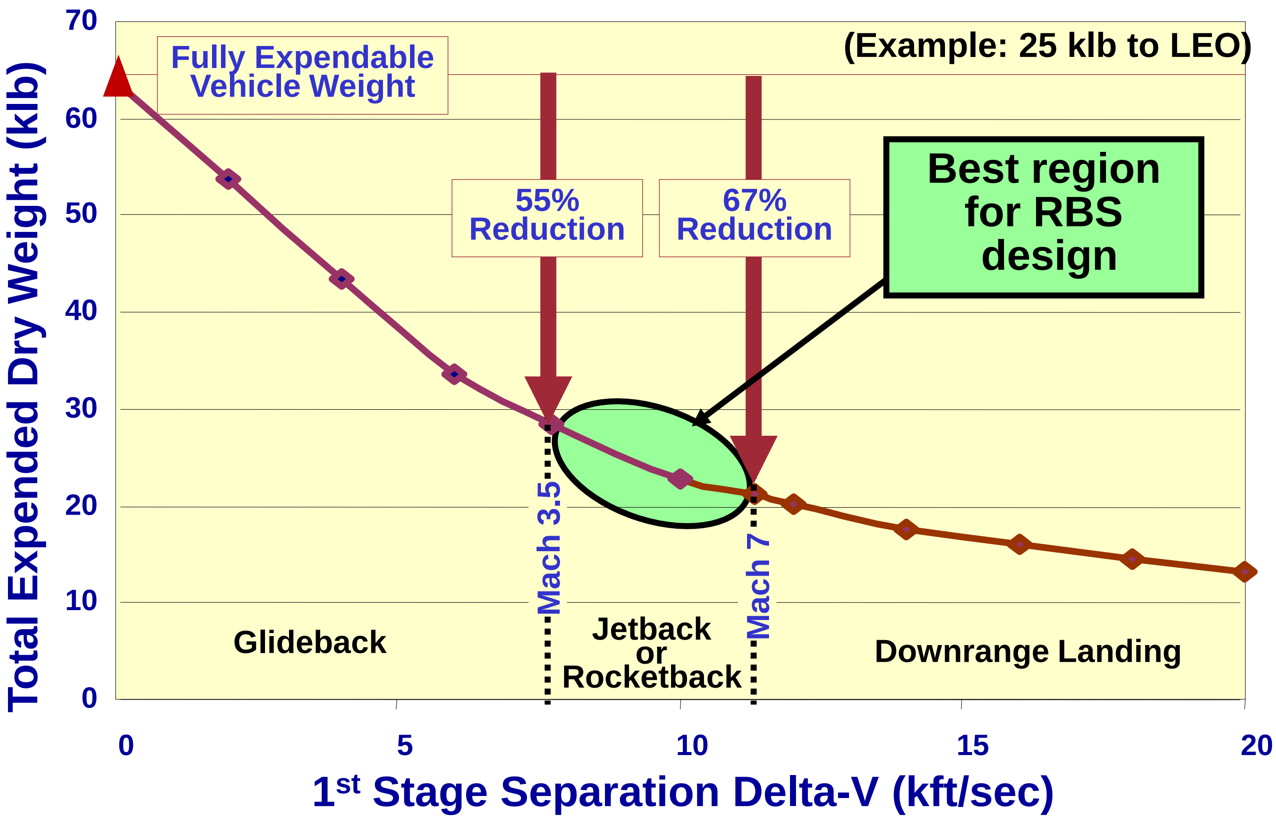
Fully-Expendable ELVs

- Expend large amounts of hardware
- Drives higher recurring costs

Note: Cost of expendable hardware is partly production, but also includes costs of documentation, testing, and reviews required to assure reliability. Reusable booster hardware can be designed with higher margins, and certified to permit reuse with minimal testing/review (similar to aircraft).

RBS Has Solid Cost Savings Potential

RBS Affordability: Reduction in Expended Hardware



Reusable Booster Staging Velocities Between Mach 3 and 7 Reduce Expended Dry Mass By Factor of 2-3

RBS vs. Shuttle Processing Manpower

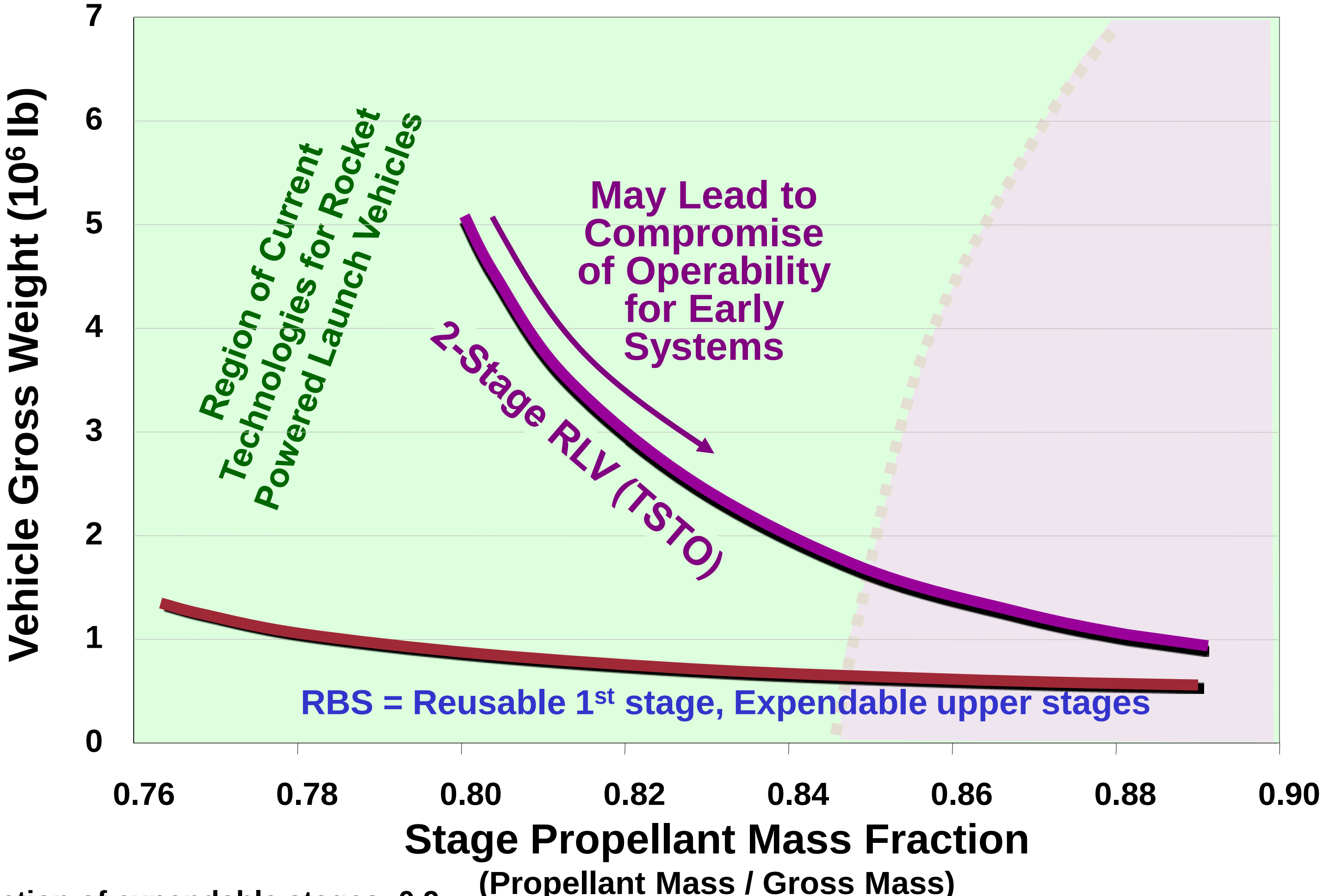
OPERATIONS

- Infrastructure
- Integration
- **Reusable Booster**
- Upper Stages
- Payloads
- Spaceport
- Post Ops

System	Shuttle Orbiter *Labor Hours*	Reusable Booster *Labor Hours*	Summary of Improvements
Thermal	18,914	12	Mach 6 or less Vs. Mach 25 Shuttle reentry creates benign reentry environment
Crew Support	15,893	0	No crew or on-orbit operations
Mechanical	12,482	42	Modern self-contained actuation Benign environment Higher margins
Vehicle Reconfig for Payload	10,434	~0	No payload bay, No reconfiguration. Payload carried in fairing on expendable upper stage.
OMS/RCS	5,771	7	No OMS. Non-toxic RCS.
Electrical	8,205	34	Batteries only. No Fuel Cells. No APUs.
Propulsion	7,774	75	Modern hydrocarbon engines, High-margins, Reduced performance requirements

Reusable Booster Avoids Maintenance Issues of Previous Reusables by Focusing on only Reusable Booster – not Orbiter

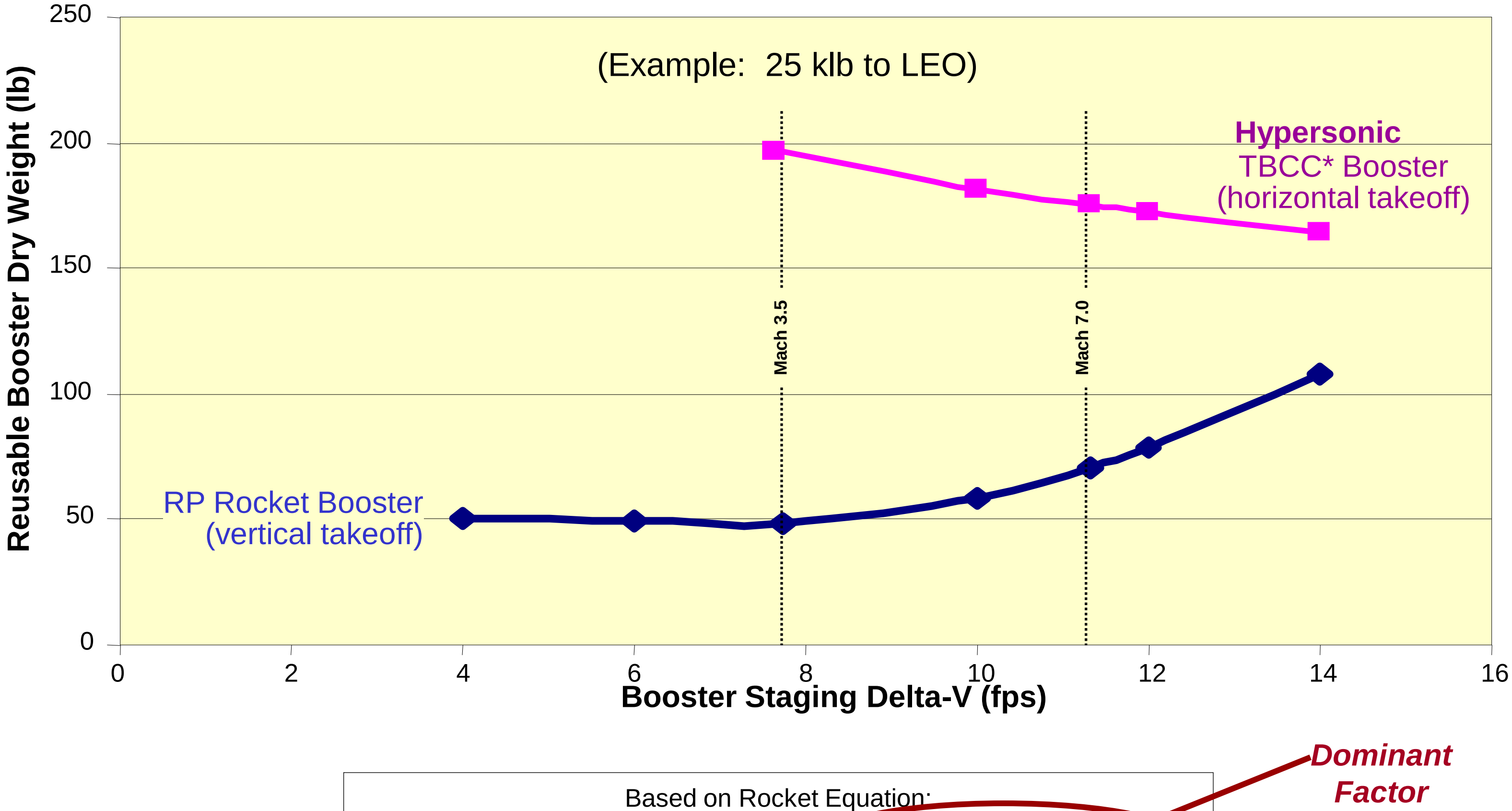
Design Region Sensitivity



Mass fraction of expendable stages: 0.9

RBS Configuration Facilitates Robust Margins

Rocket Vs. Hypersonic Propulsion Far Term 1st Stage Solution



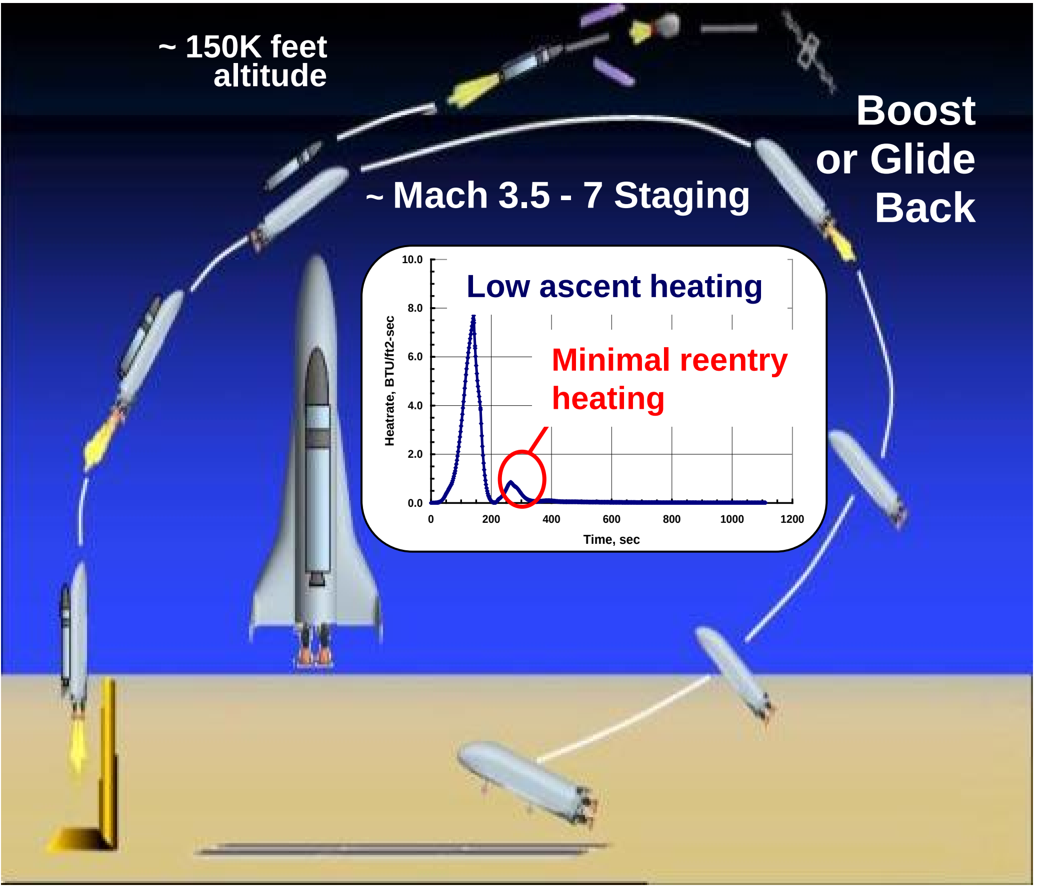
Based on Rocket Equation:

$\Delta V = I_{sp} \bullet (g) \bullet \ln(m_i/m_f) - \text{gravity/drag losses}$

Reusable boosters need high thrust to accelerate quickly & reduce gravity/drag losses. Vertical takeoff rocket (RP) preferred in long term for reusable booster.

* TBCC- Turbine Based Combined Cycle

What is Reusable Booster System?



- **Vertical lift, horizontal land, Reusable Booster System**
- **Demonstrate key features on subscale system(s)**
  - Return-to-base maneuver
  - Turn time and cost savings
- **<u>Benefit to Warfighter</u>:**
  - *> 50-66% cost reduction for launch on schedule*
  - *2-8 hr call-up, 24-48 hour turn around from call up to launch, and 90% weather availability for assured strike and launch on demand*

Hybrid Reusable Booster Technology Maturation