RASCAL

A Demonstration of Operationally Responsive Spacelift

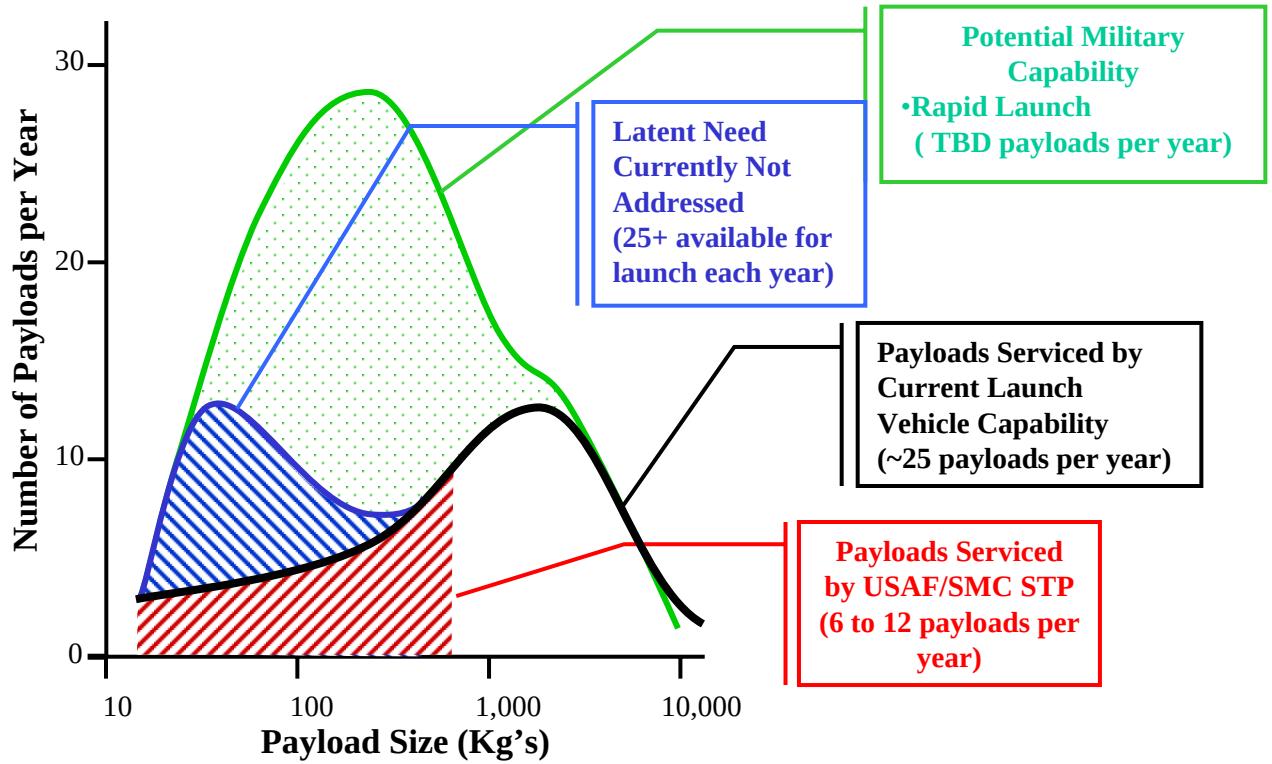
Responsive **A**ccess,
Small **C**argo,
Affordable **L**aunch

Jason M. Tardy
CENTRA Technology
tardyj@centrava.com

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

MOTIVATION

Distribution of DoD Payloads



Insufficient small spacecraft launch capability exists today, inhibiting DOD's ability to utilize space effectively, efficiently and rapidly.

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL

Operationally Responsive Spacelift!

The "Vision"

Responsive, Economical, Survivable, Flexible

MIPCC Powered Vehicle (MPV)

- 1 hr scramble, 24 hr turnaround
- Free from launch pads & ranges, able to access all inclinations. In-flight mission planning, loitering capability.
- Resilient against launch denial
- Fighter-like ops.

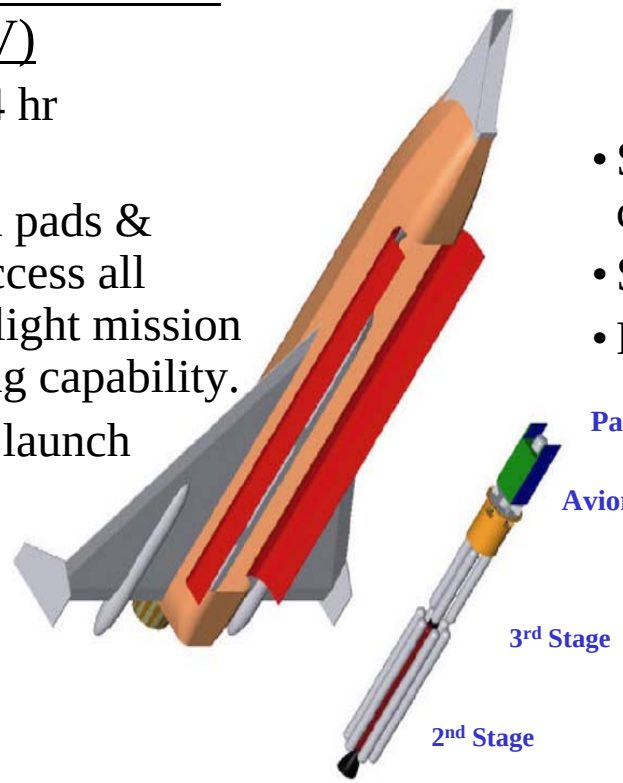


Illustration of the 1st Staging Event

Payload Satellite

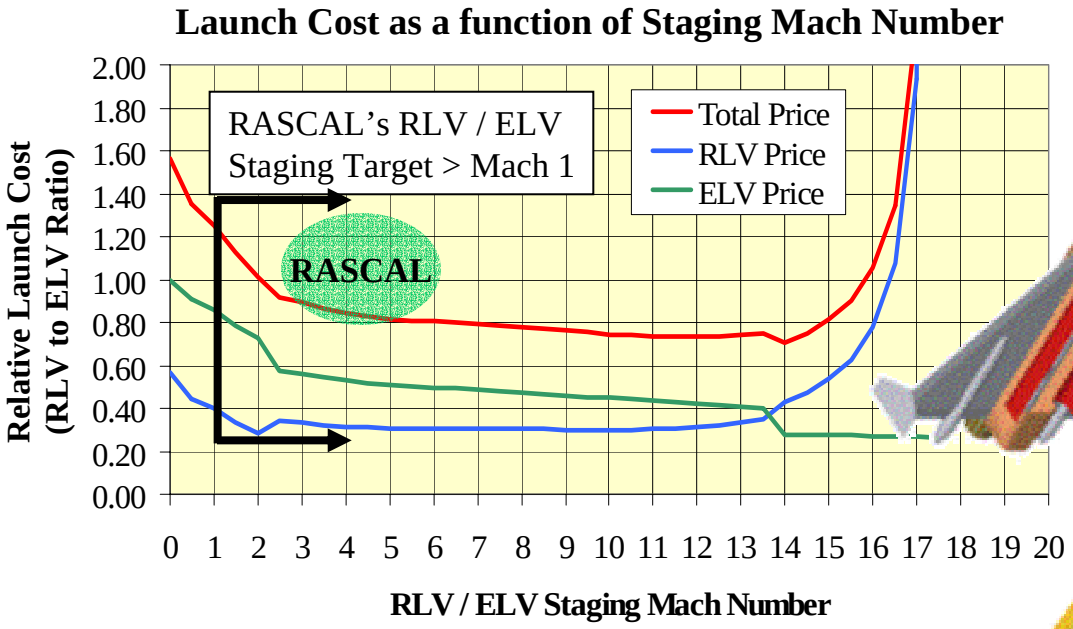
- Soft ride → Simplified (or no) compatibility analyses required
- Streamlined integration process
- Rapid on-orbit initialization

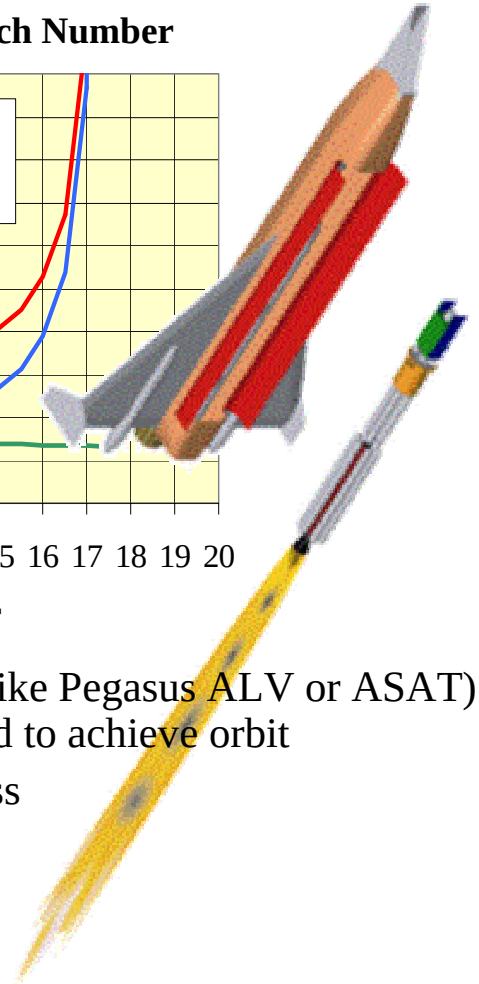
Expendable Rocket Vehicle (ERV)

- **Rapid readiness**
- **Autonomous flight systems**
- **Internally carried. Designed without aerodynamic constraints and penalties**
- **Designed for Low recurring cost. MPV adds significant amount of energy to the payload → reduces expendable size**

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL COST PAYOFF

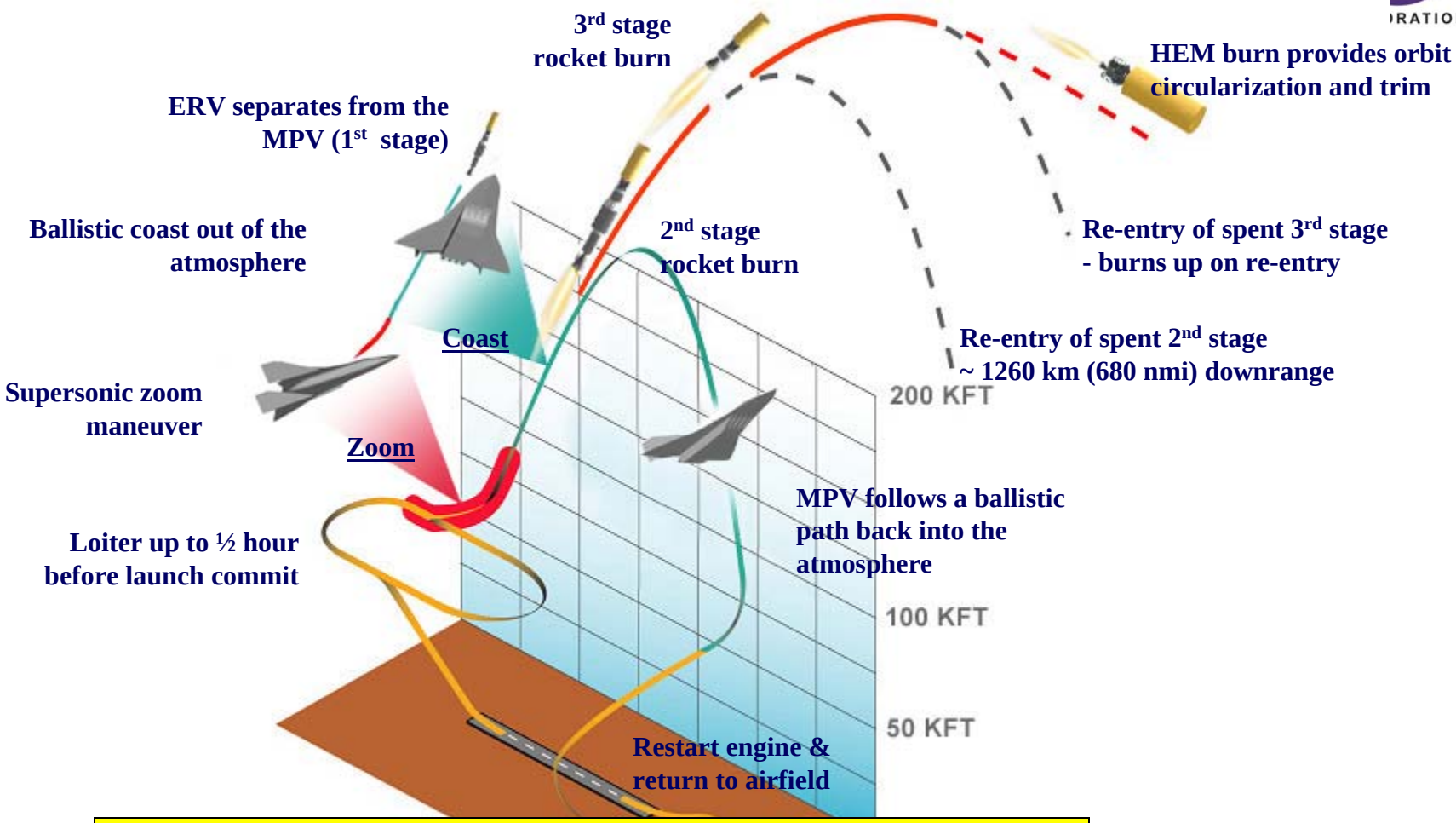




- The aircraft is not just a "Launch Platform" (like Pegasus ALV or ASAT) but a significant contributor to the energy required to achieve orbit
- The Zoom maneuver reduces throw away mass
  - Improves overall system performance
  - Reduces recurring vehicle costs
- Exo-atmospheric staging reduces launch risk
- As propulsion technology advances, RASCAL performance can continue to improve with little or no modification to the basic approach

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL CONOPS



The Responsive CONOPS of an Aircraft,
The Performance of an Exo-Atmospheric Spaceplane,
The Low Recurring Cost of a Reusable Vehicle

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

Figures of Merit

- Payload performance:
  - 75 kg to 500 km orbit (Sun-Synchronous)
  - 50 kg to 1250 km orbit (Sun-Synchronous)
- Exo-atmospheric staging
  - ERV shall see dynamic pressure less than 1 psf
- Propulsion
  - Use of MIPCC is required
- Soft ride
  - Payload vibrations isolated to 50+ Hz axial/torsional & 40+ Hz lateral
  - Loads limited to 5g axial and 4g lateral

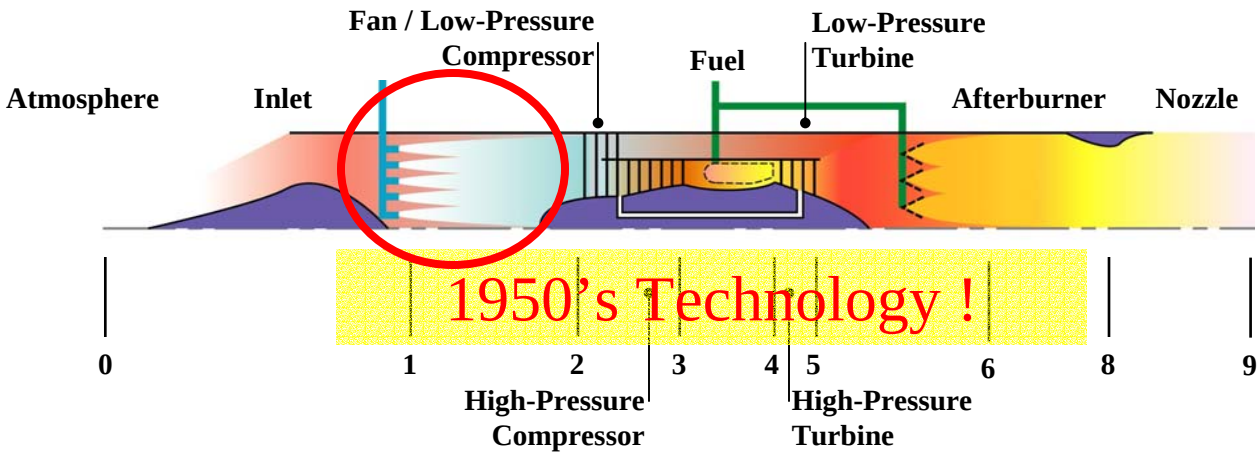
APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

Figures Of Merit

- Flexibility/Responsiveness:
  - 30 min loiter
  - 250 nm range
  - 1 hr scramble
  - 24 hr turn-around
- Reliability:
  - Comparable to current fighters
  - Design hooks for PHM on at least propulsion system
- Logisitics:
  - Minimal peculiar support equipment required
  - Runway length less than 2500 m
- Recurring Cost:
  - Less than $750,000 per launch

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

Turbojet / Turbofan Mass Injection Pre-Compressor Cooling (MIPCC)



MIPCC is a Breakthrough Reusable Propulsion Technology for Space Launch

Evaporative cooling of the incoming airflow extends the operational flight envelope in several ways

- Increased thrust
  - Lower incoming temperature – increasing flow density entering the engine
- Increased Mach number operation
  - Lower incoming temperature – allows operation without exceeding material limits
- Extended altitude operation
  - Sustained oxidizer flow in rarefied atmosphere

MIPCC is a bolt on addition, not a modification to an engine or a new engine cycle

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

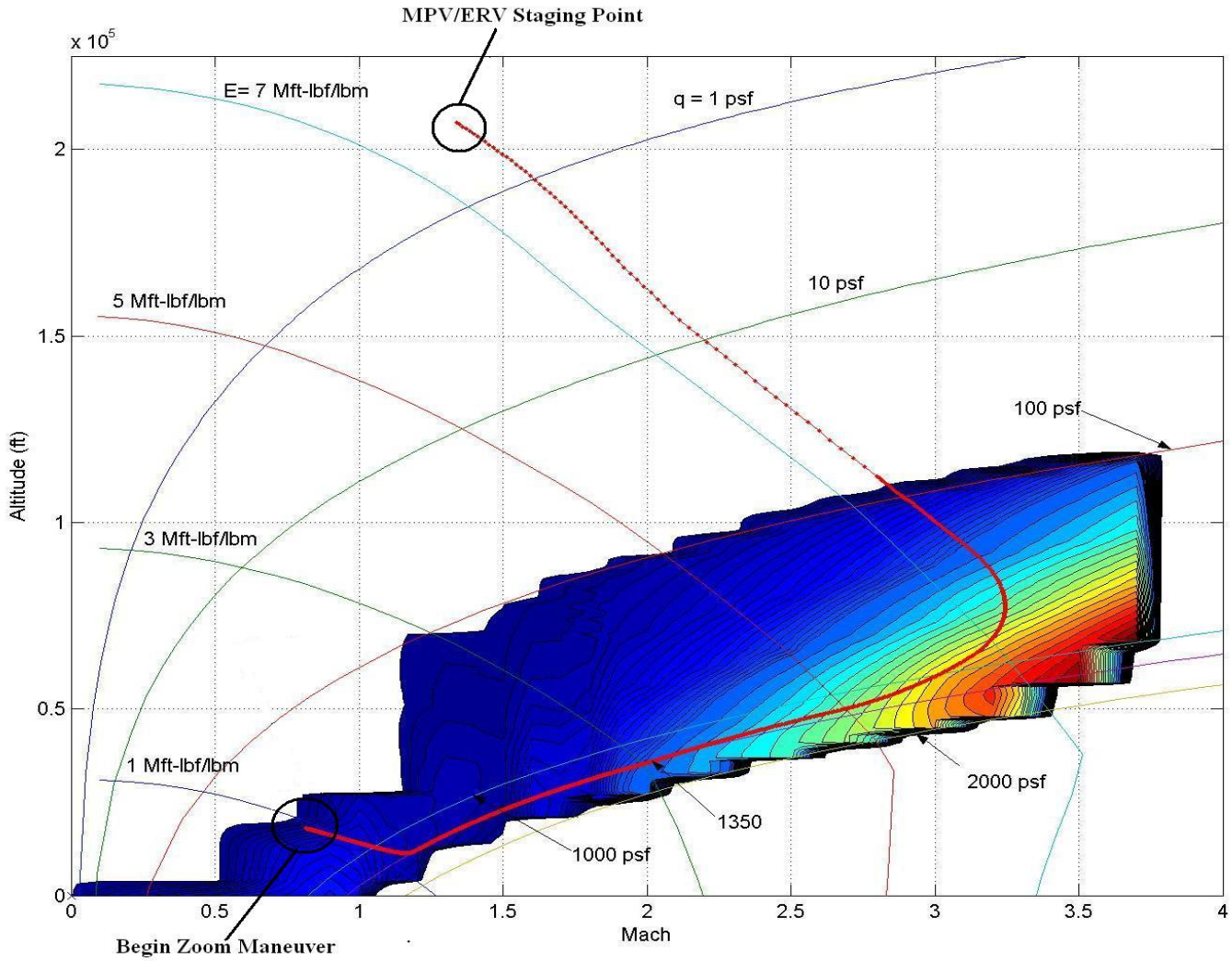
Reusable Propulsion

Typical Reusable? Rocket Engine		**Typical MIPCC Turbojet Accelerator Engine**
	Versus	
Yes	**Developed**	***Heritage***
>>$5M	**Cost**	~$1 to $4M
1000's of seconds	**TBO**	1000's of hours
~10,000 seconds	**Life**	~10,000 hours
Operation out of Atm.	**Advantages**	High Isp, Extreme Mission Flex.
Low Isp, Limited Reusability	**Disadvantages**	Operations below Mach 6

MIPCC Turbojet Accelerator Engines are an Enabling Technology to Responsive Space Access

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL Zoom Maneuver



Representative MPV Trajectory and Excess Power Map

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

Phase II Industry Team

RASCAL

DARPA

SPACE LAUNCH CORPORATION

SCALED COMPOSITES

Allied Aerospace
GASL Division

ATK
ALLIANT TECHSYSTEMS

Athena technologies

SPACE LAUNCH CORPORATION

ACEi

Cymetech

SPG
Space Propulsion Group, Inc.

UNIVERSAL SPACE LINES LLC

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL System Overview

System Performance

Performance to LEO (nominal):

400 lbs to 270 nm, 28.5° inclination

250 lbs to 270 nm, 97.1° inclination

Exceeds DARPA's RASCAL performance Requirements!

Significant performance growth for the future is possible

MPV

New aircraft design (Design Cycle 1)

81 ft span, 89 ft length, 2700 ft^2 wing area

110000 lb GTOW

4 F100-class engines with LOX/Water MIPCC

Can stage a 16,000 lb vehicle at > 190,000 ft and > 1200 fps

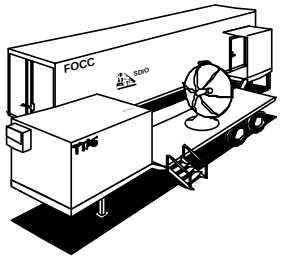
ERV

2 stage Vehicle, 16,000 lbs at release

1st Stage: Hybrid Motor

2nd Stage: Solid Rocket Motor

Huge Payload volume: 10 ft length, 6 ft diameter – no fairing

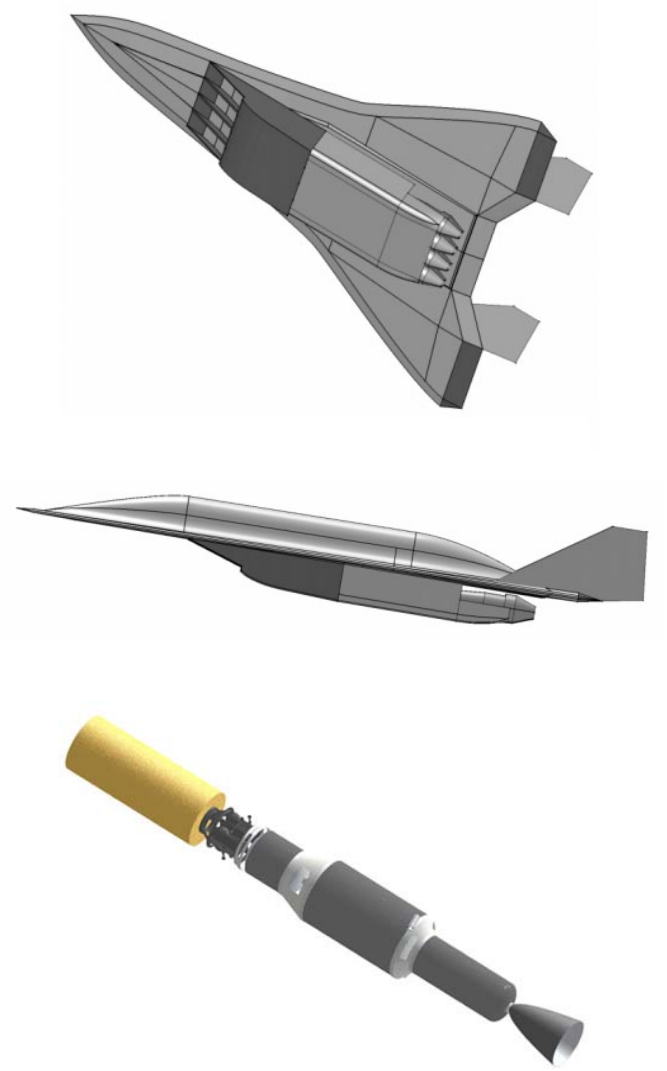


CONOPS

Highly operational, flexible system that can provide responsive space lift to any inclination with a one hour mission scramble capability and a mission turnaround time of 24 hours

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL Components



MIPCC Powered Vehicle (MPV)

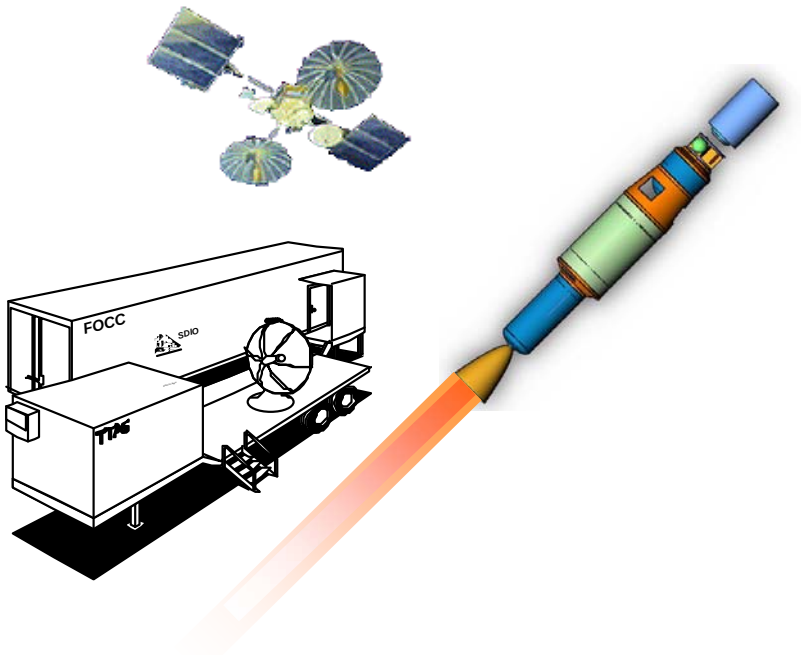
- Includes a large internal payload bay: 42 ft in length X 6 ft in diameter
- The MPV is relatively insensitive to changes in rocket vehicle gross weight
- Four engines: significant excess power available

Expendable Rocket Vehicle (ERV)

- 10 ft X 5 ft payload vol.
- 1st stage hybrid, 2st stage solid
- Non-toxic, storable propellants

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

Concept of Operations



Our approach – utilize *existing and emerging technologies* to create a truly responsive launch system at the *lowest possible cost*

- A CONOPS has been developed that is fighter-like and leverages existing infrastructure
- Automation and autonomous operations are utilized to minimize the number of ground control personnel and eliminate the use of expensive ground based tracking facilities
- A highly responsive and globally deployable system is possible due to the use of space based assets for beyond line of sight voice and data communications

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

RASCAL Growth Path

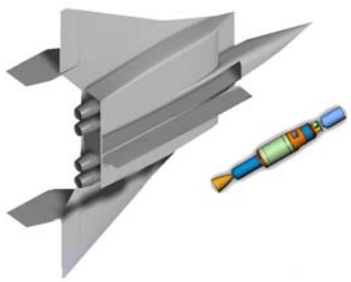
Near Term | Mid Term | Far Term

Near Term Performance

- **500 lbs total weight to LEO**
- **Delivery of large ballistic payloads up to 5,000 n.mi. range**
- **Payload volume 10 ft X 5 ft**
- **Aircraft-like sorties**
- **High system availability**

The RASCAL ATD is the first step in the development of operationally responsive space systems with increasingly larger payloads

Notional Advanced Operationally Responsive Spacelift
Fully Reusable System
Mach 6-10 MPV
Reusable ERV



RASCAL Advance Technology Demonstrator
Mach 3+ MPV
Two Stage ERV

Notional Next Generation Operationally Responsive Spacelift (RASCAL 2)
Mach 5-6 MPV
Single Stage ERV

Near/Mid Term Missions

- **Launch on Demand**
- **Force Application (CAV)**
- **Counterspace**
- **Satellite inspection**
- **On-orbit servicing**

Far Term Missions

- **Force Projection**
- **Force Enhancement**
- **Global Reach**
- **Space Support**

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

Summary

- RASCAL provides a path towards a revolution in rapid access to space
  - Reusability supported by high flight rate
  - Exo-atmospheric staging allows evolution to higher performance
- Provides future responsive, operable, economical, survivable, interoperable, and flexible spacelift capability
  - Directly addresses an identified AFSPC mission need
  - Latent need for small payloads already exists
- Manageable technology challenges
  - Extension of aircraft airframe & propulsion technologies
- Development plan demonstrable milestones
- Transition plan follows successful examples

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED