

## ***Commercial Crew Program Update***

The Next Step in U.S. Space Transportation

December 2012



***Commercial Crew Program - Same Crew...New Ride***

National Aeronautics and  
Space Administration





# Commercial Crew Program (CCP) is vital to NASA's Future

The Future of American

## **HUMAN SPACEFLIGHT**



**Space  
Launch System  
and Orion MPCV**

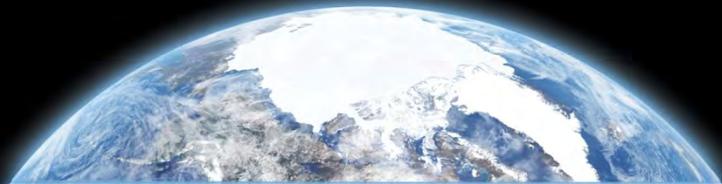
**Human  
Exploration**



**Commercial  
Crew Program**

**ISS Research &  
Development**

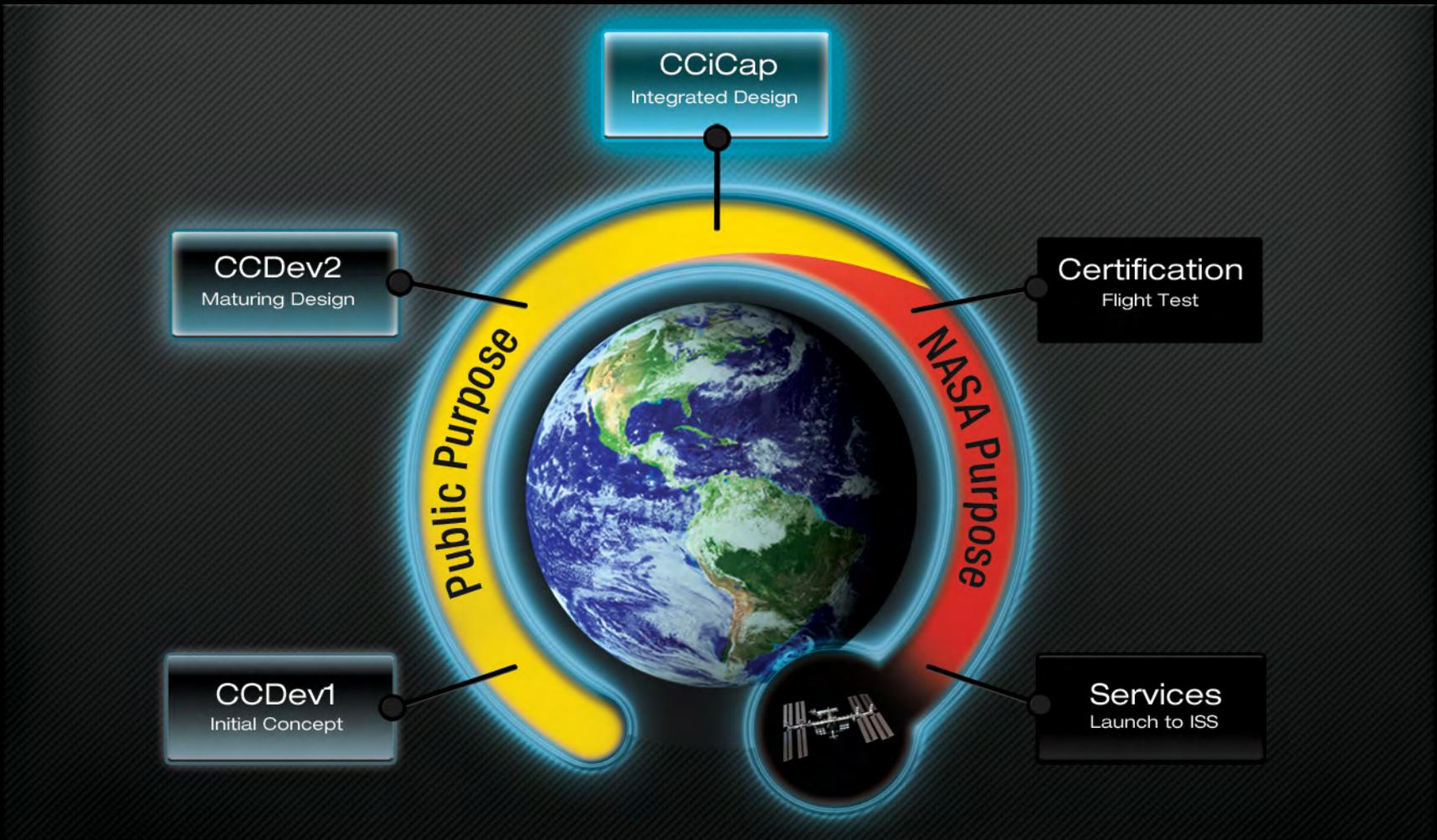




*The Commercial Crew Program (CCP) is leading NASA's efforts to develop the next U.S. capability for crew transportation and rescue services to and from the ISS by the mid-decade timeframe. The outcome of this capability will stimulate and expand the U.S. space transportation industry.*

*The CCP logo is derived from the NASA flight crew symbol as the foundation for the Program. The red/white/blue swoosh illustrates an American-led capability. The star depicts a future vehicle emerging from the overlapping double C's representing the CCP.*

# Program Design Development



# Commercial Crew Development Phase I and II



## Initial Design Concepts

**\$50M awarded in 2010**

	Blue Origin
	The Boeing Co.
	Paragon Space Development Corp
	Sierra Nevada Corp. (SNC)
	United Launch Alliance (ULA)

## Maturing Designs

**\$315M awarded in 2011**

	Blue Origin	Fund ed
	The Boeing Co.	
	Sierra Nevada Corp. (SNC)	
	Space-X	
	ATK Aerospace	
	Excaltibur Almaz Inc.	Unfund ed
	United Launch Alliance (ULA)	

## Select Phase II Photos

The Boeing Co.  
Launch Abort  
Engine **Hot Fire  
Test**



Sierra Nevada Corp.  
(SNC)  
Engineering Test  
Article **Captive Carry  
Test**



Space-X  
Launch Abort  
Engine **Hot Fire  
Test**



# Summary of CCI<sup>2</sup>CAP Portfolio



- **Diversity of Spacecraft types and Launch Vehicles**
  - **Two basic types of Spacecraft**
    - **Capsules and Lifting Body**
  - **Two different Launch Vehicles**
    - **Falcon 9 and Atlas V**
  
- **The portfolio of companies maintains competition for future phases of the Program which is expected to produce “best value” for the government**
  
- **Significant progress planned for the base period with analysis, integrated design, development, and hardware testing**
  
- **Total set of milestones provide insight into the cost and schedule required to achieve a crewed demonstration flight to low Earth orbit**



# Sierra Nevada Corporation



## ➤ Descriptions & Features

- **Dream Chaser spacecraft is a reusable, piloted, lifting body.**
  - **Carries up to 7 crew members**
  - **Utilizes non-toxic propellants**
  - **Primary Launch/Landing Site: Florida**
  - **Ability to abort to a runway landing**
- **Atlas V launch vehicle**



Artist rendition of Dream Chaser in low-Earth orbit

## ➤ Base Period

- **\$212.5M total NASA funding for 9 milestones**
- **Significant progress toward completion of Critical Design and Safety Reviews**

## ➤ Testing:

- ◆ **Engineering Test Article Flight(s)**
- ◆ **Wind Tunnel Risk Reduction**
- ◆ **Spacecraft Subsystem Risk Reduction**
- ◆ **Main Propulsion Risk Reduction**
- ◆ **Reaction Control System Risk Reduction**



Artist rendition of Dream Chaser and Atlas V on launch pad



Artist rendition of Dream Chaser landing on a runway

# Space Exploration Technologies Corporation



## ➤ Descriptions & Features

- **Spacecraft uses a crewed version of the SpaceX Dragon capsule**
  - Carries up to 7 crew members
  - Primary Launch Site: Florida
  - Primary Landing Site: "On land" landing
- **Upgraded Falcon 9 launch vehicle**



Artist rendition of Dragon attached to ISS

## ➤ Base Period

- **\$440M total NASA funding for 14 milestones**
- **Culminates in a SpaceX integrated critical design review milestone**

## ➤ Testing:

- **Dragon Primary Structure Qualification**

## ➤ Flight tests:

- **Pad Abort (SLC 40 and last quarter of 2013)**
- **In-Flight Abort (SLC 40 and 2nd quarter of 2014)**



Picture of Falcon 9 rocket on launch pad in Florida



Artist rendition of Dragon re-entering Earth's atmosphere



# The Boeing Company



## ➤ Descriptions & Features

- **CST-100 spacecraft is a reusable capsule design**
  - Carries up to 7 crew members
  - Primary Launch Site: Florida
  - Primary Landing Site: “On Land” landing
- **Atlas V launch vehicle**

## ➤ Base period

- **\$460M total NASA funding for 19 milestones**
- **Culminates in a Boeing critical design review milestone**

## ➤ Testing:

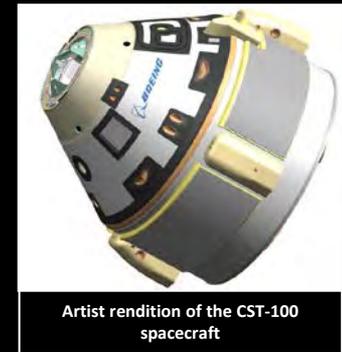
- **Integrated Stack Force & Moment Wind Tunnel**
- **Dual Engine Centaur Development**
- **Orbital Maneuvering & Attitude Control Engine Development**
- **Mission Control Center Interface Demonstration**
- **Emergency Detection System Standalone**
- **Avionics SW Integration Lab Multi-String Demonstration**
- **Pilot-in-the-Loop Demonstration**



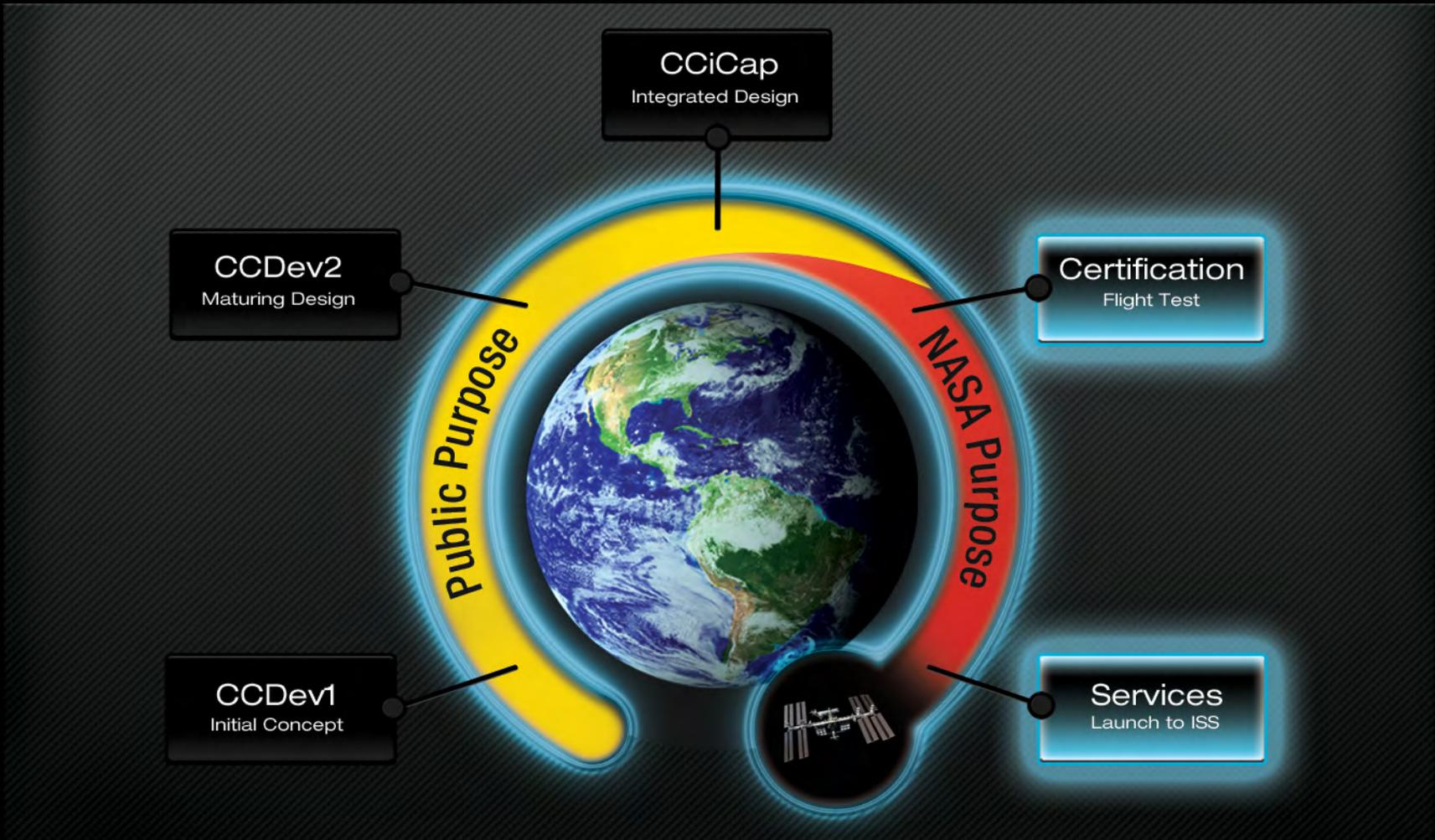
Successful parachute drop test accomplished during CCDev2



Artist rendition of CST-100 and Atlas V on the launch pad



Artist rendition of the CST-100 spacecraft



# Revised Acquisition Strategy (2012)

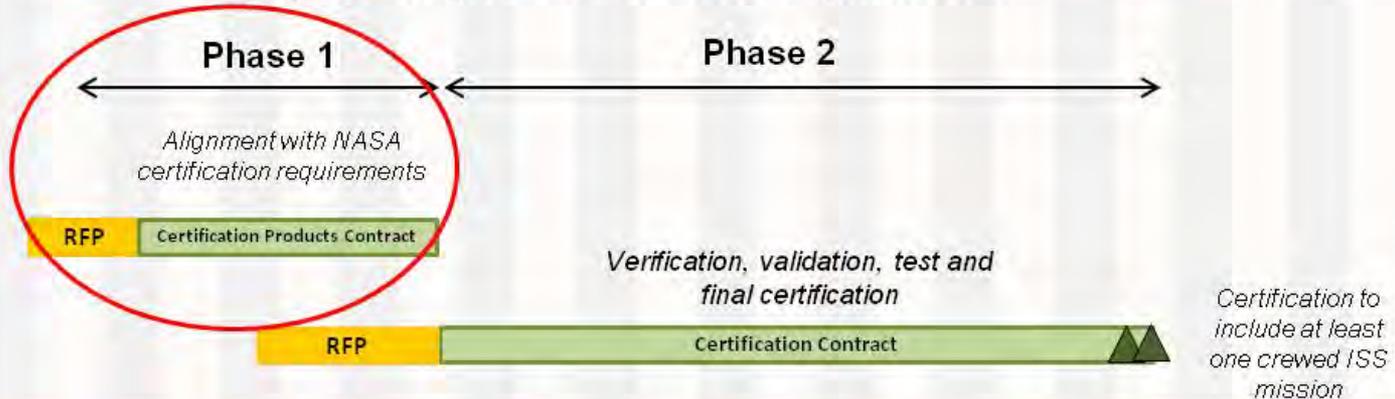


FY12				FY13				FY14				FY15				FY16				FY17				FY18			

## Commercial Crew Transportation System Development



## Certification for ISS Crew Transportation



## --Notional-- ISS Crew Transportation Services



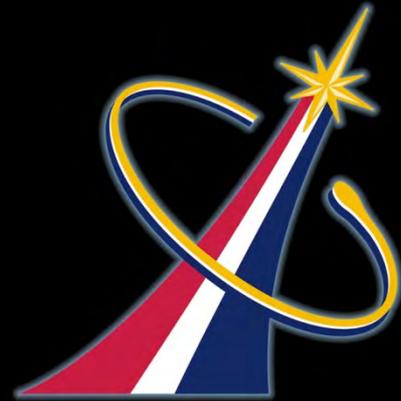
# Phase 1 – Certification Products Contracts (CPC)



- Contract Objective - Begin early, critical certification work to meet NASA Crew Transportation System (CTS) requirements
- Procurement summary
  - Multiple firm fixed price contract awards
  - Individual awards capped at a maximum of \$10M each
  - Phase 1 Period of Performance: 15 months, awarded Dec 2012
- Limited Scope
  - Submittal and discussion of specific early lifecycle certification products
    - *Alternate Standards*
    - *Hazard Analyses/Reports*
    - *Verification & Validation Plan*
    - *Certification Plan*
  - Begin the process of ISS visiting vehicle integration
  - No design/development work funded through CPC



*CPC enables the earliest ISS services date*



COMMERCIAL  
CREW  
PROGRAM

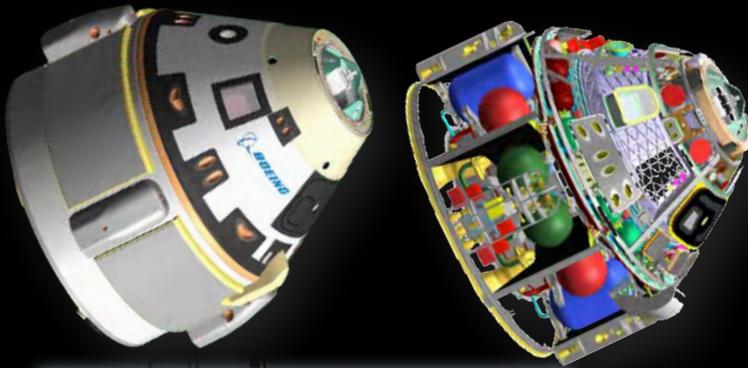


# Boeing Integrated Capability Initiative

National Aeronautics  
and Space Administration



Boeing's crew space transportation system is comprised of the reusable CST-100 spacecraft, Atlas V launch vehicle, mission operations, and ground systems.



Boeing is continuing to develop their integrated space transportation system with design reviews and hardware testing.

## Current Progress (December 2012):

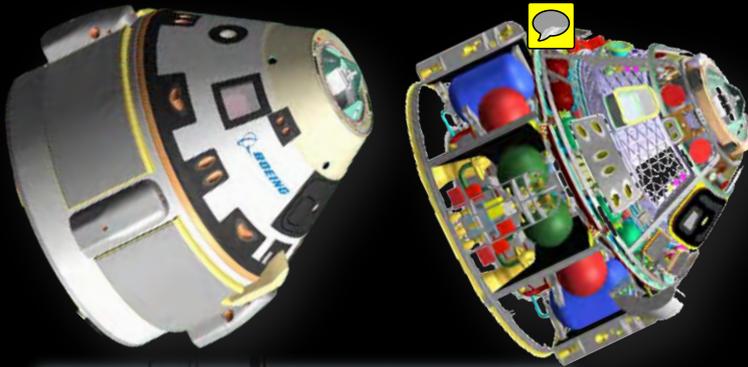
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|----------------------------|----------|
| • Integrated System Review | Complete |
| • Production Design Review | Complete |
| • Phase 1 Safety Review    | Complete |

**Total Expected NASA CCIcap Investment: \$460M**



# Boeing Integrated Capability Initiative

National Aeronautics  
and Space Administration



## Future Work:

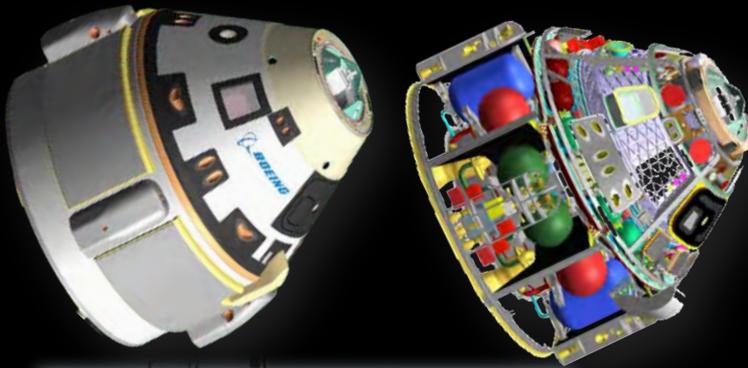
- Software Integrated Eng Release 2.0 Jan 2013
- Landing & Recovery Ground Comm Design Jan 2013
- Launch Vehicle Adapter PDR Feb 2013
- Integrated stack force and moment wind tunnel April 2013
- Dual Engine Centaur LOX Duct Development Test May 2013
- OMAC Engine development test July 2013
- Spacecraft primary structures CDR Oct 2013
- Service Module propulsion system CDR Nov 2013

**Total Expected NASA CCIcap Investment: \$460M**



# Boeing Integrated Capability Initiative

National Aeronautics  
and Space Administration



## Future Work:

- Mission Control Center interface demo test Sept 2013
- Launch Vehicle Adapter CDR Sept 2013
- Emergency detection system stand alone test Oct 2013
- Certification plan release Nov 2013
- ASIL multi-string demonstration test Dec 2013
- Pilot-in-the-loop demonstration Feb 2014
- Software CDR March 2014
- Critical Design Review April 2014



**Total Expected NASA CCIcap Investment: \$460M**



# SpaceX Integrated Capability Initiative

National Aeronautics and Space Administration



Dragon Cargo Capsule berthed with ISS

SpaceX's crew transportation system is based on the Dragon spacecraft and Falcon launch vehicle originally developed for the ISS Cargo missions.

Initially designed to carry cargo with modifications to the components for added safety and crew accommodations.

## Current Progress (December 2012):

- |  |          |
|--|----------|
| • CCIcap Kickoff Meeting                       | Complete |
| • Financial and Business Review                | Complete |
| • Integrated System Requirements Review (ISRR) | Complete |

**Total Expected NASA CCIcap Investment: \$440M**



Crew Accommodation Concept Prototype and In-Situ Trial

# SpaceX Integrated Capability Initiative

National Aeronautics  
and Space Administration

## SPACEX



Dragon Cargo Capsule  
berthed with ISS

### Future Work:

- Ground Systems and Ascent PDR Dec 2012
- Pad Abort Test Review March 2013
- Human Certification Plan Review May 2013
- On-Orbit and Entry PDR July 2013
- In-Flight Abort Test Review Sept 2013
- Safety Review Oct 2013
- Flight Review of Upgraded Falcon 9 Nov 2013
- Pad Abort Test Dec 2013
- Dragon Primary Structure Qualification Jan 2014
- Integrated Critical Design Review March 2014
- In-Flight Abort Test April 2014



Crew Accommodation Concept  
Prototype and In-Situ Trial

**Total Expected NASA CCiCap Investment: \$440M**

# Sierra Nevada Integrated Capability Initiative



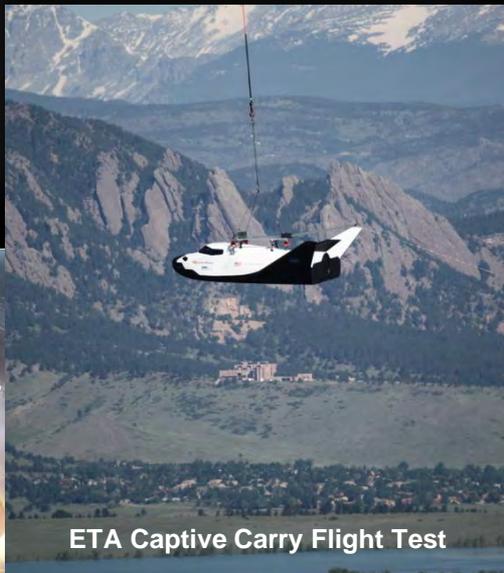
SNC crew transportation system consists of the Dream Chaser lifting body spacecraft, the Atlas V launch vehicle, mission operations, and associated ground systems.

SNC Dream Chaser is a reusable, piloted lifting body spacecraft, derived from the NASA HL-20 spacecraft design.

## Current Progress (December 2012):

- Program Implementation Plan Review Complete
- Integrated System Baseline Review Complete

Total Expected NASA CCIcap Investment: \$212.5M



ETA Captive Carry Flight Test

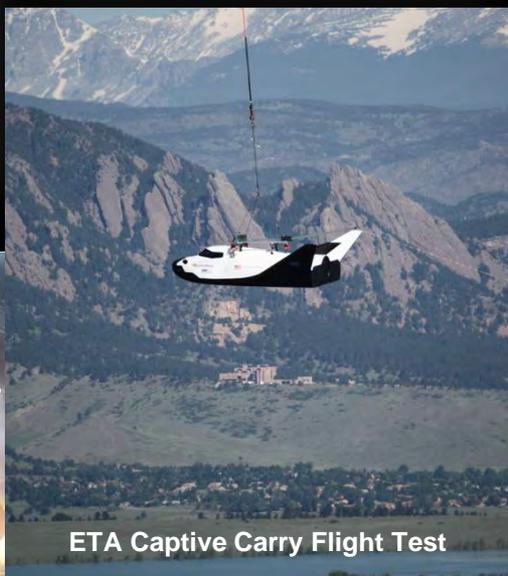


# Sierra Nevada Integrated Capability Initiative



## Future Work:

- Integrated System Safety Analysis Review #1 Jan 2013
- Engineering Test Article Flight Testing April 2013
- SNC Investment Financing #1 July 2013
- Integrated System Safety Analysis Review #2 Oct 2013
- Certification Plan Review Nov 2013
- Wind Tunnel Testing Feb 2014
- Risk Reduction and TRL Adv Testing May 2014
  - Main Propulsion and RCS Risk Reduction May 2014



**Total Expected NASA CCIcap Investment: \$212.5M**



# Blue Origin CCDev2 Project

National Aeronautics  
and Space Administration



The Blue Origin crew transportation system is comprised of a reusable biconic Space Vehicle (SV) launched first on an Atlas V launch vehicle.

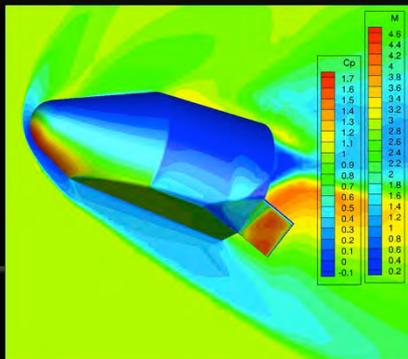
Blue Origin is simultaneously developing its own Reusable Booster System (RBS). The capsule is designed to ride on multiple launch vehicles including the Blue Origin RBS.



## Current Progress (December 2012):

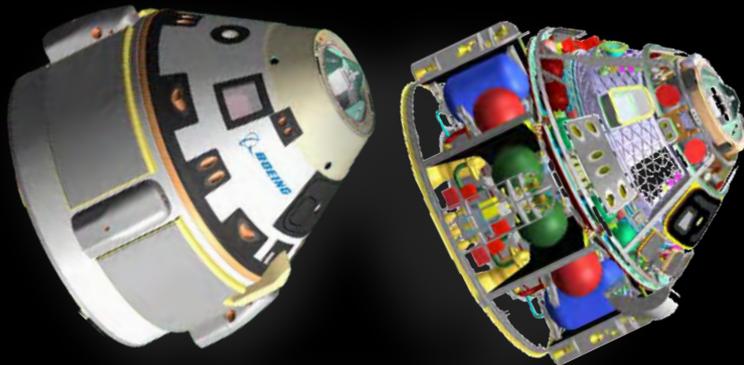
- |   |          |
|---|----------|
| • Kickoff Meetings  | Complete |
| • RBS Engine Thrust Chamber Assembly (TCA) Interface and Test Plan Review | Complete |
| • Space Vehicle Mission Concept Review                                    | Complete |
| • Space Vehicle SRR   | Complete |
| • Partial-Throttle RBS Engine TCA Test                                    | Complete |
| • Pusher Escape Ground Firing   | Complete |
| • Pusher Escape Pad Test  | Complete |
| • Full-Throttle RBS Engine TCA Test                                       | Complete |

**Total NASA CCDev2 Investment: \$22M**



CFD Analysis from Blue Origin's Independent Wind Tunnel Testing

# Boeing CCDev2 Project



Boeing's crew space transportation system is comprised of the reusable CST-100 spacecraft, Atlas V launch vehicle, and ground systems.

Boeing is continuing to develop their spacecraft design with numerous system tests during the CCDev2 timeframe.

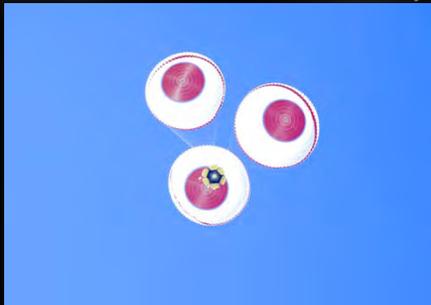
## Current Progress (December 2012):

- Delta Systems Definition Review (SDR) Complete
- Phase 0 Safety Review Complete
- Phase 1 Wind Tunnel Tests Complete
- Launch Abort Engine (LAE) Fabrication & Hot Fire Test Demo Complete
- Parachute Drop Test Demonstration Complete
- Preliminary Design Review (PDR) Complete
- Phase 1 Flight Software PDR Complete
- Orbital Maneuvering & Abort Control (OMAC) Hot Fire Test Complete
- Service Module Propulsion Cold Flow Tests Complete
- Service Module Propellant Tank Development Test Complete

## Future Work:

- Phase 2 Ground Software PDR

**Total Expected NASA CCDev2 Investment: \$112.9M**



Parachute Drop Testing



LAE Hot Fire Test

# Sierra Nevada Space Systems CCDev2 Project



SNC crew transportation system consists of the Dream Chaser lifting body spacecraft and the Atlas V launch vehicle.

SNC Dream Chaser is a reusable, piloted lifting body spacecraft, derived from the NASA HL-20 spacecraft design.

## Current Progress (December 2012):

- System Requirements Review (SRR) Complete
- Canted Airfoil Fin Selection Complete
- Cockpit Based Flight Simulator Complete
- Vehicle Avionics Integration Laboratory Complete
- System Definition Review (SDR) Complete
- Flight Control Integration Laboratory Complete
- Engineering Test Article (ETA) Complete
- Landing Gear Drop Tests Complete
- ETA Captive Carry Flight Test Complete
- Preliminary Design Review (PDR) Complete

## Future Work:

- ETA Free Flight Test

**Total Expected NASA CCDev2 Investment: \$105.6M**



ETA Captive Carry Flight Test

# United Launch Alliance CCDev2 Project

National Aeronautics  
and Space Administration



ULA's launch vehicle for crew transportation is the existing Atlas V from the family of Evolved Expendable Launch Vehicles (EELV).

Atlas V 400 Series has zero to three strap-on solid rocket boosters and a Dual-Engine Centaur upper stage configuration.

## Current Progress (September 2012):

- |  |          |
|--|----------|
| • Kick-off Review  | Complete |
| • Design Equivalency Review Summary                              | Complete |
| • Probabilistic Risk Assessment Review                           | Complete |
| • Tailored Systems Requirements Review                           | Complete |
| • Systems Requirements Review (SRR)                              | Complete |
| • Hazard, System Safety and Probabilistic Risk Assessment Review | Complete |

## **Unfunded Agreement**

*Agreement Completed in September 2012*



# SpaceX CCDev2 Project

National Aeronautics  
and Space Administration

## SPACEX

SpaceX's crew transportation system is based on the Dragon spacecraft and Falcon launch vehicle originally developed for the ISS Cargo missions.

Initially designed to carry cargo with modifications to the components for added safety and crew accommodations.

### Current Progress (August 2012):

- |  |          |
|--|----------|
| • Launch Abort System (LAS) Propulsion Conceptual Design Review  | Complete |
| • Design Status Reviews  | Complete |
| • LAS Propulsion Component PDR                                   | Complete |
| • Crew Accommodation Concept Prototype and In-Situ Trial 1       | Complete |
| • LAS Propulsion Component Test Articles                         | Complete |
| • LAS Prop. Component Initial Test Cycle                         | Complete |
| • Concept Baseline Review  | Complete |
| • Crew Accommodation Concept Delta Prototype and In-Situ Trial 2 | Complete |

**Total NASA CCDev2 Investment: \$75M**

*Agreement Completed in August 2012*



**Crew Accommodation Concept  
Prototype and In-Situ Trial**

# Alliant Techsystems CCDev2 Project

National Aeronautics  
and Space Administration



ATK worked to develop the Liberty Launch Vehicle with flight proven heritage elements.

The 1st stage is the ATK five-segment solid rocket motor based on the Space Shuttle Reusable Solid Rocket Motor design. The upper stage is the Astrium core stage from the Ariane 5 rocket, which includes the Vulcain 2 engine.

## Current Progress (August 2012):

- |  |          |
|--|----------|
| • Kick-off Review                      | Complete |
| • Technical Interchange Meeting 1      | Complete |
| • Launch Systems Initial System Design | Complete |
| • Technical Interchange Meeting 2      | Complete |
| • Program Status Review (PSR)          | Complete |

## **Unfunded Agreement**

*Agreement Completed in August 2012*



# Excalibur Almaz, Inc. CCDev2 Project

National Aeronautics  
and Space Administration



The Excalibur Almaz Incorporated (EAI) utilized heritage flight hardware to develop their concept for LEO crew transportation.

EAI crew transportation system consists of a Human Spacecraft (HSC) and a commercially available launch vehicle.

## Current Progress (June 2012):

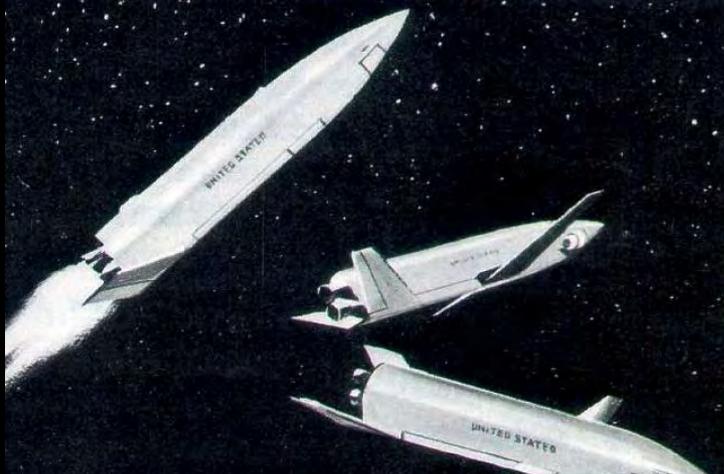
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|---------------------------------------|----------|
| • Development Program Kickoff Review  | Complete |
| • Systems Requirements Status Review  | Complete |
| • Test Status Review                  | Complete |
| • Design Status Review                | Complete |
| • Launch Vehicle Compatibility Review | Complete |

## **Unfunded Agreement**

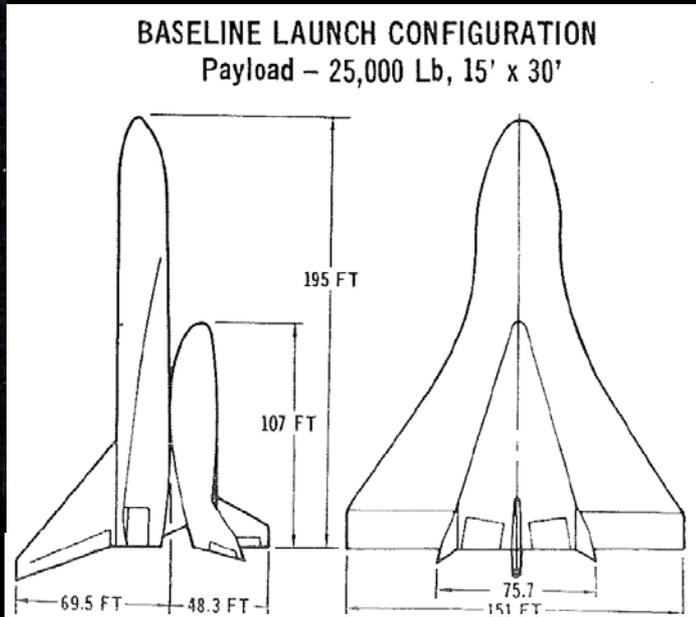
*Agreement Completed in June 2012*



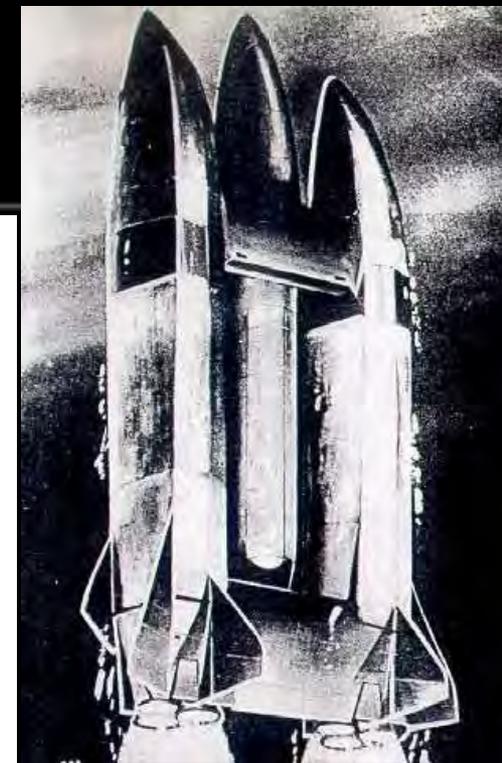
# Space Shuttle Early Integrated Design Competition was key



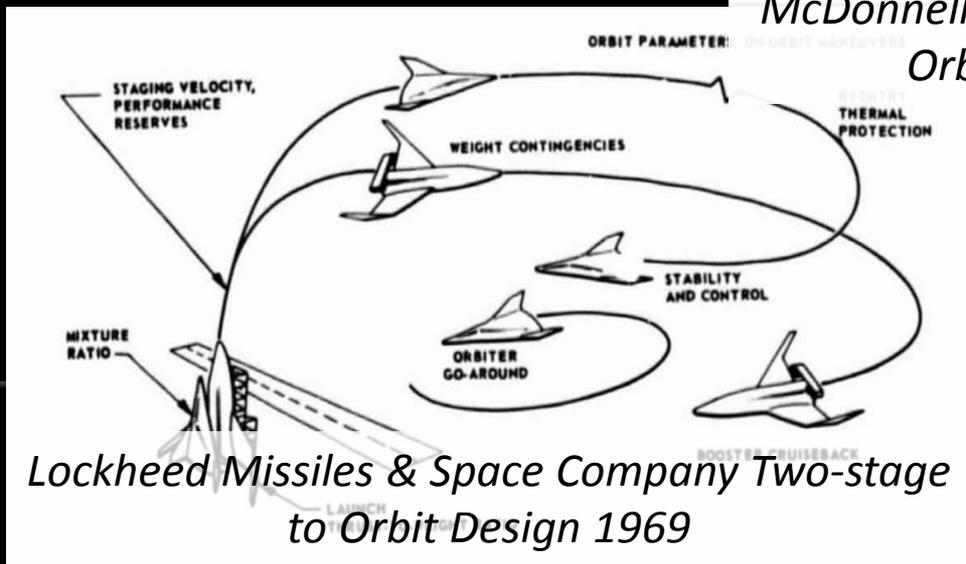
*General Dynamics Triamese Design 1969*



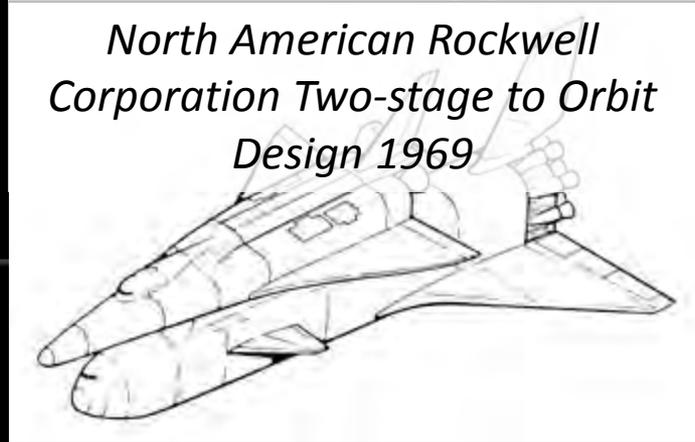
*McDonnell Douglas Two-stage to Orbit Design 1969*



*Martin Marietta Catamaran Booster and Wing-Body Re-entry Configuration 1969*



*Lockheed Missiles & Space Company Two-stage to Orbit Design 1969*



*North American Rockwell Corporation Two-stage to Orbit Design 1969*



# McDonnell Douglas Two-stage to Orbit Design 1969

## GENERAL ARRANGEMENT HL-10

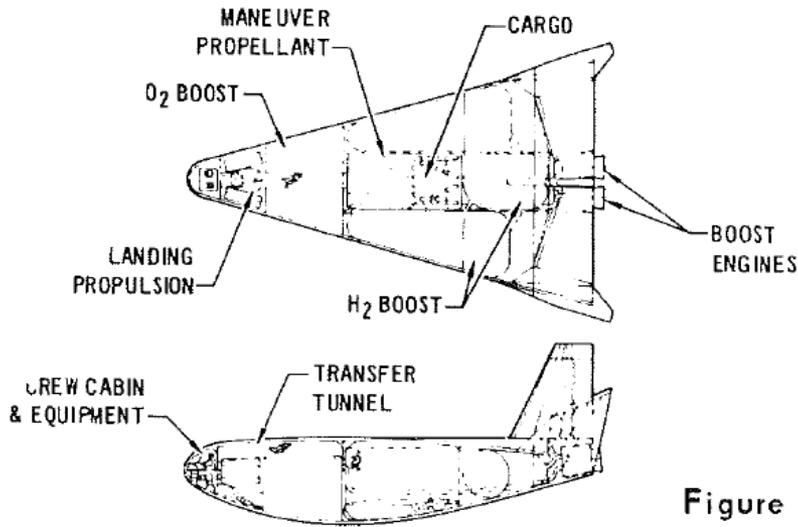
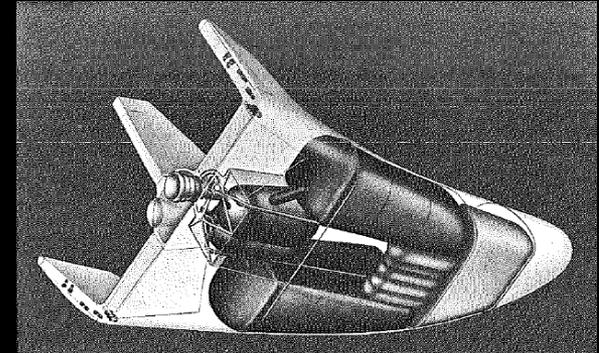
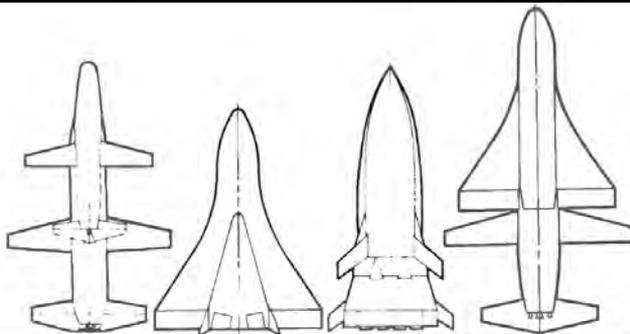
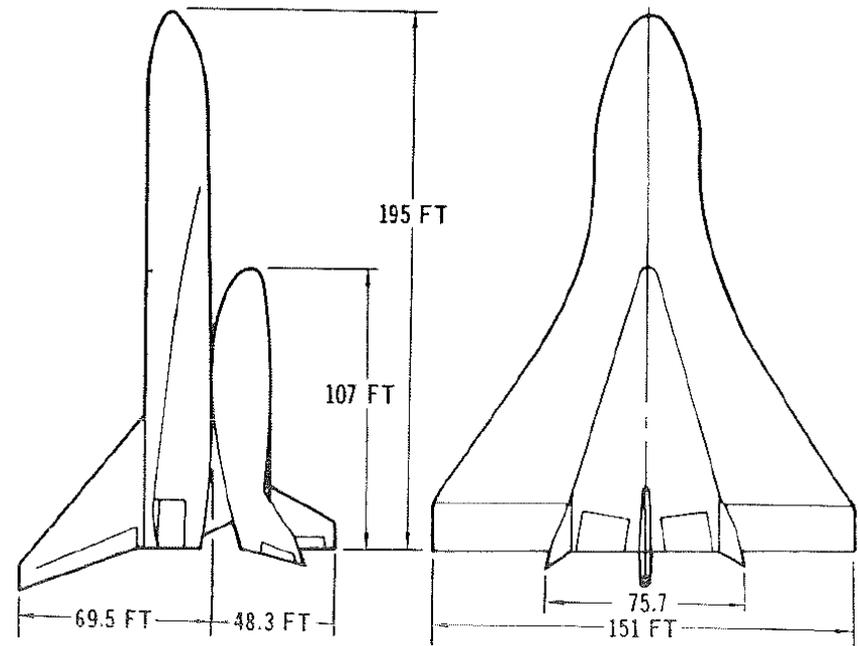


Figure 5-7



## BASELINE LAUNCH CONFIGURATION

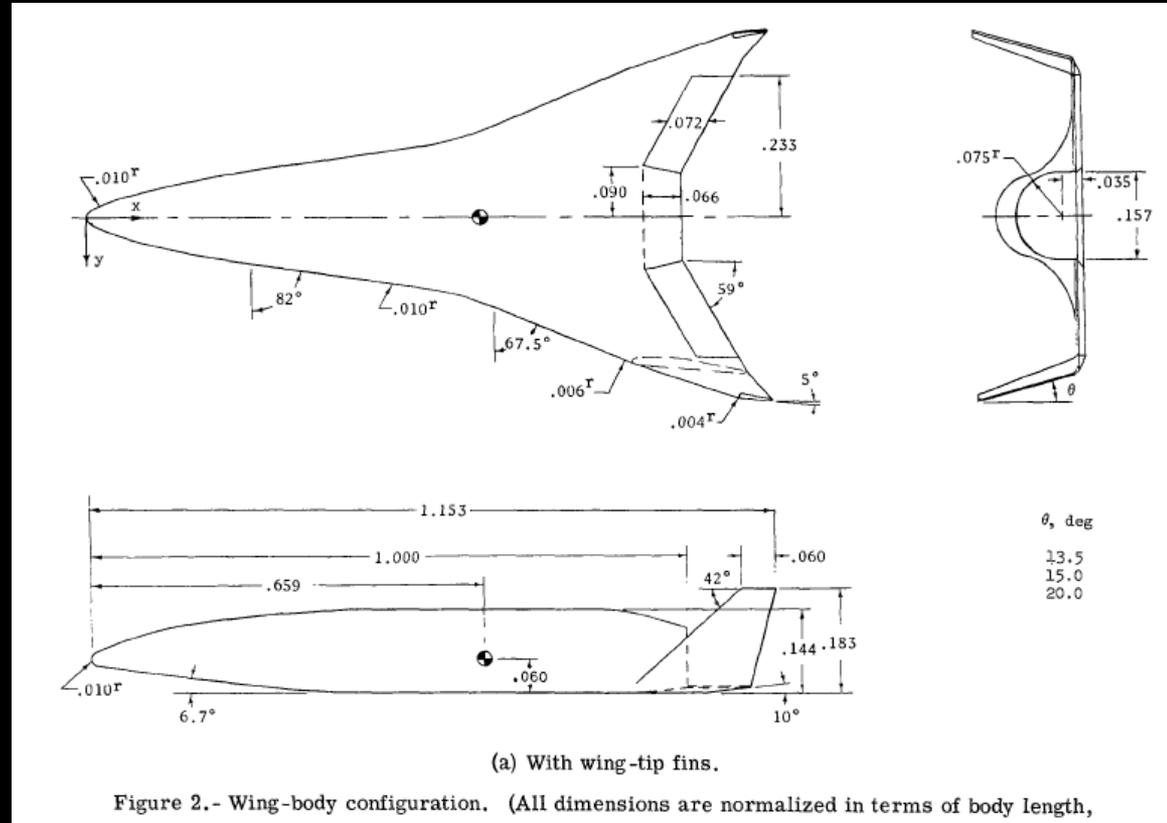
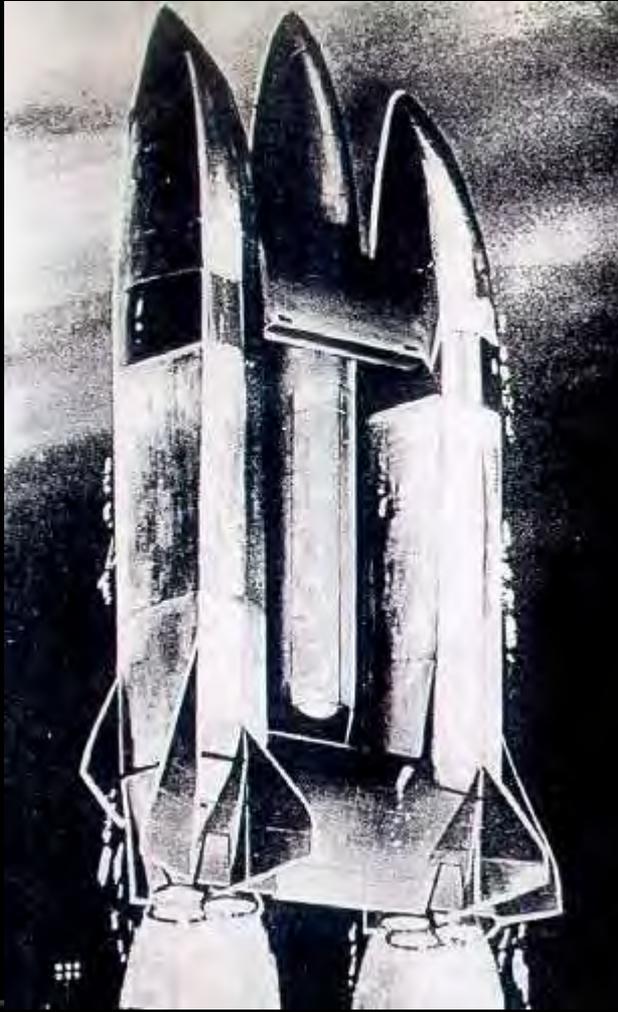
Payload – 25,000 Lb, 15' x 30'



	FIXED STRAIGHT WING	HL-10 CLIPPED DELTA	SWING WING	CLIPPED DELTA/FIXED WING
MINIMUM REQUIREMENTS	61,000 LB.	57,000 LB.	56,000 LB.	55,000 LB.
NOMINAL REQUIREMENTS	42,000 LB.	38,000 LB.	32,000 LB.	37,000 LB.

FIGURE-21

# Martin Marietta Corp. Two-stage to Orbit Design 1969



Martin Marietta shuttle Phase A design. X-24B type lifting body orbiter with unique catamaran-configuration booster



# North American Rockwell Corp. Two-stage to Orbit Design 1969

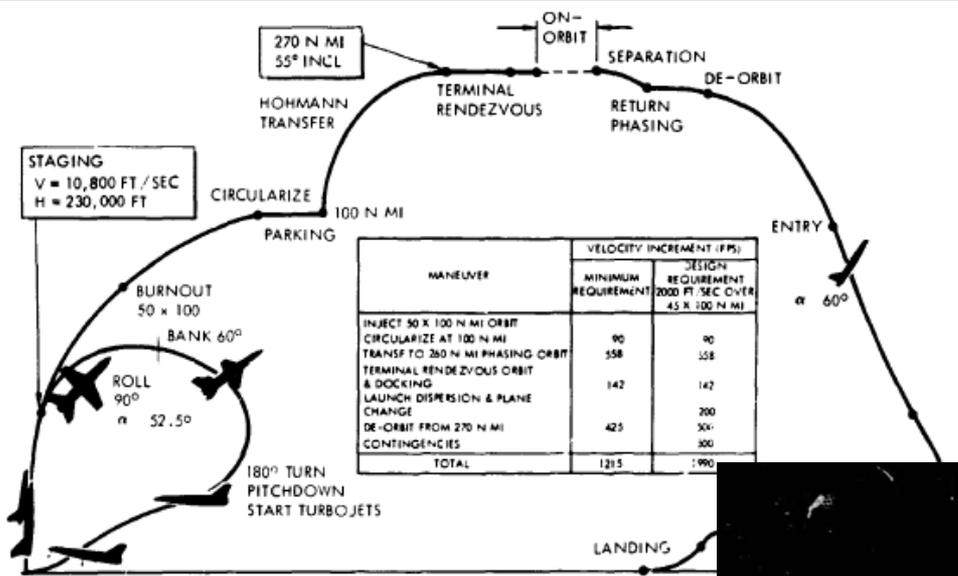


Figure 2. Flight Profile

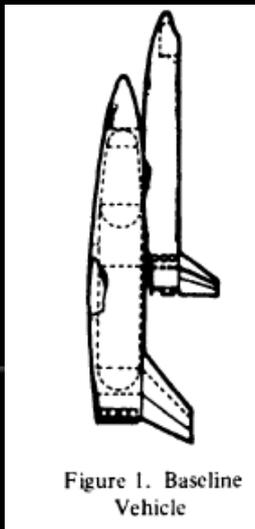
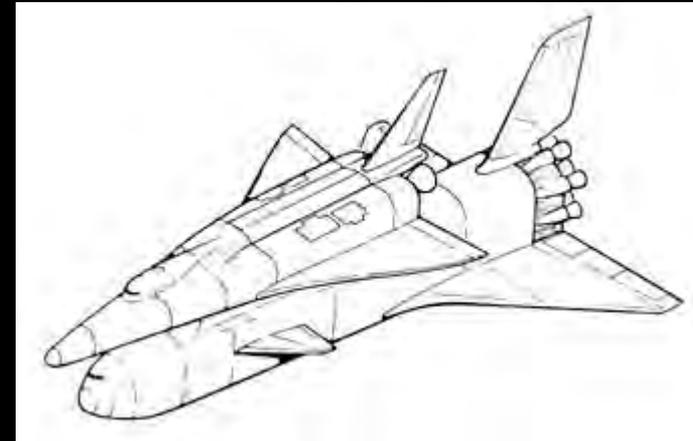


Figure 1. Baseline Vehicle



