Commercial Crew Program Update
The Next Step in U.S. Space Transportation

December 2012

Commercial Crew Program - Same Crew…New Ride
Commercial Crew Program (CCP) is vital to NASA’s Future

The Future of American Human Spaceflight

- Space Launch System and Orion MPCV
- Commercial Crew Program

Human Exploration

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

CCiCap
Integrated Design

CCDev2
Maturing Design

Certification
Flight Test

CCDev1
Initial Concept

Services
Launch to ISS

Public Purpose

NASA Purpose
# 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
- The Boeing Co.
- Sierra Nevada Corp. (SNC)
- Space-X
- ATK Aerospace
- Excalibur Almaz Inc.
- 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 CCiCAP 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

- **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
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

- **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)
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
Revised Acquisition Strategy (2012)

Commercial Crew Transportation System Development

<table>
<thead>
<tr>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Certification for ISS Crew Transportation**

**Phase 1**
- Alignment with NASA certification requirements
- RFP - Certification Products Contract

**Phase 2**
- Verification, validation, test and final certification
- RFP - Certification Contract

Certification to include at least one crewed ISS mission

---Notional---

**ISS Crew Transportation Services**

- RFP - ISS Services Contract

Commercial Crew Program
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*
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):
- Integrated System Review Complete
- Production Design Review Complete
- Phase 1 Safety Review Complete

Total Expected NASA CCiCap Investment: $460M
Boeing Integrated Capability Initiative

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

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'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
SpaceX Integrated Capability Initiative

Future Work:
- Ground Systems and Ascent PDR
- Pad Abort Test Review
- Human Certification Plan Review
- On-Orbit and Entry PDR
- In-Flight Abort Test Review
- Safety Review
- Flight Review of Upgraded Falcon 9
- Pad Abort Test
- Dragon Primary Structure Qualification
- Integrated Critical Design Review
- In-Flight Abort Test

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
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

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
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 Complete
- (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
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) 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
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’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*
Alliant Techsystems CCDev2 Project

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
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):**
- 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
General Dynamics Triamese Two-stage to Orbit Design 1969
McDonnell Douglas Two-stage to Orbit Design 1969

**GENERAL ARRANGEMENT HL-10**

- MANEUVER PROPELLANT
- O₂ BOOST
- LANDING PROPULSION
- H₂ BOOST
- CARGO
- BOOST ENGINES
- CREW CABIN & EQUIPMENT
- TRANSFER TUNNEL

**BASELINE LAUNCH CONFIGURATION**

Payload – 25,000 Lb, 15’ x 30’

**Fixed Straight Wing**
- Minimum Requirements: 61,000 Lb.
- Nominal Requirements: 42,000 Lb.

**HL-10 Clipped Delta**
- Minimum Requirements: 57,000 Lb.
- Nominal Requirements: 38,000 Lb.

**Swing Wing**
- Minimum Requirements: 56,000 Lb.
- Nominal Requirements: 32,000 Lb.

**Clipped Delta/Fixed Wing**
- Minimum Requirements: 55,000 Lb.
- Nominal Requirements: 37,000 Lb.
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 1. Baseline Vehicle

Figure 2. Flight Profile
The Martin Co. designed Dyna-Soar 1961 (drawings delivered to USAF)