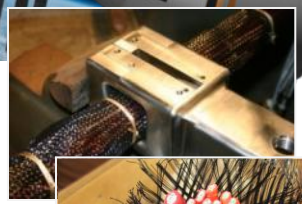
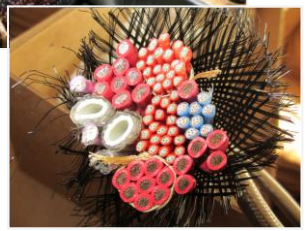
Boeing 2012 CCTS Progress and 2013 Plan

January 2013

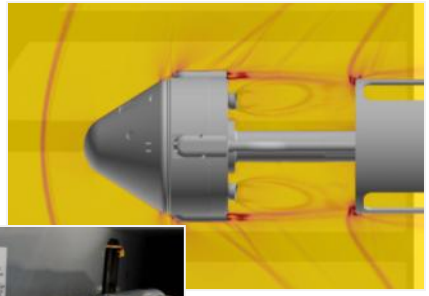
CCTS Design Maturation Under CCDev2

- **Structures & Mechanisms Testing**
  - CM Pressurized Structure Producibility & Material Properties Testing for Lighter Weight Alloy (Al 7475)
  - BMI Composite Material Property Development
  - CM/SM Umbilical Pyrotechnic Guillotine Cutter
  - MMOD Hypervelocity Impact Testing
- **Landing System Testing**
  - Airbag Drop Testing
  - Rotation Handle Testing
  - Parachute Drop Testing
  - Inflation System Development
  - FHS Separation Testing
- **Propulsion Systems Testing**
  - Launch Abort Engine Hot Fire Tests
  - SM Propulsion Tank Tests
  - Orbital Maneuvering and Attitude Control Engine Hot Fire Test
  - SM Propulsion Cold Flow Test
  - SM Propulsion Helium Pressurization Flow Test
- **Wind Tunnel Testing**
  - Launch Abort Wind Tunnel Testing at NASA Ames Research Center

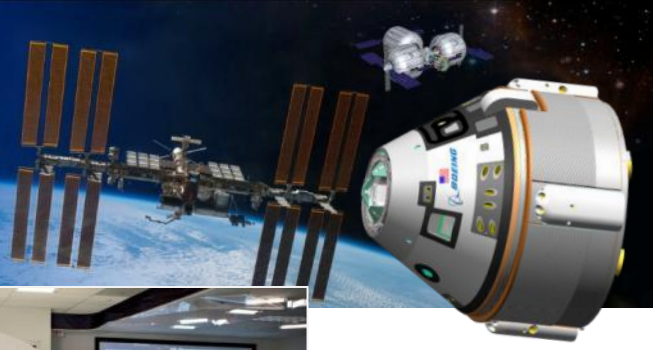






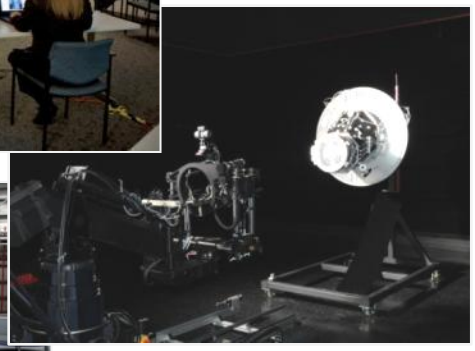




CCTS Design Maturation Under CCDev2



- **Avionics Testing**
  - Launch Vehicle EDS Testing with CST-100 Avionics
  - ASIF/VENUS Closed-Loop Ascent/Rendezvous Flight Simulation
  - ASIL Deployment
- **Production and Ground Systems Development**
  - AI&T Site Selection (refurbished KSC OPF3)
  - DELMIA Design for Manufacture and Assembly Assessments
- **Crew and Cargo Systems Development**
  - Crew Ingress/Egress Assessment
  - Cargo Capability Assessment
  - Crew Reach Assessment
  - Crew Control Panels Layout Development
  - Crew Seat Prototype Development



CCiCap Base Period Major Milestones 2013-2014

2012					2013											2014				
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May

- Aug-2012 #1 - Integrated System Review
- Oct-2012 #2 - Production Design Review
- Nov-2012 #3 - Phase 1 Safety Review Board
- Jan-2013 #4 - Software Integrated Engineering Release 2.0
- Jan-2013 #5 - Landing & Recovery/Grnd. Comm. Design Review
- Feb-2013 #6 - LVA Preliminary Design Review
- Apr-2013 #7 - Integrated Stack Force & Moment Wind Tunnel Test
- May-2013 #8- Dual Engine Centaur (DEC) Liquid Oxygen Duct Dev. Test
- Jul-2013 #9 - Orbital Maneuvering & Attitude Control Engine Dev. Test
- Oct-2013 #10 -Spacecraft Primary Structures CDR
- #11 - Service Module Propulsion CDR Nov-2013
- #12 - Mission Control Center Interface Demonstration Test Sep-2013
- #13 - Launch Vehicle Adapter CDR Sep-2013
- #14 - Emergency Detection System (EDS) Standalone Testing Oct-2013
- #15 - Certification Plan Release Nov-2013
- #16 - Avionics Software Integ. Lab (ASIL) Multi-String Demo Dec-2013
- #17 - Pilot-in-the-Loop Demonstration Feb-2014
- #18 - Software CDR Mar-2014
- #19-Critical Design Review Board Apr-2014

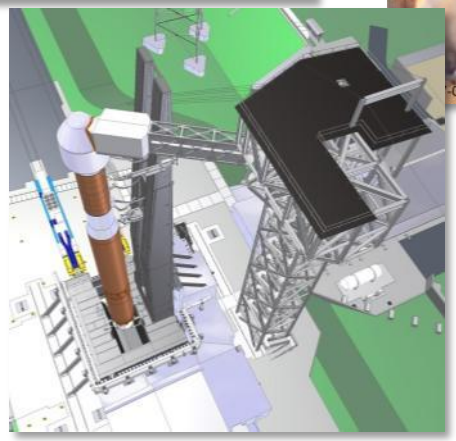
CCTS Design Maturation Under CCiCap Aug. 2012 through Jan. 2013

- **Integrated System Review**
  - Established and demonstrated CCTS Vehicle and operations that meets system requirements
- **Production Design Review**
  - Established the baseline plan, equipment and infrastructure for performing the manufacture, assembly and acceptance testing of the CST-100
  - Leveraged successful and extensive Boeing Commercial production practices
- **Phase 1 Safety Review Board**
  - Conducted a comprehensive safety review to access conformance with NASA's Crew Transportation System certification process
  - Focused on hazard reports, cause descriptions and controls
- **CST-100 Interior Layout Evaluation**
  - Completed three-day evaluation with NASA astronauts on reach and visibility of controls/displays
  - Received feedback on the design of the crew seats, interior lighting, and optimum layout for Crew Resource Management
- **Software Engineering Release 2.0**
  - Initial release of flight software
- **Landing & Recovery/Ground Comm. Design Review**
  - Preliminary design of ground and communications architecture

CCTS Design Maturation Under CCiCap 2013 Milestones

Boeing's CCTS 2013 Plan:

- Continue system design maturation – multiple demonstrations
- CST-100, Atlas V integration and Launch Pad Modifications
- Mission Control demonstrations
- Continued re-development of the ULA Dual Engine Centaur
- Launch Vehicle Adapter PDR & CDR
- Continued development of KSC OPF-3



Commercial Crew Market Potential

- Agreement with SA to make extra seating capacity available to private space flight participants

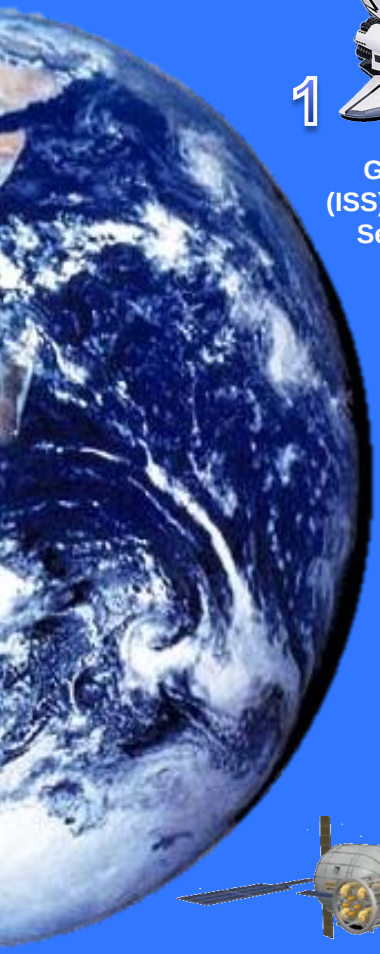
- Boeing CCTS will provide transportation to Bigelow Station
- Bigelow provides test articles and facilities supporting CCTS development

And more...

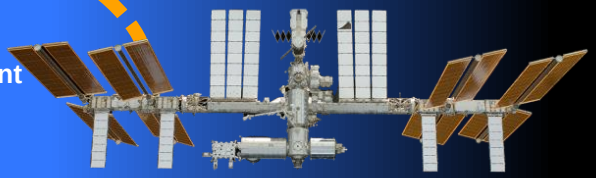
- Boeing is working with potential international customers and exploring other opportunities to continue to foster the market

NASA development funding is providing the stimulus to enable future commercial market growth

Low Earth Orbit Progression



1 Government Led (ISS) with Government Services (Shuttle)



International Space Station (ISS)

2 Government Led Destination (ISS) with Commercial Services (CST-100)

3 Commercial Transportation (CST-100) to Commercial Destination (Bigelow Station)

4 Commercial Transportation (CST-100) to Multipurpose Commercial Destinations

Low Earth Orbit

Scientific research and technology testing that improves life on Earth and acts as a stepping stone for future deep space exploration

Today's Elements of Human Space Exploration

Commercial | NASA

Suborbital

Technology payloads and commercial passengers

SpaceShipTwo
Virgin Galactic

Low Earth Orbit

Scientific research and technology testing that improves life on Earth and enables future deep space exploration

International Space Station (ISS)
Boeing

GEO

Geosynchronous Orbit

Cis-Lunar

Space environment to test and prove exploration capabilities and operations

Deep Space

Human journeys of exploration and discovery beyond low Earth orbit, taking us further into space than every before

Asteroids

Curiosity (Robotic Precursor to Human Exploration)

Commercial Cargo

Commercial Crew

Orion Crew Vehicle
Lockheed Martin

Space Launch System (SLS) - 130 mt
Boeing, Pratt & Whitney Rocketdyne

Why Do Humans Explore?

Discovery, Scientific Knowledge, Technology & Economic Growth, Expansion of Human Civilization, International Cooperation, Public Engagement

LEO and Beyond: Architectural Differences

LEO

- Point-design for ISS /Space Complex Mission
  - Battery/Solar Power
  - Routine day/night cycles for heating/cooling
  - Lower re-entry velocities=lower weight thermal protection systems
  - Rapid return to Earth if needed
  - Short-term crew system solutions
- Moderate investment; reasonable timeframe for investment recovery based on NASA planned missions; emerging commercial market

Beyond LEO

- Multi-purpose design for multiple destinations
  - Solar/Fuel cell power
  - High capacity active cooling
  - Higher re-entry velocities with increased thermal protection system requirements
  - Increased redundancy; rapid Earth return not an option
  - Long-term solutions for crew systems
- Significantly higher investment; long-term investment recovery; NASA future services not defined; no current commercial market

LEO and Beyond

- LEO can be done commercially because we have done it for years
- A LEO vehicle is a point-design; Especially in the case of a commercial craft designed to be efficient and cost effective
- Going beyond LEO requires technologies associated with more demanding environments at greater cost
- The business case for beyond LEO for commercial providers would be very challenging considering the potential markets
- NASA Commercial Crew Program is enabling LEO commercial transportation to ISS, a pivotal first step in fostering commercial human space exploration
- Maintaining the ISS foothold in LEO will cultivate other commercial LEO opportunities