Nondestructive Evaluation Education, Experiences and Career at NASA

Brazosport College

August 2017

Part 1

Ajay M. Koshti, D.Sc. PE
ASNT Level III (UT,RT, ET, PT, MT)
NDE Lead Engineer
NASA Johnson Space Center

Agenda

- Education and Experiences
- Publications/Patents
- NASA Programs with NDE Involvement

Publications/Patents

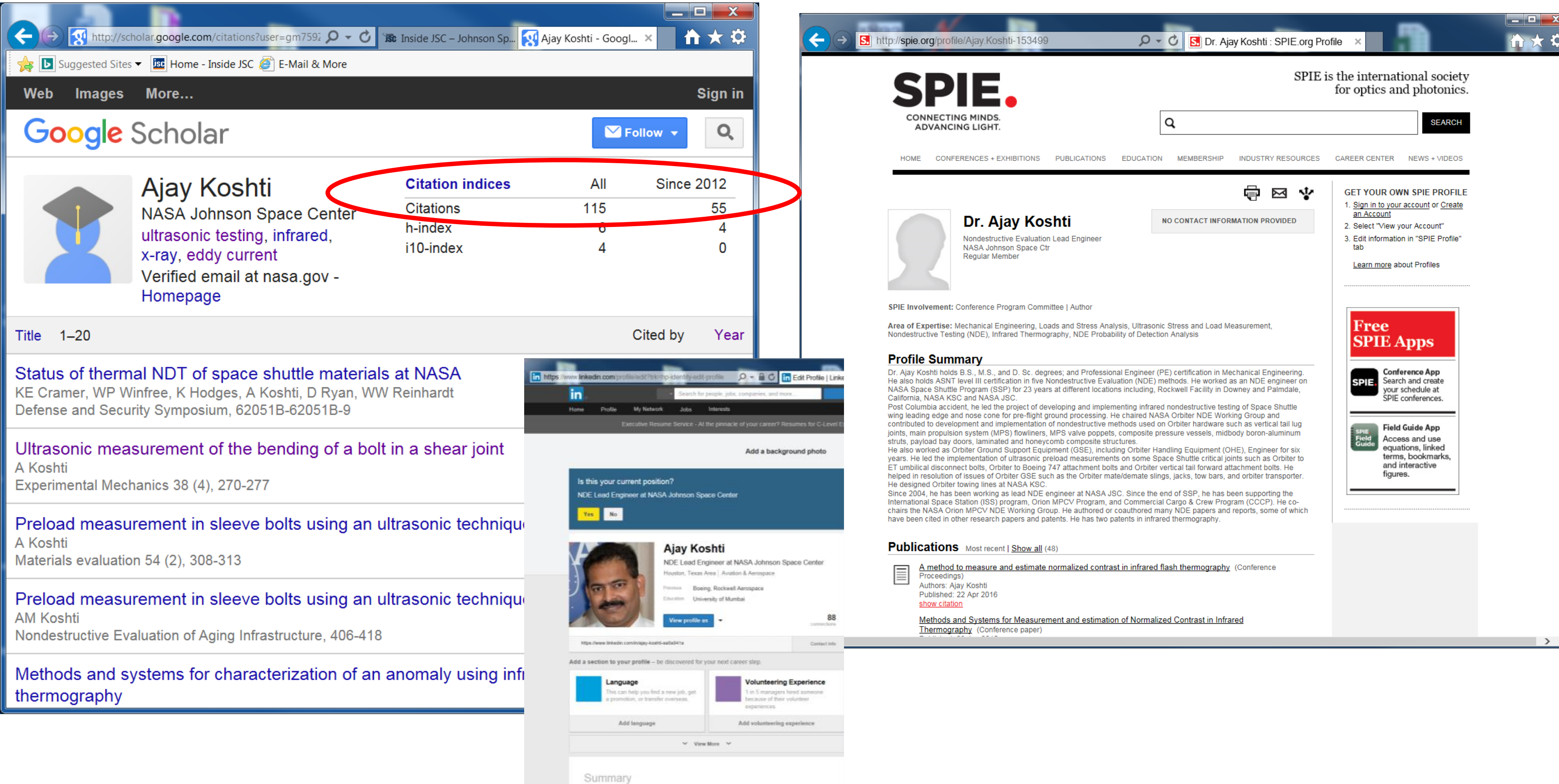
- Areas
  - Ultrasonic stress/preload measurements: Modeling and measurement
  - Residual stress measurement
  - Thermal NDE, Temperature measurement: modeling, analysis, measurement, data processing
  - Eddy current flaw detection
  - Computed Tomography: POD Analysis
  - POD data analysis
  - X-ray Flaw detection: Modeling and analysis
- Publication Sites
  - NASA Tech Briefs, Materials Evaluation, SPIE, Experimental Mechanics, Experimental Techniques, U.S. Patent, and NDE Proceedings.
- U.S. Patent
  - Thermal NDE, two patents for NASA
  - Citation in Patent: 1 (used by Boeing for bolt assembly of critical joints on commercial planes)

Publications

1	Preload measurement in sleeve bolts using an ultrasonic technique, A Koshti - Materials evaluation, 1996 - proceedings.spiedigitallibrary.org
2	Effect of bending on ultrasonic preload measurements in bolts, AM Koshti - ... on NDE for Health Monitoring and ..., 2001 - proceedings.spiedigitallibrary.org
3	Simulation of ultrasonic measurement on a bolt in a shear joint, Proc. SPIE 4702, A M Koshti, Smart Nondestructive Evaluation for Health Monitoring of Structural and Biological Systems, 411 (June 11, 2002); doi:10.1117/12.469903
4	Simulation of effect of bending stress on the ultrasonic beam, A M Koshti, Proc. SPIE 4702, Smart Nondestructive Evaluation for Health Monitoring of Structural and Biological Systems, 148 (June 11, 2002); doi:10.1117/12.469874
5	Simulation of ultrasonic preload measurement on a bolt in an interference fit joint, A M Koshti - NDE For Health Monitoring and ..., 2002 - proceedings.spiedigitallibrary.org
6	Estimation of accuracy in ultrasonic preload measurements, A M Koshti, Proc. SPIE 4335, Advanced Nondestructive Evaluation for Structural and Biological Health Monitoring, 300 (July 24, 2001); doi:10.1117/12.434186
7	Ultrasonic measurement of the bending of a bolt in a shear joint, A M Koshti - Experimental mechanics, 1998 - Springer
8	Stress measurement via the acoustoelastic effect and water-coupled ultrasonic waves, A M Koshti, D M Egle - NDT and E International, 1995 - ingentaconnect.com
9	Estimating temperature rise in pulsed thermography using irreversible temperature indicators, A M Koshti, Proc. SPIE 4702, Smart Nondestructive Evaluation for Health Monitoring of Structural and Biological Systems, 191 (June 11, 2002); doi:10.1117/12.469878
10	Measuring and Estimating Normalized Contrast in Infrared Flash Thermography, Koshti, Ajay M. NASA Technical Reports Server (NTRS), Collection, Johnson Space Center, February 2013, Document ID: 20130009802.
11	Applicability of a Conservative Margin Approach for Assessing NDE Flaw Detectability, A M Koshti, NASA Technical Reports Server (NTRS, Johnson Space Center, Apr. 16, 2007, Document ID: 20070016672
12	Nondestructive Crack Detection in a Fuel System Component, A M Koshti, NASA Technical Reports Server (NTRS)Johnson Space Center; Kennedy Space Center; Langley Research Center; Marshall Space Flight Center, May 10, 2010, Document ID: 20100020162
13	X-Ray Computed Tomography Inspection of the Stardust Heat Shield, NASA Technical Reports Server (NTRS), Ames Research Center; Goddard Space Flight Center; Johnson Space Center, June 14, 2010, Document ID: 20100027549, Subject Category: SPACECRAFT DESIGN, TESTING AND PERFORMANCE, Report:ARC-E-DAA-TN1350
14	An Alternate Technique for Implementing Center-Hole Drilling/Residual-Stress Measurements A M KOSHTI, D M EGLE - Experimental Techniques, 1985 - Wiley Online Library
15	Exploration of COTS Ultrasonic NDE Methods for ISS MMOD Impact Analysis, Daniel P Violette, University of Connecticut, Storrs, CT, 06798 , Ajay M Koshti, Johnson Space Center, Houston, TX, 77058, and David Stanley Johnson Space Center, Houston, TX, 77058, NASA MUST – Internship Final Report, NASA Technical Reports Server (NTRS), Johnson Space Center, 2012 Document ID: 20120013518, Report/Patent Number: JSC-CN-26785
16	IR Thermography of International Space Station Radiator Panels, Koshti, Ajay; Winfree, William; Morton, Richard; Howell, Patricia, NASA Technical Reports Server (NTRS), NASA Johnson Space Center; Langley Research Center, 2010, Document ID: 20100035740
17	Eddy-Current Detection Of Cracks In Reinforced Carbon/Carbon, Christensen, Scott V.; Koshti, Ajay M., Johnson Space Center, NASA Technical Reports Server (NTRS), Nov 1, 1995, Document ID: 19950070376
18	Wedge Heat-Flux Indicators for Flash Thermography, Koshti, Ajay M., NASA Technical Reports Server (NTRS), NASA Johnson Space Center, November 2003, Publication Year: 2003, Document ID: 20110023942
19	Modeling the X-ray Process, and X-ray Flaw Size Parameter for POD Studies, Ajay M. Koshti, NASA Johnson Space Center, SPIE Smart Structures and NDE, San Diego, CA, March 2014
20	Methods and Systems for Characterization of an Anomaly Using Infrared Flash Thermography, US Patent 8,577,120 B1, Nov. 5, 2013, Ajay Koshti, Assigned to NASA.
21	The Critical Role of High Resolution X-ray Micro-computed Tomography for Ultra-thin Wall Space Component Characterization, D. J. Roth, R. W. Rauser, R.R. Bowman, R.E. Martin, A. M. Koshti, and D. S. Morgan, Materials Evaluation, March 2014, page 383.

Internet Sites with Profile and Publications

http://spie.org/profile/Ajay.Koshti-153499
https://www.linkedin.com/
http://scholar.google.com/



Contains information that is publically available on the internet

Education and Experience

1974-1976: Junior College, University of Bombay (Mumbai)
1976-1981: **Bachelor of Technology (Mechanical Engineering)**
Indian Institute of Technology, Bombay
1981-1982: Union Carbide India Ltd. (Bombay)
Maintenance Engineer
!983- 1985: **M.S. (Mechanical Engineering**)
University of Oklahoma
1985-1987: Pace Setter Inc. Manufacturing Engineer
ASNT Level III (UT)
1988-1993: Rockwell International, Downey, CA
NDE/Quality Engineer, Space Shuttle Orbiter Program
ASNT Level III (PT, MT, RT, ET)
PE (Mechanical Engineering)
1993-2003: Rockwell International and Boeing North American
Kennedy Space Center
NDE, Ground Support Engineering and Orbiter Handling Engineering
2002: **Doctor of Science in Mechanical Engineering**, University of Mumbai
2004-Current: NASA Johnson Space Center
Lead NDE Engineer

Contains information that is publically available on the internet

University of Mumbai (Bombay)

University of Mumbai

Established 1857
Established by British Rulers in India

University is Ranked 5th in India

Indian Institute of Technology, Bombay

Established in 1958
Ranked 39th in Asia
IIT Undergraduate Brand
is Recognized worldwide
as IIT Engineers have emigrated to
most developed countries and
done very well.


Main Building


Sports Field


Mechanical Eng. Side View

Mechanical Eng. Entrance

University of Oklahoma

Well known in College Football
7 national **championships**,
44 conference **championships**
#88 in Mechanical Eng. by U.S. News

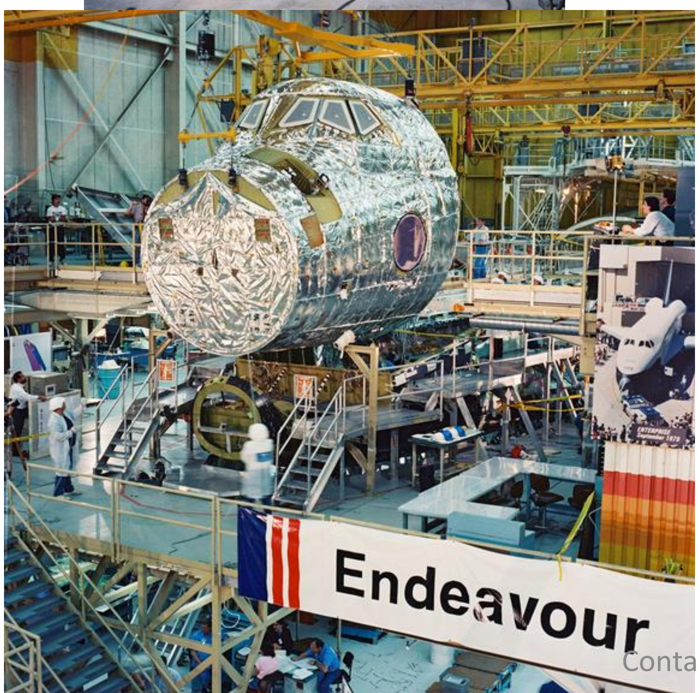
Mechanical Engineering

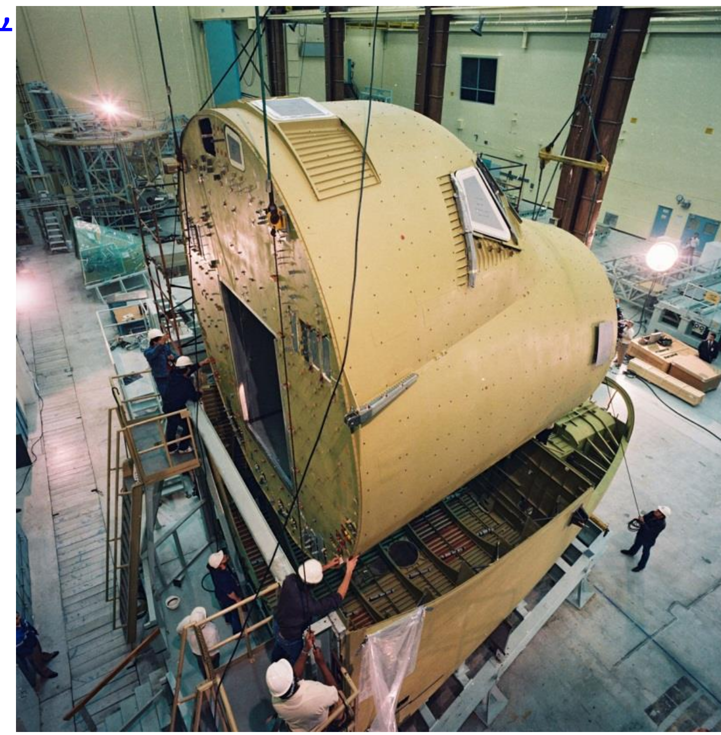
Space Shuttle Program
Rockwell Intl., Downey and Palmdale CA

Rockwell

Space Shuttle First flight	April 12, 1981
Last flight	July 21, 2011

Rockwell International





Worked in Downey plant from 1988 to 1993

Kennedy Space Center
Space Shuttle Launch Pad & VAB Area

Space Shuttle Orbiter Towlines
Designed by Ajay Koshti

VAB

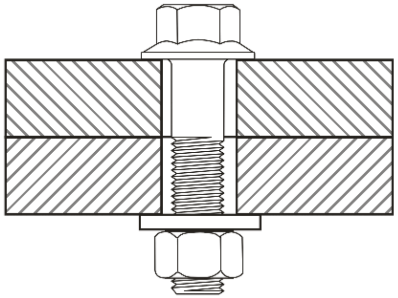
Google Map of Vehicle Assembly Building Area

BOEING®

Worked at Kennedy Space Center for Boeing from 1993 to 2003

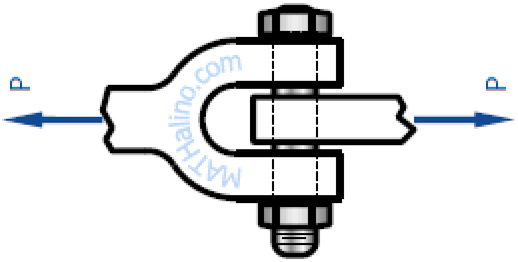
Ultrasonic Preload Measurement Applications

Case 1: Clamp Joint (Shank in Clearance)



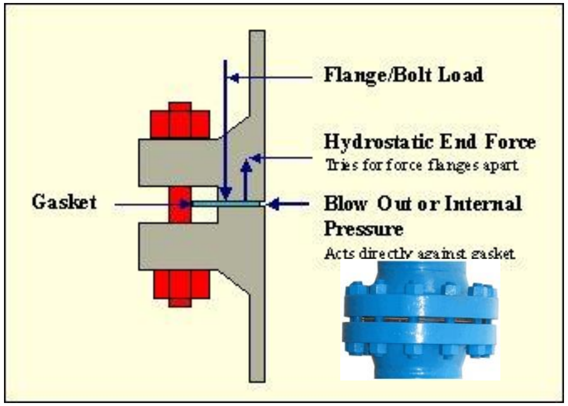
Measure bolt preload

Case 2: Double Shear Joint



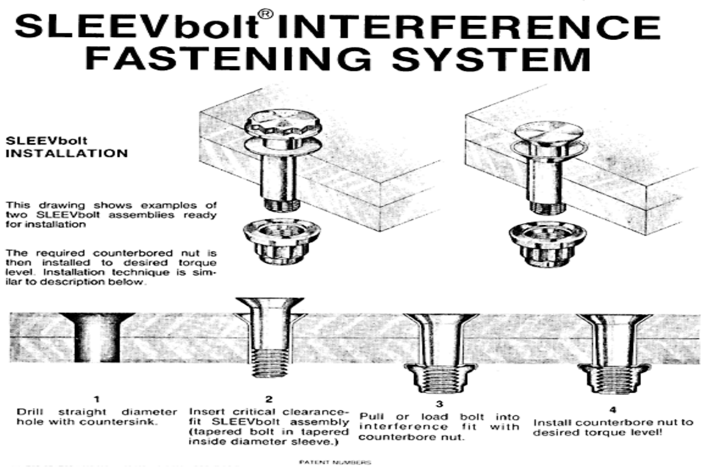
Measure Load P

Case 3: Flange Joint



Measure bolt preload

Case 4: Clamp Joint with Interference

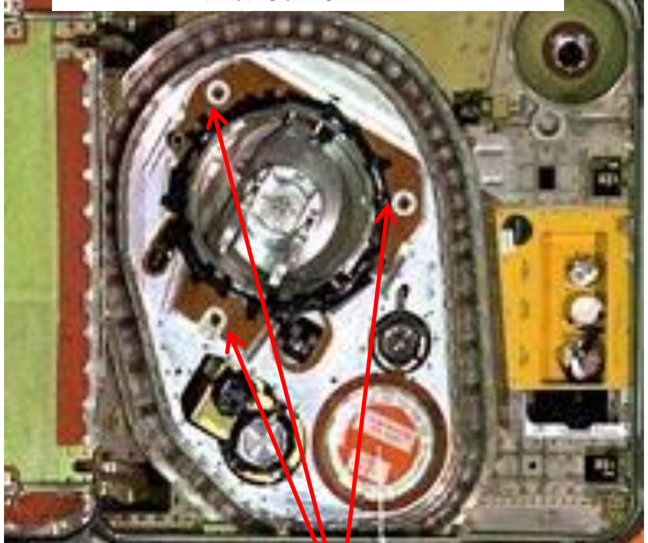


Measure preload and shank pressure

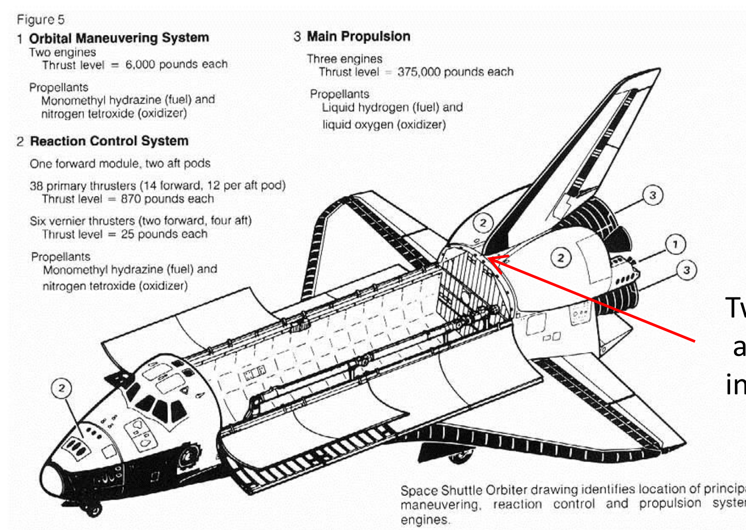
- Ultrasonic transducer contacts on bolt head or tail
- Measures ultrasonic wave return trip
- transit time through the length of the bolt

See papers 1 through 7 by Ajay Koshti
for applications of four cases. Covers modeling and experimental results.

Space Shuttle Ultrasonic Preload Applications



Two 2” Dia. Orbiter to Aircraft attachment bolts in Clamped Joint

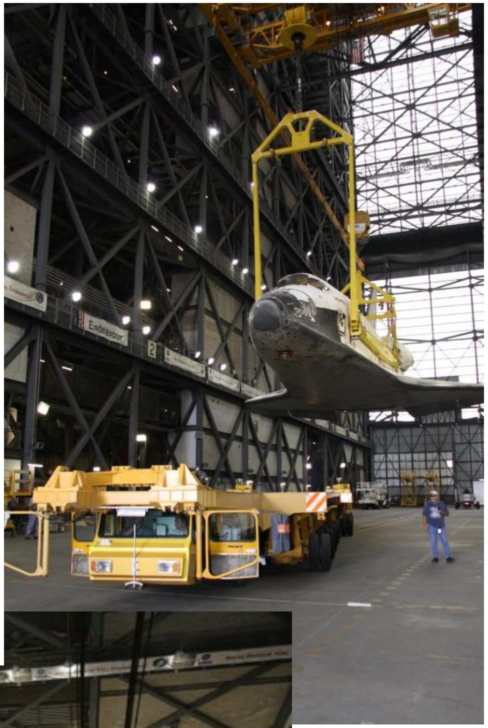


Two Vertical Tail attachment sleeve bolts in Interference Joint

Three bolt (0.7” Dia) locations in a Flange Joint in the 17” Orbiter/ET Disconnect

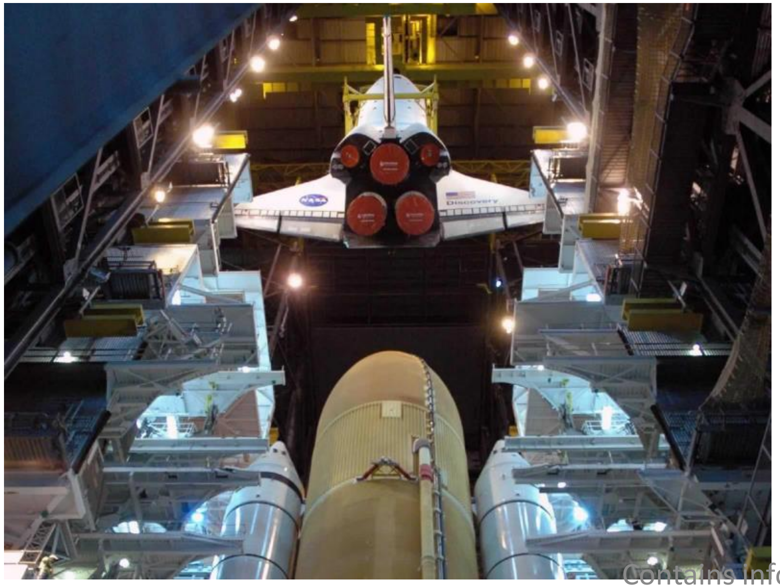
Led development of above ultrasonic preload applications.

Vehicle Assembly Building



USA

United Space Alliance



Orbiter to Carrier Aircraft Mate/Demate Facility and Launch Pad

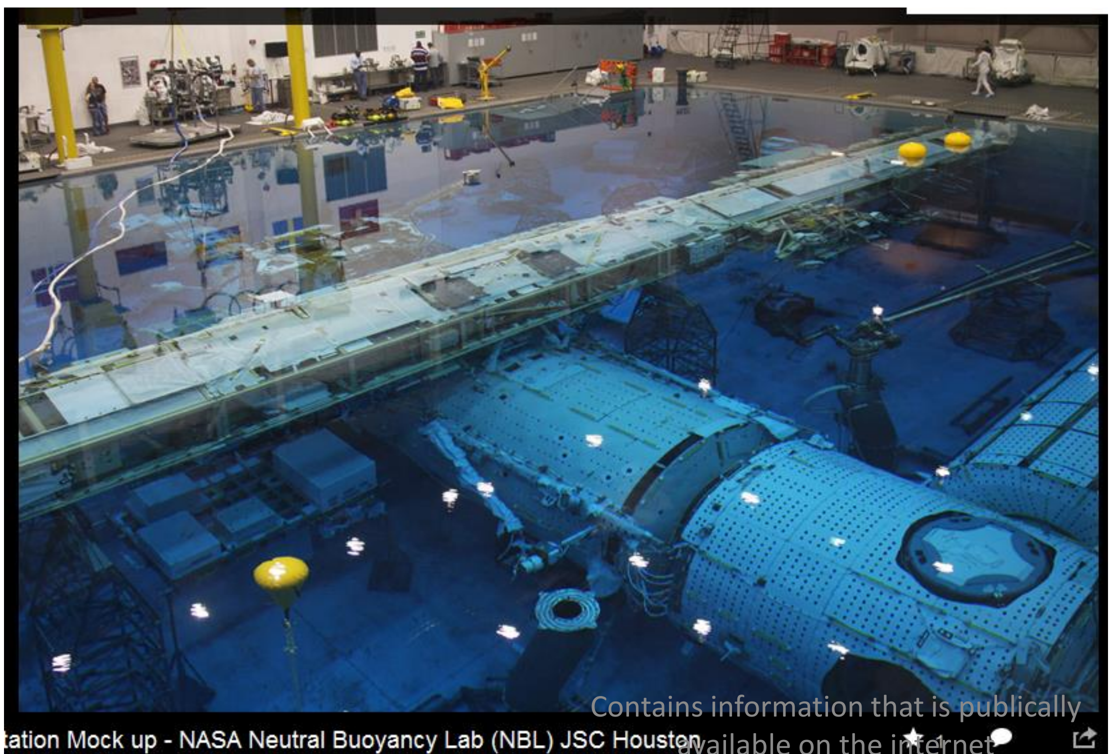
USA™

United Space Alliance

NASA NDE Engineers at Shuttle Launch Pad

Tailcone is the only hardware built
by Boeing before acquiring Rockwell Aerospace
and McDonnell Douglas.
Tailcone was used for a ferry flight atop Boeing 747.

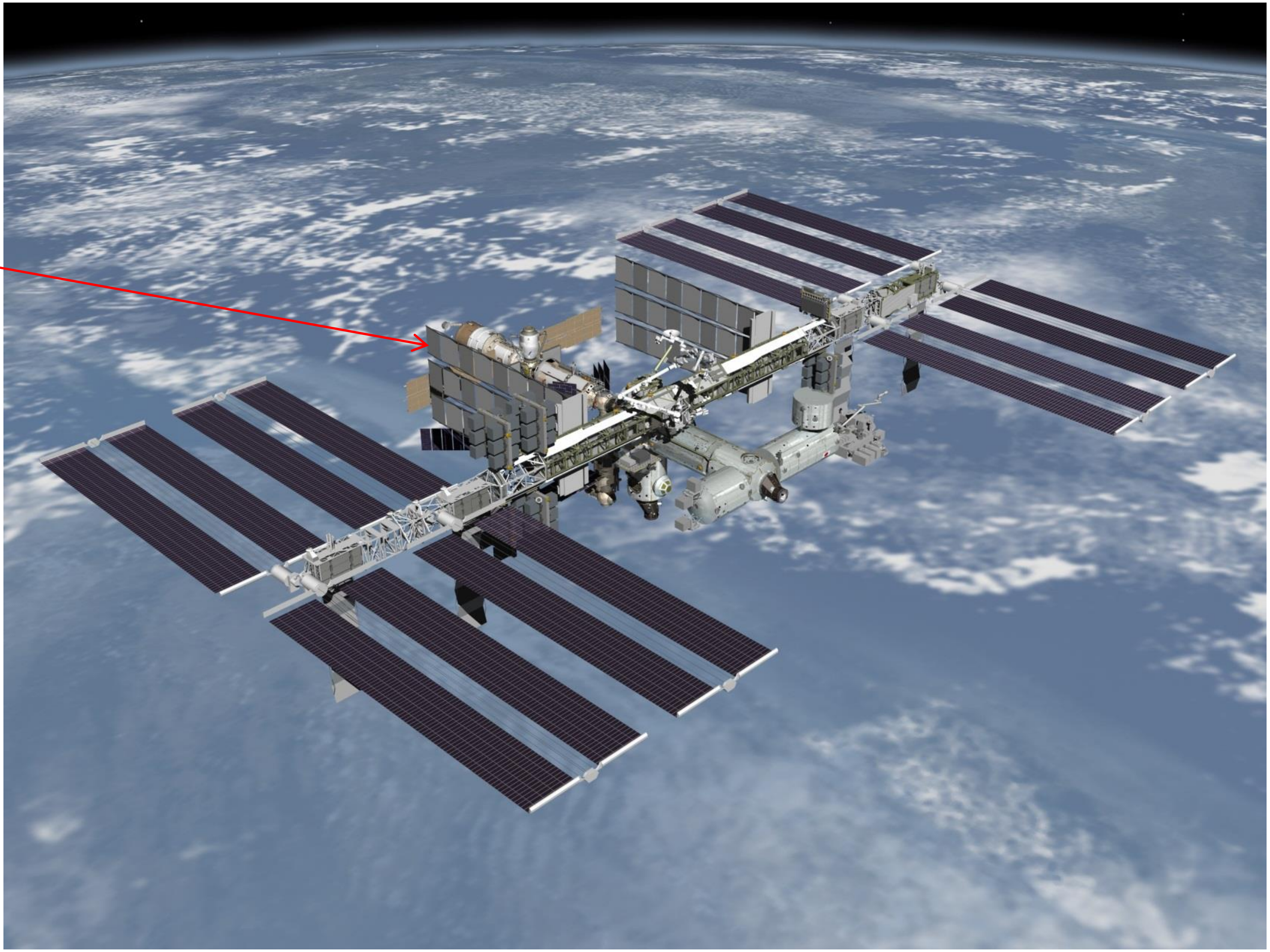
NASA Johnson Space Center



Robonaut R2 above ISS

International Space Station

EVA Infrared Imaging NDE of radiators

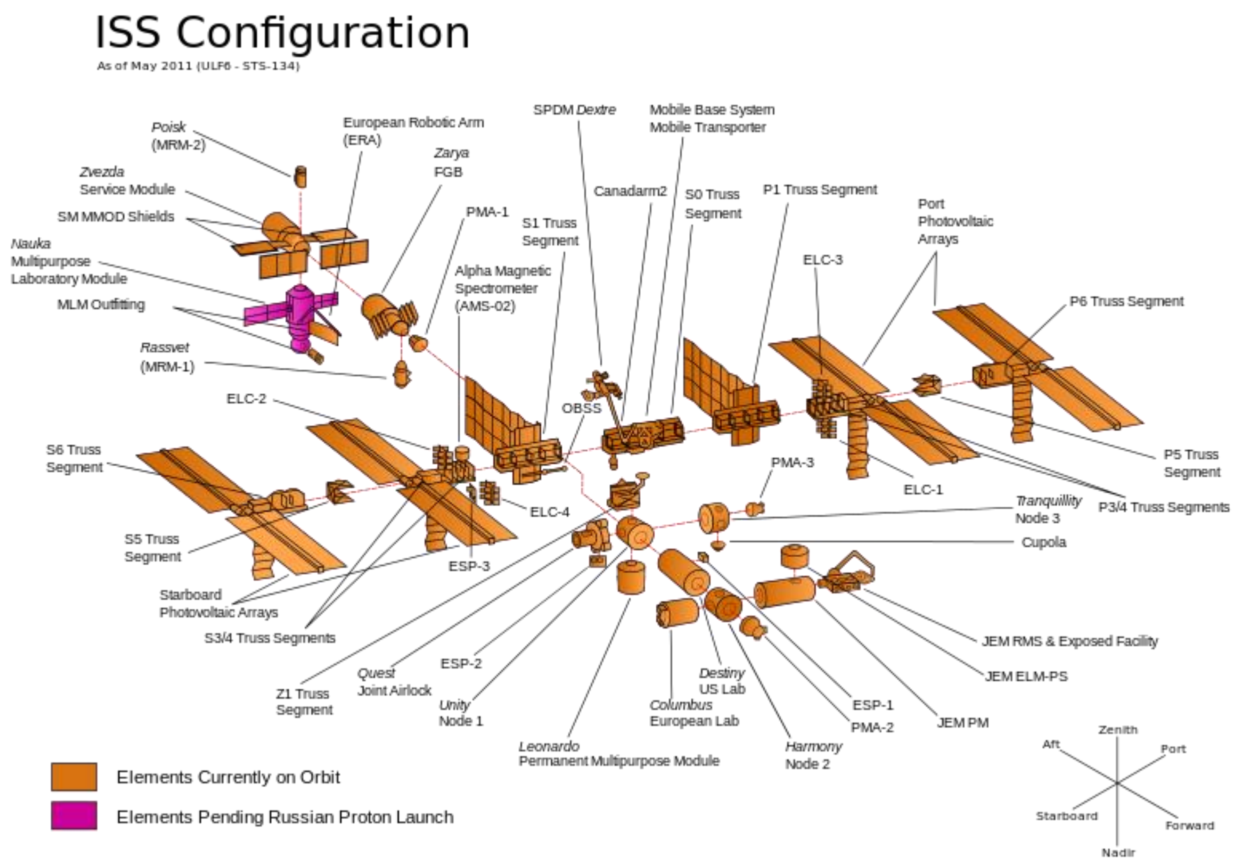


Currently ISS is the largest program for NASA Johnson space Center

International Space Station

Station statistics	
COSPAR ID	1998-067A
Call sign	*Alpha*
Crew	Fully crewed 6 Currently aboard 6 (Expedition 38)
Launch	1998
Launch pad	Baikonur 1/5 and 81/23 Kennedy LC-39
Mass	approximately 450,000 kg (990,000 lb)
Length	72.8 m (239 ft)
Width	108.5 m (356 ft)
Height	c. 20 m (c. 66 ft) nadir–zenith, arrays forward–aft (27 November 2009)[dated info]
Pressurised volume	837 m³ (29,600 cu ft) (21 March 2011)
Atmospheric pressure	101.3 kPa (29.91 inHg, 1 atm)
Perigee	417 km (259 mi) AMSL[1]
Apogee	422 km (262 mi) AMSL[1]
Orbital inclination	51.65 degrees[1]
Average speed	7.66 kilometres per second (27,600 km/h; 17,100 mph)[1]
Orbital period	92.83 minutes[1]
Orbit epoch	8 March 2014[1]
Days in orbit	5587 (8 March)
Days occupied	4874 (8 March)
Number of orbits	87564[1]
Orbital decay	2 km/month

Statistics as of 9 March 2011



NASA Ellington Field, Houston

Jose Hernandez, former astronaut and JSC Nondestructive Evaluation Engineer at NASA Ellington Field with T-38

T-38

WB-57

Super Guppy

WB-57

Zero G

Project Morpheus

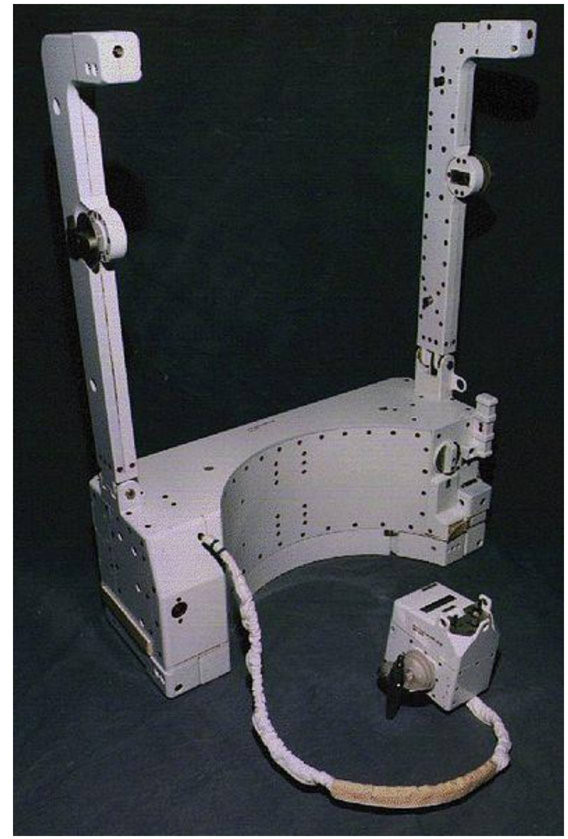
USA	
Designer	NASA
Manufacturer	NASA/JSC
Application	Planetary and lunar lander
Status	In development
Liquid-fuel engine	
Propellant	liquid oxygen / methane[1]
Performance	
Thrust	22000 N [2]
Specific impulse	321 s [3]
Burn time	tested: 123 s [4]
Used in	
Morpheus Lander	

Astronaut Suits

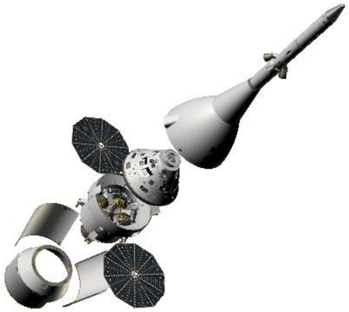
Mark III Suit

ISS EMU Suit

NASA Simplified Aid for EVA Rescue (SAFER)



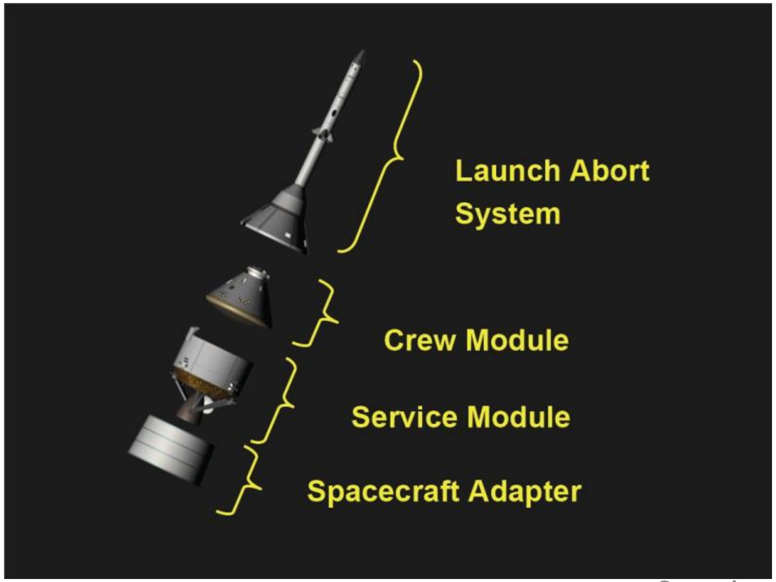
NASA Orion Spacecraft



- The **Orion Multi-Purpose Crew Vehicle** (**Orion MPCV**) is an American spacecraft intended to carry a crew of four astronauts to destinations at or beyond low Earth orbit (LEO). Currently under development by NASA for launch on the Space Launch System, Orion is intended to facilitate human exploration of asteroids and of Mars and to retrieve crew or supplies from the ISS if needed.
- The MPCV's first test flight (uncrewed), known as Exploration Flight Test 1 (EFT-1), was launched atop a Delta IV Heavy rocket on December 5, 2014, on a flight lasting 4 hours and 24 minutes, landing at its target in the Pacific Ocean at 10:29 Central . The first mission to carry astronauts is not expected to take place until 2023 at the earliest, although NASA officials have said that their staff is working toward an "aggressive internal goal" of 2021.

NASA Orion Spacecraft

LOCKHEED MARTIN



Description

Role:	Beyond LEO, back-up for commercial cargo and crew to the ISS[1]
Crew:	2–6[2]
Carrier rocket:	Space Launch System (planned-deep space), Delta IV (test flight), Ares I (cancelled)
Launch date:	December 5, 2014 (uncrewed test launch)[3]

Dimensions

Height:	
Diameter:	5 m (16.5 ft.)
Pressurized volume:	19.56 m^3 (691 cu ft) [4]
Habitable volume:	8.95 m^3 (316 cu ft) [4]
Capsule mass:	8,913 kg (19,650 lb.)
Service Module mass:	12,337 kg (27,198 lb.)
Total mass:	21,250 kg (46,848 lb.)
Service Module propellant mass:	7,907 kg (17,433 lb.)

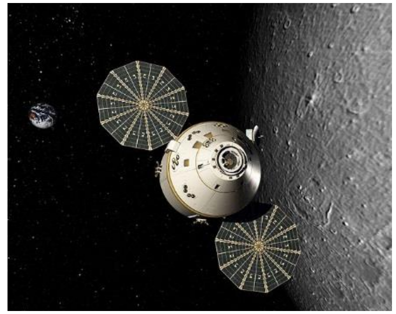
Performance

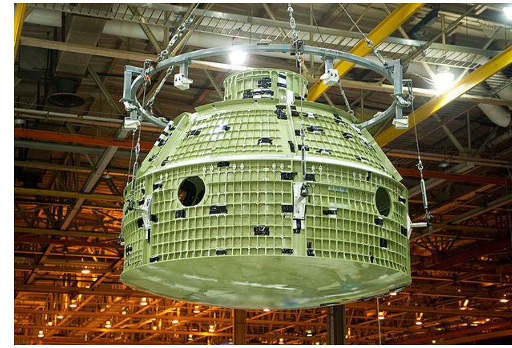
Total delta-v:	1,595 m/s
Endurance:	21.1 days[2][4]

Orion Spacecraft

- NASA's Orion spacecraft will carry astronauts further into space than ever before using a module based on Europe's Automated Transfer Vehicles (ATV).
- The ATV-derived service module, sitting directly below Orion's crew capsule, will provide propulsion, power, thermal control, as well as supplying water and gas to the astronauts in the habitable module.
- The first Orion mission will be an uncrewed lunar flyby in 2018, returning to Earth's atmosphere at 11 km/s – the fastest reentry ever.

Orion Spacecraft





EFT-1 Orion after final weld on June 22, 2012.

Engineers successfully tested the parachutes for NASA's Orion spacecraft at the U.S. Army Yuma Proving Ground in Arizona Wednesday, March 8, 2017

Exploration Flight Test 1 Recovery on December 5, 2014

Exploration Flight Test 1 Recovery on December 5, 2014

Interior of the Orion mock-up, October 2014.

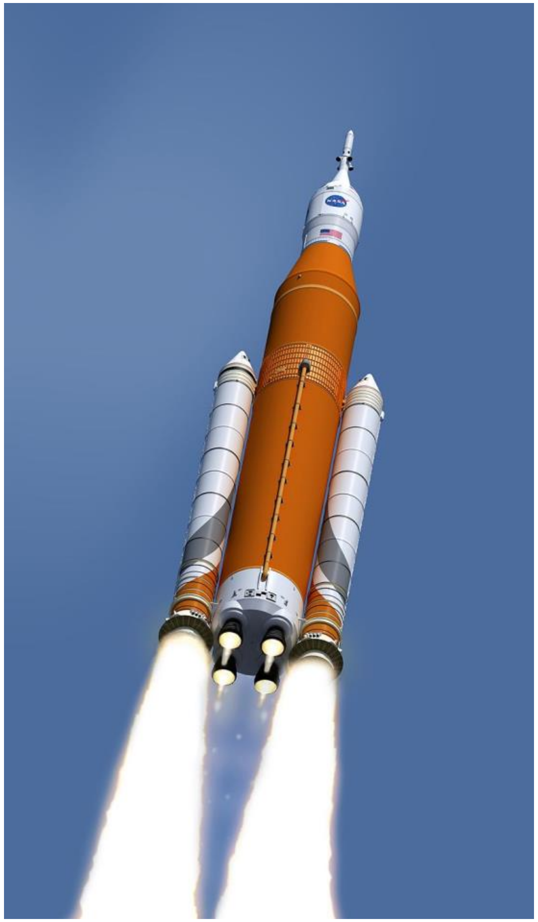
Orion Spacecraft

Assembly operation to prepare Orion EFT 1 for its first flight in December 2014.

Orion Lifting off on top of a Delta IV Heavy on December 5, 2014

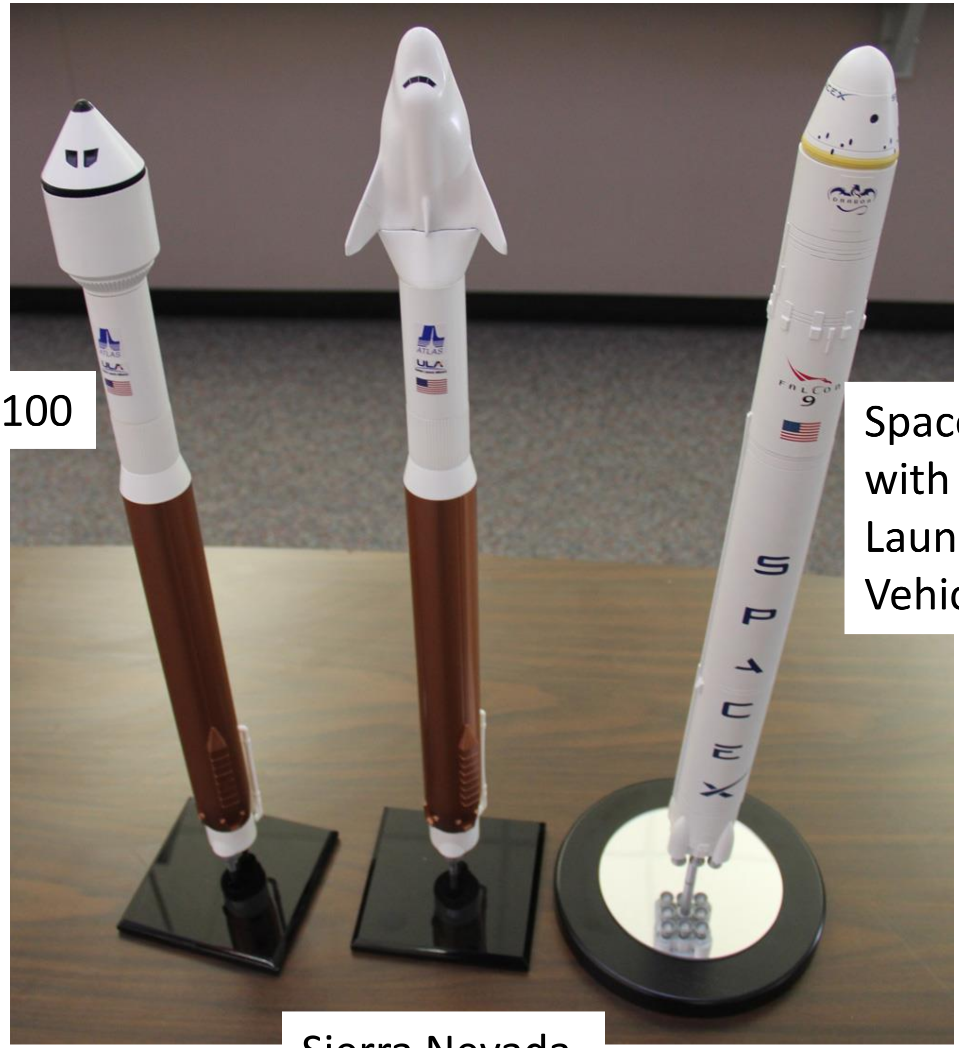
Space Launch System (SLS)

- The **Space Launch System** (**SLS**) is an American Space Shuttle-derived heavy expendable launch vehicle being designed by NASA. It is to replace the retired Space Shuttle. The SLS will be the most powerful rocket ever built, with about 20% more thrust than the Saturn V and a comparable payload capacity, putting the SLS into the super heavy-lift launch vehicle class of rockets.
- The SLS launch vehicle is to be upgraded over time with more powerful versions. Its initial Block 1 version is to lift a payload of 70 metric tons to low Earth orbit (LEO), which will be increased with the debut of Block 1B and the Exploration Upper Stage.
- Block 2 will replace the initial Shuttle-derived boosters with advanced boosters and is planned to have a LEO capability of more than 130 metric tons to meet the congressional requirement. These upgrades will allow the SLS to lift astronauts and hardware to various beyond-LEO destinations: on a circumlunar trajectory as part of Exploration Mission 1 with Block 1, to a near-Earth asteroid in Exploration Mission 2 with Block 1B, and to Mars with Block 2. The SLS will launch the Orion Crew and Service Module and may support trips to the International Space Station if necessary. SLS will use the ground operations and launch facilities at NASA's Kennedy Space Center, Florida.



NASA Commercial Crew

COMMERCIAL
CREW
PROGRAM



Boeing CST 100

SpaceX Dragon with Falcon 9 Launch Vehicle

Sierra Nevada Dream Chaser With Atlas

Contains information that is publically available on the internet

SpaceX Dragon Spacecraft

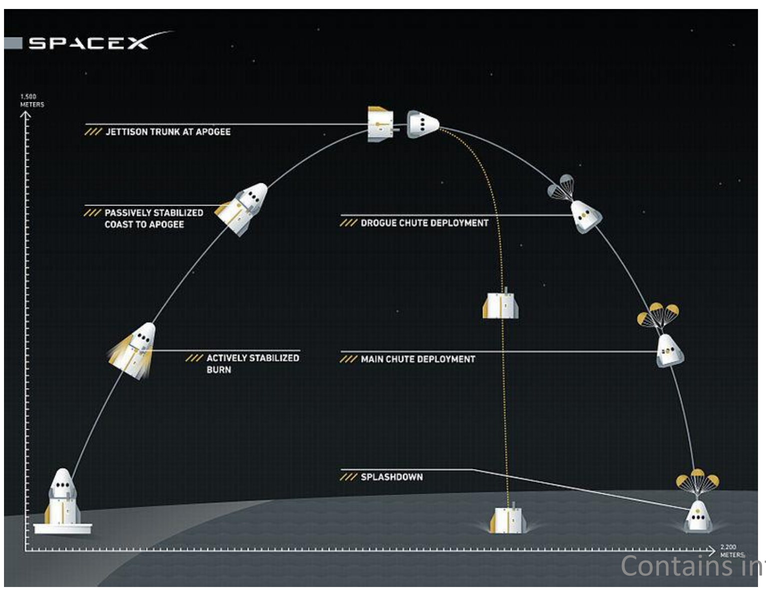
- **Dragon** is a spacecraft developed by SpaceX, an American private space transportation company based in Hawthorne, California. Dragon is launched into space by the SpaceX Falcon 9 two-stage-to-orbit launch vehicle, and SpaceX is developing a crewed version called the Dragon 2.
- During its maiden flight in December 2010, Dragon became the first commercially built and operated spacecraft to be recovered successfully from orbit. On 25 May 2012, a cargo variant of Dragon became the first commercial spacecraft to successfully rendezvous with and attach to the International Space Station (ISS). SpaceX is contracted to deliver cargo to the ISS under NASA's Commercial Resupply Services program, and Dragon began regular cargo flights in October 2012. With the Dragon spacecraft and the Orbital ATK Cygnus, NASA seeks to increase its partnerships with domestic commercial aviation and aeronautics industry.

Dragon

Dragon 2 Manned Spacecraft

Dragon 2 spacecraft conducting a propulsive hover test, Nov. 2015

Crew Dragon Pad Abort Test Launch, May 6, 2015

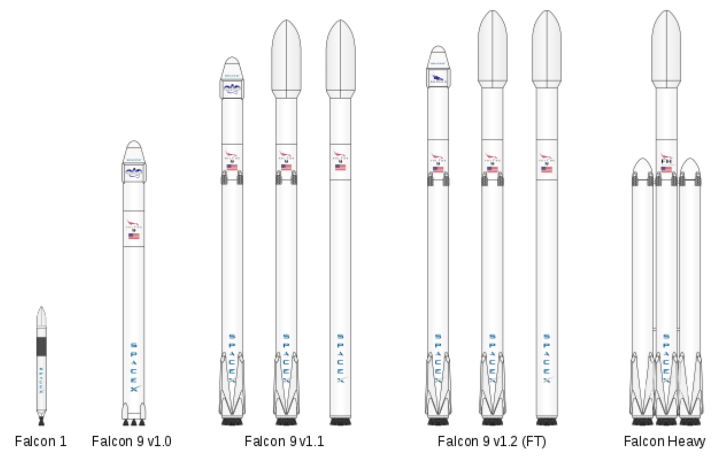


An infographic of the SpaceX Dragon 2 Pad Abort Test for the May 2015 test, produced by SpaceX

SpaceX Falcon 9

The **Falcon rocket family** is an American family of multi-use rocket launch vehicles developed and operated by Space Exploration Technologies (SpaceX). The vehicles in this family include the flight-tested Falcon 1 and Falcon 9. The Falcon 1 made its first successful flight on 28 September 2008, after several failures on the initial attempts. The larger Evolved Expendable Launch Vehicle (EELV)-class Falcon 9 flew successfully into orbit on its maiden launch on 4 June 2010. The Falcon 9 is eventually intended to be a reusable vehicle. SpaceX is currently in production of the first Falcon Heavy launch system. Other designs for boosters with even larger payload lifting capabilities are currently being researched, but not yet confirmed.

SpaceX Falcon



Conceptual rendering of Falcon Heavy at Pad 39A, Cape Canaveral

Falcon 9 first stage on an ASDS barge after the first successful landing at sea, CRS-8 Mission. April 2016

Boeing CST-100 Starliner

General information	
Manufacturer	Boeing
Country of origin	United States
Applications	Crew Transfer Vehicle
Orbit regimes	Low Earth
Operator	Boeing Bigelow Aerospace
Lifetime	210 days (docked to ISS)[1]
Production	
Status	In development
Typical spacecraft	
Average mass	≈10 tonnes[1]
Power	4 x 26300 Kg[1][clarification needed]
Dimensions	
	4.56 m CM+SM: 5.03 m CM: 3.14 m[1]

NASA Commercial Crew: Dream Chaser by Sierra Nevada

Size Comparison to Space Shuttle

Description		
Role:	Part of NASA's Commercial Crew Program to supply crew and cargo to the International Space Station	
Crew:	Up to 7[1][2]	
Dimensions[3]		
Length:	9.0 m	29.5 ft.
Wing Span:	7.0 m	22.9 ft.
Volume:	16.0 m^3	565 cu ft.
Mass:	11,300 kg	25,000 lb.[4]
Performance		
Endurance:	At least 210 days[5]	
Re-entry:	Less than 1.5	

SIERRA NEVADA CORPORATION
Space Systems

Contains information that is publically available on the internet

Bigelow Expandable Activity Module

Full-scale mock-up of BEAM, January 16, 2013

Station statistics

Launch date:	2015
Launch vehicle:	Falcon 9
Mass:	3,000 lb (1,360 kg)[1]
Length:	13 ft. (4 m)[1]
Diameter:	10.5 ft. (3.2 m)[1]
Living volume:	565 cu ft (16 m^3)[2]

Blue Origin


Incremental Development
BLUE ORIGIN
• Suborbital program in flight testing stage
– Goddard subscale demonstrator flown 2006-2007
– New Shepard system in development
• Propulsion Module
– 2011 testing demonstrated boost, landing and flight to 45,000 feet/Mach 1.2
– Development of next vehicle underway
• Crew Capsule – successful pad escape test October 2012
• Orbital Transportation System
– Reusable orbital Space Vehicle (SV)
• Transport to LEO or ISS for up to seven people
• ~22,000 lbm with crew at launch
– Two-stage Orbital Launch Vehicle (OLV)
• Expendable upper stage
• Reusable first stage
2006
2011
2012
Crew Capsule
Propulsion Module
Suborbital New Shepard System
Space Vehicle
Expendable Upper Stage
Reusable First Stage
Orbital Transportation System
Commercial Crew Program
14

Blue Origin

New Shepard Launch on April 29, 2015.

New Shepard landing with parachutes on April 29, 2015.