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NASA -

[Engineering Design Process](#)

[NASA Educator Guide to the Engineering Design Process](#)

Resources at the Library of Congress can be used alone or in conjunction with NASA images to promote STEM and space education. Materials can be used as a form of research and inspiration for design challenges. The resources also help students connect to the past of space exploration and the people who made it possible. Students can examine the evolution of space exploration by analyzing past and present documentation. They can then take the next step in imagining the future.

ALAN LOMAX

GER (NASA)

American Folklife Center, Library of Congress  
Alan Lomax Collection (AFC 2004/004)  
folder 17.02.04  
professional activities  
project folders, 1958-1987  
Voyager (NASA)

**Reference Link:** <http://www.loc.gov/item/afc2004004.ms170204/>

Contributor Names: Lomax, Alan, 1915-2002 (Collector)

Created / Published: 1977-1992

Subject Headings: - United States

- correspondence
- notes
- project files
- press releases
- research (document genres)
- professional papers

Genre: correspondence

notes

project files

press releases

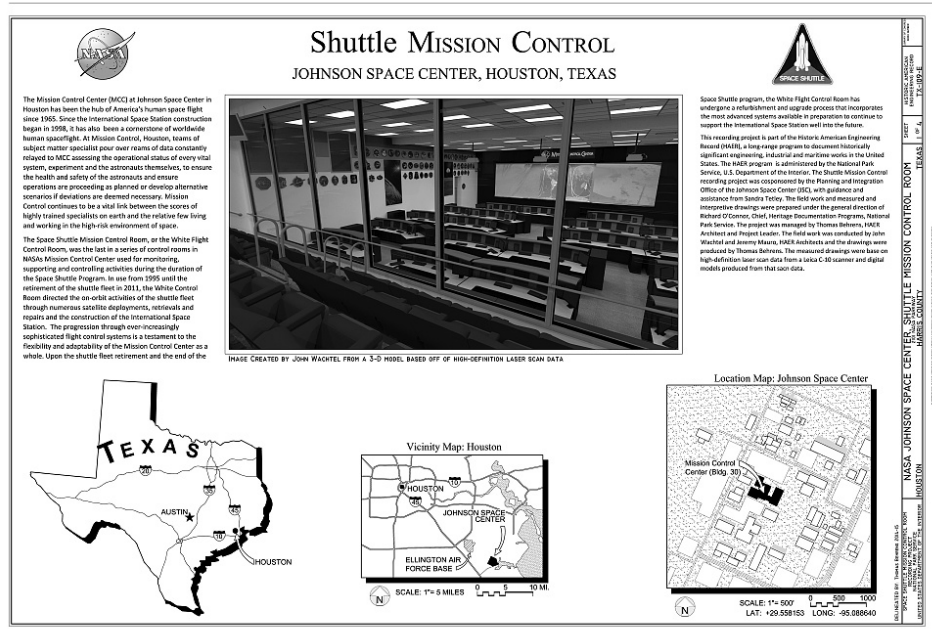
research (document genres)

professional papers

Notes: - 1977-1992; Carl Sagan; Warner New Media, Blake Lewin; Random House

Repository: American Folklife Center

## NASA JOHNSON SPACE CENTER, SHUTTLE MISSION CONTROL ROOM, 2101 NASA DADEWAY, HOUSTON, HARRIS COUNTY, TX



**Reference Link:** <http://www.loc.gov/item/tx1182/>

Contributor Names: Historic American Engineering Record, creator  
Behrens, Thomas, project manager

Wachtel, John, delineator

Mauro, Jeremy T, field team

Behrens, Thomas, delineator

NASA - Photo Operations Group - JSC, photographer

Johnson Space Center, Planning and Integration Office, sponsor

Created / Published: Documentation compiled after 1968

Subject Headings: - national space program

- space flight

- man in space

- control rooms

- Shuttle Program

- Texas -- Harris County -- Houston

Notes: - Significance: The Mission Control Center (MCC) at Johnson Space Center in Houston has been the hub of America's human space flight since 1965. Since the International Space Station construction began in 1998, it has also been a cornerstone of worldwide human spaceflight. At Mission Control, Houston, teams of subject matter specialists pour over reams of data constantly relayed to MCC assessing the operational status of every vital system, experiment, and the astronauts themselves, to ensure the health and safety of the astronauts and ensure operations are proceeding as planned or develop alternative scenarios if deviations are deemed necessary. Mission Control continues to be a vital link between the scores of highly trained specialists on earth and the relative few living and working in the high-risk environment of space. The Space Shuttle Mission Control Room, or the White Flight Control Room, was the last in a series of control rooms in



NASA's Mission Control Center used for monitoring, supporting, and controlling activities during the duration of the Space Shuttle Program. In use from 1995 until the retirement of the shuttle fleet in 2011, the White Control Room directed the on-orbit activities of the shuttle fleet through numerous satellite deployments, retrievals and repairs, and the construction of the International Space Station. The progression through ever-increasingly sophisticated flight control systems is a testament to the flexibility and adaptability of the Mission Control Center as a whole. Upon the shuttle fleet retirement and the end of the Space Shuttle program, the White Flight Control Room has undergone a refurbishment and upgrade process that incorporates the most advanced systems available in preparation to continue to support the International Space Station well into the future.

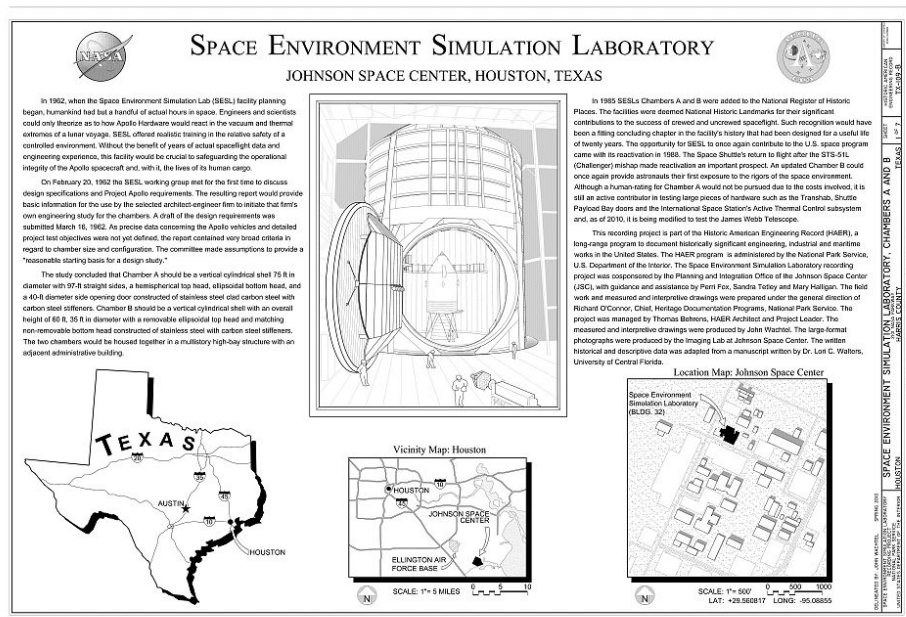
- Unprocessed Field note material exists for this structure: N1697

- Survey number: HAER TX-109-E

Repository: Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA

<http://hdl.loc.gov/loc.pnp/pp.print>

## NASA JOHNSON SPACE CENTER, BUILDING NO. 32, SPACE ENVIRONMENT SIMULATION LABORATORY CHAMBERS A & B 2101 NASA PARKWAY HOUSTON HARRIS COUNTY, TX



**Reference Link:** <http://www.loc.gov/item/tx1124/>

Contributor Names: Historic American Engineering Record, creator  
National Aeronautics and Space Center  
Bechtel Corporation  
Chicago and Bridge Iron  
Ets-Hokin and Galvan, Inc.  
Industrial, Fisher, and Diversified  
Paul Hardeman, Inc.  
Radio Corporation of America  
Brown & Root Construction Company  
Space Task Group  
Eisenhower, Dwight D  
Kennedy, John F  
Wilson, W K, Jr  
Gilruth, Robert  
Charles Luckman and Associates  
General Electric  
Army Corps of Engineers  
Rucker Company  
Bausch and Lomb  
McDonnell  
North American Aviation  
Rockwell International  
Johnson Space Center, sponsor



Behrens, Thomas, project manager

Created / Published: Documentation compiled after 1968

Subject Headings: - man in space

- national space program
- space exploration
- laboratories
- simulators
- Texas -- Harris County -- Houston

Notes: - Significance: Chambers A and B of the Space Environment Simulation Laboratory were critical to the success of Project Apollo and to the manned spacecraft program. Chamber A could achieve conditions similar to those at 87 miles above the earth's surface and was used in testing of the Apollo vehicle. When completed, it was the largest man-rated vacuum chamber built. Chamber B was used for testing the Apollo command module, as well as providing a simulated space environment for training astronauts.

- Survey number: HAER TX-109-B
- Building/structure dates: 1963-1964 Initial Construction
- Building/structure dates: 1965 Subsequent Work
- Building/structure dates: 1966 Subsequent Work
- Building/structure dates: 2008 Subsequent Work

Repository: Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA

<http://hdl.loc.gov/loc.pnp/pp.print>



**ROCKET ENGINE TESTING FACILITY. NASA GLENN RESEARCH CENTER. CLEVELAND,**



**Reference Link:** <http://www.loc.gov/item/oh1920/>

Contributor Names: Historic American Engineering Record, creator

National Aeronautics & Space Administration (NASA)

H. K. Ferguson Company

Cleveland Municipal Airport

National Advisory Committee on Aeronautics

Kumar, Rebecca, transmitter

Bates, Jeff, photographer

NASA Information Technology Center (ITC), photographer

Stewart, Robert C, historian

Dawson, Virginia P, historian

Hampton, Roy A, historian

Created / Published: Documentation compiled after 1968

Notes: - Significance: NASA began construction of the Rocket Engine Test Facility (RETF) in 1955 on land that was formerly part of the Cleveland Municipal Airport. In 1940, the National Advisory Committee on Aeronautics selected 200 acres of the airport site for the construction of an Aircraft Engine Research Laboratory. The site of this original lab and the RETF is the present NASA John H. Glenn Research Center at Lewis Field. The construction of RETF was related to post-war missile development, which required the construction of facilities dedicated to the research and testing of rocket engines and auxiliary equipment...

Source number: HAEF OH 124



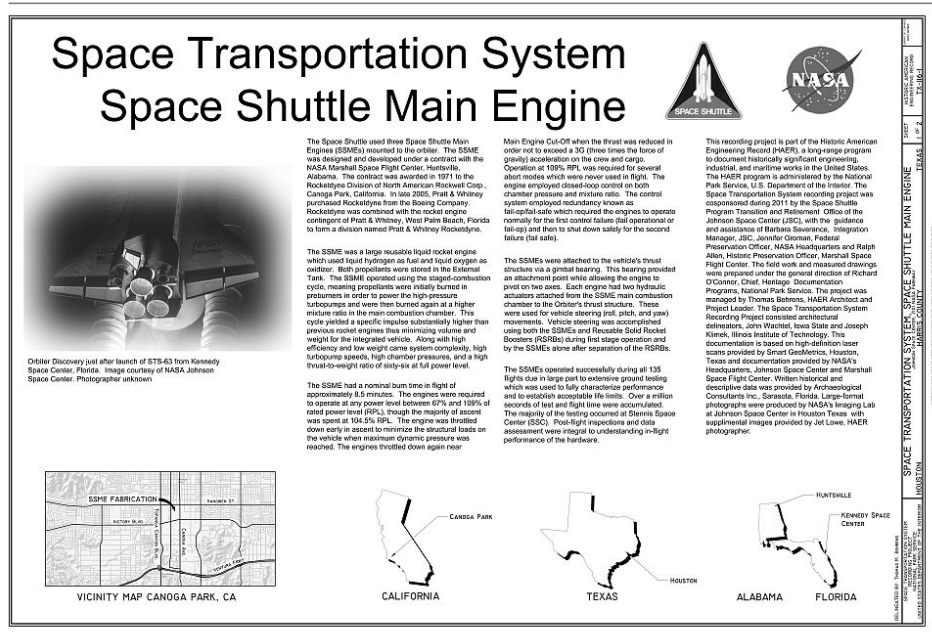
- Building/structure dates: 1955-1957 Initial Construction
- Building/structure dates: 1995 Subsequent Work
- Building/structure dates: 2003 Demolished

Repository: Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA

<http://hdl.loc.gov/loc.pnp/pp.print>



**SPACE TRANSPORTATION SYSTEM, SPACE SHUTTLE MAIN ENGINE, LYNDON B. JOHNSON SPACE CENTER, 2101 NASA PARKWAY, HOUSTON, HARRIS COUNTY, TX**



**Reference Link:** <http://www.loc.gov/item/tx1115/>

**Contributor Names:** Historic American Engineering Record, creator  
National Aeronautics and Space Administration, Owner  
Groman, Jennifer, Historic Preservation Officer  
Severance, Barbara

Allen, Ralph, Historic Preservation Officer

Smart GeoMetrics, contractor

**Created / Published:** Documentation compiled after 1968

**Subject Headings:** - Shuttle Program

- national space program
- space exploration
- space flight
- man in space
- rocket engines
- liquid propellant
- Texas -- Harris County -- Houston

**Notes:** - **Significance:** The Space Shuttle used three Space Shuttle Main Engines (SSMEs) mounted to the orbiter. The SSME was designed and developed under a contract with the NASA Marshall Space Flight Center, Huntsville, Alabama. The contract was awarded in 1971 to the Rocketdyne Division of North American Rockwell Corp., Canoga Park, California. In late 2005, Pratt & Whitney purchased Rocketdyne from the Boeing Company. Rocketdyne was combined with the rocket engine contingent of Pratt & Whitney, West Palm Beach, Florida to form a division named Pratt & Whitney Rocketdyne. The SSME was a large reusable liquid rocket engine which used liquid hydrogen as fuel and liquid oxygen as oxidizer. Both propellants were stored in the External Tank. The SSME operated using the staged combustion cycle.


meaning propellants were initially burned in preburners in order to power the high-pressure turbopumps and were then burned again at a higher mixture ratio in the main combustion chamber. This cycle yielded a specific impulse substantially higher than previous rocket engines thus minimizing volume and weight for the integrated vehicle. Along with high efficiency and low weight came system complexity, high turbopump speeds, high chamber pressures, and a high thrust-to-weight ratio of sixty-six at full power level. ...

- Survey number: HAER TX-116-I

Repository: Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA

<http://hdl.loc.gov/loc.pnp/pp.print>

## SPACE TRANSPORTATION SYSTEM, LYNDON B. JOHNSON SPACE CENTER, 2101 NASA DAVEWAY, HOUSTON, HARRIS COUNTY, TX



**Space Transportation System Stack Assembly**

Development of the Space Shuttle began in 1969 and a contract for the construction of the Space Shuttle was awarded in July 1972. The Space Shuttle launch configuration, or Stack Assembly, was composed of four main components, the Orbiter Vehicle (OV), built by North American Rockwell (later Boeing), three Space Shuttle Main Engines (SSMEs), built by Rocketdyne (later Boeing), two Solid Rocket Boosters (SRBs) built by Thiokol (later ATK Launch Systems) and an External Tank (ET) built by Martin Marietta (later Lockheed Martin). Of these four components only the external tank was not reusable.

During prelaunch preparations in the Vehicle Assembly Building (VAB), the SRBs were attached to the Mobile Launcher Platform (MLP) or their air skirts with four frangible nuts that were severed by explosive charges at liftoff. The ET was then attached to the SRBs at the booster air attachment rings and at a point near the SRBs forward skirt. The Orbiter was then mated to the SRB-ET assembly at the ET via attach points near the propellant and electrical umbilical connections on the Orbiter's aft fuselage and an attach point behind its nose landing gear door on the forward fuselage. As a result, the SRBs carried the entire weight of the stack and transferred it through their structure to the MLP.

A complete Stack Assembly measured 184.2 feet from the base of the SRB's air skirt to the nose of the ET. The depth of the assembly, from the exterior edge of the ET to the tip of the Orbiter's vertical stabilizer, was 76.5 feet and the width of the assembly was 78.05 feet from wing tip to wing tip of the Orbiter.

When the prelaunch activities at the Vehicle Assembly Building were complete, a Carrier Transporter was used to lift the MLP, with the Stack Assembly attached, and carry it out to launch complex 39 A or B for further launch preparations.

Orbiter Discovery just after launch of STS-66 from Kennedy Space Center, Florida. Image courtesy of NASA Johnson Space Center. Photographer unknown

At launch, the two SRBs provided the majority of the thrust required for liftoff. With a combined thrust of 6,000,000 pounds of force, the SRBs contributed approximately 72% of the power through the first launch stage, which ended at SRB separation, about 2 minutes after launch. After separation and at a predetermined altitude parachutes were deployed to slow the boosters' descent for safe splashdowns in the ocean about 141 nautical miles downrange, where they were retrieved, refurbished and reused for subsequent launches.

The orbiter's Main Propulsion System consisted of the External Tank, propellant delivery and control systems and three SSMEs which produced a combined thrust of 1,181,400 pounds of force at sea level. The liquid hydrogen fuel and liquid oxygen oxidizer were stored in the ET and supplied the SSMEs with propellant from approximately 6 seconds before liftoff until Main Engine Cut Off (MECO) and jettisoned, approximately 8 minutes, and 30 seconds after launch. Under the influence of gravity, the ET would fall towards Earth, eventually disintegrating as it reentered Earth's atmosphere.

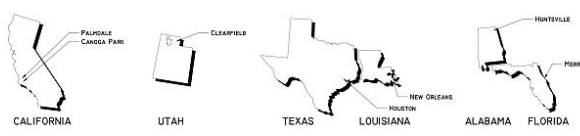
After MECO and ET jettison the SSMEs were no longer used. The shuttle relied on the Orbital Maneuvering System (OMS) and the Reaction Control System (RCS) during the orbital phase for velocity changes. The OMS was located in two pods on the aft section of the Orbiter at the base of the vertical stabilizer. The pods also contained the all RCS. The forward RCS was located just past the nose of the Orbiter. The RCS was used for small velocity and orientation adjustments and the two OMS engines were used for large velocity changes.

The Shuttle was designed to transport payloads into low Earth orbit, between 100 and 300 nautical miles, and have nominal mission durations of 4 to 16 days in space. The Orbiter provided accommodation to up to seven astronauts, four seated on the flight deck during the launch while another three were seated in the mid-deck area, although eight astronauts flew on STS-64. After orbital insertion the flight deck, mid deck, additional hardware and software were configured for on-orbit activities.


At the conclusion of orbital operations the payload bay doors were closed, the Orbiter was turned to a tail-first attitude, the OMS engines were fired to reduce the Orbiter's velocity and permit descent, then it was turned back to a nose-first attitude for reentry. During reentry the all RCS was used to control the roll, pitch and yaw until the atmospheric density was sufficient for the air surfaces to become effective. The Orbiter would perform a series of banking maneuvers, using atmospheric drag, to decrease its velocity. Combined with the descent angle and continued drag these maneuvers reduced the velocity to about 230 mph at main landing gear touchdown.

Spacecraft recovery operations began as soon as the Orbiter stepped rolling. Ground support personnel, wearing protective gear, approached the vehicle with sensors to determine if the area around the Orbiter was safe. After determining the area safe for operations, ground support equipment was attached to the orbiter to begin purging systems, dissipating reentry heat and preparing for crew egress. After crew egress the spacecraft was powered down and transported to the Orbiter Processing Facility. If the shuttle landed at sites other than Kennedy Space Center (KSC) the spacecraft was carefully inspected and prepared for mating to the Shuttle Carrier Aircraft and ferried back to KSC for further processing and prelaunch preparations for its next scheduled mission.


This recording project is part of the Historic American Engineering Record (HAER), a long-term program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. The Space Transportation System recording project was cosponsored during 2011 by the Space Shuttle Program Transition and Reinvestment Office of the Johnson Space Center (JSC), with the guidance and assistance of Barbara Severance, Integration Manager, JSC, Jennifer Gorman, Federal Preservation Officer, NASA Headquarters and Rayn Allen, Historic Preservation Officer, Marshall Space Flight Center. The field work and measured drawings were prepared under the general direction of Richard O'Connor, Chief, Heritage Documentation Programs, National Park Service. The project was managed by Thomas Behrens, HAER Architect and Project Leader. The Space Transportation System Recording Project consisted architectural delineators, John Wachtel, Iowa State and Joseph Orme, Brooks Institute of Technology. This documentation is based on high-definition laser scans provided by Smart GeoMetrics, Houston, Texas and documentation provided by NASA's Headquarters, Johnson Space Center and Marshall Space Flight Center. Written historical and descriptive data was provided by Archaeological Consultants Inc., Sarasota, Florida. Large-format photographs were produced by NASA's Imaging Lab at Johnson Space Center with supplemental images provided by Jet Lowe, HAER photographer.




CALIFORNIA




UTAH




TEXAS



LOUISIANA



ALABAMA



FLORIDA

**Reference Link:** <http://www.loc.gov/item/tx1106/>

Contributor Names: Historic American Engineering Record, creator  
National Aeronautics and Space Administration, Owner  
Smithsonian Institution, Owner  
Deming, Joan, historian  
Slovinac, Patricia, historian  
Archaeological Consultants, Inc., contractor  
Wolfe, Jeffrey, field team  
Nehr, Adam, field team  
Farrar, Tom, field team  
Behrens, Thomas M, project manager  
Wachtel, John, delineator  
Klimek, Joseph, delineator  
Pierce, Ryan, delineator  
Smart GeoMetrics, field team  
Lowe, Jet, photographer

Created / Published: Documentation compiled after 1968

Subject Headings: - national space program

- space exploration
- space flight
- man in space
- Shuttle Program
- rocket propulsion
- fuel tanks



- Texas -- Harris County -- Houston

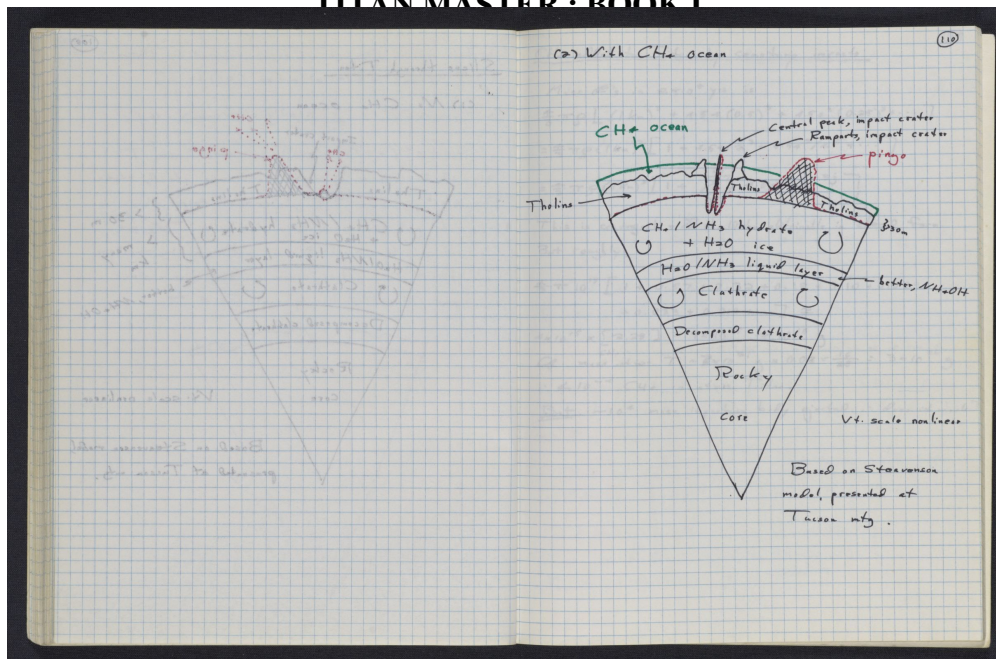
Notes: - Significance: The Orbiter Discovery, OV-103, is considered eligible for listing in the National Register of Historic Places (NRHP) in the context of the U.S. Space Shuttle Program (1969-2011) under Criterion A in the areas of Space Exploration and Transportation and under Criterion C in the area of Engineering. Because it has achieved significance within the past fifty years, Criteria Consideration G applies. Under Criterion A, Discovery is significant as the oldest of the three extant orbiter vehicles constructed for the Space Shuttle Program (SSP), the longest running American space program to date; she was the third of five orbiters built by NASA. Unlike the Mercury, Gemini, and Apollo programs, the SSP's emphasis was on cost effectiveness and reusability, and eventually the construction of a space station. Including her maiden voyage (launched August 30, 1984), Discovery flew to space thirty-nine times, more than any of the other four orbiters; she was also the first orbiter to fly twenty missions. She had the honor of being chosen as the Return to Flight vehicle after both the Challenger and Columbia accidents. Discovery was the first shuttle to fly with the redesigned SRBs, a result of the Challenger accident, and the first shuttle to fly with the Phase II and Block I SSME. Discovery also carried the Hubble Space Telescope to orbit and performed two of the five servicing missions to the observatory. She flew the first and last dedicated Department of Defense (DoD) missions, as well as the first unclassified defense-related mission. In addition, Discovery was vital to the construction of the International Space Station (ISS); she flew thirteen of the thirty-seven total missions flown to the station by a U.S. Space Shuttle. She was the first orbiter to dock to the ISS, and the first to perform an exchange of a resident crew. Under Criterion C, Discovery is significant as a feat of engineering. According to Wayne Hale, a flight director from Johnson Space Center, the Space Shuttle orbiter represents a "huge technological leap from expendable rockets and capsules to a reusable, winged, hypersonic, cargo-carrying spacecraft." Although her base structure followed a conventional aircraft design, she used advanced materials that both minimized her weight for cargo-carrying purposes and featured low thermal expansion ratios, which provided a stable base for her Thermal Protection System (TPS) materials. The Space Shuttle orbiter also featured the first reusable TPS; all previous spaceflight vehicles had a single-use, ablative heat shield. Other notable engineering achievements of the orbiter included the first reusable orbital propulsion system, and the first two-fault-tolerant Integrated Avionics System. As Hale stated, the Space Shuttle remains "the largest, fastest, winged hypersonic aircraft in history," having regularly flown at twenty-five times the speed of sound.

- Survey number: HAER TX-116

Repository: Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA

<http://hdl.loc.gov/loc.pnp/pp.print>

**TITAN MASTER • BOOK I**



**Reference Link:** <http://www.loc.gov/resource/mss85590.032/?sp=57&r=-0.121,0.07,1.056,0.455,0>

Contributor Names: Sagan, Carl (Author)

Created / Published: 1981

Subject Headings: - Astronomy

- Sagan, Carl
- Saturn (Planet)
- Outer space--Exploration
- Titan (Satellite)
- Atmosphere
- Clouds
- Organics
- Manuscripts

Genre: Manuscripts

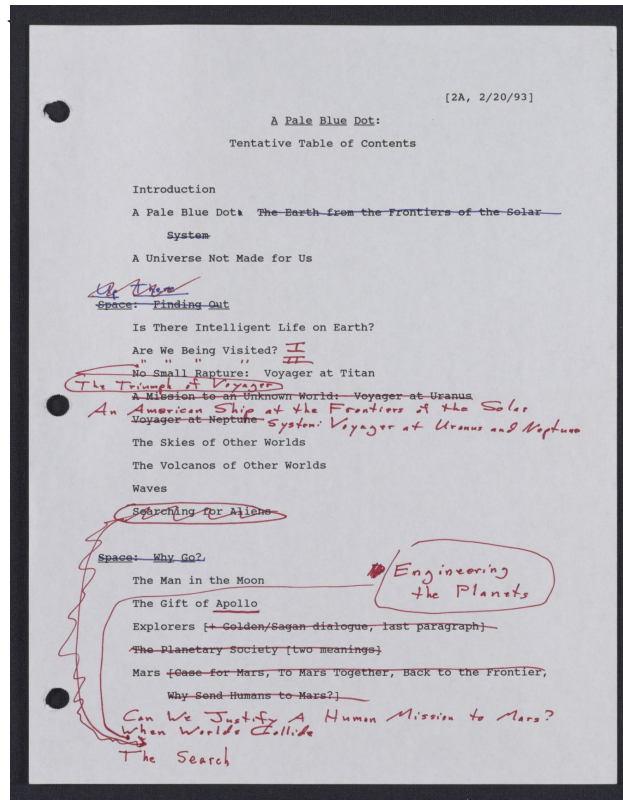
Notes: - A set of notes on Titan, Saturn's largest moon. The notes include discussion of the Titan's clouds, tides, and the possibilities of floating organics on Titan.

Repository: Manuscript Division



PALE BLUE DOT : A

CE : SECOND DRAFT



Reference Link: <http://www.loc.gov/resource/mss85590.042/?sp=3>

Contributor Names: Sagan, Carl (Author)

Subject Headings: - Sagan, Carl

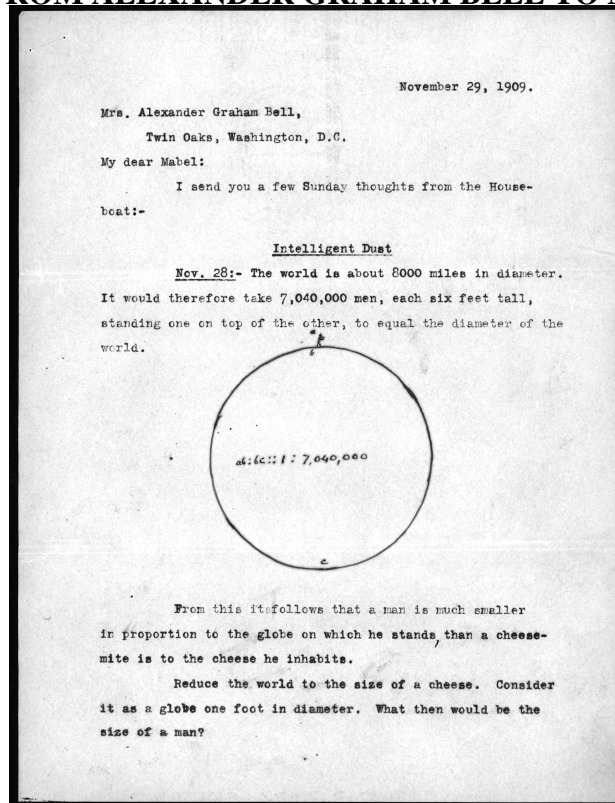
- Outer space--Exploration
- Planets
- Space colonies
- Astronautics--Human factors
- Asteroids
- Manuscripts

Genre: Manuscripts

Notes: - The second of twenty full drafts of Pale blue dot : a vision of the human future in space, published in 1994. Sagan discusses the history of astronomy and considers the future of humanity in space, arguing that it is necessary for humanity's survival to explore and ultimately terraform and create human settlements on planets and asteroids. The draft is made up of interleaved notes. These notes were transcribed from audio recordings dictated by Carl Sagan. The resulting assembled document was then extensively marked up and revised by Sagan. In cases where Sagan wrote notes on the back of printed pages those pages were digitized.

Repository: Manuscript Division

**IMAGE 1 OF LETTER FROM ALEXANDER GRAHAM BELL TO MABEL HUBBARD BELL,**



**Reference Link:** <http://www.loc.gov/resource/magbell.04300515/?sp=1>

Contributor Names: Bell, Alexander Graham

Bell, Mabel Hubbard

Created / Published: November 29, 1909

Subject Headings: - Astronomy

- Correspondence

Genre: Correspondence

Repository: Manuscript Division

Digital Id: <http://hdl.loc.gov/loc.mss/magbell.04300515>