National Park Service
U.S. Department of the Interior

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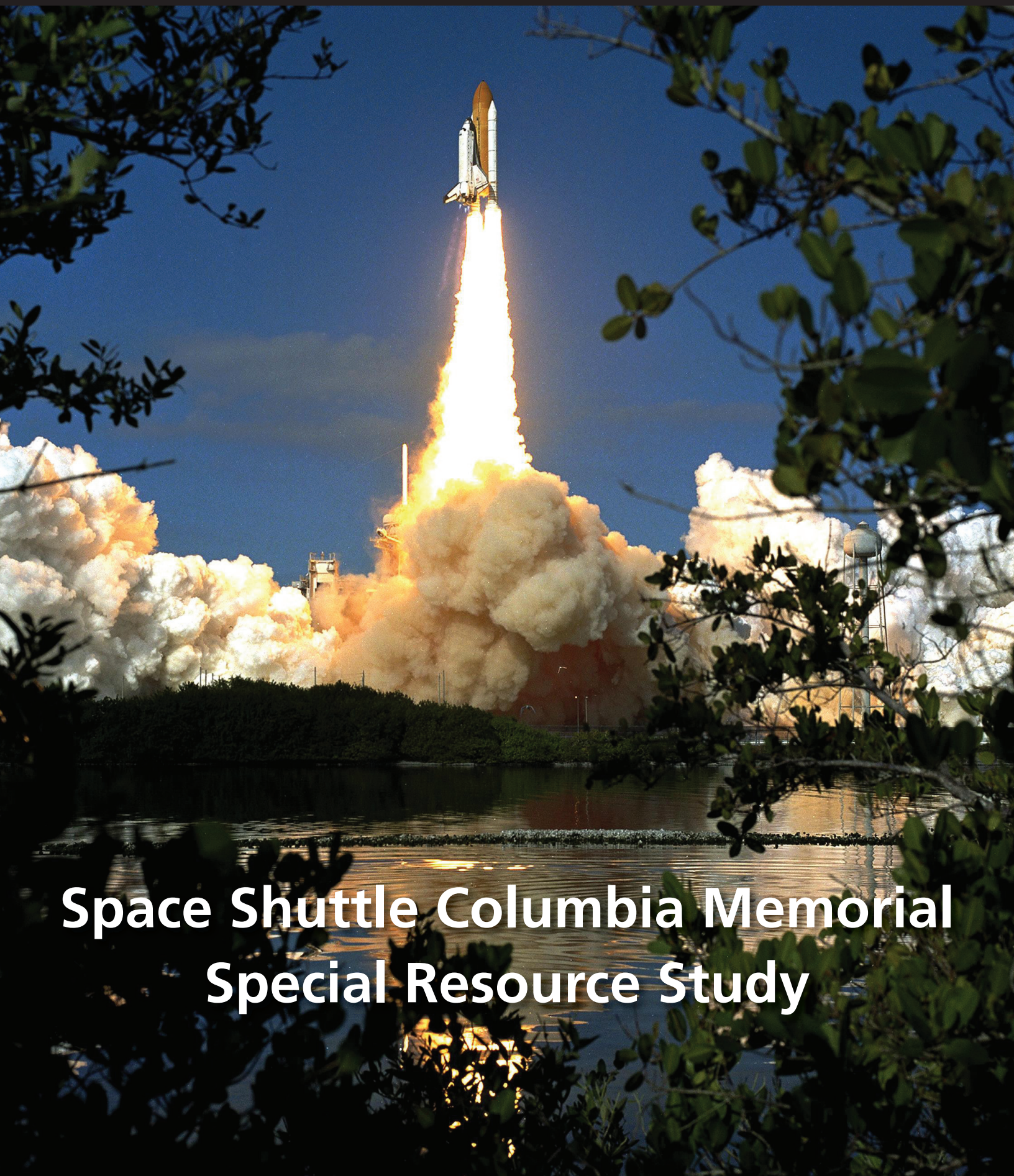


Space Shuttle Columbia Memorial Special Resource Study

Art panel tribute to space shuttle Columbia *and the crew of STS-107. (NASA/Amy Lombardo)*

Front Cover: *Kennedy Space Center, Florida – Framed by branches across from Launch Pad 39A, space shuttle* Columbia *leaps toward space on mission STS-107. (NASA photo)*

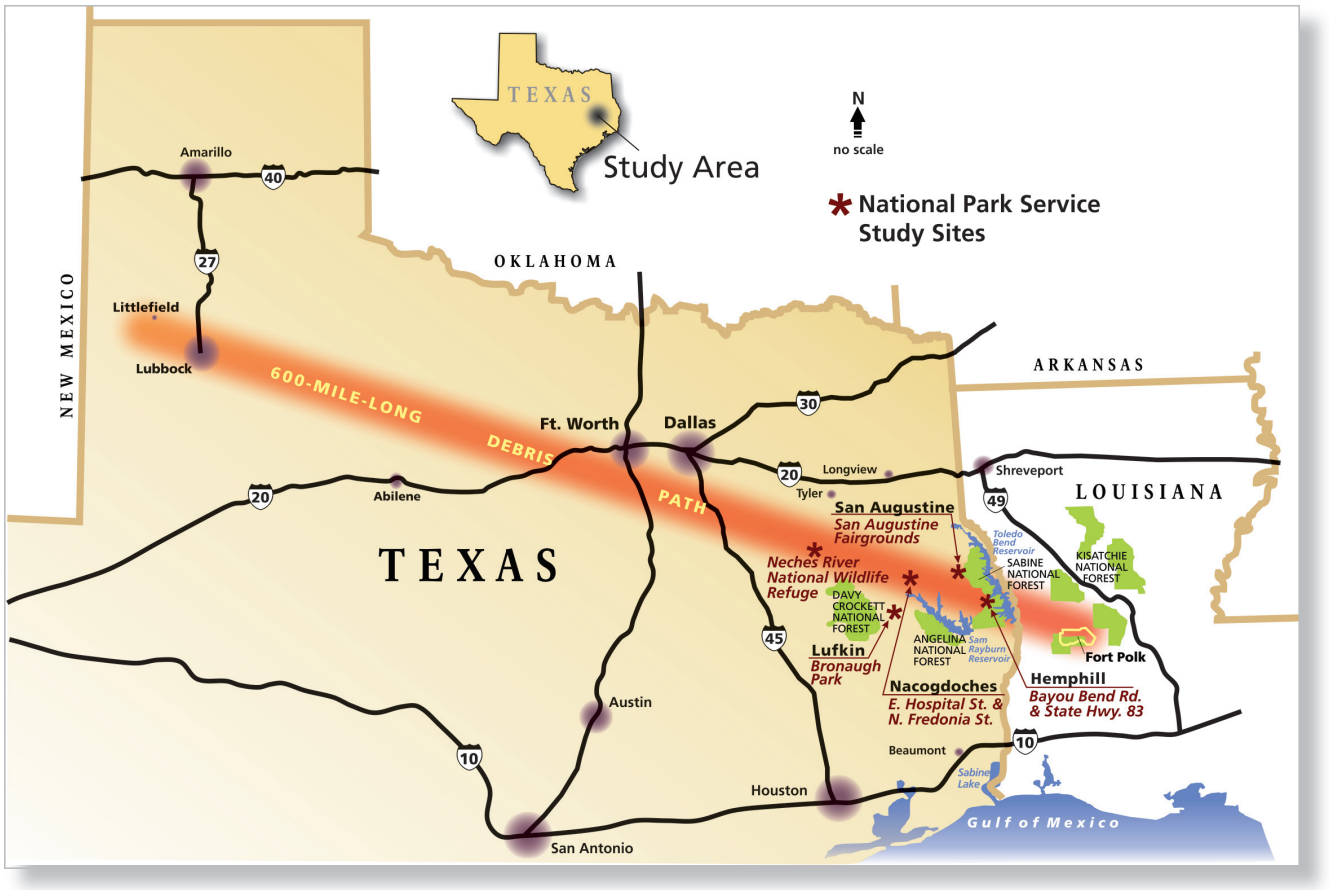
Executive Summary

Scope of Study

The Space Shuttle Columbia Memorial Special Resource Study (SRS) investigated a number of sites within East Texas, for possible designation as a new unit of the national park system.

Special resource studies are initiated at the direction of Congress. On May 8, 2008, President Bush signed Public Law 110-229, *The Consolidated Natural Resources Act of 2008*. Under this omnibus legislation, Section 324 directs the Secretary of the Interior to conduct a special resource study to determine the suitability and feasibility of establishing a memorial to the space shuttle *Columbia* on land in the state of Texas as a unit or units of the national park system. The legislation specifically identified four sites to study: Hemphill, Lufkin, Nacogdoches, and San Augustine, all of which are located in East Texas. In addition, the legislation includes a provision that the secretary may recommend additional sites in the state relating to the space shuttle *Columbia* for establishment as memorials. The legislation was crafted as a result of the *Columbia* disaster. The remains of all seven astronauts and the most significant parts of the shuttle were recovered in several communities across this East Texas region.

Space shuttle *Columbia* was the National Aeronautics and Space Administration's (NASA) first space transportation system orbiter to launch into space, return to Earth, and launch again. The last mission (STS–107) of NASA's first orbiter lifted off on January 16, 2003, for a 17-day science mission featuring numerous microgravity experiments. On the morning of February 1, 2003, *Columbia* began its return back to base at the John F. Kennedy Space Center. As re-entry into the Earth's atmosphere continued over the Pacific, problems were noticed by NASA, contact with the shuttle was lost, and the craft began to break apart. In the resulting disintegration, all of *Columbia*'s STS-107 crew perished: Rick D. Husband, mission commander; William C. McCool, pilot; David M. Brown, Laurel B. Clark, Kalpana Chawla and Michael P. Anderson, all mission specialists; and Ilan Ramon, payload specialist representing the Israeli Space Agency.



As soon as radar reports of falling shuttle debris started coming in, a massive recovery effort was mobilized. The effort resulted in the recovery of shuttle debris along a 600-mile-long corridor between Littlefield, Texas and Fort Polk, Louisiana.

In addition to hundreds of federal, state, and local agencies, the recovery effort included thousands of private citizen volunteers, many of whom call East Texas home. Over 25,000 people contributed more than 1.5 million hours to the recovery of almost 84,000 pieces of *Columbia* and the remains of the crew.

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Coincident to the recovery effort, the Columbia Accident Investigation Board was convened to identify the factors that led to the shuttle disaster and make recommendations for future actions. The accident investigation and the recovery effort provided much of the data required to reconstruct the reasons behind the *Columbia* disaster. Their report concluded that just after launch, a large piece of foam insulation from the external tank broke free and struck the leading edge of the shuttle's left wing, damaging the protective carbon heat-shielding panels. This damage allowed super-heated gases to enter and melt the aluminum wing structure during re-entry into the Earth's atmosphere and caused the destruction of the space shuttle. In addition to identifying the physical cause of the accident, the report also identified a number of concerns that eventually led President George W. Bush to call for the shuttle program's retirement in his January 2004 "Vision for Space Exploration" speech.

The final chapter of the U.S. Space Shuttle Program concluded with the last flight of space shuttle *Atlantis* in July 2011, the decommissioning of the fleet, and NASA's transfer of the retired orbiters and artifacts for permanent museum display during the spring and summer of 2012.

Special Resource Study Process

For a determination to be made as to whether a resource should be considered for potential designation as a unit of the national park system, an analysis is conducted based on criteria established by Congress under Public Law 105-39 and in accordance with NPS Management Policies 2006. To be eligible for favorable consideration as a new unit, an area must meet all four of the following criteria:

- possess nationally significant natural or cultural resources
- be a suitable addition to the system
- be a feasible addition to the system
- require direct NPS management instead of protection by others

National Significance Findings

The national significance of cultural resources is evaluated by applying the National Historic Landmark (NHL) criteria contained in 36 Code of Federal Regulations Part 65.4. There are two key factors for finding historic resources eligible for NHL designation: 1) the site must illustrate nationally significant stories, persons, or events; and 2) districts, sites, buildings, structures or objects must possess a high degree of integrity.

While it is especially challenging to be dispassionate and to achieve historical perspective about an event that occurred just over 11 years ago, resulted in the loss of human life, and continued to influence the course of the U.S. Space Program throughout much of this study effort, there are some very compelling initial conclusions that can be made.

NASA's space shuttle program, officially, the Space Transportation System (STS), marked a major shift in the U.S. Space Program. After the *Apollo* program, NASA transformed from a program focusing on space exploration to one emphasizing space utility. Between 1981 and 2011, the space shuttle program provided a new method of space flight, taking off like a rocket and landing like an airplane. *Columbia*, the first reusable manned spaceship, initiated the space shuttle flight program with its first successful launch and return in April 1981. The role of the space shuttle *Columbia* prior to the disaster was an integral part of the many successes NASA accomplished under this major shift in program priorities.

In contrast, the crash of the *Columbia* on February 1, 2003 and the subsequent findings of the Columbia Accident Investigation Board marked the beginning of the end of the shuttle program and a re-examination of human spaceflight.

The *Columbia* disaster is considered a nationally significant event; it is of exceptional importance to the nation because of the enduring value of the shuttle's historical association with the beginning and end of the U.S. Space Shuttle Program. Two study sites were found to have an important association with this nationally significant event. They also retain a high degree of integrity as their undeveloped landscape settings have remained relatively unchanged since the time of the disaster.

Suitability Findings

To be considered a suitable addition to the national park system, an area must represent a natural or cultural theme or type of recreational resource that is not already adequately represented in the national park system or is not comparably represented or protected for public enjoyment by another entity.

The national park system does not include a park specifically set aside to tell *Columbia*'s story, although the U.S. Space Program is commemorated in a limited way at the Dayton Aviation Heritage National Historical Park in Dayton, Ohio.

There are a number of existing memorials to *Columbia* and her STS-107 crew and they vary widely in size, cost and level of effort to create or maintain. Some include honorary naming, as is the case with NASA's Columbia Scientific Balloon Facility in Palestine, Texas as well as other public streets, buildings, parks, asteroids, satellites, and landscape features on Earth and on Mars. Others, like the Astronaut Memorial at the Kennedy Space Center Visitor Complex, which was formally recognized by Congress as the national memorial honoring astronauts who die in the line of duty or the Columbia memorial at Arlington National Cemetery are more extensive and serve annually as national destinations and tributes to *Columbia*'s fallen heroes.

The decommissioned shuttles *Atlantis*, *Discovery*, and *Endeavour*, the shuttle prototype *Enterprise*, and other shuttle artifacts coupled with the extensive museum facilities and educational programs that accompany them, provide the public with distinct and rich opportunities to reflect on the meaning of *Columbia*'s mission and tragic final flight. They also offer educational programs that can teach children and adults about the role the U.S. Space Program has played in the nation's history and development.

Of special note, the location of the recently opened Space Shuttle Atlantis exhibit and the national memorial honoring fallen astronauts at the Kennedy Space Center Visitor Complex are in a venue that also provides visitors with unparalleled opportunities for learning about and visiting some of the most significant artifacts, structures, and sites related to the U.S. Space Program. The Kennedy Space Center is also the repository of *Columbia*'s recovered shuttle debris.

In assessing a comparison of each study site with the vast array of other memorials at the federal, state, and local levels commemorating space shuttle *Columbia* and her STS-107 crew, it was found that the national perspective of this event is richly

Astronaut Memorial (Space Mirror Memorial) at Kennedy Space Center. (NASA photo)

represented by other institutions. Therefore, none of the study sites qualify as a suitable addition to the national park system. These sites appear better suited for local initiatives where each community would have the freedom to commemorate *Columbia* in their own way, as well as their unique role in responding to this nationally significant event.

Study Conclusion

The study team analyzed five sites to determine if they met the criteria for new national parklands as specified under Public Law 110-229, which authorized the special resource study. While the loss of space shuttle *Columbia* over East Texas is considered a nationally significant event of exceptional importance to the nation and a number of study sites have a direct association with this tragedy, none of the sites meet the suitability criteria for establishing a new unit of the national park system. A national memorial was previously designated by Congress to honor astronauts who die in the line of duty. The national perspective of this event is also richly represented by a vast array of other federal, state, and local museums and memorials commemorating *Columbia* and her STS-107 crew. As a result of the negative suitability findings, the study team did not evaluate the criteria for feasibility or the need for NPS management in detail. There was no basis for further consideration of new unit potential, the study process was concluded and no federal action is proposed.

Contents

Background

Previous page: *A quarter moon is visible in this oblique view of Earth's horizon and airglow, recorded with a digital still camera aboard the space shuttle* Columbia. *(NASA photo)*

Purpose and Need

The Space Shuttle Columbia Memorial Special Resource Study was authorized by Congress and signed into law on May 8, 2008 as Public Law 110-229, *The Consolidated Natural Resources Act of 2008* (see Appendix A). Under this omnibus legislation, Section 324 directs the Secretary of the Interior to conduct a special resource study to determine the suitability and feasibility of establishing a memorial to the space shuttle *Columbia* on land in the state of Texas as a unit or units of the national park system. The legislation identified four sites in East Texas to study: Hemphill, Lufkin, Nacogdoches, and San Augustine. In addition, the legislation includes a provision that the secretary may recommend additional sites in the state relating to the *Columbia* for establishment as memorials. The original bill introduced for this study was H.R. 807 sponsored by Congressman Louie Gohmert, Texas 1st Congressional District in response to the February 1, 2003 *Columbia* disaster. The remains of the seven astronauts and the most significant parts of the shuttle were recovered in several communities across this East Texas region.

The purpose of this study is to provide Congress with information about the quality and condition of the study sites outlined under Public Law 110-229, and their relationship to criteria for establishing new national parklands. New areas are typically added to the national park system by an act of Congress. However, before Congress decides to create a new park they need to know whether the area's resources meet established criteria to ensure only the most outstanding sites are considered for addition to the national park system. The National Park Service (NPS) is often tasked to evaluate potential new areas for compliance with this criteria and to document their findings in a special resource study.

Study Methodology

The methodology used in this study follows the requirements outlined under Public Law 105-391, *The National Park System New Areas Study Act of 1998* and NPS policy. Potential new units of the national park system must 1) possess nationally significant resources, 2) be a suitable addition to the system, 3) be a feasible addition to the system, and 4) require direct NPS management instead of protection by another governmental agency or by the private sector. The study sites must meet all four of these criteria to be recommended for inclusion in the national park system. The process begins with the NPS gathering information about the history, significance, and condition of each study site.

The study sites must meet all four of these criteria to be recommended for inclusion in the national park system.

The national significance of cultural resources is evaluated by applying the National Historic Landmark (NHL) criteria contained in 36 Code of Federal Regulations Part 65.4. There are two key factors for finding historic resources eligible for NHL designation: 1) the site must illustrate nationally significant stories, persons, or events; and 2) districts, sites, buildings, structures or objects must possess a high degree of integrity.

To be considered a suitable addition to the national park system, an area must represent a natural or cultural resource type that is not already adequately represented in the national park system or is not comparably represented and protected for public

enjoyment by other federal agencies; tribal, state, or local governments; or the private sector.

To be feasible as a new unit, an area's natural systems or historic settings must be of sufficient size and appropriate configuration to ensure long-term protection of the resources and to accommodate public use. It also must have potential for efficient administration at a reasonable cost. Important feasibility factors include landownership, acquisition costs, access, threats to the resource, and staff or development requirements.

Unless direct NPS management of a studied area is identified as the clearly superior alternative, the service will recommend that another entity assume a lead management role, and that the area not receive national park system status.

Overview of Study Sites

The study sites include the four sites specifically identified in the legislation authorizing this study as well as one additional site approximately 40 miles west of Nacogdoches. Most of the sites lie within the East Texas section of the 600-mile-long shuttle debris corridor. While shuttle debris was also recovered in Louisiana, the focus of this report, as outlined in the legislation authorizing this special resource study, was limited to only sites in Texas.

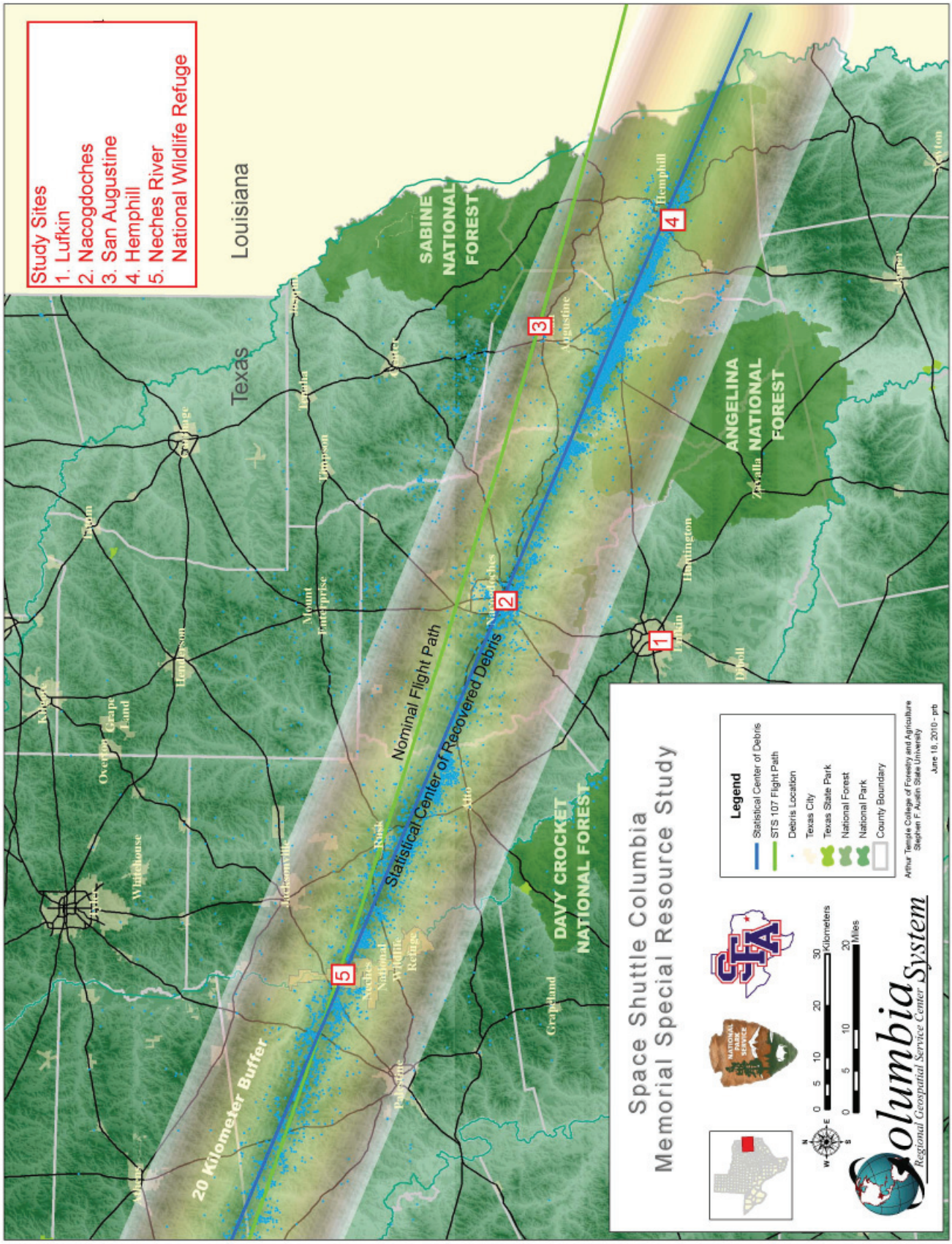
The map on page 3 was created by the Columbia Regional Geospatial Service Center and highlights the East Texas portion of the debris corridor. Every location where shuttle debris was discovered in the field was recorded using Global Positioning System (GPS) receivers.[1] Each position is represented on the map by a single blue dot. Note the heavy concentration of material recovered between Neches River National Wildlife Refuge and Hemphill, Texas. At the time of the *Columbia* disaster, the geospatial service center was in fact the combined forces of the Forest Resources Institute and Humanities Urban Environmental Sciences Laboratory located at Stephen F. Austin University in Nacogdoches, Texas.[2] They developed the primary search vector during the first few days of the search and recovery, which substantially aided the search activity. These geospatial first responders provided hundreds of maps and massive amounts of imagery to the various state and federal agencies involved in the *Columbia* recovery effort.

Lufkin Site

Background

The city of Lufkin (population 34,500), located at the crossroads of U.S. Highway 59 and 69, and State Highways 94 and 103, is the county seat of Angelina County. It is the first major city north of Houston, which is approximately 120 miles south. The city has been characterized as a gateway to the East Texas region.

Very little shuttle debris fell around Lufkin itself. However, the city transformed overnight into the Lufkin Disaster Field Office, the 'command hub' and main communications point in the region during the *Columbia* recovery effort. Aside from NASA and the FBI, 26 other federal, state, and local agencies set up their communication and command posts in the Lufkin Civic Center for eight days, and then these services were moved to the Bank of America building. Among other things, the city helped erect temporary communications towers and provided access to adequate power for the equipment necessary for the recovery effort. City officials and residents helped in providing meals and housing for more than 2,000 government workers and



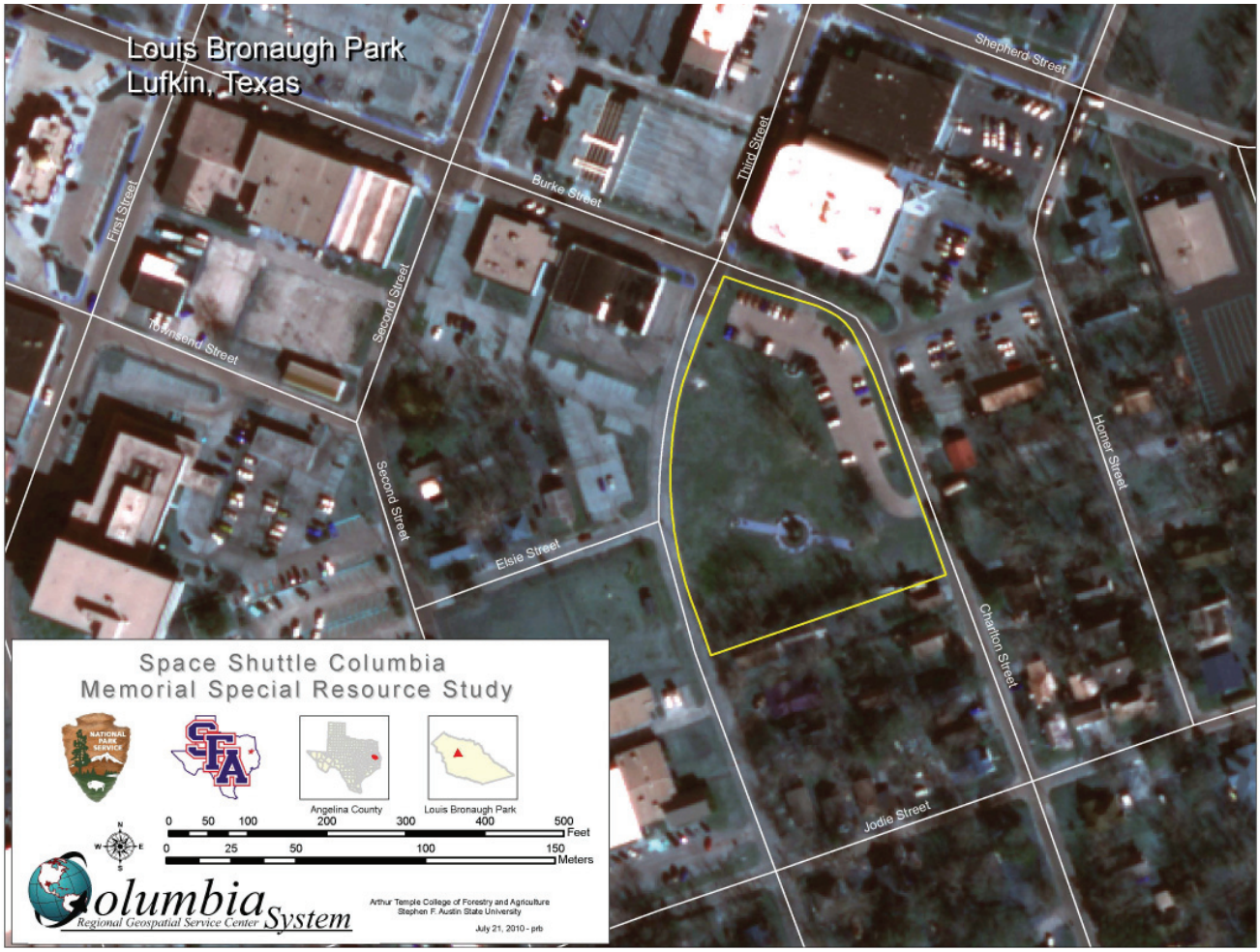
Map showing the statistical center of recovered Columbia shuttle debris in relation to the five study sites.

search volunteers. As the first major city north of Houston, it was not surprising that Lufkin took on this role, because it was already designated as a 'shelter hub' during major hurricanes. Local officials believed that they were well prepared to deal with the *Columbia* disaster because of these other experiences.[3]

Study Site

In the legislation authorizing this study, the Lufkin site is described as *"the parcel of land owned by the city of Lufkin, Texas, located at City Hall Park, 301 Charlton Street, Lufkin, Texas."* City Hall Park has since been renamed Louis Bronaugh Park. While the site of Louis Bronaugh Park did not play a role during the *Columbia* disaster or the recovery effort, it is location of the community's representative reflection of its overall association with this

Louis Bronaugh Park's circle of flags, with NASA Columbia commemorative plaque and STS-107 mission flag shown at right.



Aerial view of Lufkin's Louis Bronaugh Park outlined in yellow, just south of Lufkin's City Hall.

NASA Columbia commemorative plaque and STS-107 mission flag.

Columbia STS-107 exhibit in the Lufkin Civic Center.

nationally significant event. The city has incorporated a bronze plaque, provided by NASA commemorating *Columbia* and the STS-107 crew and thanking the city for their contributions in the *Columbia* recovery effort, onto a low profile red granite marker placed in the park. A circle of flagpoles, including one that flies the space shuttle *Columbia* STS-107 mission flag, ring an assemblage of memorials honoring persons and events important to the city of Lufkin.

Other Commemorative Efforts

A scale model of *Columbia* along with its mission flag signed by recovery workers is on display within the city hall complex. At the Lufkin Civic Center, a number of exhibits honoring the STS-107 crew and the city's role in the recovery effort are on display.

Nacogdoches Site

Background

The city of Nacogdoches (pop. 30,500), the oldest city in Texas, is the county seat of Nacogdoches County. Located at the crossroads of U.S. Highway 59 and State Highways 7 and 21, it is approximately 140 miles north of Houston, 130 miles southeast of Dallas and 90 miles southwest of Shreveport, Louisiana.

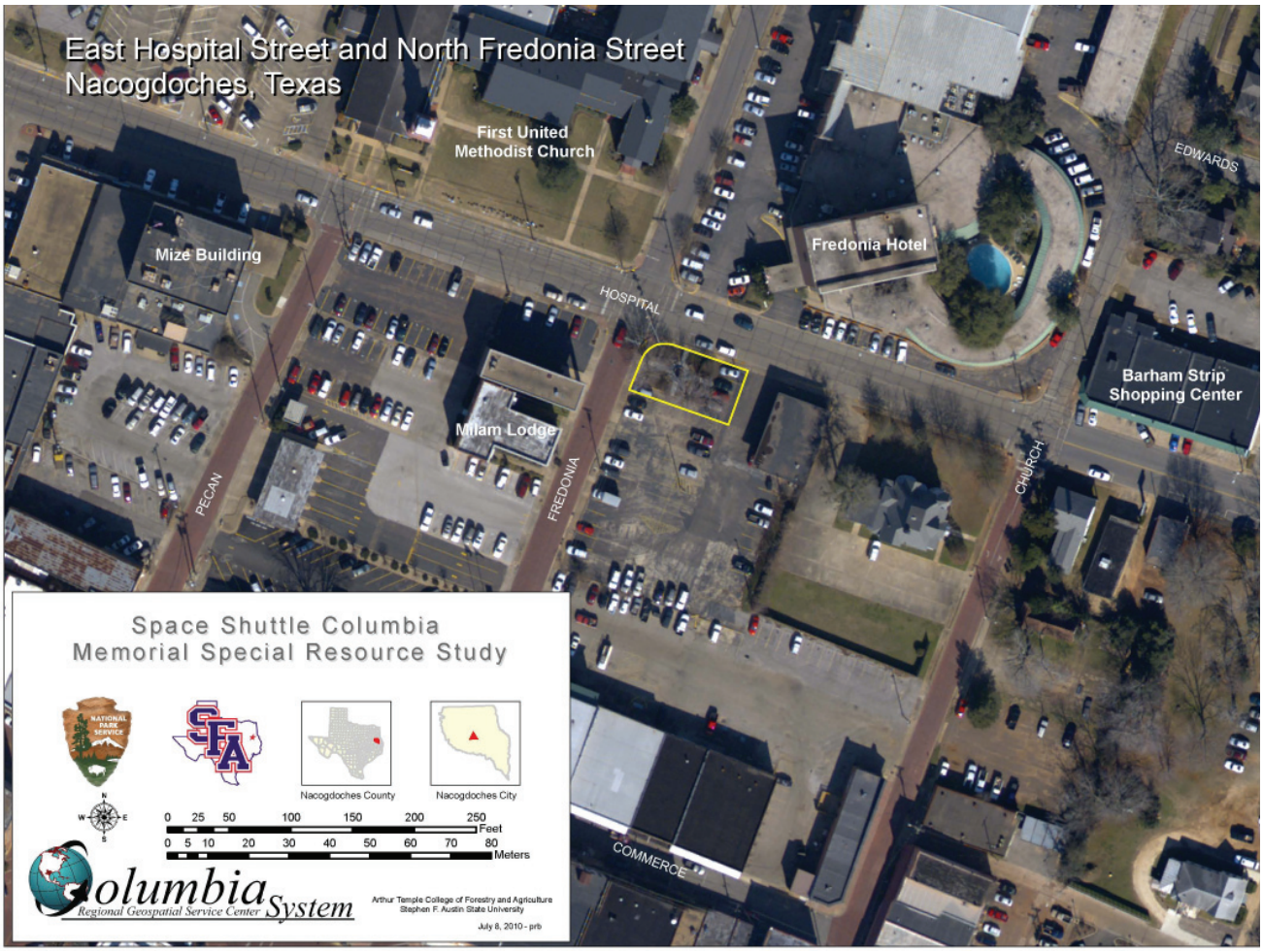
The city and county of Nacogdoches is found along the statistical centerline of the shuttle debris corridor. Early attention focused on Nacogdoches, the largest city in the debris corridor, because it was thought to be the first place where shuttle debris was found. The city became the physical center for the recovery efforts and main point of contact for the press. Community leaders and local citizens were joined by hundreds of officials and workers from across the United States who came to help with the search and recovery efforts.

Jason Grogan and Terry Corbett, Jr. of the Forest Resources Institute, SFASU, organize GPS mapping support for the recovery effort. (Hardy Meredith, SFASU photo)

In addition to the early geospatial mapping support provided by The Forest Resources Institute and Humanities Urban Environmental Sciences Laboratory at Stephen F. Austin University, the county provided mounted patrols, treetop searches, command briefings, and press briefings. The town provided lodging and food for 35 agencies and 600 responders and recovery workers. The community believes that their involvement in the recovery effort helped contribute to NASA's ability to reconstruct the event and determine the cause of the disaster.

Study Site

In the legislation authorizing this study, the Nacogdoches site is described as "*the parcel of land owned by the Fredonia Corporation, located at the southeast corner of the intersection of East Hospital Street and North Fredonia Street, Nacogdoches, Texas.*" The property has since changed hands and is now owned by SE Pack Hospitality. However, a provision in the deed allows for the transfer



Aerial view of the Nacogdoches study site outlined in yellow.

of the property to the city for the purposes of erecting the community's proposed Columbia memorial.

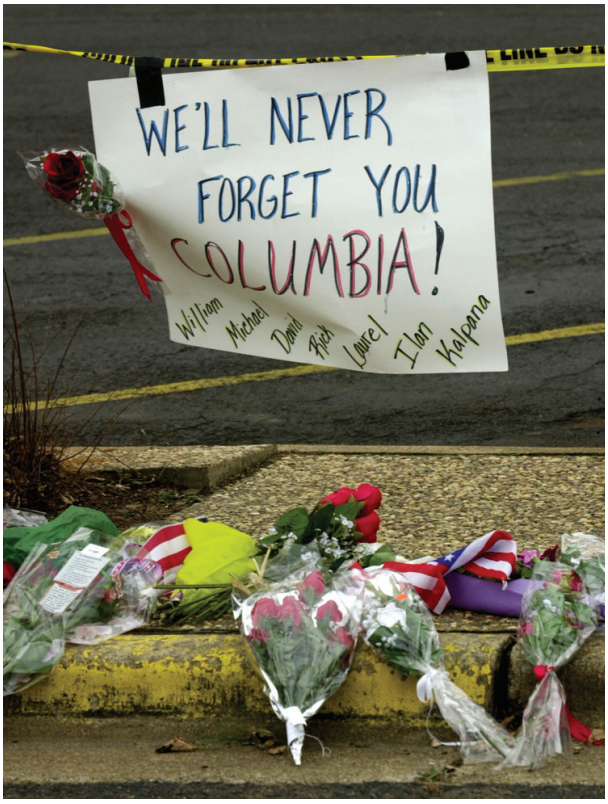
The site is located in downtown Nacogdoches and includes an approximately one-fifth-acre pocket park. The site is bordered by a parking area to the south, and a small, one-story structure to the east, both of which are owned by the SE Pack Hospitality group, the current owners of the Fredonia Hotel. The design firm KBAS from Alexandria, Virginia was selected by the city's Space Shuttle Columbia Memorial Fund board of directors to design a Columbia memorial for the site. KBAS designed the Pentagon Memorial honoring the people who lost their lives on September 11, 2001.[4] The memorial is intended to honor each of the seven astronauts, recognize those who assisted in the search and recovery, and celebrate the spirit of space exploration. Design concepts have been prepared, but construction of the memorial is pending available funding.

Study site looking east. (Google Images photo)

The study site is located in the landscaped area just north of the parking area.

Other Commemorative Efforts

The study site is across the street from where the first piece of shuttle debris was discovered in town. A six-inch bronze disc has been embedded into the pavement to mark the location.



Impromptu memorials sprang up all across the East Texas. This one in the parking lot of Commercial National Bank in downtown Nacogdoches, Texas was one of the first. (Hardy Meredith, SFASU photo)

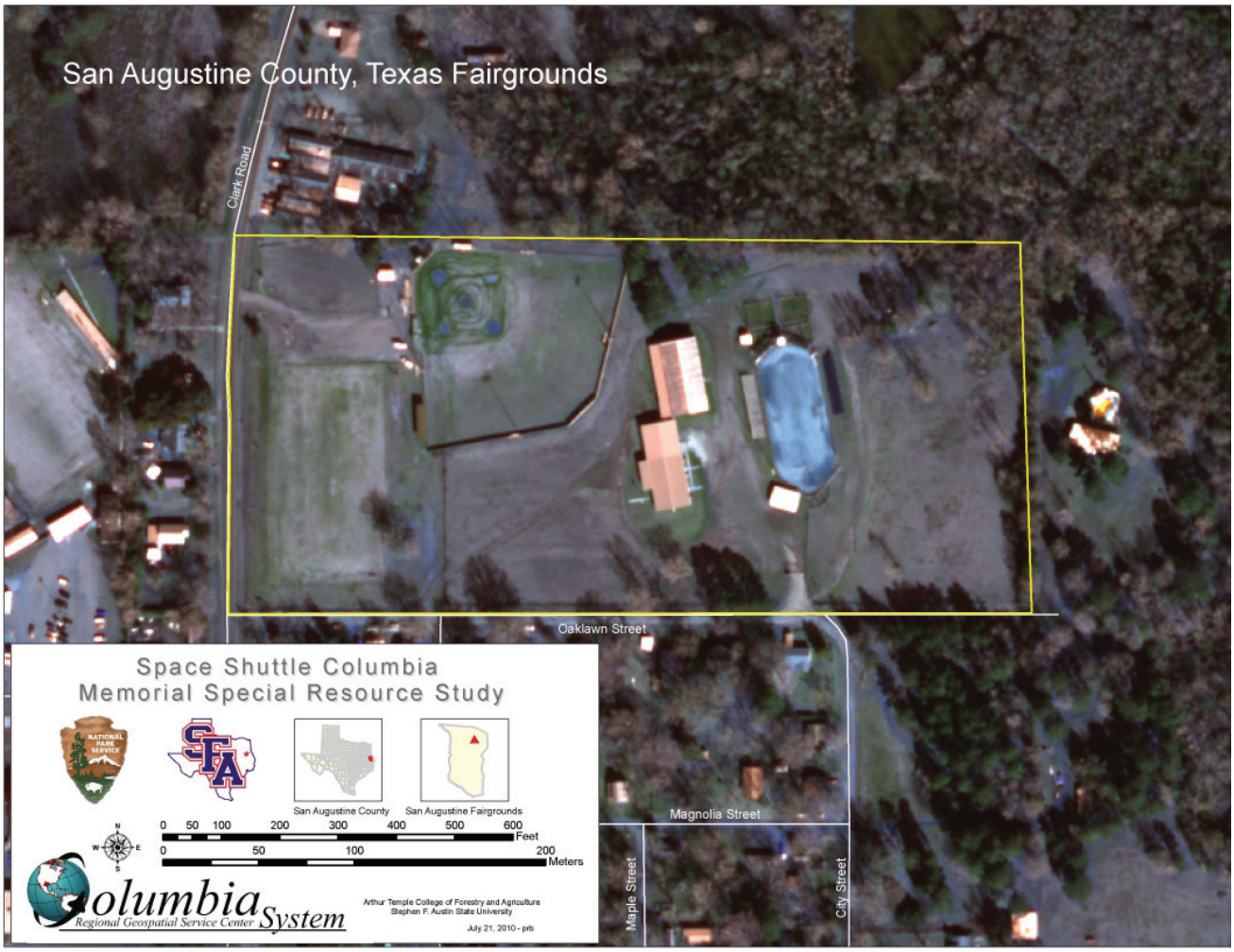
Bronze disc marking the location of the first shuttle debris found in downtown Nacogdoches, Texas.

San Augustine Site

Background

San Augustine County (population 9,000) is in the East Texas timberlands region, adjacent to Sabine County. The county seat is San Augustine, a small city with a population of 2,475. Located along State Highway 21, San Augustine is 35 miles east of Nacogdoches.

The statistical centerline of the shuttle debris corridor travels through San Augustine County, while the city of San Augustine and the county fairgrounds are found within the northern edge of this corridor. The county proved to be one of the key search areas for the *Columbia* and its crew. The greatest concentration of shuttle debris was recovered here along with the partial remains of some crew members. According to Randy Williams, the justice of the peace during the time of the shuttle crash, the county basically shut down during the recovery efforts. As debris began raining down on the county, the sheriff's department organized groups to start the recovery effort. More than 1,000 local volunteers assisted federal, state, and county agencies in the recovery effort, while the county fairground became an important staging area. The Texas Department of Public Safety contributed 200 officers to San Augustine alone. Human remains, fuel canisters, and other shuttle debris were found in the area. Some houses were also damaged by falling debris. Various groups and individuals prepared and served 3,000-4,000 meals per day for the recovery workers.



Aerial view of San Augustine study site outlined in yellow.

Study Site

In the legislation authorizing this study, the San Augustine site is described as "*the parcel of land owned by San Augustine County, Texas, located at 1109 Oaklawn Street, San Augustine, Texas.*" This is the location of the county fairgrounds and includes a rodeo arena and two multi-purpose structures that provide for meeting space for community gatherings including the 4-H Club, office space for the county extension agent, and storage space. The site was used as a key staging area during the recovery effort and the north building was used to temporarily stockpile collected shuttle debris.

San Augustine County Fairgrounds.

North building used for staging recovered shuttle debris.

Other Commemorative Efforts

The town of San Augustine has installed two memorials to *Columbia* and its crew. The first is the NASA Columbia commemorative plaque displayed inside the city's Civic and Tourism Center. Outside, a stone monument was placed within a small landscaped area at the corner of West Columbia Street and West Main Street in the center of town. The community has mixed opinions on whether the memorial site should be at the county fairgrounds or if it is better suited at the existing Civic and Tourism Center.

San Augustine's memorial to Columbia *and her STS-107 crew, located at their Civic and Tourism Center.*

Hemphill Site

Background

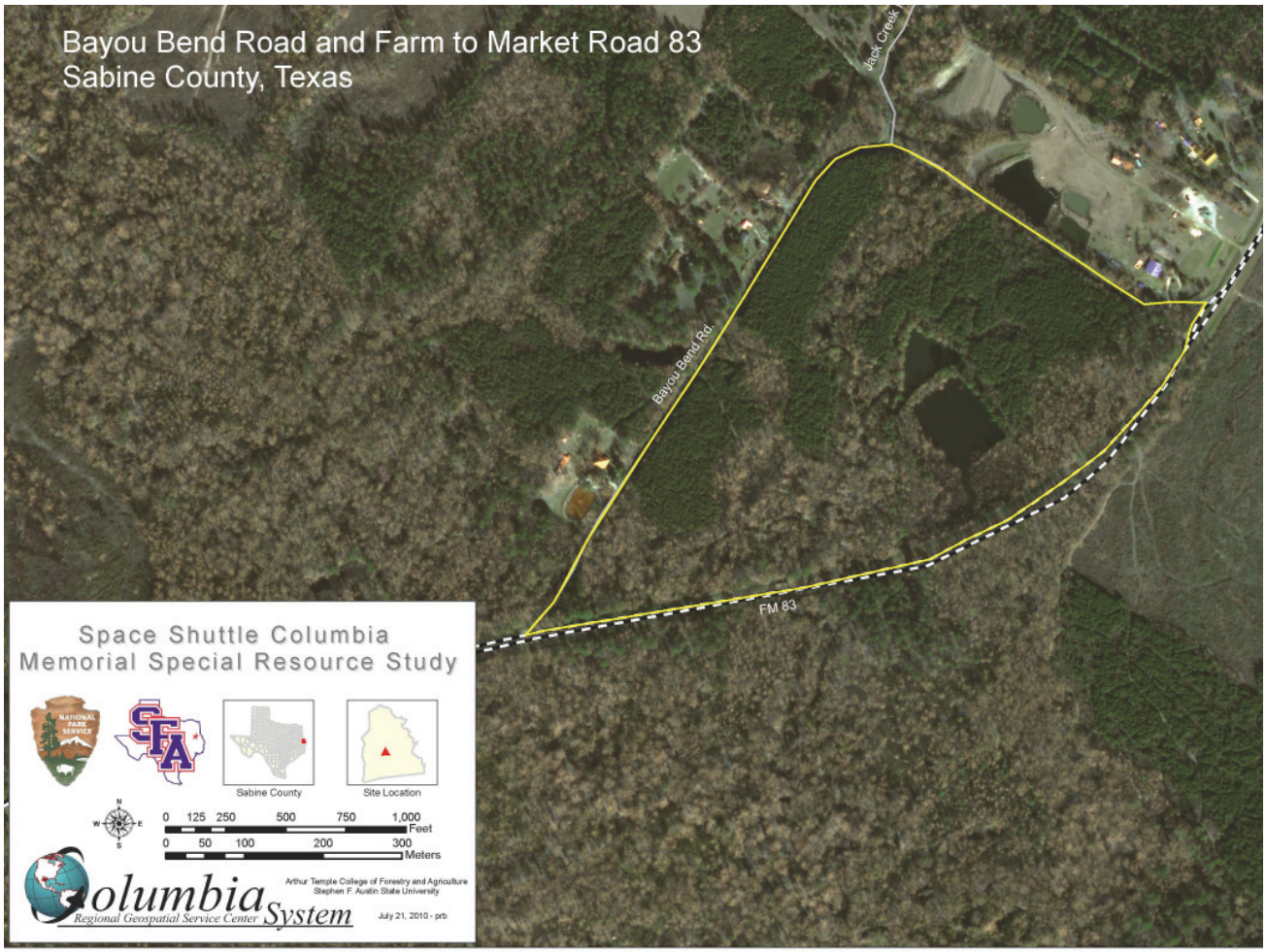
The city of Hemphill, with a population of just under 1,100 residents, is the county seat of Sabine County. The city is 64 miles southeast of Nacogdoches and 150 miles northeast of Houston. Located on State Highway 87 at the junction of State Highway 184, Hemphill is surrounded by the Sabine National Forest and the Toledo Bend Reservoir. Sabine County

extends to the Texas Louisiana border and has a population of almost 11,000.

The city of Hemphill and Sabine County are found along the statistical centerline of the shuttle debris corridor. Hundreds of local volunteers assisted federal, state, and county agencies in the recovery effort. This area proved to be one of the key search areas for the *Columbia* wreckage. The partial remains of all seven crew members were found within Sabine County. Pastor Fred Raney accompanied the FBI evidence recovery team and conducted a "chapel in the woods" memorial service for each astronaut. Search crews also found *Columbia*'s orbiter experiments recorder, a tape recorder that stored key data about the shuttle's performance during re-entry. This "black box" provided key evidence for accident investigators. One of the largest and most recognizable pieces of *Columbia*—the 500-pound nose cone—was recovered from the study site. The community considers this place hallowed ground. Estimates are that the population of Hemphill tripled during the event. With only five restaurants in town, locals still provided more than 3,000 free meals a day over 15 days for workers engaged in the search and related activities. Local resident and budding writer, Byron Starr, recounted the events in Sabine County immediately after the *Columbia* disaster in his book *Finding Heroes: The Search for Columbia's Astronauts*.[5]

Study Site

In the legislation authorizing this study, the Hemphill site is described as "*the parcel of land*



Aerial view of the Hemphill study site outlined in yellow.

Members of the U.S. Forest Service search team walk a grid during a Columbia *recovery search near Hemphill, Texas. The group is accompanied by a space program worker able to identify potential hazards of shuttle parts. (NASA photo)*

Trail to the shuttle nose cone discovery site.

Shuttle's nose cone recovery marker.

owned by Temple Inland Inc., 10 acres of a 61-acre tract bounded by State Highway 83 and Bayou Bend Road, Hemphill, Texas."
The property is actually located just outside Hemphill's city limits and has since been acquired by the Campbell Group. The current owners have expressed a willingness to support a memorial proposal on their site. The area includes the location where *Columbia*'s nose cone was recovered.

Several design concepts were developed by graduate students at Texas A&M University to use this site as a memorial and museum to honor not only the astronauts but also the hospitality of the East Texas community during the recovery effort.

Other Commemorative Efforts

The Sabine County Columbia Memorial Committee was formed shortly after the disaster and initiated a number of commemorative efforts. A granite marker with the NASA Columbia commemorative plaque was installed in front of the county courthouse. In the library, there is a replica of the shuttle.

NASA's Columbia commemorative plaque, which is similar to the plaques given Lufkin, Nacogdoches, and San Augustine.

At the intersection of State Highway 87 and Farm Road 83, the community converted a large, circular stone dais with a white star into the Columbia STS-107 Memorial, laying down colored tiles to replace the existing blue field with a U.S. flag and putting an image of the shuttle's mission patch at the center of the star. An inscription circling the edges of the memorial reads, "Their mission became our mission." The date of the disaster is there, and flying directly behind the memorial are the U.S., Texas and STS-107 mission flags. Two stone monuments flank the circle, one for the STS-107 astronauts and another that commemorates Jules F. Mier, Jr. and Charles Krenek, the two recovery workers who lost their lives in a helicopter crash while searching for shuttle debris in San Augustine County.

Hemphill's Columbia STS-107 Memorial.[6]
(Photo credit: see endnote #6)

On the eighth anniversary of the *Columbia* disaster (February 2011), residents of Hemphill, Texas celebrated the grand opening of their new 3,400-square-foot Patricia Huffman Smith NASA Museum "Remembering Columbia." Constructed as an addition to the town's library, the museum was made possible through the generosity of many individuals, including Mr. Albert Smith, in remembrance of his deceased wife, Patricia Huffman Smith.

The museum contains a tribute to the ship and her crew, including exhibits that tell the story of space exploration from the first mission of *Columbia* to its last mission. It also reveals the efforts of local citizens during the *Columbia* and the STS-107 crew recovery effort. An area is dedicated to each crew member that was lost in the tragedy, including the Texas Forest Service employee and the helicopter pilot who lost their lives during the recovery effort. The families of the crew have contributed personal items belonging to their loved ones to be on permanent display. The museum also houses many items and artifacts from NASA, its contractors, and other individuals.

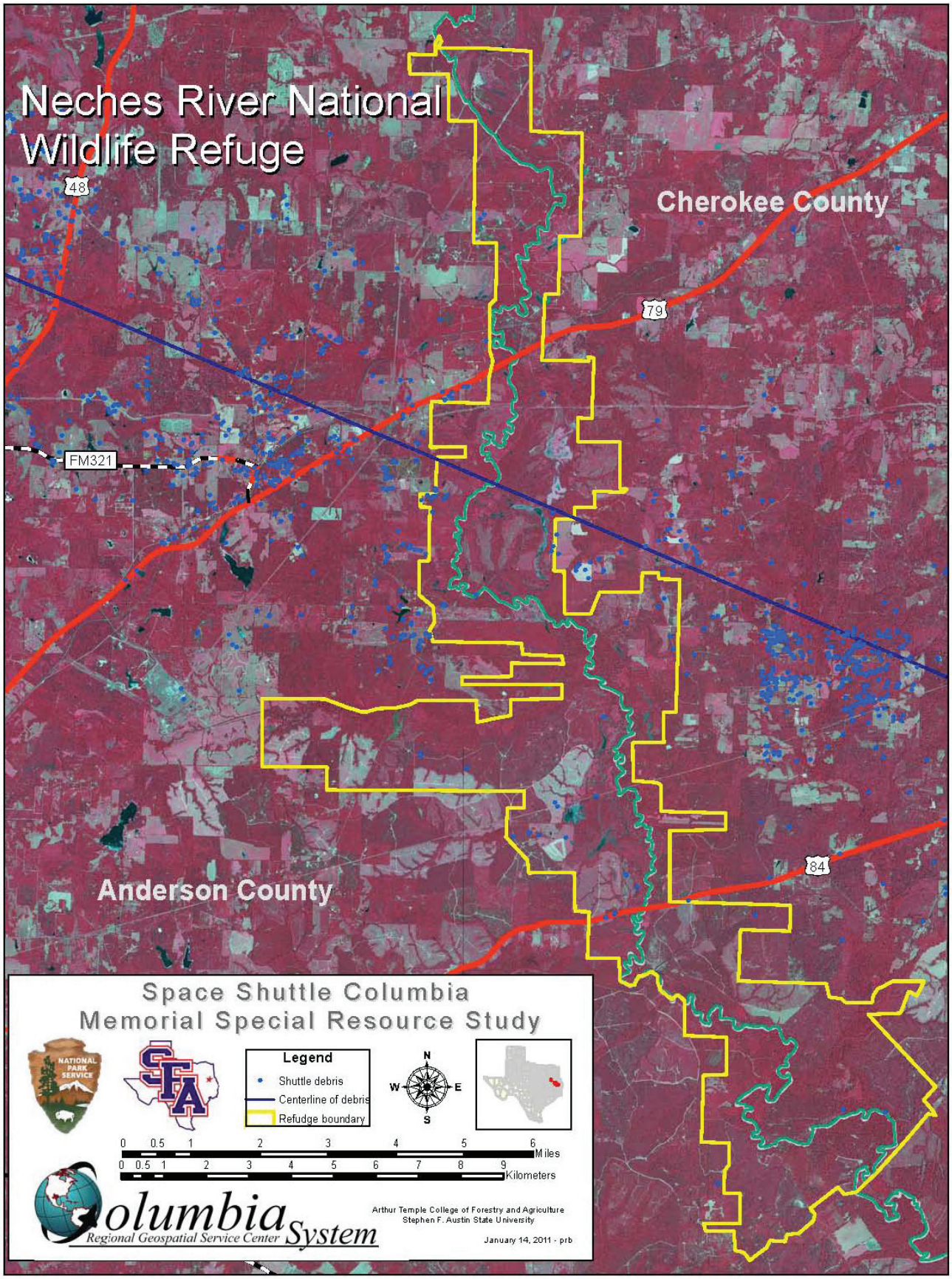
The museum will feature two simulator interactive devices that emulate activities of the shuttle and orbiter. A planned classroom/digital learning center will provide an excellent opportunity for the advancement of education for people of all ages.[7]

Neches River National Wildlife Refuge Site

Background

The Neches River National Wildlife Refuge was established in 2006 to conserve, protect and enhance a diversity of habitats and the wildlife resources found along a 38-mile reach of the upper portion of the Neches River dividing Anderson and Cherokee Counties.[8] The Neches River flows through two national forests, two state parks, and Big Thicket National Preserve. The national wildlife refuge provides the northern anchor of protection for the river system.

The statistical centerline of the shuttle debris corridor travels through the Neches River National Wildlife Refuge. Almost 60 shuttle remnants were recovered within the refuge. In conjunction with early shuttle debris reports from Nacogdoches and San Augustine, debris reports from Anderson County were used by



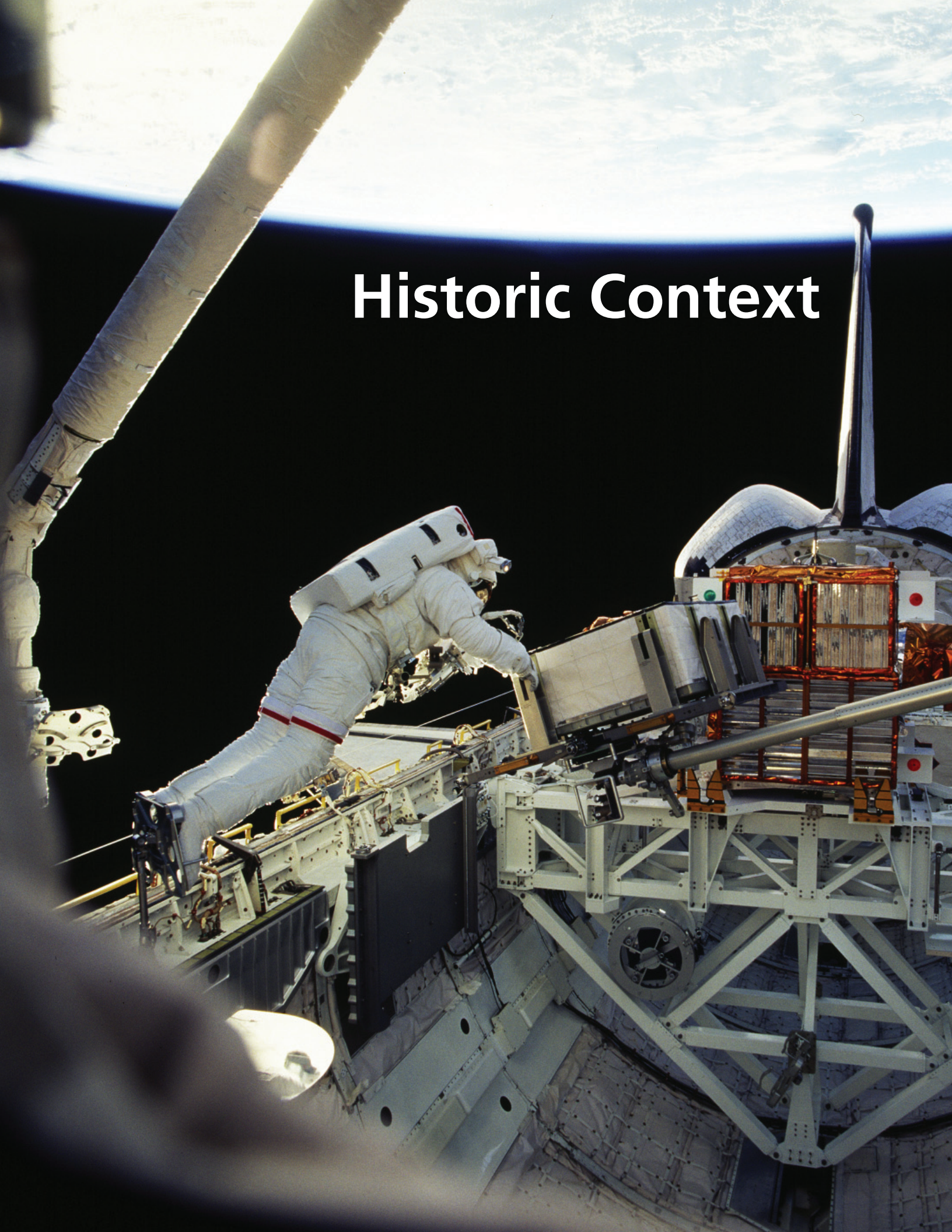
Aerial view of the Neches River National Wildlife Refuge.

Neches River National Wildlife Refuge.

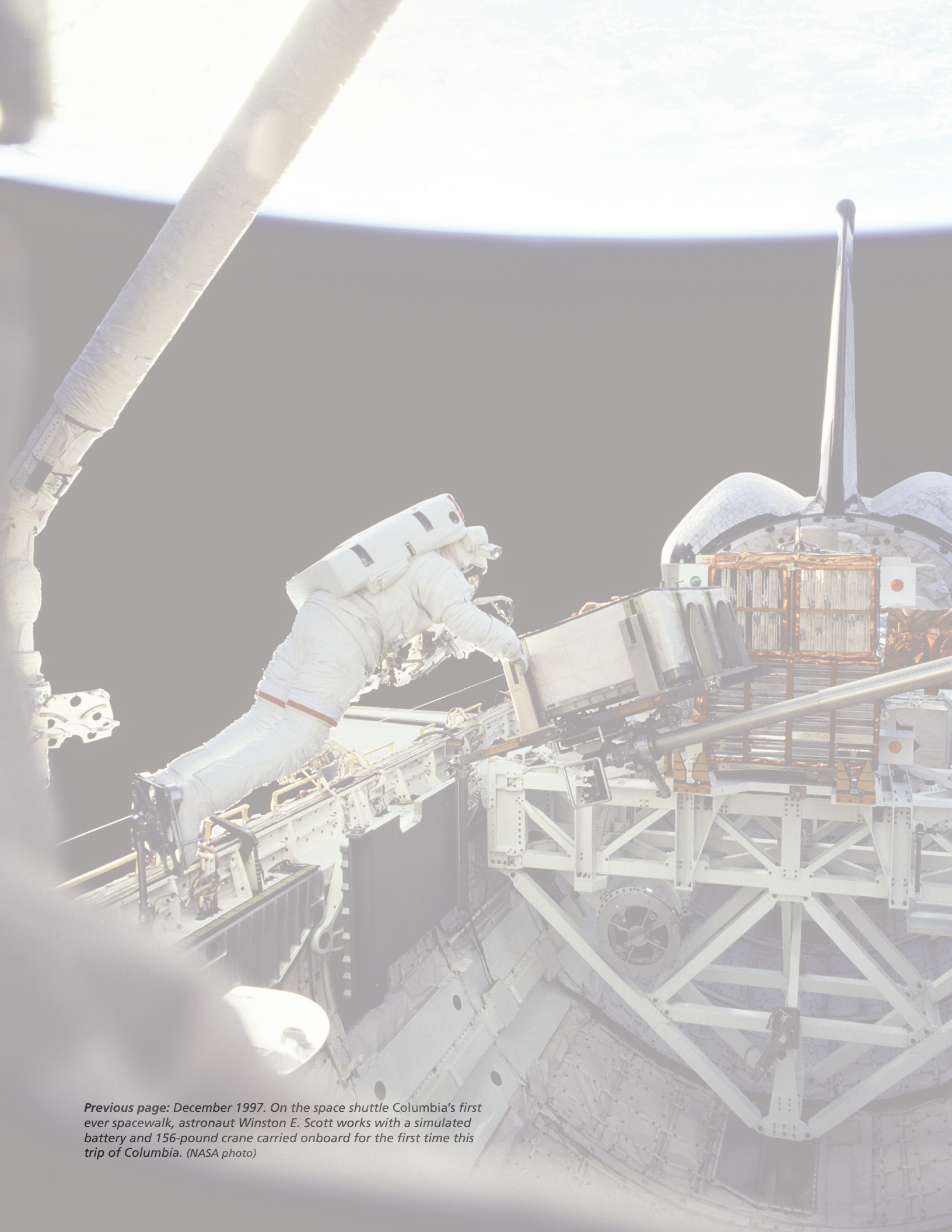
the geospatial first responders in Nacogdoches to establish the primary search vector mapping for recovery teams. Similarly to the other study sites, residents from both counties found themselves in the middle of the shuttle debris corridor and participated in the extensive search and recovery efforts led by the Texas Forest Service.[9]

Study Site

The Neches River National Wildlife Refuge was added to the scope of the special resource study. The U.S. Fish and Wildlife Service, who manages the refuge, and The Conservation Fund, which holds in trust 6,700 acres within the refuge, advocated the consideration of dedicating a portion of the national wildlife refuge as a "living memorial" to *Columbia*, which could provide a federally protected natural setting for reflection and commemoration. They proposed that the Department of Interior would retain oversight, USFWS would remain the management entity, and the National Park Service could possibly provide interpretation and design guidance with USFWS input. Such additions are warranted under the 2008 legislation which states: *"Additional sites. The Secretary may recommend to Congress additional sites in the State of Texas relating to the Space Shuttle Columbia for establishment as memorials to the Space Shuttle Columbia."*



Historic Context



Previous page: *December 1997. On the space shuttle* Columbia*'s first ever spacewalk, astronaut Winston E. Scott works with a simulated battery and 156-pound crane carried onboard for the first time this trip of Columbia.* *(NASA photo)*

Origins of the U.S. Space Shuttle Program

Beginning with the Soviet's launch of *Sputnik* in 1959, the United States and the Union of Soviet Socialist Republics (USSR) entered a frantic 'space race' as part of their Cold War competition.[10] The space race itself essentially scaled back with the U.S. moon landings in 1969 and the early 1970s. In its first years, NASA—established by President Dwight Eisenhower in 1958—primarily focused on setting and breaking records and achieving space "firsts." During the course of these endeavors, the space agency developed new technologies, supported the massive growth of the aerospace industry, and made new scientific discoveries. But the importance of these activities to the space agency paled in comparison to building international prestige by "beating" the Soviet Union in space exploration.[11]

Space exploration was a 'stretch' activity rather than a long-term enterprise. That is, it focused on sending astronauts the maximum possible distance, to the moon and bringing them back. Until approximately 1970 this "stretch" activity dominated NASA. However, the missions themselves resulted in no sustainable presence either on the moon or in space. The *Apollo* spacecraft, for example, had barely enough capacity to reach its destination and return home, much less carry a commercially significant payload.[12] In addition, the idea of "manned" spaceflights—as opposed to drones or robotic technologies—continued to be an important source of debate in the larger American community. This was particularly true in light of the *Apollo* 1 accident in 1967, the near tragedy of *Apollo* 13 in 1970, the *Challenger* explosion in 1986, and the *Columbia* disaster in 2003.[13]

Space shuttle Columbia *as it lifts off from Launch Pad 39A on mission STS-107. (NASA photo)*

NASA began thinking about a shuttle spacecraft (or an orbiter) and the missions that it would pursue—most likely beginning after the moon landings—as early as 1965, before a single *Apollo* capsule had reached orbit. The formal "shuttle decision," however, was not made until the administration of President Richard M. Nixon. In 1972, the president laid out a new vision for space, saying the United States would develop "an entirely new type of space transportation system" that would "transform the space frontier of the 1970s into familiar territory, easily accessible for human endeavor" in the decades to come.[14]

At the heart of the new system lay "a space vehicle that can shuttle repeatedly from Earth to orbit and back," thus revolutionizing spaceflight "by routinizing it" and "delivering the rich benefits of practical space utilization

Columbia *being prepared for liftoff on its maiden voyage and the first flight of the space shuttle program, the STS-1 mission. (NASA photo)*

. . . into the daily lives of Americans and all people. . .” That function—shuttling back and forth to orbit—gave the new system its name: the space shuttle. The promise of cheap, routine access to space essentially replaced exploration goals with utility objectives, and changed the very focus of the space race.[15]

The new direction for NASA replaced a goal that was at once scientific, adventurist, and competitive (a la the Cold War) with one that—while certainly competitive—was more pragmatic. It promised cheap, routine access to space, including a commitment to such activities as carrying commercial payloads into orbit and supporting longer-duration space research projects, such as an eventual space station. It also required that NASA restructure itself as an organization to support the new mission.[16]

The Space Shuttle: NASA's New Centerpiece

The space shuttle itself was a major technical achievement for the U.S. Space Program. It was the first reusable human-capable launch vehicle, and it included a number of technological breakthroughs, especially its main engines and its computerized control systems.[17]

Space shuttle Columbia *(STS-80) lands at Kennedy Space Center at dawn on December 7, 1996. (NASA photo)*

Almost from the inception, however, the space shuttle was a compromise design, meant to meet the needs of multiple players, especially NASA and the U.S. Air Force. The Air Force, in particular, expected to use the vehicle in a variety of reconnaissance roles, suggesting that it might launch spy satellites, conduct overflights of the Soviet Union (an orbital version of the mission performed by aircraft like the *SR-71* and *U-2*), and even conduct missions to capture enemy spy or weapons satellites in orbit and bring them back to Earth.[18]

NASA also expected to sell shuttle services to private industry. By the time *Columbia* lifted off for the first shuttle flight, telecommunications firms had begun launching large numbers of satellites, and NASA estimated that such launches would make up 38 percent of its business in the first decade of shuttle trips. In the area of launch services, the agency had to compete against other providers; the European Space Agency's *Ariane* rockets, in particular, proved very successful as launch vehicles. NASA, nonetheless, could offer services that other providers could not, including the potential to repair, service, or even bring back satellites already in orbit and the ability to take researchers—eventually designated as "payload specialists"—into orbit to conduct experiments on behalf of private companies.[19]

NASA desired to provide services to a variety of customers in part because it needed that business to offset the cost of developing the shuttle. Many think of 1969—the year of the first moon landing—as NASA's heyday, but the space agency's budget told a different story.

According to the *New York Times*, between 1965 and 1969, the NASA budget was "cut more sharply than that of any other federal agency." It shrunk by 35 percent, from $5.9 billion to $3.8 billion, in just four years.[20] In the words of the agency's administrator, Thomas Paine, "the space program, caught between the pressure on the right for ever-larger defense appropriations and on the left for massive social projects," risked being "ground down to insignificance."[21] By securing Air Force and corporate support, NASA hoped not only to have a government customer eventually paying for its flights, but to have Department of Defense support that would help the space agency cling to federal appropriations during the long and costly shuttle development process.[22]

The support came with a high cost, however. According to NASA shuttle historian T. A. Heppenheimer, "The Air Force was very much in the pilot's seat when it came to steering the shuttle program." When representatives of the two sides met in 1971 to define the requirements for the final shuttle system, NASA gave the Air Force anything that it wanted.[23]

To serve its most important customer, shuttle designers had to accept a series of compromises in the design of the spacecraft, affecting even its shape. Early shuttle proposals called for a vehicle with relatively small, straight wings. Such features traded very limited flight capabilities for simplicity and the attendant reliability and safety advantages, high payload capacity because smaller wings weigh less, and a vehicle with less of its body exposed to the intense heat of re-entry. The Air Force, however, demanded that orbiters be able to fly once-around polar orbit missions, meaning that the shuttle would lift off from Vandenberg Air Force Base in Santa Barbara County, California, and return to the same location after a single trip around the Earth. During that time the planet's rotation would carry the base 1,265 miles east, so a returning orbiter would need to go "cross-range," veering off of its orbital track during re-entry to fly east and reach the base.[24]

View of wingtip vortices as Columbia *(STS-2) lands at Edwards Air Force Base, November 1981. (NASA photo)*

The polar-orbit capability, combined with other cross-range demands, eventually led NASA to choose an orbiter design that had large, delta-shaped wings and could fly complex return trajectories during re-entry. The vehicle's new profile would subject it to a great deal of additional heat. This last requirement became one of several new technologies that would define the space shuttle during its development, and influence its performance.[25]

Along with overcoming technical hurdles, the shuttle program faced constant budget criticism. Two of NASA's primary opponents throughout the decade-long shuttle development program were the Office of Management and Budget (OMB) and the Government Accountability Office (GAO). The OMB twice forced long delays in the

shuttle program in order to shift funds across fiscal years.[26]

In order to justify the shuttle program to these and other critics, NASA promised eventually to achieve extremely high flight rates—between two and four flights per month. Two categories of costs were used to determine high flight rates: per-flight costs and fixed costs. Per-flight costs included items such as the liquid hydrogen and oxygen consumed at launch. More flights, of course, meant more expenditures. Fixed costs, by contrast, included such items as spacecraft construction, annual building maintenance at Cape Kennedy in Florida, and salaries for NASA personnel attached to the shuttle program. The program incurred these costs even if no shuttle flights were scheduled in a given year.[27]

In selling the shuttle program to Congress and the White House, NASA promised to reduce the per-flight cost of launching payloads into space. Increasing the number of flights would allow the agency to reduce the percentage of fixed costs "assigned" to each flight, thus reducing the "per-flight" costs. NASA, therefore, had accepted the logic of purchasing in bulk. Flying 24 missions in a year would cost the agency more in absolute dollars than flying 12 missions, but the agency would be able to claim that each individual flight on the 24 mission schedule cost less. Such accounting practices not only affected NASA's budget, but also how it functioned in keeping the shuttle program viable and pressing the limits of NASA's workload.[28]

NASA's emphasis on high flight rates for the shuttle program also fit into the agency's goal of making spaceflight a "routine" endeavor. The most popular metaphor for the shuttle as a routine work vehicle was described in the *Space Shuttle Operator's Manual*, first released in 1982. It noted that the orbiter, while "an amazing flying machine," would not "open the 'space frontier' by itself." The shuttle existed, the guide explained, "to support all types of space missions," providing "the conveyance 'truck' that gets things [to orbit]."[29]

This image of the "space truck"—a rugged utility vehicle designed for hauling cargo repeatedly into orbit—in combination with the demand that the shuttle "fly" back from orbit (rather than plunging through the atmosphere and slowing at the end with parachutes), represented a radical shift from the smaller, simpler capsules that had characterized spaceflight from *Mercury* through the end of the *Skylab* program.[30]

As a part of the focus on utility, The shuttle program followed *Skylab* in placing a much heavier emphasis on scientific and commercial experimentation as a primary mission than had previous programs, such as *Apollo*.

Changes in the Astronaut Program

Just as it traded in rocket capsules for a science-heavy "space truck," NASA also changed the face of its astronaut program with its new focus. Instead of test pilots and fighter jocks with the "right stuff," the orbiter, like utility vehicles back on Earth, would carry ordinary workers into space. Between 1959 and 1967, NASA had six rounds of astronaut selection. Prior to the moon landing, NASA mostly selected pilots for the astronaut program in part because space vehicles carried small crews.

Each vehicle needed at least one pilot, and, if possible, a back-up or copilot. In a spacecraft like *Apollo*, which had room for three people, this left space for only one "scientist-astronaut." The shuttle, by contrast, had space for seven crew members. Even with a dedicated flight crew of three, the orbiter could still carry up to four extra crew

members, generally described as "payload specialists" or "mission specialists."[31]

Not only the size of the crews and their expertise changed with the space shuttle, but also the gender, race, and nationality makeup as well. An important part of NASA's message was the space shuttle's commitment to flying a more diverse group of astronauts than previous programs. From *Mercury* through *Skylab*, every NASA astronaut was white and male. As early as 1972, NASA administrator James Fletcher talked about the agency's desire to broaden its selection criteria for shuttle astronauts, "with full consideration being given to minority groups and women." [32]

Astronaut Eileen M. Collins, the first woman shuttle mission commander, signs autographs for several members of the large crowd gathered on July 28, 1999, to welcome home the STS-93 astronauts. (NASA photo)

The agency pursued this goal in a number of ways, including hiring Nichelle Nichols, the black actress who played the role of Lieutenant Uhura on the popular *Star Trek* television series, to do outreach events and sending out recruitment announcements through organizations such as the National Association for the Advancement of Colored People (NAACP), the League of United Latin American Citizens, and the Society of Women Engineers.[33] The efforts bore immediate fruit in the shuttle program; in 1983 America's first female astronaut, Sally Ride, flew on *Challenger* STS-7 and the first African American astronaut, Guion S. Bluford, Jr., flew on *Challenger* STS-8.[34]

On another level, the space shuttle program, for much of its history, has been used as a means of international cooperation and goodwill—a move beyond the earlier Cold War context of NASA in the 1950s and 1960s. The U.S. invited many other countries to participate in its space program by sending national representatives to train and fly on the shuttle as astronauts. *Columbia*, on its final flight, carried one such representative: Ilan Ramon of Israel.[35]

Space Shuttle *Columbia*

By February 1, 2003, when the *Columbia* disaster occurred, the space shuttle program had operated for three decades, with two-thirds of that time spent in flight operations. The space shuttle remains far and away America's longest-running spaceflight program. In spite of setbacks and difficulties, the shuttle program achieved much of what President Nixon envisioned, making orbital flight much more common and dramatically increasing the duration and utility of missions.

Columbia was NASA's first completed orbiter, and it flew the longest mission on record, STS-80 (1996). It flew the first five shuttle missions STS-1-5 (1981-82); the first four were classified as "test flights," and the fifth was regarded as the first "operational" mission. In addition, there are many other 'firsts' in the space shuttle program that can be attributed to *Columbia*.

Prior to her loss, *Columbia* had served the shuttle program for two decades, longer than any other orbiter in the fleet. Since the shuttle program itself was so important to NASA's overall development and impact, *Columbia* has a special place in NASA history. That place includes both its enviable list of 'firsts' as well as its tragic disintegration.

While all of the orbiters were similar in design and function, *Columbia* set several precedents and also incorporated some unique features. *Columbia* was the first true shuttle orbiter in the sense of being a space-worthy craft equipped to fly missions to orbit. Prior to the construction of *Columbia*, NASA set aside money to construct a model orbiter, dubbed *Enterprise*, after a nationwide campaign by fans of the television show *Star Trek*. *Enterprise* had all of the systems necessary for atmospheric flight, and it sported an assortment of dummy rocket motors and exhaust ports that gave it the appearance of a true orbiter. The purpose of both real systems and simulations was to enable *Enterprise* to conduct test flights as part of the Approach and Landing Test (ALT) program.[36]

ALT served two important functions. First, it allowed NASA to test out the aerodynamic gliding performance of its spacecraft. Because orbiters would make unpowered landings, it was critical to ensure that the shuttle design would perform well as a glider in spite of its immense weight and irregular shape. Second, the ALT program gave NASA an opportunity to test out the "Shuttle Carrier Aircraft" (SCA), a Boeing 747 modified to transport the shuttles piggyback style from one location to another. Astronauts Gordon Fullerton, Fred Haise, Joe Engle, and Dick Truly flew five successful ALT flights. There was some talk in NASA of eventually converting *Enterprise* into a working orbiter, but feasibility studies conducted after the loss of *Challenger* ultimately concluded that it would be more cost effective to simply build a new spacecraft, the *Endeavor*, from the ground up.[37]

Shuttle orbiter Enterprise *in 1978, undergoing vibration tests to verify whether the shuttle performed its launch configuration as predicted. (NASA photo)*

Columbia *flying piggy back on a modified Boeing 747 from Palmdale, Calif., to Kennedy Space Center in Florida. (NASA photo)*

On April 12, 1981, the first space shuttle orbiter, *Columbia*, successfully launched into orbit; exactly seven months later, on November 12, it flew a second mission. *Columbia*'s successful flights represented a major milestone in space operations. NASA had many reasons to celebrate. By launching twice in less than a year, *Columbia* had become the first-ever reusable spacecraft. The shuttle program also demonstrated some administrative success for the agency. Accounting for inflation, it ran just 15 percent over the original projected cost, well within

the bounds of the program's budget and, as the Columbia Accident Investigation Board (CAIB) noted in 2003, a particularly impressive feat given the complexity, uncertainty, and length of the task.[38]

Technical Features

In technical terms, *Columbia*'s initial flights demonstrated the viability of a number of new systems and technologies, including the tile-based thermal protection system, computer-controlled flight, and a new propulsion system. The orbiter had a suite of instruments that recorded in-flight data from sensors positioned all around the spacecraft. Originally intended to capture data during the test-flight process, these sensors provided useful information during the accident investigation that followed the loss of the orbiter.[39] *Columbia* also was the last orbiter to retain its internal airlock, a feature which made it impossible for the orbiter to dock with the International Space Station. *Columbia*, however, was equipped with a special module, the "Extended Duration Orbiter" package that extended the feasible length of its flights. As a result, it flew several long-duration science missions, including the longest-ever shuttle mission, STS-80 (1996), which lasted for 17 days and almost 16 hours.[40]

Perhaps the most impressive of the new technologies on *Columbia* were the three space shuttle main engines (SSMEs). In many ways, the SSME represented a sort of microcosm of the new technological demands that made the space shuttle design so revolutionary. NASA wanted an engine that was more powerful than previous designs of a similar size. During flight, computers would precisely regulate the new engine's thrust, and the SSME would have to be capable of flying many missions with only a short turnaround time between flights. Taken together, these requirements meant that the new design would have to be significantly more robust than its predecessors. To get an increase in power without increasing weight, the engine had to burn its propellant more efficiently, generating much higher pressures and heat loads in the process and using up fuel at a faster rate, which in turn required innovative technologies. To meet the reusability requirement, all of these systems had to perform in this new, hotter, higher-pressure environment for long periods of time without degrading, and they had to be accessible for inspection and repair.[41]

Columbia's *first lift-off on April 12, 1981. (NASA photo)*

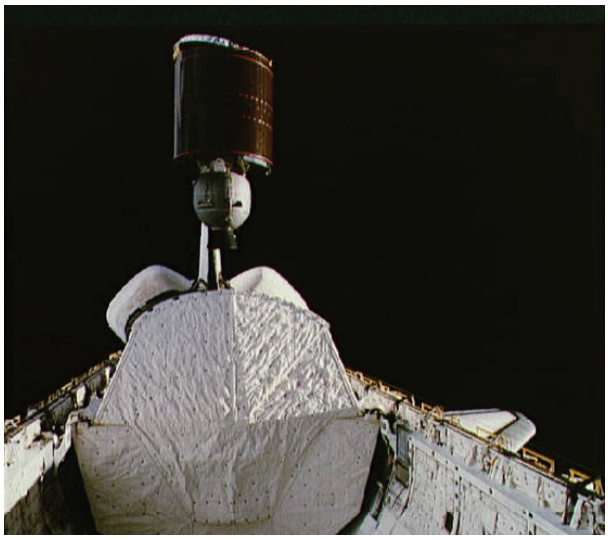
Unfortunately, the SSME also exemplified an important problem for the space shuttle program. The original engines delivered to

NASA could not reach the full desired power, nor could they operate for the hoped-for 55 flights. NASA had to replace the units after just six flights, or 10 percent of the desired flight time.[42]

Writing in 1986 as part of the Rogers Commission's report on the loss of *Challenger*, Richard Feynman pointed out that some parts of the fuel system originally required replacement more often—every three to four flights—and that even engines capable of operating at the higher, desired levels of performance rapidly developed cracks in their fuel-pump turbines, necessitating a regime of inspecting and replacing key components after each flight. This process was effective insofar as no mission has ever been lost to a catastrophic in-flight engine failure. Yet, it directly contributed to the lengthy turnaround time between orbiter flights which prevented the space shuttle program from ever reaching its goal of flying large numbers of flights each year. Thus the space shuttle main engine, like the space shuttle program as a whole, made major technological strides, but not as far forward as NASA would have hoped.[43]

Payload Performance

Columbia hauled the first commercial space load to orbit during STS-5 (1982), whose crew advertised themselves with the slogan, "We Deliver." STS-5 successfully launched two commercial communications satellites—*ANIK-C3* and *SBS-C*—for paying customers. By launching communications satellites during the shuttle's first "operational" flight (the four previous launches were considered test missions to prove the orbiter's space worthiness); NASA signaled the beginning of a new era of public-private cooperation in manned spaceflight. When President Nixon announced the shuttle program, he promised it would help bring the benefits of space to ordinary Americans. *Columbia*'s mission



Telesat Canada ANIK C-3 communications satellite rises from its protective cradle in the cargo bay of Columbia. (NASA photo)

seemed to make that goal a reality, providing communications services to customers across the United States and Canada.[44]

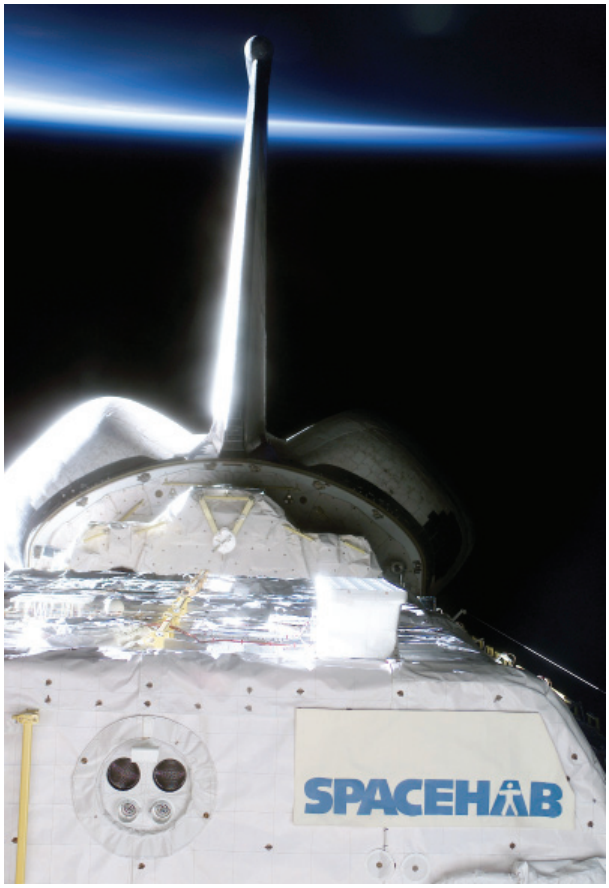
In addition to the focus on commercial payloads, NASA emphasized the role of scientific investigation and exploration from the very beginning of the shuttle program. *Columbia*'s second flight included a U-shaped pallet full of sensory instruments designed to look back at the Earth, including photographic equipment used to identify geological formations that might contain valuable minerals; instruments to measure carbon monoxide levels in Earth's northern and southern hemispheres; and a radiometer designed to supplement the visible-light cameras by capturing emissions in the other parts of the electromagnetic spectrum.[45]

The Earth-observation pallet produced some excellent results, but it also represented the sort of big-ticket scientific research conducted by earlier NASA programs. With the shuttle program, the space agency also committed itself to providing room for small-scale, affordable experimentation, particularly for students. *Columbia* carried the first such experiments during STS-3 (1982), as part of its

"Shuttle Student Involvement Project." One—designed by a Minnesota high school student for a NASA contest—involved photographing moths and honeybee drones carried in glass cages aboard the orbiter to determine how they would behave in microgravity. The other experiment consisted of a miniature, 96-plant arboretum prepared by the University of Houston for the purpose of studying plant growth in microgravity conditions.[46]

On STS-4 (1982), *Columbia* carried the first payloads in the popular "Getaway Special" (GAS) program. The GAS program consisted of small canisters—roughly the size of 30-gallon garbage cans—that would fly in the orbiter's cargo bay, using some of the spare space not taken up by satellites and other large payloads. NASA charged only a few thousand dollars for flying GAS payloads, making the service available to organizations that could never otherwise have afforded the expense of sending experiments into orbit. Student groups, in particular, ranging from university students to elementary-age children, sent experiments into orbit as part of the program. For STS-4, *Columbia* carried a GAS payload containing nine experiments designed by students at Utah State University in a canister paid for and donated to the university by Thiokol Corporation manager R. Gilbert Moore.[47]

The orbiter's ability to carry out laboratory experiments was another dimension of the science operations conducted by the shuttle program. Orbiters had some space for experiments in their crew modules, but the most exciting expansion to experimental capabilities came from the addition of special modules flown in the payload bay. The first of these, *Spacelab*, flew in *Columbia*'s payload bay on STS-9 (1983).[48] *Spacelab*, constructed by the European Space Agency, consisted of cylindrical, pressurized modules where crew could work and U-shaped pallets that would hold instruments and experiments designed for exposure to the space environment. The modular design allowed the shuttle to carry five instrument pallets, enough crew modules to fill the cargo bay, or, more commonly, a mix of the two types of units.[49] By working in dual, 12-hour shifts for the duration of the mission (a system that began with STS-9), astronauts eked out the maximum amount of experimental time from a flight.[50] STS-107 (2003) flew in part because of heavy lobbying by Spacehab Incorporated to launch a mission using the last of these piggyback labs (the eponymous *Spacehab*), and NASA "emptied the closet" to fill the double-wide module with experiments ranging from student biology projects to theoretical physics research.[51]



The SPACEHAB *Research Double Module in the space shuttle* Columbia's *payload bay and vertical stabilizer are backdropped by the blackness of space and a thin slice of Earth's horizon. (NASA photo)*

The crew of STS-107. Seated in front are astronauts Rick D. Husband (left), mission commander; Kalpana Chawla, mission specialist; and William C. McCool, pilot. Standing are (from the left) astronauts David M. Brown, Laurel B. Clark, and Michael P. Anderson, all mission specialists; and Ilan Ramon, payload specialist representing the Israeli Space Agency. (NASA photo)

Columbia and Her Crew

Columbia carried a crew of four into space on its fifth flight, STS-5 (1982); including the first two mission specialists. Mission Specialists Joseph P. Allen and William B. Lenoir were astronauts, but neither man came to NASA as a pilot. Allen was a Ph.D. physicist; Lenoir's doctorate was in electrical engineering.[52] For the first time, a NASA spacecraft had flown carrying as many technical personnel as pilots. In the years to come, the space agency would expand on that initiative, adding doctors, politicians, and teachers, among others, on its various shuttles. In practice, the number of people who flew aboard the shuttle remains low—fewer than 500 in 30 years of flights. In principal at least NASA nevertheless could make an important claim: With enough hard work, anyone can become an astronaut.[53]

Many of these "firsts" took place aboard *Columbia*. The STS-61C (1986) mission featured the first African-American pilot, Charles F. Bolden, a former Marine who was eventually appointed to the position of NASA Administrator by President Barack Obama, and the first Latino astronaut, Costa Rican-born Franklin Chang-Diaz.[54]

Eileen Collins became the first female shuttle commander when she flew aboard *Columbia* in 1999, heading the STS-93 (1999) mission that launched the Chandra X-Ray Observatory in NASA's popular "Great Observatories" program, and performed one of the Hubble Telescope servicing missions in its second-to-last flight, STS-109 (2002).[55]

Few flights emphasized NASA's commitment to carrying all people into space more than *Columbia*'s final mission. Its diverse crew

included two women, Navy physician Laurel Clark and aerospace engineer Kalpana Chawla, both classified as mission specialists. Chawla was the second Indian-American to fly on the shuttle, and the first to have actually been born in India, moving to the United States in 1982 and becoming a U.S. citizen in 1990. A second naval aviator and flight surgeon, David Brown, also flew on STS-107. In addition to the Indian-American Chawla, the *Columbia*'s crew included African-American Michael Anderson, an Air Force pilot with an M.A. in physics, and a foreign national, Israeli Ilan Ramon. Beyond merely his nationality, Ramon embodied the "right stuff" legend that characterized astronauts going back to the early days of NASA. He had a decorated history as an Israeli fighter pilot and participated in the legendary June 1981 raid on an Iraqi nuclear facility. *Columbia*'s commander and pilot, Rick Husband and William McCool, also fit into this tradition; both men were military test pilots prior to joining the astronaut corps.[56]

The STS-107 crew members strike a 'flying' pose for their traditional in-flight crew portrait in the SPACEHAB *Research Double Module (RDM) aboard the space shuttle* Columbia. *(NASA photo)*

The position of specialist also made possible the first privately-sponsored human spaceflight. NASA announced that organizations sending up a payload aboard the shuttle could nominate a "payload specialist" to fly as part of the trip. These payload specialists would receive basic training to function as part of the shuttle's crew, but they would not be professional astronauts, flying instead as private representatives of their organizations. The first private payload specialist, Byron K. Lichtenberg, flew aboard *Columbia* as part of the STS-9 (1983) mission, conducting a variety of experiments on behalf of his co-sponsors, MIT and Canadian Vestibular.[57]

Another payload specialist also rode into orbit aboard *Columbia* with the STS-9 mission: Ulf Merbold, a West German physicist with the European Space Agency. When President Nixon announced the shuttle program in 1972, he promised that it would make spaceflight relevant not only for Americans, but for "all people." *Columbia* was the first orbiter to deliver on that promise, first by carrying scientific payloads—an experiment put together by members of a British institution, the University of Kent, Canterbury, flew on STS-3 (1982), and STS-5 (1982) included an experimental package for the West German Ministry of Research and Technology—and then by carrying Merbold.[58] Many other foreign nationals would follow, including a variety of Europeans, several Japanese astronauts, a citizen of Mexico, and even a member of the Saudi royal family. Israeli astronaut, Ilan Ramon, also flew on *Columbia*'s final flight.[59]

Retirement of the U.S. Space Shuttle Program

The *Columbia* disaster on February 1, 2003, was a human tragedy that had a fatal impact on the future of the space shuttle program. Spaceflight has always entailed significant risks, as the *Apollo* missions graphically demonstrated early in the manned space program. NASA lost two of its five orbiters with their crews to in-flight disasters. Both the *Columbia* disaster and the *Challenger* explosion before it provoked national conversations about the risks versus the rewards of this perilous activity. According to the Columbia Accident Investigation Board, "The loss of *Columbia* and her crew represents a turning point, calling for a renewed public policy debate and commitment regarding human space exploration."[60]

Apollo 1 and *Apollo* 13

The *Apollo* program, like the shuttle program that followed it, suffered two disastrous spacecraft mishaps. In the posthumously designated "*Apollo* 1" incident, the spacecraft caught fire, leading to the deaths of all three of its astronauts.[61] *Apollo* 13 suffered a catastrophic explosion in one of its fuel cells while *en route* to the moon, but the flight controllers and astronauts involved in the mission successfully devised and employed a series of workarounds to bring the astronauts safely back to Earth.[62] Interesting parallels exist between these *Apollo* incidents and the later shuttle disasters.

Speaking to a 2001 symposium celebrating "Forty Years of U.S. Human Spaceflight," Frederick D. Gregory noted that NASA had not lost an astronaut during either the *Mercury* or *Gemini* programs, and he concluded that safe returns had become "routine and expected" at the space agency, in spite of

Water-level view of recovery operations for the Apollo *13 mission in the South Pacific Ocean. (NASA photo)*

"increasingly complex equipment and quick turnarounds between missions."[63] According to the investigators of the *Challenger* and *Columbia* mishaps, similar expectations of safety, rather than danger, characterized attitudes in the agency prior to those disasters and caused NASA decision-makers to misjudge the level of risk associated with a safety concern. The safety concern in this case was the 100 percent oxygen environment used in the *Apollo* spacecraft cabin, which, due to pressure differences, was relatively safe in space but incredibly dangerous at sea-level.[64]

Operating in the atmosphere of assurance, most NASA employees asked about the *Apollo* 1 fire described it as having "caught them by surprise." In another foreshadowing of the shuttle catastrophes, critics like Eric Bergaust, author of *Murder on Pad 34*, accused the space agency of a second oversight, charging that NASA, "even while denying it was in a space race," had allowed schedule pressures to crowd out safety considerations.[65]

Unlike *Apollo* 1, *Challenger*, and *Columbia*, the *Apollo* 13 incident had a happy conclusion, as all three of the astronauts returned home safely following an explosion that disabled their spacecraft. Perhaps because it did not end in tragedy, the *Apollo* 13 mission provoked less soul-searching and acrimony, even though investigators uncovered several problems after the accident.[66]

Space shuttle Challenger *lifted off Jan. 28, 1986. (NASA photo)*

Main engine exhaust, solid rocket booster plume and an expanding ball of gas from the external tank is visible seconds after the space shuttle Challenger *accident. (NASA photo)*

The *Challenger* Explosion

On January 28, 1986, *Challenger*—the second of NASA's five orbiters—exploded on take-off. *Challenger* was 73 seconds into its 10th flight (the 25th shuttle mission, STS 51-L), when one of its two solid rocket boosters (SRBs) suffered a catastrophic failure—the result of a design flaw in the SRB's O-rings and unusual weather conditions. The resulting changes in the orbiter's flight profile subjected the orbiter to aerodynamic forces which immediately destroyed the vehicle.[67] The crew—Michael Smith, Dick Scobee, Ronald McNair, Elison Onizuka, Christa McAuliffe, Gregory Jarvis, and Judith Resnik—perished when their cabin hit the ocean surface.[68]

In the aftermath of the accident, an expert panel was assembled to investigate the incident. Named after its chairman, William P. Rogers, the Rogers Commission identified the O-ring failure, but also described a series of flaws in NASA's safety-culture and decision-making process. Managers had access to all necessary information to foresee a catastrophe, but they gave the go-ahead to launch *Challenger*, responding in part to budgetary and schedule pressure on the program. NASA spent just over two years making internal and technical changes following the commission's report. Altogether, 32 months elapsed between the loss of *Challenger* and the next launch (STS-26, *Discovery*, September 29, 1988).[69]

The *Columbia* Disaster

Columbia had several "near-miss" episodes prior to its destruction in 2003. Numerous problems in the first launch, on April 12, 1981, led to fears about the possible loss of the orbiter. Perhaps most strikingly, debris and ice struck the orbiter during liftoff, damaging some of its thermal protection tiles. Astronauts Crippen and Young could see missing tiles and dings in several places, but the real danger lay in parts of the vehicle not visible from the cabin: the wings and underbelly, which would experience the greatest thermal and aerodynamic forces during re-entry. Reflecting on the situation, NASA engineer Kenneth Iliff later wrote, "I don't know how Young and Crippen felt about it, but to me [the re-entry] did seem risky," because damage could change vehicle's flight profile or "get into the wing's aluminum structure and damage it to the point

where the vehicle could no longer fly." This, of course, is exactly what happened on STS-107.[70] Problems with the space shuttle main engines almost led to an in-flight abort during STS-93 (1999), when the shuttle ended up reaching a lower-than-planned orbit safely.[71]

On its final flight *Columbia* was engaged exclusively in research, conducting microgravity experiments and Earth observation studies from orbit. It had suffered damage during the launch of the STS-107 mission on January 16, 2003, when a large piece of insulating foam broke off of the external fuel tank and struck the orbiter's left wing, damaging the thermal protection system tiles on the leading edge of the wing. *Columbia* reached orbit safely. We cannot know the true extent of the damage with any certainty, but investigators eventually concluded that the foam must have knocked a 6-10 inch hole in the reinforced carbon-carbon panels that made up the wing's leading edge.[72] On Flight Day 2, a small object drifted away from the orbiter (the phenomenon was only discovered during the investigation through careful scrutiny of Air Force tracking radar data). This was probably a piece of the damaged tile.[73]

On the Saturday morning of February 1st, the vehicle de-orbited to land at the Kennedy Space Center. As *Columbia* passed through the atmosphere at incredibly high speeds, air friction steadily heated up the orbiter's leading edges, including the damaged wing panel. Normally the reinforced carbon-carbon panels keep this heat at bay, but the breach in panel 8 allowed a steady stream of superheated gas to flow into the orbiter's wing. The wing's shape is supported by an aluminum frame, and that frame soon began to melt.[74]

Pieces began falling off, and shuttle watchers in California saw flashes of light as the bits of the wing fell into the shuttle's shimmering plasma trail.

Because the orbiter's computer sensors did not report temperature measurements, the astronauts did not know what was going on, even as the spacecraft's entire wing structure began softening and deforming. Pieces began falling off, and shuttle watchers in California saw flashes of light as the bits of the wing fell into the shuttle's shimmering plasma trail. As the wing's shape changed, the orbiter began losing aerodynamic control. The spacecraft essentially flies on autopilot during most of the period after it enters the atmosphere, and the flight computers began trying to adjust to the problem, first by changing the orbiter's flaps, and then by firing its maneuvering rockets.[75]

As the shuttle flew overhead from California to Texas, the increasingly structureless wing steadily shed debris, and the computers continued fighting to hold the shuttle on-course. The tug of war continued until the shuttle reached Texas; as it passed over central Texas, the orbiter's left wing either folded over or broke off (it is impossible to know which). The orbiter immediately began to tumble, and, like *Challenger*, *Columbia* suffered a catastrophic break-up due to overwhelming aerodynamic forces.[76] *Columbia*'s crew perished immediately from a combination of cabin depressurization and high G-force trauma.[77]

Columbia: Emergency Response and Recovery Effort

With the disintegration of the *Columbia*, 1,459 debris reports came in from 42 states, Canada, Jamaica, and the Bahamas. Video telemetry indicated that *Columbia* was losing pieces west of California. However, the most westerly piece of the shuttle recovered was in Littlefield, Texas, and at the most easterly, in Fort Polk, Louisiana. This represented a debris corridor approximately 600 miles long.[78]

Terry Corbit, Jr., Field Measurements Technician for the Forest Resources Institute, directs searchers using mapping products produced at Stephen F. Austin State University. (Hardy Meredith, SFASU photo)

One of NASA's first responses to the accident—for purposes of investigation—was to "impound data, software, hardware, and facilities at NASA and contractor sites in accordance with the pre-existing mishap response plan" and to lock the door to Mission Control at the Johnson Space Center and other pertinent facilities. In addition, the NASA Mishap Investigation Team "was activated to coordinate debris recovery efforts with local, state, and federal agencies." The team moved from Barksdale Air Force Base in Louisiana to Lufkin and Carswell Field in Texas.[79]

Within a very short time after the accident, President Bush declared Texas and Louisiana federal disaster areas. This enabled sending of emergency response personnel from the Federal Emergency Management Agency (FEMA) and Environmental Protection Agency (EPA). Search and recovery activities took place from February 2 to May 10, 2003—particularly focused in Lufkin, Nacogdoches, San Augustine, and Hemphill. The work began immediately after the breakup of *Columbia*. Initially, local officials and volunteers searched the pine forests and thickets for human remains and shuttle debris. Local law enforcement groups and the National Guard protected the debris sites themselves. Researchers from Stephen F. Austin University—later to be part of what became the Columbia Regional Geospatial Service Center (CRGSC)—sent out teams with Global Positioning System (GPS) units to mark the exact debris locations. This data was used to update the distribution of debris on Geographic Information System (GIS) maps.[80]

The task was daunting for the local emergency personnel, the National Guard, and the Texas Department of Public Safety. Given the scale of the debris field, NASA and FEMA officials engaged the Texas Forest Service wildland firefighters to make up the primary

search teams.[81] FEMA was the overall lead agency for the search and recovery effort. The Federal Bureau of Investigation (FBI) had primary responsibility for collecting human remains. EPA became the lead agency for debris, decontamination, and collection. The Texas Forest Service was the lead state agency, responsible for planning and providing logistical support to federal operations. And NASA took the lead in information and intelligence.[82]

Under the direction of the Texas Forest Service, and co-sponsored by the U.S. Forest Service, Region 8, and FEMA, Region VI, 21 Incident Management Teams (IMT's) and 597 crews from the wildland fire service performed "a central response role" by conducting a ground search over 680,000 acres (the size of Rhode Island). Over all, searchers worked over 1.5 million hours covering more than 2.3 million acres in any area where debris was found. FEMA alone spent $305 million to fund the search. According to the Incident Management Team report, "The *Columbia* recovery operation was one of the largest in history, and it coincides with one of the most significant government reorganizations in history: the creation of the new Department of Homeland Security."[83]

The August 2003 report had a two-fold purpose: 1) to assess the response to the *Columbia* disaster, and 2) to assess the capacity of the IMT's to respond "to future Homeland Security missions." The events of September 11, 2001, had changed "the policy environment of the United States" and motivated, through the President's directive, federal agencies to support homeland security efforts of all kinds. The *Columbia* recovery also was central to prompting the efforts to assess and improve future incident management efforts, which included revising the National Response Plan and developing a National Incident Management System.[84]

Although the mission of the Department of Homeland Security focuses primarily on preventing terrorist attacks and minimizing damage from them if they occur, the *Columbia* operation and other response efforts provided lessons learned that IMT's could pass along to the department itself and to "the broader public safety community."[85]

Recovery search teams consisted of law enforcement personnel along with volunteer GPS specialists, and amateur radio operators.
(Hardy Meredith, SFASU photo)

Sue Kennedy, Nacogdoches County Judge, addresses the press as Nacogdoches County Sheriff Thomas Kerss looks on. (Hardy Meredith, SFASU photo)

Taking part in the search were approximately 270 government agencies, private companies and nonprofit groups, and more than 25,000 people (some of these outside the East Texas corridor), including countless volunteers. What made the effort imperative was not only the need to recover the crew and also to gather physical evidence critical to the investigation of the cause of the accident, but to protect the public from hazardous shuttle material and to provide necessary public assistance (especially financial assistance to local governments).[86]

Water and air searches complemented the land search. The United States Navy Supervisor of Salvage organized a water search of Lake Nacogdoches and Toledo Bend Reservoir, which were located in dense debris fields. In addition, 37 helicopters and seven aircraft also were deployed in the search. Often, sophisticated surveillance technology failed to penetrate the dense forests and thickets and thus spotter teams visually scanned the debris corridor. Civil Air Patrol volunteers and others also participated. Sadly, during the air search a helicopter crashed in San Augustine County, killing Jules F. "Buzz" Mier Jr., a contract pilot, and Charles Krenek, a Texas Forest Service employee. Three others were injured.[87]

The level of cooperation among government agencies, private groups, and the populations themselves was unparalleled. Overall, the response was well organized and jurisdictional tensions were at a minimum. Initially, however, "chaos and confusion" reigned, partly because FEMA was not accustomed to being the lead agency as opposed to supporting a state government. However, FEMA developed necessary flexibility in allowing the IMTs to utilize their collective expertise. Quite useful was the role of the Texas Forest Service as an intermediary in communicating essential information to many parties. The Texas Interagency Coordination Center worked well with the national resource distribution system, along with myriad volunteers, in providing necessary supplies and equipment.[88]

The IMTs were very positive about their interactions and contacts with local communities during the search and recovery. This included a "high level of local support and generosity." The teams felt "warmly welcomed" by local residents, which was

particularly important because the search was to be conducted on large areas of private land.[89]

The IMT report made it clear that several issues raised by *Columbia* "apply to all-risk incidents more broadly." These included: 1) the need to determine the complexity of any incident to determine the necessary expertise to address it; and 2) human resource management in situations where a variety of agencies need to work together.[90]

Approximately 38 percent of the spacecraft, more than 84,000 pieces weighing more than 84,900 pounds was recovered; the lion's share of these were located in East Texas.[91] This remarkable search and recovery underscores not only the federal and state effort, but emergency management preparedness that was in place in the region. As the IMT report suggests, the response to the *Columbia* disaster had impacts beyond the event itself, including future planning for the Department of Homeland Security.

Another important offshoot of the search and recovery activity was the emergence of the Columbia Regional Geospatial Service Center (CRGSC) and its heightened role in emergency response. The center (renamed after the *Columbia* disaster) has four regional geospatial centers at Stephen F. Austin State University in Nacogdoches, Texas; University of Texas at El Paso; Texas Tech University in Lubbock; and Lamar University in Beaumont. The Nacogdoches site is primarily engaged in issues related to forestry, rural mapping, questions related to 9-1-1, and economic development. It promotes itself as "the prototype for a system of regional geospatial service centers across Texas" and a national model "demonstrating the benefit of a regionally distributed, bottom-up approach to geospatial technology for emergency response, economic development and natural resource management."[92]

Volunteer GPS operators check setting on their receivers before deploying with search teams.
(Hardy Meredith, SFASU photo)

CRGSC's primary mandate has been to provide geospatial support for emergency response and preparedness in an area where serious hurricane events, not to mention the *Columbia* disaster, have taken place. It refined its approach—quick and effective local response—"through first-hand experiences during the Space Shuttle *Columbia* recovery effort [acknowledged in the CAIB report], and later through hurricanes Katrina and Rita." It follows the maxim not unlike IMT's that "all disasters are local."[93] However, the implications of the CRGSC program are and have been transferrable to other areas.

The predecessors of CRGSC—the Forest Resources Institute (FRI) and the Humanities Urban Environmental Sciences Laboratory (HUES) at Stephen F. Austin—"rose to international attention" and demonstrated the capabilities of "geospatial first responders" with the *Columbia* disaster, supporting to first responders during the early stages of the recovery with hundreds of maps and other imagery.[94] GIS technology uses computers to combine traditional cartographic data, such as satellite photos, plat maps, and topographic information, with other types

Jeff Williams, GIS technician with the Forest Resources Institute, Stephen F. Austin State University during the early days of the response effort. (Hardy Meredith, SFASU photo)

of information to produce precise, up-to-date maps. According to P.R. Blackwell, Director of CRGSC, the mapping effort during the recovery activities demonstrated the usefulness of this technology as an emergency response tool in several ways.

1. The images produced using GIS proved useful in controlling the flow of information to the public during the search effort. GIS maps shown to the media, for example, drew attention away from some of the more sensitive search areas, especially Hemphill, where the human remains were found.
2. Combining the information from the different search teams helped investigators to better target their efforts. FRI and HUES developed the "Primary Search Vector" during the first few days of the search and recovery, which substantially aided the search activity.[95] As they worked, search teams carried GPS devices, which they used to log the precise location where they found pieces of debris. By looking for patterns in the debris field, coordinators could make educated guesses about where as-yet-unlocated pieces of the orbiter might have landed. Using this technique, the search teams successfully located *Columbia*'s modular auxiliary data system (MADS) recorder in a previously-searched field where it had been missed. The MADS recorder, which performed a function similar to the "black box" flight data recorder on a commercial airplane, proved invaluable in settling the question of what caused *Columbia*'s demise.[96]
3. In addition to manipulating information, FRI and HUES provided an even more basic, yet critical, service to the search effort: GIS maps helped people to get to where they needed to be. Because much of the debris fell in remote locations, it was a challenge for search teams to reach some of the likely debris sites. By combining resources like satellite photographs, county road maps, and non-road resources, like utility corridors, GIS made it possible for searchers to get accurate, detailed, up to date maps that allowed them to reach and coordinate efforts in remote, difficult to access locations. Without this tool, efforts in remote areas would have been severely hampered.[97]

By demonstrating these useful applications of GIS technology, the *Columbia* disaster brought national and international attention to the value of GIS mapping itself in cases of emergency management. Those on the ground were deeply impressed with the geospatial tools provided, a fact reflected in the CAIB report, and Congress, in the spring of 2005, allocated $4.1 million to fund the consolidation of HUES and the GIS component of FRI into the CRGSC for the specific purpose of providing "emergency planning and response" for the greater East Texas region.[98]

That investment paid off almost immediately, when Hurricane Rita struck the region just a few years later, in September of 2005. FEMA officials, local police, and emergency responders all relied on CRGSC, as described by P.R. Blackwell, for exactly the same sorts of data they had used in the *Columbia* recovery operation: "strategic maps for planning, operational maps for rescue teams in the field,

analytical maps that combine data sets to assist in official decision-making and maps for media purposes." By the end of operations, the CRGSC had produced more than 1,400 such maps and attracted further federal interest, including additional grant money from the Department of Defense, and the program was expanded to include new regional centers at the campuses of the University of Texas: El Paso, Texas Tech University, and Lamar University.[99]

Columbia: Local Voluntarism and Local Recovery Responses

The local response to the disaster and its very impressive participation clearly reflected a deeply felt reaction to the human tragedy. The *Columbia* disaster, however, was so much more than a random accident to the people of East Texas. In some respects less tangible than the other themes, but probably most poignant, was the extraordinary level of voluntarism driving the local recovery activities in Lufkin, Nacogdoches, San Augustine, and Hemphill as well as other Texas and Louisiana communities. In many respects, the level of voluntarism and participation was indicative of the support for the space program itself—as stated by several local officials—as well as for the astronauts who died and their surviving families.

The commitment of the local populations of Lufkin, Nacogdoches, San Augustine, Hemphill, and the surrounding areas to the recovery activities after the *Columbia* disaster was a testament to several characteristics in the American identity: love of place, love of God, love of country. These feelings were expressed in a documentary about the disaster, *Of Good Courage,* produced by David Perry and David Wayne, and winner of film awards in 2006-2007. The film also details the role of the community of Hemphill in the various recovery activities, mirroring what was going on in the other communities within the debris corridor.

Chow line at the Nacogdoches County Emergency Operations Center. Many businesses and individuals volunteered to feed the emergency workers throughout the response.(Hardy Meredith, SFASU photo)

The local participation in the recovery activities was disproportionate to the size of the communities and included people of all classes and races. Many of the East Texas towns and cities in the area are among the hardest hit economically in the last decade. Yet, their participation in the recovery activities grew out of more than compassion for the families who lost loved ones in the disaster, but out of a sustained effort to rely upon local people and local resources in difficult times.

This story of voluntarism is not unique *per se*; examples can be found throughout U.S. history in small town America and elsewhere. Nevertheless, it is an integral and abiding part of the story of the *Columbia* recovery effort, putting a human face on the task at hand to recover the crew's remains and important evidence to effectively evaluate what went wrong.

The Columbia Accident Investigation Board Report

As in the case of *Challenger*, a national safety panel, the 13-member "Columbia Accident Investigation Board" (CAIB), was convened and tasked with investigating the disaster. It was "established within two hours of the loss of signal from the returning spacecraft in accordance with procedures established by NASA following the *Challenger* accident 17 years earlier." Its work lasted seven months until August 2003.[100] CAIB's staff numbered more than 120, along with approximately 400 NASA engineers in support. Investigators examined more than 30,000 documents, conducted more than 200 formal interviews, heard testimony from several expert witnesses, and received additional information from the public. On the ground, more than 25,000 searchers worked to recover spacecraft debris at various sites in the western United States, especially in East Texas.[101]

CAIB began its report on a positive note: "NASA is a federal agency like no other. Its mission is unique, and its stunning technological accomplishments, a source of pride and inspiration without equal, represent the best in American skill and courage."[102] The body of the report, however, quickly moved beyond accolades.

Like the Rogers Commission, the CAIB went beyond investigating the specific physical cause of the *Columbia* accident. In its view, "complex systems almost always fail in complex ways," and thus it was necessary to go beyond a simple explanation of the disaster and its causes. CAIB identified three categories of factors: 1) physical failures of the shuttle; 2) weaknesses in NASA's organization and history; and 3) "other significant observations."[103]

NASA complex, Kennedy Space Center, Florida. (NASA/Frank Michaux photo)

The Board focused on NASA's history and human space flight culture, believing that the accident was "probably not an anomalous, random event, but rather likely rooted to some degree" in organizational shortcomings of NASA itself and the shuttle program in particular. The most important of these appeared to be original compromises that were required to get approval for pushing forward the shuttle missions, historic budget constraints, changing priorities, schedule pressures, viewing the shuttle as 'operational' rather than 'developmental,' and "lack of an agreed national vision for human space flight." It added, "Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past success as a substitute for sound engineering practices. . .; organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision making processes that operated outside the organization's rules."[104]

In its strongest statement in the report, CAIB concluded: "We are convinced that the management practices overseeing the space shuttle program were as much a cause of the accident as the foam that struck the left wing."[105]

CAIB viewed the shuttle in general as "a compromise vehicle that was less than optimal for manned flights," essentially turning on its head the argument that the space shuttle demonstrated flexibility in carrying out a variety of tasks.[106]

The report emphasized the "inherently vulnerable design of the space shuttle," which it dated from its point of approval in 1972. "That approval process," it added, "also produced unreasonable expectations, even myths, about the shuttle's future performance that NASA tried futilely to fulfill as the shuttle became 'operational' in 1982…At the beginning of 1986, the goal of 'routine access to space' established by President Ronald Reagan in 1982 was ostensibly being achieved. That appearance soon proved illusory." The event that undermined the credibility of the program was the explosion of the *Challenger* on January 28, 1986. The Rogers Commission, in its June 6, 1986 report, concluded that the loss of *Challenger* was "caused by a failure of the joint and seal between the two lower segments of the right solid rocket booster."[107]

Like the case of the *Columbia*, the *Challenger* disaster also was attributed to a series of poor decisions that increased the risk of a catastrophe over time. The Rogers Commission also believed that NASA officials had access to enough information to determine that there was a significant danger of exactly the shattering event that happened, but they chose not to act on that information.[108]

The *Challenger* accident had a major impact on the U.S. Space Program. President Reagan announced that NASA would no longer launch private satellites; the Air Force and intelligence groups would no longer use the shuttle for its national security payloads; efforts would be made to find alternative technologies. It took NASA 32 months after the *Challenger* accident to redesign and requalify the solid rocket booster and to return the shuttle to flight. The first post-accident flight was launched on September 29, 1988.[109]

After the Rogers Commission report, NASA made many of the organizational changes the commission recommended. In the years between the return to flight and the *Columbia* disaster, orbiters were being used for research in space. In the fifteen years since the *Challenger* explosion, shuttles flew 87 missions, compared to only 24 before then.[110] It took NASA until July 26, 2005, to resume manned flights after the *Columbia* disintegration, with remaining uncertainty about the future fate of the shuttle program itself.

CAIB member and former astronaut Dr. Sally Ride (who also served on the Rogers Commission) believed there were "echoes" of *Challenger* in the *Columbia* disaster. Given how the two investigatory bodies viewed the events, her comments seem apt. The CAIB report concluded that "both the accidents were 'failures of foresight' in which history played a prominent role."[111]

Yet even with the comparison between the two disasters, CAIB still asserted that "The loss of *Columbia* and her crew represents a turning point, calling for a renewed public policy debate and commitment regarding human space exploration."[112]

Despite the criticisms of CAIB, *Columbia* exemplified many of the things that had gone right with the space shuttle program. True to its name, the first orbiter had spent 20 years traveling back and forth between Earth and orbit. In 23 missions, *Columbia* had carried astronauts and communications satellites, secret Department of Defense payloads and high profile foreign emissaries.

Columbia *wreckage at Kennedy Space Center. (NASA photo)*

Columbia, more than any other orbiter, had spent her career in the pursuit of science. The orbiter's final flight carried the newest and last of the shuttle-mounted laboratory modules, a spacious unit called "Spacehab," which the astronauts used to carry out 85 different experiments ranging from insect studies designed by school children to a "pure science" experiment that used low-power flame balls (difficult to produce outside a microgravity environment) to examine the process of combustion to medical research conducted using the crew's own bodies. Even after the crash, a great deal of this research survived, either in the form of data sent back to Earth ahead of time or in experiments whose protective casings made it possible to recover them amongst the debris.[113]

After the accident investigation of the *Challenger* disaster was completed, NASA buried the wreckage in two abandoned *Minuteman* missile silos at Cape Canaveral. With *Columbia*, by contrast, the space agency has painstakingly preserved all of the wreckage in a storeroom on the 16th floor of the Vehicle Assembly Building—the same building where *Columbia* was mated to its external fuel tank and solid rocket boosters prior to the ill-fated STS-107 mission. All 42 tons of the wreckage is catalogued, bar-coded, and (where necessary) bubble-wrapped, and a banner signed by the shuttle preparation and debris-recovery teams hangs in the room. The various cards and letters of sympathy sent in by the public following the accident are also stored here. Debris taken from the crew module is in a special, walled-off section. Only a few people have the key to the room, but NASA has made the debris available, with program approval, for analysis, especially with respect to material failure in re-entry environments,

A Reconstruction Team member uses 1:1 engineering drawings as a tool in the process of identifying recovered RCC debris material. (CAIB Photo-no photographer listed. 2003)

for which, after all, there remains a relative paucity of evidence. NASA has expressed the hope that *Columbia*'s wreckage may one day lead to the design of safer spacecraft and the prevention of future tragedies. In the words of NASA Deputy Administrator Fred Gregory, "*Columbia* will forever be used as a learning opportunity."[114]

Post-*Columbia:* Shuttle Retirement

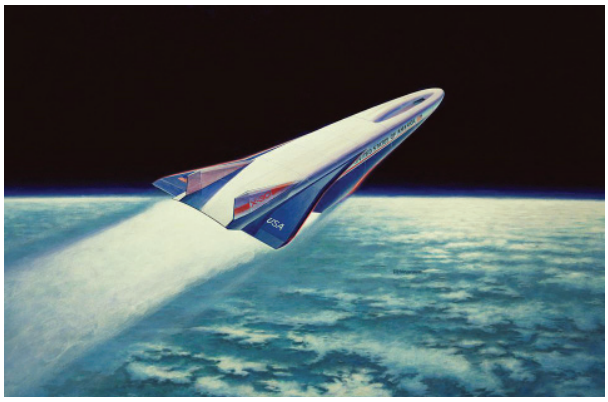
In the aftermath of STS-107, NASA faced short, medium, and long-term questions about the future of the shuttle fleet. The short-term issues, which the board described as "Return to Flight" issues, were primarily technical.[116] In response to the circumstances that led to the loss of *Columbia* and her crew, the Columbia Accident Investigation Board demanded that the space agency address four technical issues: 1) preventing foam-shedding during liftoff; 2) devising a means to inspect the orbiter for damage after liftoff; 3) providing shuttle crews with a means to repair the orbiter in the event of damage; 4) creating a rescue capability for future crews trapped in a damaged shuttle. NASA's "Return to Flight" task group approved solutions to each of these problems, although foam-loss continued to be an issue on flights after *Columbia*.[117]

The medium-term, or "Continuing to Fly," question for NASA was more difficult, and it revolved around the issue of culture.[118] The CAIB recommended that the space agency change a variety of management practices with regard to shuttle flights, and NASA followed these recommendations. The agency shifted control of the space shuttle program away from the Johnson Space Center and back to NASA Headquarters, and established new, independent safety organizations and procedures to act as unbiased checks on the authority of mission-oriented managers. It created new lines of communication that would theoretically allow alternative channels for engineers with safety concerns.[119]

With regard to the CAIB's recommendation that NASA change its "culture," however, the space agency struggled to interpret the board's mandate.[120] It hired a private contractor, Behavioral Science Technology (BST), to do agency-wide cultural surveys, make recommendations, and implement programs, but the results of this effort seemed mixed at best. When a new administrator, Michael Griffin, took over the agency in 2005, he terminated the BST contract, preferring to focus instead on the aforementioned strengthening of alternative communications channels and processes.[121]

The long-term question was twofold: Should NASA continue to rely on the shuttle system for the foreseeable future? At what level and for what mission was the U.S. willing to support the space agency? As the CAIB report explained at length, this discussion was not new; in fact, questions about the future of the shuttle program had arisen as early as 1986, when a Congressionally chartered policy group, the National Commission on Space, issued a January report predicting

obsolescence for the orbiter fleet by the turn of the century and calling for the creation of a replacement vehicle.[122] The subsequent loss of *Challenger* that same year only added impetus to this analysis. President Reagan, speaking just nine days later, called for the development of a second-generation reusable launch vehicle, eventually called the "National Aerospace Plane" (NASP), that "could, by the end of the decade, take off from Dulles Airport," accelerate up to Mach 25, and either reach low-Earth orbit or "fly to Tokyo within two hours."[123]



Artists concept of the X-30 aerospace plane flying through Earth's atmosphere on its way to low-Earth orbit. (NASA photo)

Unfortunately, the NASP project's objectives, according to NASA engineer Kenneth W. Iliff, proved "far too grandiose"; Iliff likened it to "the Wright brothers trying to design an SR-71 as their first flight vehicle." According to the engineer, the NASP proposal "went beyond what the laws of physics told us we could do." As a result, in spite of being "the only focus of hypersonic research from the mid-1980s until the early 1990s," the NASP program "failed to build a vehicle of any kind," much less a replacement for the orbiters, and left in its wake "little more than a huge stack of view graphs, a lot of disappointed people, and a substantial loss of credibility by NASA."[124]

As the CAIB notes, the NASP debacle created a pattern – "optimistic pronouncements about a revolutionary shuttle replacement" eventually followed by "program cancellation due to technical difficulties," often in the face of budget cuts – that "was repeated again in the 1990s" with the X-33 and X-34 programs. In 1986, the year 2000 had represented a rough goalpost for retiring the shuttle program. Under the auspices of the X-33 and -34 programs, as detailed in a NASA headquarters "Access to Space Study," the goalpost for replacing the orbiters with a new vehicle would shift to 2006—a goal which fell by the wayside when NASA abandoned the programs in 2001.[125]

In May of 2001, Homer Hickam, the former NASA engineer and popular author, gave a paper at the "Looking Backward, Looking Forward" symposium celebrating the 40th anniversary of U.S. human spaceflight. In the shadow of the X-projects' demise, Hickam dissected the problem bluntly: "The Bush administration here in Washington is even now trying to figure out what to do with NASA. It's a problem. President George W. Bush knows, as all of us know when we are honest, that we are essentially spinning our wheels as far as spaceflight is concerned."[126] In the meantime, NASA kept the shuttle program flying. The agency had no choice—it needed a vehicle capable of lifting components and crews up to the incomplete International Space Station (ISS). And when the agency, under another new presidential administration, made another attempt at planning for a future vehicle, the new vision incorporated the existing orbiter fleet as an essential component, proposing to extend the shuttle program's life rather than simply retiring it.

When *Columbia* flew her final mission, NASA was operating under a new management initiative, known as the "Integrated Space Transportation Plan" (ISTP), released in

Space shuttle Discovery *docked to the Destiny laboratory of International Space Station. (NASA photo)*

November 2002.[127] Like previous plans, the ISTP called for the development of a new vehicle, described in the NASA press releases as "an Orbital Space Plane" that could "ferry space station crew members and to ensure that a capability exists to get the crew home if there's an emergency." Unlike previous plans, however, the ISTP envisioned the new vehicle as a complement to the orbiter fleet rather than a replacement for the shuttle program. According to Sean O'Keefe, NASA's chief administrator at the time, the purpose of the new, smaller vehicle would be to "[free] up the orbiter fleet to focus on heavy cargo delivery."[128] The existing shuttles would in turn receive upgrades under the "Shuttle Service Life Extension Program beginning in Fiscal Year 2004. NASA would continue to schedule orbiter missions until at least 2010, at which point the agency would decide how much further to extend the shuttle program. An illustration accompanying the report, reprinted in the CAIB report, showed a chart with two tapered bars representing the two most likely scenarios for the shuttle program. One bar extended to 2016; the other tapered off in 2022. The Bush administration publicly endorsed this plan, explicitly accepting the logic that the orbiter fleet would continue to fly for at least the next sixteen years.[129]

Just a few short months later, *Columbia* broke up in the skies over Texas. In the aftermath of the disaster, the CAIB, through its report, began to raise very serious questions about the wisdom of extending the orbiter fleet's service life. The board suggested that NASA, if it wanted to fly orbiters after 2010, should undertake a comprehensive "recertification" process to assess the safety of the fleet against its original design considerations and mandates.[130] This demand all but doomed the shuttle program, which, as previously discussed, had never been able to live up to its original design mandates in the areas of safety and reliability, durability and reusability, or cost.[131] The CAIB moreover, identified a variety of other problems with the program in general, including neglect and disrepair

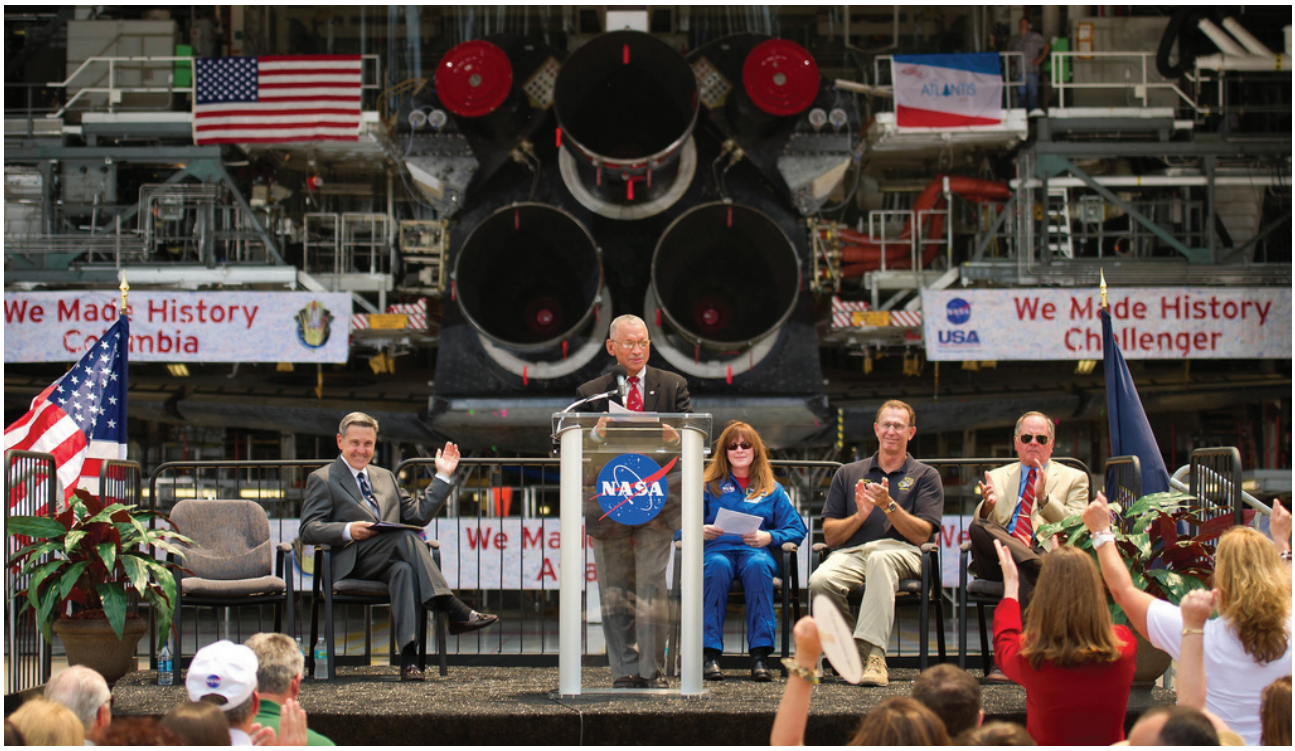
at the various facilities devoted to orbiter maintenance and a shortage of properly-trained personnel for shuttle program operations. The board concluded these conditions reflected an underlying problem: NASA did not have a large-enough budget to support safe shuttle operations over a long period. The Bush administration did not pursue increased funding for the agency. Instead, President Bush explicitly scrapped the ISTP and accepted the retirement of the orbiter fleet with the President's "Vision for Space Exploration" speech in January 2004.[132]

The "Vision for Space Exploration" replaced the Orbital Space Plane with yet another new set of launch vehicles and crew modules, the *Ares* class rockets. In a reversal of the previous plan, however, the President declared that these new vehicles would replace the shuttle program, rather than supplementing it, and rather than looking to 2010 as the time for assessing the future of the orbiters, President Bush called on NASA to complete construction of the International Space Station by 2010, and to retire the shuttle fleet immediately thereafter. This explicit timeline represented a serious departure from previous plans, all of which predicated the end of the shuttle program on the success of a new launch vehicle. President Bush made it clear that, if necessary, NASA would have to accept a gap in time where it would not have a launch vehicle in order to retire the shuttle fleet.[133]

The "Vision for Space Exploration" represented a major departure from the "Integrated Space Transportation Plan" that the administration had endorsed just a few months before the *Columbia* disaster. Moreover, President Bush's plan abandoned the underlying "space truck" model of the shuttle program. Far from envisioning a renewed national commitment to funding space exploration, the plan promised to abandon the expensive, multi-purpose orbiter and replace it with cheaper, simpler alternatives: capsule-style spacecraft, strongly reminiscent of the *Apollo* and *Gemini* programs. A prime feature of this plan, the administration argued, was that NASA could pursue exciting new exploration goals, including a return to the moon, without needing major funding increases.[134] Given the administration's previous support of the ISTP and its efforts to reorganize NASA's budget and find funds for the specific purpose of upgrading the orbiters and extending their service life, it seems clear that the impetus for these dramatic shifts in focus and policy arose from the *Columbia* tragedy and the CAIB's report.

In essence, the* Columbia *disaster effectively ended the nationally significant U.S. Space Shuttle Program.

The Barack Obama administration has not entirely embraced the "Vision for Space Exploration," but it has reconfirmed that the orbiter fleet has reached the end of its working life. In his 2010 signature policy speech outlining the administration's plan for NASA, President Obama left no room for a further extension of the shuttle program's life, describing its retirement as a settled matter, "based on a decision that was made six years ago, not six months ago." Besides this and a few other brief references, the shuttle program received relatively little attention in the President's speech, and the *Columbia* disaster went unmentioned.[135] These absences, as much as the things that President Obama said, leave no doubt that the change in NASA's future direction brought on by *Columbia*'s demise brought the shuttle program to its final act. In essence, the *Columbia* disaster effectively ended the nationally significant U.S. Space Shuttle Program.



NASA Administrator Charles Bolden announces where four space shuttle orbiters will be permanently displayed at the conclusion of the space shuttle program. (NASA photo)

As part of the preparations for retiring the space shuttle program, NASA announced it would dispose of, reuse, sell or donate properties related to the program, including the three remaining shuttles. Competition for the decommissioned shuttles that had played a key role in America's space program was fierce, both politically and in cities that felt a connection to the shuttle program.[136] This despite NASA's estimated costs and complexities of acquiring one: $42 million—$28.2 million to remove hazardous materials from the shuttle, $5.8 million for transportation, and $8 million to help get the shuttle ready for public display in a "climate-controlled indoor display space."

NASA also required potential shuttle recipients to have the ability and funds to make sure they would be kept in good condition. And it pointed out that transportation of a shuttle would be daunting. After a shuttle is drained of all chemicals, it weighs about 170,000 pounds, meaning a carrier aircraft would be required to move the shuttle to a landlocked location.[137]

On April 12, 2011, the 30th anniversary of *Columbia*'s first shuttle launch, NASA Administrator Charles Bolden announced NASA's decision for the disposition of the program's artifacts.

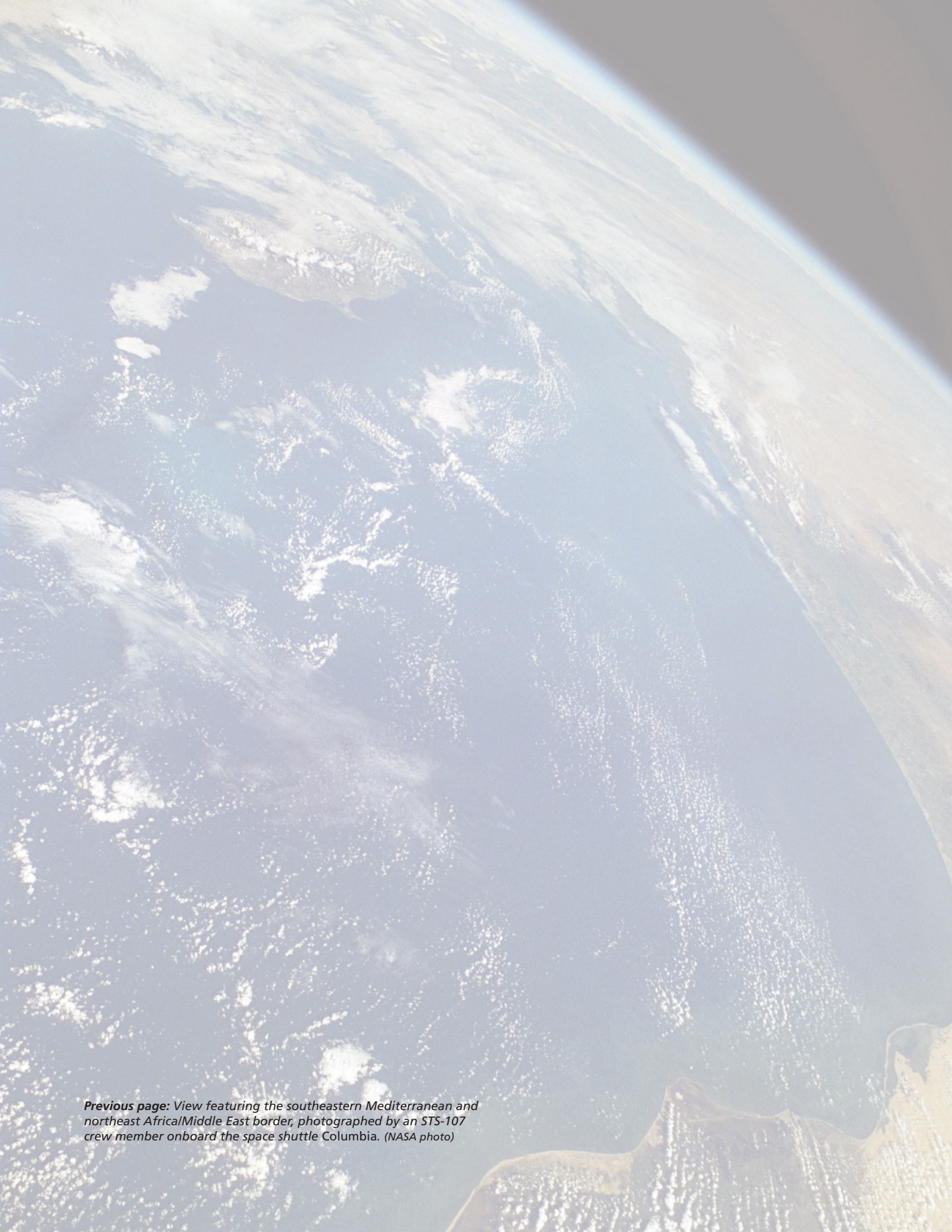
- The Smithsonian's National Air and Space Museum Steven F. Udvar-Hazy Center in Chantilly, Virginia would become the new home for the shuttle *Discovery*. The craft was retired after completing its 39th mission in March 2011.
- The shuttle *Enterprise*, NASA's first unpowered prototype orbiter, would be moved from the Smithsonian's Udvar-Hazy Center to the Intrepid Sea, Air & Space Museum in New York City, New York.
- The shuttle *Endeavour*, which was NASA's fifth orbiter and flew its final mission in May 2011, would go to the California Science Center in Los Angeles, California.

- The shuttle *Atlantis*, which was scheduled to fly its final mission in July 2011—officially ending America's shuttle program, would be displayed at the Kennedy Space Center Visitor's Complex in Florida.

NASA also announced that hundreds of shuttle artifacts would be allocated to museums and education institutions.

"We want to thank all of the locations that expressed an interest in one of these national treasures," Bolden said at the time. "This was a very difficult decision, but one that was made with the American public in mind. In the end, these choices provide the greatest number of people with the best opportunity to share in the history and accomplishments of NASA's remarkable space shuttle program. These facilities we've chosen have a noteworthy legacy of preserving space artifacts and providing outstanding access to U.S. and international visitors."[138]

Evaluation of National Significance



Previous page: *View featuring the southeastern Mediterranean and northeast Africa/Middle East border, photographed by an STS-107 crew member onboard the space shuttle* Columbia. *(NASA photo)*

Historical Significance of the *Columbia* Disaster

Ordinarily, events that have occurred within the past fifty years are difficult to characterize as historically significant. However, under National Historic Landmark criteria, if it can be demonstrated that an event has extraordinary national importance, an exception may be granted to ensure preservation of the recent past. This category is called *Exception 8*, which is sometimes referred to as the 50-year rule. National Register Bulletin 22, "Guidelines for Evaluating and Nominating Properties that Have Achieved Significance Within the Past Fifty Years," provides the framework for assessing the historical significance of the 2003 *Columbia* disaster.

"Their Mission became our Mission…the mission of returning the* Columbia *and her crew home."

The guidelines observe, "The passage of time allows our perceptions to be influenced by education, the judgment of previous decades, and the dispassion of distance." Furthermore, the guidelines indicate that properties should not be determined to be historically significant "solely for their contemporary impact and visibility." The *Columbia* disaster was an event that captured the world's attention and had a profound emotional impact on crew member families, NASA, and all who participated in the recovery effort. This is also true for the communities across East Texas where a majority of shuttle debris and crew member remains were recovered. Not only did they host thousands of recovery workers but many also played a critical role in the recovery effort, as they best knew the terrain and how to navigate through it. East Texans are still very much emotionally connected to their role in the recovery and are committed to bringing closure to this event through the realization of a fitting tribute to the cabin and crew. It has been difficult to separate the discussion of the historical significance of the disaster event from the compelling stories of the recovery effort. The Sabine County Columbia Memorial Committee characterized the community's focus at that time as "Their Mission became our Mission…the mission of returning the *Columbia* and her crew home."[139]

It is especially challenging to be dispassionate and to achieve a historical perspective for an event that occurred just over 11 years ago, resulted in the loss of human life, and continued to influence the course of the U.S. Space Program throughout much of this study effort. However, there are some very compelling initial conclusions that can be made regarding the event's national significance:

1. NASA's space shuttle program, officially, the Space Transportation System (STS), marked a major shift in the United States Space Program. After the Apollo program, NASA transformed from a program focusing on space exploration to one emphasizing space utility. Between 1981 and 2011, the space shuttle program provided a new method of space flight, taking off like a rocket and landing like an airplane. *Columbia*, the first reusable manned spaceship, initiated the Space Shuttle flight program in April 1981 and this new era for the U.S. Space Program. The role of Space Shuttle *Columbia* prior to the disaster is an integral part of NASA's major shift. In other words, *Columbia* had an important association with a nationally significant broad pattern of history, in this case the shuttle program, even before its tragic disintegration on February 1, 2003.

   In contrast, the crash of the *Columbia* on February 1, 2003 over East Texas and the subsequent findings of the Columbia Accident Investigation Board marked the beginning of the end of the shuttle

program and the United States' re-examination of human spaceflight.

2. The focus of space utility is central to NASA's history, the history of the space program, and flight itself. It is an integral part of the historical theme of "Man in Space".
3. The large body of reports and secondary materials on NASA, the space program in general, and the various studies of disasters including the *Challenger* and *Columbia* offer an extensive body of literature upon which to contextualize the event.

Therefore, the space shuttle *Columbia* disaster is considered a nationally significant event; it is of exceptional importance to the Nation because of the enduring value of the shuttle's historical association with the beginning and end of the U.S. Space Shuttle Program.

National Significance Evaluation of the East Texas Study Sites

Methodology

National Park Service management policies require the use of National Historic Landmark (NHL) criteria (36 CFR Part 65) in establishing national significance for cultural properties under special resource study consideration. There are two key factors for finding historic resources eligible for NHL designation: 1) the site must illustrate nationally significant stories, persons, or events; and 2) districts, sites, buildings, structures or objects must possess high level of physical integrity.

Proposed additions to the national park system must also meet the following four National Park Service standards for national significance.

1. The area must be an outstanding example of a particular resource type.
2. The area must possess exceptional value or quality in illustrating or interpreting the natural or cultural themes of our nation's heritage.
3. The area must offer superlative opportunities for public enjoyment or for scientific study.
4. The area must retain a high degree of integrity as a true, accurate, and relatively unspoiled example of the resource.

NHL and NPS criteria are very similar, with the exception of item 3 under the NPS standards for significance, which requires that the site "offers superlative opportunities for public enjoyment or for scientific study." To help simplify the presentation, an assessment of the NHL specific criterion is addressed first, followed by an assessment of the four NPS standards for significance.

National Historic Landmark Criterion

For the purposes of this study, National Historic Landmark Criterion #1 was used because (1) the space shuttle program marked a major shift in the United States Space Program from an emphasis on space exploration to a program focused on space utility; (2) the space shuttle *Columbia* prior to the disaster was an integral part of NASA's major shift; and (3) the *Columbia* disaster effectively brought an end to the U.S. Space Shuttle Program.

National Historic Landmark Criterion #1 states:

> *Properties that are associated with events that have made a significant contribution to, and are identified with, or that outstandingly represent the broad patterns of United States history and from which an understanding and appreciation of those patterns may be gained.*

Under this criterion, events associated with the property must be outstandingly represented by that property and the events be related to the broad national patterns of U.S. history. Thus, the property's ability to convey and interpret its meaning must be strong and definitive and must relate to national themes. The property can be associated with either a specific event marking an important moment in American history or with a pattern of events or a historic movement that made a significant contribution to the development of the United States.

The following table summarizes the evaluation of each study site's level of association with the *Columbia* disaster:

PROPERTY	LOCATION	NHL Criterion #1- Level of Association with the *Columbia* Disaster Event
Lufkin Site	Louis Bronaugh Park. City of Lufkin, Angelina County	While the Lufkin site (Louis Bronaugh Park) represents the community's representative reflection of its overall association with this nationally significant event, the site did not play a role during the *Columbia* disaster or the related recovery effort. Therefore, this property does not meet NHL Criterion #1.
Nacogdoches Site	City of Nacogdoches, Nacogdoches County	While this study site represents the community's preferred location for commemorating *Columbia* and her crew, the site did not play a role during the *Columbia* disaster or the related recovery effort. Therefore, this property does not meet NHL Criterion #1.
San Augustine Site	San Augustine County Fairgrounds. City of San Augustine, San Augustine County	The statistical centerline of the shuttle debris corridor travels through San Augustine County, while the city of San Augustine and the county fairgrounds are found within the northern edge of this corridor. The county proved to be one of the key search areas for *Columbia* and her crew, the greatest concentration of shuttle debris was recovered here along with the partial remains of some crew members. The San Augustine County Fairgrounds has an **important association** with the *Columbia* recovery effort, as this site was used as a key staging area during the recovery effort and the north building was used to temporarily stockpile collected shuttle debris.
Hemphill Site	Sabine County	The city of Hemphill and Sabine County are found along the statistical centerline of the shuttle debris corridor. The entire county proved to be a key search area for the *Columbia* and her crew, where shuttle debris including the Orbiter Experiments Recorder, a tape recorder that stored key data about the shuttle's performance during re-entry were recovered. The partial remains of all seven crew members were also recovered within Sabine County. The Hemphill site has an **important and symbolic association** with the *Columbia* disaster and the related recovery effort, as this is the site where *Columbia*'s nose cone was recovered.
Neches River National Wildlife Refuge Site	Neches River National Wildlife Refuge, Anderson and Cherokee Counties	The statistical centerline of the shuttle debris corridor travels through Anderson and Cherokee Counties, including the Neches River National Wildlife Refuge. Early shuttle debris reports from Anderson County were used by the geospatial first responders in Nacogdoches to establish the primary search vector mapping for recovery teams. The Neches River National Wildlife Refuge has an **important association** with the *Columbia* disaster and the related recovery effort as almost 60 remnants from the shuttle were recovered there.

Summary of NHL Assessment

While three of the study sites have an important association with the *Columbia* recovery effort, only two sites, Hemphill and Neches River National Wildlife Refuge, have an important association with both the *Columbia* disaster and the related recovery efforts, and therefore best meet NHL criterion #1. Both sites have the potential for providing understanding and appreciation of this nationally significant event. They also retain a high degree of integrity as their undeveloped landscape settings have remained relatively unchanged since the time of the disaster. While the extensive shuttle debris field makes it difficult to pinpoint any singular location to best exemplify the *Columbia* disaster, the Hemphill site where *Columbia*'s nose cone was recovered could be considered the symbolic representation of *Columbia*'s final return to Earth. The county is also the only area where the remains of all seven crew members were recovered.

NPS Standards for National Significance

This section focuses on the degree to which each of the two study sites (Hemphill/Sabine County and Neches River National Wildlife Refuge) that best meet NHL criteria also meet National Park Service standards for national significance.

1) Outstanding example of a particular type of resource

What was left of the space shuttle *Columbia* after the crash has been recovered and placed in storage at the Kennedy Space Center. However, the East Texas landscape setting where the disaster took place has been well preserved at Hemphill and Neches River National Wildlife Refuge. These sites represent the relatively rural setting of the pineywoods ecoregion of East Texas where *Columbia* made its final return to Earth.

2) Exceptional value or quality in illustrating or interpreting the themes of our Nation's heritage

There is no better place to illustrate history than in the actual setting where events took place. Both sites possess the potential for exceptional value or quality in illustrating and interpreting the *Columbia* disaster event, the massive recovery effort that immediately followed the tragedy, and how the recovered debris became an essential component for the Columbia Accident Investigation Board in understanding the important details of the accident scenario. Without it there would be significant uncertainty in the cause and the location of the initial damage to the *Columbia*.[140] The findings of the Columbia Accident Investigation Board ultimately influenced President Bush's decision to retire the U. S. Space Shuttle Program.

Categories appropriate under the NPS Thematic Framework include:

Primary Theme: Expanding Science and Technology – The American Space Program

The *Columbia* disaster was the catalyst for ending the U.S. Space Shuttle Program. The relationship of the East Texas properties to the *Columbia* disaster is particularly strong when connecting the recovery activities to the disaster and the disaster to the retirement of the U.S. Space Shuttle Program. The East Texas sites are the places where not only *Columbia* made its final return to Earth, but where the U.S. Space Shuttle Program was brought to an end—symbolically if not practically. This relationship makes for a compelling story—one that reveals important issues relevant to our national history.

Secondary Theme: Changing Role of the United States in the World Community

The U.S. Space Shuttle Program has been a significant core activity of NASA for many years, touching the world community in several ways. On one extreme was its role in the Cold War and the space race, in competition with the USSR for global prestige and status, and for claims of scientific and technical achievements. On the other extreme was the role of the shuttle program in advancing international cooperation, especially through its astronaut program. On *Columbia*'s last mission, the crew included two foreign born astronauts. Also, the human tragedy of the *Columbia* disaster was a world-riveting event.

3) Superlative opportunities for public enjoyment or scientific study

Both sites have the potential for providing a fitting tribute to this remarkable flying machine and those who perished on her last mission. The Hemphill community has initiated their own unique approach to this, by seeking ideas on a range of memorial concepts from Texas A&M University students. There are superlative opportunities to provide for commemoration, contemplation, and reflection on the meaning of what transpired over East Texas on February 1, 2003, to ensure that the *Columbia* disaster event becomes a major part of the official memory of the United States.

4) Retains a high degree of integrity as a true, accurate, and relatively unspoiled example of the resource

The Hemphill and Neches River National Wildlife Refuge properties all retain a high degree of integrity as their landscape settings have remained relatively unchanged since the *Columbia* disaster.

National Significance Findings

One property identified in the 2008 legislation, the Hemphill site as well as one additional site, the Neches River National Wildlife Refuge meet National Historic Landmark criteria and National Park Service standards for national significance. These sites represent the relatively rural setting of the pineywoods ecoregion of East Texas where *Columbia* made its final return to Earth. The relationship of these properties to the national significance of the *Columbia* disaster is particularly strong when connecting the recovery activities to the disaster and the disaster to the retirement of the U.S. Space Shuttle Program. Both sites have the potential to provide superlative opportunities for commemoration, contemplation, and reflection on the meaning of what transpired over East Texas on February 1, 2003, to ensure that the *Columbia* disaster event becomes a part of the official memory of the United States.

While this phase of the special resource study is focused on the evaluation of national significance for five study sites in East Texas, it should be noted that the entire 600-mile-long shuttle debris corridor between Littlefield, Texas and Fort Polk, Louisiana will forever be a part of the *Columbia* recovery story. In many ways, this region forms a coherent whole in appreciating this tragedy and the government and civilian response to it. Almost every aspect of the search and recovery activities, from the role of voluntarism to the importance of local action in disaster management, points to the overlapping and interconnected roles of these communities in America's response to this tragic event.

Evaluation of Suitability

***Previous page**: February 4, 2003. Stephen Escalante (USNR) and the United States Navy Band Sea Chanters are pictured during the tolling of the bells at the memorial for the* Columbia *astronauts on the mall of the Johnson Space Center. (NASA photo)*

Background

An area that is nationally significant must also meet criteria for suitability to qualify as a potential addition to the national park system. For an area to be considered suitable, it must represent a natural or cultural resource type that is not already adequately represented in the national park system, or is not comparably represented and protected for public enjoyment by other federal agencies; tribal, state, or local governments; or the private sector.

Adequacy of representation is determined on a case-by-case basis by comparing the potential addition to other comparably managed areas representing the same resource type, while considering differences or similarities in the character, quality, quantity, or combination of resource values. The comparative analysis also addresses rarity of the resources, their interpretive and educational potential, and whether there are similar resources already protected within the national park system or in other public or private ownership. The comparison results in a determination of whether the proposed new area would expand, enhance, or duplicate resource protection or visitor use opportunities found in other comparably managed areas.[141]

For the purposes of comparison under this special resource study, the study team first examined the range of commemorative efforts previously undertaken to honor *Columbia* and her STS-107 crew. This is followed by an overview of entities that recognize the nation's space shuttle program in a significant way, provide visitor opportunities to learn more about the program, and offer visitor opportunities to reflect on the *Columbia* tragedy.

Existing Commemorative Efforts

There are over 75 existing commemorative efforts to *Columbia* and her STS-107 crew, and the number continued to grow at the time of this writing. Some are relatively simple, such as renaming a feature in honor of the shuttle or crew member, while others are correspondingly more elaborate such as the placement of memorials, monuments, or markers. Together they all underscore the importance Americans and people all around the world place on the sacrifice that was paid by the shuttle astronauts in 2003.

Together they all underscore the importance Americans and people all around the world place on the sacrifice that was paid by the shuttle astronauts in 2003.

National Initiatives

There are at least three examples of commemoration honoring *Columbia* and her STS-107 crew that have been recognized or initiated by an act of Congress. These include a monument in Arlington National Cemetery, the Astronaut Memorial at John F. Kennedy Space Center, and the Columbia Memorial Space Center in Downey, California.

Arlington National Cemetery

Arlington National Cemetery is considered our nation's most hallowed ground. In March 2003, three of the STS-107 crew members were buried there: Captain David Brown, Captain Laurel Blair Salton Clark, and Lieutenant Colonel Michael P. Anderson.

On April 16, 2003 President George W. Bush signed the Emergency Wartime Supplemental Appropriations Act, making it Public Law Number 108-11. A provision in the bill, the Columbia Orbiter Memorial Act, authorized funding for the Secretary of the Army to place a memorial marker in honor of the STS-107 crew in Arlington National Cemetery.

Columbia STS-crew memorial at Arlington National Cemetery. (Arlington National Cemetery photo)

The memorial is a marble monument adorned with a bronze replica of the STS-107 mission patch on one side and a bronze bas-relief of crew members on the other. The monument is located near an earlier memorial to the crew of the shuttle *Challenger*.

Mrs. Sandy Anderson, wife of Columbia *astronaut Michael Anderson, looks at the memorial along with astronauts Steve Robinson (right) and Carlos Noriega (left). (NASA/Bill Ingalls photo)*

The memorial was formally dedicated on February 2, 2004 in a service attended by NASA's administrator at the time, Sean O'Keefe, as well as more than 400 family members, former astronauts, and friends. Commemoration ceremonies are conducted annually at the cemetery.

Astronaut Memorial

On January 3, 1991, Congress passed Joint Resolution 214, which recognizes the Astronaut Memorial at the Kennedy Space Center Visitor Complex as the national memorial honoring astronauts who die in the line of duty. Dedicated in the same year by Vice President Dan Quayle, the memorial is more commonly known as the Space Mirror Memorial and is administered by the Astronauts Memorial Foundation (AMF). Its design was the result of a national competition that drew entries from more than 750 architects. Only the Vietnam Veterans Memorial attracted more design concepts.

The memorial is 42.5 feet high and 50 feet wide and constructed of mirror-finished granite. It consists of 90 granite panels. There are 80 5-foot x 5-foot panels, and 10 half-sized panels. Each full panel is 2 inches thick and weighs 500 pounds. The astronauts' names are engraved through the granite and filled with refracting crystal-clear acrylic that allows the sun's rays to project through them. Powerful electric lights also illuminate the astronauts' names 24 hours a day, 365 days a year.

In February 2000, the AMF unveiled a new 6-foot by 6-foot granite wall showcasing the photos and biographies of the 17 U.S. astronauts depicted on the giant Space Mirror Memorial. Then, in 2003, the names of all seven *Columbia* astronauts were added to the memorial and a second biographic wall.

"The granite biographic walls serve as the perfect complement to the Space Mirror

Kennedy Space Center employees and guests placed wreaths and flowers at the Space Mirror Memorial at the spaceport's Visitor Complex during NASA's Day of Remembrance. The annual event took place on the 10th anniversary of the loss of the space shuttle Columbia *and its crew and was hosted by the Astronauts Memorial Foundation. The ceremony also honored the astronauts of* Apollo *1, who perished in 1967, and the shuttle* Challenger, *lost in 1986, as well as other astronauts who lost their lives while furthering the cause of exploration and discovery. (NASA/Jim Grossmann photo)*

memorial," said Stephen Feldman, Ph.D., president of the AMF. "Looking at the granite walls, people will get a better sense of these remarkable individuals. This addition lets the visitors put a face on these heroes and learn about their exemplary contributions to our society," he added.[142]

In addition to maintaining the memorial, the AMF partners with NASA to provide technology training to educators nationwide. It emphasizes space-related technology so that teachers and their students are prepared to meet the challenges of the information age. More than 8,000 educators, administrators, educational decision makers and university professors have attended the AMF's wide variety of programs.[143]

Columbia Memorial Space Science Learning Center

City officials in Downey, California were already working with NASA representatives to develop a space science learning center at the former space shuttle manufacturing site when Congress passed House Joint Resolution 57 on October 30, 2004. This resolution expressed Congress's support for designating the center as the Columbia Memorial Space Science Learning Center to provide a living memorial to the seven *Columbia* astronauts who died serving their country in the name of science and research.

The site includes a 20,000-square-foot visitor center and museum which opened in October 2009. It is a space science learning center

aimed primarily at enhancing educational opportunities for children and teachers that include hands-on exhibits and other activities and information derived from American space research. The space center hosts one of 48 Challenger Learning Centers on the planet. When operating the simulation, visitors can "journey" to the moon, experience the excitement of mission control and pilot a shuttle flight. The center's website includes a section commemorating STS-107 crew members.[144]

NASA initiatives

NASA has memorialized the *Columbia* and the STS-107 crew in a variety of unique ways, some notable examples include:

Websites

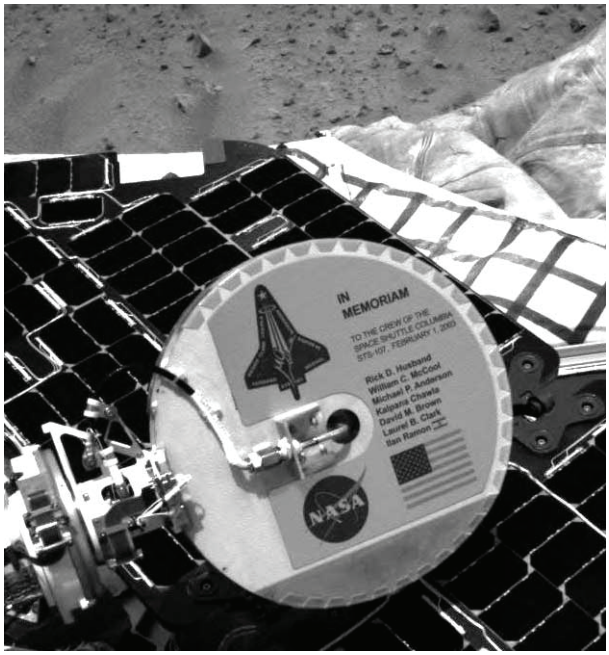
The agency maintains a comprehensive website "*Remembering Columbia STS-107*", which presents information about *Columbia*'s last flight, as well as information related to the accident and subsequent investigation by the formal Columbia Accident Investigation Board. It features STS-107 crew profiles and biographies, as well as related links to other NASA websites that document the history of *Columbia* and the space shuttle program (including photo imagery).[145] NASA also maintains another website "*STS-107 Crew Memorial*", which includes biographies of each astronaut, photos, tribute videos, explanation of the STS-107 mission science, a condolences "book" for supporters, messages from the crew families, and an opportunity for viewers to donate to various organizations in the crew's memory.[146]

Honorary Naming

A number of features have been renamed in honor of *Columbia* and the STS-107 crew, including:

Asteroids. In 2003, the International Astronomical Union approved NASA's request to name seven asteroids (numbers 51823-51829) orbiting in the belt between Mars and Jupiter after *Columbia's* crew. Each asteroid has a single moniker composed of the first and last name of a fallen astronaut, so the asteroids are "Rickhusband" (51823), "Mikeanderson" (-824), "Davidbrown" (-825), "Kalpanachawla" (-826), "Laurelclark" (-827), "Ilanramon" (-828), and "Williemccool" (-829).[147]

Landscape features on Mars. NASA's Mars Exploration Rover *Spirit* landed on Mars January 3, 2004, it was decorated with a small commemorative plaque bearing the names of the seven astronauts. The plaque reads: "In memoriam to the crew of Space Shuttle *Columbia* STS-107, February 1, 2003," and includes the names of each crew member.[148] Flight controllers also named the Mars landing site Columbia Memorial Station and several nearby hills after the crew.[149]



Spirit captured this image of the Columbia memorial plaque, mounted to the back of the rover's high-gain antenna. (NASA photo)

Facilities. The National Scientific Balloon Facility in Palestine, Texas, was renamed the Columbia Scientific Balloon Facility in 2005. Representative Jeb Hensarling proposed the change, saying it would help commemorate the crew's "honor, bravery and the quest for knowledge for generations to come."[150]

Equipment. NASA renamed a supercomputer at its Ames Research Center in Moffett Field, California after *Columbia* astronaut Kalpana Chawla. At Ames, Chawla had the challenging task of computing the airflow surrounding a jet-supported delta-wing aircraft such as the shuttle during landing. The SGI(r) Altix(tm) 3000 supercomputer that was named 'Kalpana' is being used to develop simulations to better assess the evolution and behavior of the Earth's climate system.[151]

Memorials

Astronauts Memorial Grove. In April 2003, seven oaks were planted at the Lyndon B. Johnson Space Center in Houston, Texas to honor the STS-107 crew. The trees are part of a stand of live oaks and shumard red oaks that was started near NASA Road 1 in 1996 to honor the memories of astronauts who have lost their lives.[152]

Monuments, markers and plaques. NASA commissioned a series of bronze plaques to commemorate *Columbia* and the STS-107 crew. The plaques also included text to recognize the vital contributions of participants in the *Columbia* recovery effort. A number of which were given to communities in East Texas who played a critical role in *Columbia*'s search and recovery efforts.

Inukshuk memorials. During the summer field seasons of 2003 and 2004, the NASA Haughton-Mars Project established seven memorials on the remote Devon Island in Baffin Bay, Canada. A geographical feature

Inukshuk memorials on Devon Island in Baffin Bay, Canada. (NASA photos)

on the island was named for each astronaut and workers erected traditional Inuit "inukshuk" or "stone person" memorials at each location that included a sealed capsule with biographical information and mission patches.[153]

A stone monument with bronze plaque is dedicated to the memory of *Columbia*'s crew located within a small garden area with benches outside the Spacehab Payload Integration Facility at the Kennedy Space Center.

Exhibits. NASA produced a travelling exhibit to pay tribute to the crews of the Columbia STS-107 mission, Challenger STS-51L mission, and Apollo 1 mission. The exhibit includes recovered *Columbia* hardware and reflects on the importance of each person's contributions to safety in spaceflight.

As part of the preparations for retiring the shuttle fleet, NASA commissioned the design of five graphic panels to pay tribute to each shuttle orbiter. The Columbia display includes an image of each mission patch encircling the shuttle with the last mission patch also including a photo of the STS-107 crew.

The recently opened Space Shuttle Atlantis attraction at the Kennedy Space Center Visitor Complex includes the exhibit "Forever Remembered" wall that allows visitors to pay their respects to the lost crews of *Challenger* and *Columbia*.

Recovered Shuttle Debris

NASA has preserved all of *Columbia*'s wreckage in a storeroom on the 16th floor of the Vehicle Assembly Building. The recovered shuttle remains are catalogued, bar-coded, and (where necessary) bubble-wrapped. A banner signed by the shuttle preparation and debris-recovery teams hangs in the room. The various cards and letters of sympathy sent in by the public following the accident are also stored here. Debris taken from the crew module is in a special, walled-off section. NASA has expressed the hope that *Columbia*'s wreckage may one day lead to the design of safer spacecraft and the prevention of future tragedies. In the words of NASA Deputy Administrator Fred Gregory, "*Columbia* will forever be used as a learning opportunity."[154]

Initiatives by Others

There have been numerous initiatives by others to honor the crew, not only within the United States but also throughout the world. Some examples include a satellite, planetarium, military camp, village, airports, schools, buildings, landscape features, parks, or streets that were renamed in the astronauts' honor. Other commemorative efforts include memorials in the form of a museum dedicated to the memory of *Columbia* and her

In memory of Columbia*'s crew members, a massive collection of flowers, balloons, flags, signs, and other arrangements were placed at the main entrance of the Johnson Space Center in Houston. (NASA photo)*

STS-107 crew or the placement of trees, statues, monuments, and markers as tributes to the crew. While not a comprehensive list, examples of some of these commemorative efforts include:

Honorary Naming

Satellite. India's space agency, ISRO, renamed one of its meteorological satellites, *METSAT* 1, as *Kalpana* 1 in memory of astronaut Kalpana Chawla.[155]

Planetarium. A planetarium was named in honor of astronaut Kalpana Chawla in the town of Kurukshetra in Haryana, India.[156]

Military camp. Camp McCool was named after astronaut William C. McCool. Camp McCool is located in Bagram Air Field, and is the home of rotating EA-6B Prowler Squadrons supporting ISAF in Afghanistan. As a naval aviator, McCool's first assignment was to a unit flying EA-6B Prowler electronic warfare craft, and McCool also worked with Prowlers as a test pilot later in his career.[157]

Village. Gawad Kalinga village in Baquero Sur, Philippines was renamed "USN Commander Willie McCool GK Village" in honor of the astronaut.[158]

Airports. An airport in Amarillo, Texas was renamed the "Rick Husband Amarillo International Airport" in honor of STS-107 commander Rick Husband.

A new regional airport in Timna, Israel was named for astronaut Ilan Ramon and his son, Assaf, a fighter pilot who died in 2009 when he crashed during a training flight.[159]

Schools. The Department of Defense renamed an elementary school in Santa Rita, Guam after astronaut William C. McCool.[160]

The city of Palmdale, California renamed a school after *Columbia* in honor of the lost shuttle and its crew.[161]

The city of Palm Bay, Florida renamed an elementary school after *Columbia* in tribute to the orbiter and crew. The school also has a large mural depicting *Columbia* in space.

The William McCool Science Center, located at the Frank Lamping Elementary School in Henderson, Nevada, is a facility where students in the Clark County School District can learn about space and other fields of science.[162]

The Kalpana Chawla Medical College has been planned for Karnal Town, Haryana, in India. Chawla was born in Karnal Town and lived there for some time as a child.[163]

A number of schools in Israel were named after astronaut Ilan Ramon, including the Ilan Ramon High School, in Hod Hasharon.[164]

Geospatial Service Center. In 2005, Congress provided funding to consolidate the Humanities Urban Environmental Sciences Laboratory and the GIS component of the Forest Resources Institute at Stephen F. Austin University in Nacogdoches, Texas into the Columbia Regional Geospatial Science Center. This was in recognition of their vital role as "geospatial first responders" during the *Columbia* recovery effort.

Buildings. Maxwell Air Force Base in Montgomery, Alabama renamed their auditorium in Rick Husband's honor. He was a distinguished graduate from the U.S. Air Force's Squadron Officer School program located on-post.

The Naval Aerospace Medical Institute in Pensacola, Florida named a building after astronauts Laurel Clark and David Brown.

The National Naval Medical Center in Bethesda, Maryland dedicated an auditorium to Laurel Clark on July 11, 2003.[165]

McCool Hall, located on Tinker Air Force Base, Oklahoma is a bachelors enlisted quarters named after McCool.[166]

The University of Texas at Arlington and Punjab Engineering College in India named dormitories after Chawla.

Several buildings were named for Ilan Ramon in Israel, including the Ilan Ramon Emergency Center in Rehovot, the Ramon Control Tower at Ben-Gurion Airport, and the Ilan Ramon Youth Physics Center at Ben-Gurion University of the Negev, in Beersheba.

Landscape features. A mountaintop in Colorado near Kit Carson Peak and Challenger Point in the Sangre de Cristo Range was renamed Columbia Point in August 2003.[167]

Cherokee County, Texas has proposed naming a new reservoir Lake Columbia.[168]

Parks. Anderson Park in Canton, Mississippi was renamed in honor of astronaut Michael Anderson in June 2004.

On October 23, 2004, Willie McCool Memorial Air Field, located in North Las

Vegas, Nevada, was posthumously named for McCool.[169] The field is actually a model airplane park, and it is part of a much larger, 160-acre park, which was also renamed for the astronaut.[170]

McCool Field at Officer Training Command-Newport, in Rhode Island was named in honor of astronaut McCool.[171]

The community of Friendswood, Texas commemorated astronaut David Brown with the Dave Brown Memorial Park.[172]

A popular local fountain/water-play area in Racine, Wisconsin was renamed the Laurel Salton Clark Memorial Fountain in 2003, and the city council subsequently expanded the area around the fountain to create a park and memorial area.[173]

In tribute to astronaut Ilan Ramon, two parks in Israel have been named Ramon Park, one in Givat Shmuel and the other in Beersheba.

Streets. City officials in Palmdale, California renamed a major thoroughfare, Avenue M, as Columbia Way in honor of the lost shuttle and its crew.[174]

New York City renamed 74th Street, in an Indian-American neighborhood, Kalpana Chawla Way.

In El Paso, Texas an entire set of subdivision streets was named for the seven *Columbia* astronauts.

State Route 904 in Cheney, Washington was renamed Lt. Michael P. Anderson Memorial Highway.

Il Ramon Boulevard in Vaughan, Ontario, was renamed in honor of astronaut Ilan Ramon.

Memorials

Patricia Huffman Smith NASA Museum "Remembering Columbia". The 3,400 square-foot museum contains a tribute to the ship and her crew including exhibits that tell the story of space exploration from the first mission of *Columbia* to its last mission, STS-107. It also reveals the efforts of local citizens during the recovery of space shuttle *Columbia* and the remains of the STS-107 crew. An area is dedicated to each crew members that was lost in the tragedy, including the Texas Forest Service employee and the helicopter pilot who lost their lives during the recovery effort. The families of the crew have contributed personal items belonging to their loved ones to be on permanent display. The museum also houses many items and artifacts from NASA, its contractors, and other individuals.[175]

Statues. Creighton University in Omaha, Nebraska named a plaza for Michael Anderson and erected a bust of the astronaut along with a memorial plaque; Anderson earned his M.A. in physics at Creighton.[180]

The airport terminal in Amarillo, Texas contains a bronze statue of Commander Husband.[181]

Statues of astronauts Willie McCool at left (Lubbock Avalanche-Journal photo) and Michael Anderson at right (NASA photo)

Coronado High School in Lubbock, Texas renamed its athletic field the Willie McCool Track and Field in his honor, and a Willie McCool bronze sculpture was put in the school library. (McCool was a Coronado graduate.) The city also erected the Willie McCool Memorial in the city's Huneke Park at 82nd and Quaker Avenue in 2005.[182]

The city of Spokane, Washington erected a bronze statue of favorite son, Astronaut Michael P. Anderson.[183]

Tree plantings. Two groves of cypress trees in Lompoc, California, 14 trees in all representing each member of the Challenger and Columbia crew members, stands in a memorial park near Vandenberg Air Force Base. The park also has benches and plaques dedicated to the crews of the two shuttles.[176]

Toledo Blade Elementary School in North Port, Florida has a memorial plaque on its grounds next to a tree planted in honor of the crew.[177]

The city of Bastrop, Texas erected a memorial plaque with a replica of the STS-107 mission patch in Bob Bryant Park and planted a *Gingko biloba* tree in honor of the crew.[178]

The Galilee Prayer Garden, located on Highway 90 beside the Lackland Air Force Base in San Antonio, Texas includes a small plaque next to an olive tree. The plaque explains that the tree was planted in memory of astronaut Ilan Ramon.[179]

Monuments, markers, and exhibits. The Portal of the Folded Wings, located in North Hollywood, California is a large memorial structure dedicated as a shrine to aviation in 1953, containing the remains of many notable pilots. In 2008, a scale model of a space shuttle and bronze plaques were dedicated to the crews of *Columbia* and *Challenger*.[184]

Portal of the Folded Wings memorial (Yelp/Christine A. photo)

The Colorado Springs airport in Colorado has a permanent memorial exhibit featuring photos and mission patches from the lost *Apollo* 1, *Challenger*, and *Columbia* crews.[185]

The New Mexico Space Museum and Space Hall of Fame in Alamogordo has an obelisk with a plaque containing the names of the lost *Columbia* astronauts. The memorial

Memorial garden and monument to the crews of Apollo *1,* Challenger, *and* Columbia *at the New Mexico Museum of Space History in Alamogordo, New Mexico. (Wikimedia Commons/AllenS photo)*

was originally erected to memorialize the *Challenger* disaster, but plaques for the STS-107 and *Apollo* 1 astronauts were subsequently added.[186]

In the town of Hemphill, Texas a granite marker with the NASA Columbia commemorative plaque was installed in front of the county courthouse. In the library there is also a replica of the shuttle. At the intersection of State Highway 87 and Farm Road 83, the community converted a large, circular stone dais with a white star into the Columbia STS-107 Memorial, laying down colored tiles to replace the existing blue field with a U.S. flag and putting an image of the mission patch at the center of the star. An inscription circling the edges of the memorial reads, "Their mission became our mission." The date of the disaster is there, and flying directly behind the memorial are the U.S., Texas and STS-107 mission flags. Two stone monuments flank the circle, one for the STS-107 astronauts and another commemorates the two recovery workers who lost their lives in a helicopter crash while searching for shuttle debris in San Augustine County.

Tranquility Park in downtown Houston, Texas has a Columbia memorial in the form of a large bronze plaque on a stone block.[187]

The city of Lufkin, Texas incorporated the NASA Columbia commemorative plaque onto a low profile red granite marker placed in the Louis Bronaugh Park. A circle of flagpoles, including one that flies the STS-107 mission flag, ring an assemblage of memorials honoring persons and events important to the city of Lufkin. A scale model of *Columbia* along with it's mission flag signed by recovery workers is on display within their city hall complex. The Lufkin Civic Center also contains a number of interpretive panels honoring the STS-107 crew and the city's recovery efforts.

To mark the location of the first discovered shuttle debris, a six-inch bronze medallion with the inscription "Columbia February 1, 2003" was embedded in the pavement of downtown Nacogdoches, Texas.

In Nassau Bay, Texas a 75-foot fountain with seven water spouts was created in front of the city's Arts Alliance Center, just outside the NASA Johnson Space Center. The white brick fountain has bronze plaques located along its length with one plaque corresponding to each spout and bearing the name of a *Columbia* astronaut.[188]

A four-part collage of images from STS-107 and a memorial plaque were put up at the Texas State Railroad Park in Rusk; the railway was used as a path through the woods by searchers looking for debris from *Columbia*.[189]

The city of San Augustine, Texas erected a Space Shuttle Columbia memorial, which includes a stone monument within a small landscaped area at the site of their Civic and Tourism Center. Inside hangs the NASA Columbia commemorative plaque.

Recognition of the U.S. Space Shuttle Program

There are a number of museums and institutions that either feature or are dedicated to telling the story of America's space program, including the story of the space shuttle program. Many of them offer excellent educational opportunities to the public about the space program—opportunities that only expanded when NASA made its decommissioned shuttles and other artifacts available to them. Some notable examples of those sites include the Smithsonian National Air and Space Museum, the Kennedy Space Center Visitor Complex, the California Science Center, the Intrepid Sea, Air and Space Museum, and Space Center Houston.

Art panel tribute features Discovery *demonstrating the rendezvous pitch maneuver on approach to the International Space Station during STS-114. (NASA photo)*

Smithsonian National Air and Space Museum

The Smithsonian's Steven F. Udvar-Hazy Center near Washington Dulles International Airport is the companion facility to the Smithsonian's National Air and Space Museum on the National Mall in Washington, DC. The center opened in December 2003, and provides enough room for the Smithsonian to display thousands of aviation and space artifacts. Together, both sites showcase the largest collection of aviation and space artifacts in the world.

The center was named in honor of its major donor, and features the large Boeing Aviation Hangar in which aircraft are displayed on three levels. Visitors can walk among aircraft and small artifacts in display cases located on the floor, and view aircraft hanging from the arched ceiling on elevated skywalks. Many engines, helicopters, ultra-lights, and experimental flying machines are on display in a museum setting for the first time. Among the aviation artifacts on display are the Lockheed SR-71 *Blackbird*, the fastest jet in the world; the Boeing *Dash* 80, the prototype of the 707; the Boeing B-29 Superfortress *Enola Gay*; and the deHavilland *Chipmunk* aerobatic airplane.

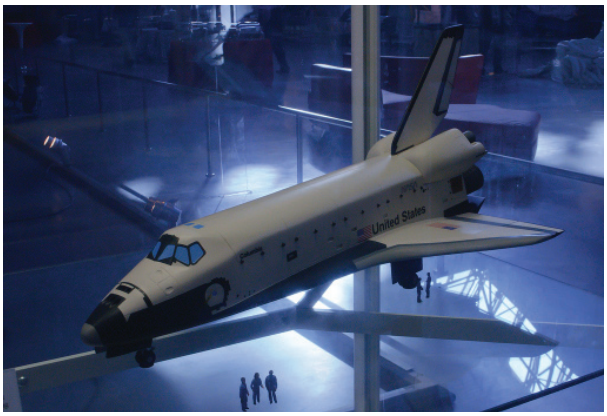
Educational opportunities are abundant at the center. The Donald D. Engen Observation Tower allows visitors to watch air traffic at Dulles Airport, and the center also offers the Airbus IMAX Theater; flight simulators; a museum store; free docent tours; daily educational programs; and school group tours and activities.[190]

The center's James S. McDonnell Space Hangar opened in November 2004 and displays hundreds of famous spacecraft, rockets, satellites and space-related artifacts such as the *Gemini* VII space capsule; the Mobile Quarantine Unit used upon the return of the *Apollo* 11 crew; and a *Redstone* rocket. For many years, the centerpiece of the space hangar was the prototype space shuttle orbiter *Enterprise* until it was replaced by the space shuttle *Discovery* in April 2012. The arrival of *Discovery* atop a Boeing 747 was a grand event. Making several passes over Washington, DC to the delight of onlookers, the event signified the first of the decommissioned shuttle transfers from NASA to other institutions for museum display. Within days, *Enterprise* was removed from the hanger and placed nose to nose with *Discovery*, before it was then "shuttled" off to its new home at the Intrepid Sea, Air, and Space Museum in New York City.

According to the Smithsonian's website "*Discovery* has earned a place of honor in the collection of national treasures preserved by the National Air and Space Museum. The longest-serving orbiter, *Discovery* flew 39 times from 1984 through 2011 — more missions than any of its sister ships — spending altogether 365 days in space. *Discovery* also flew every type of mission during the space shuttle era and has a record

Space shuttle Discovery *arriving in Washington. (NASA photo)*

of distinctions. *Discovery* well represents the full scope of human spaceflight in the period 1981-2011." It's new mission now is to educate and inspire. A 1:50 scale model of *Columbia* is on display just under *Discovery*'s left wing.



A scale model of Columbia *is displayed under* Discovery's *left wing at the Smithsonian.*
(Smithsonian National Air and Space Museum photo)

Space shuttle Discovery *at the Udvar-Hazy Center, an annex of Smithsonian National Air and Space Museum.*
(Wikimedia/ InSapphoWeTrust from Los Angeles, California, USA photo)

Apollo *display at the Smithsonian.*
(Wikimedia/Craigboy photo)

A special feature of the center is the National Aviation and Space Exploration Wall of Honor. Situated along the entryway to the center, the Wall of Honor is a permanent memorial to the thousands of people who have contributed to America's aviation and space exploration heritage. Names of honorees are inscribed on the air-foil-shaped wall, and include the names of the seven astronauts who were aboard the *Columbia* when it broke apart.[191]

Additional opportunities to learn about the space shuttle program are provided at the Smithsonian's National Air and Space Museum main location on the Mall. The "Moving Beyond Earth" is an immersive exhibition that places visitors "in orbit" in the shuttle and space-station era to explore recent human spaceflight and future possibilities. An expansive view of the Earth as viewed from the space station drifts over one gallery wall, while a fly-around tour of the International Space Station fills another wall.

Signature artifacts reflect the exhibition's themes: a 12-foot-tall space shuttle model and other launch-vehicle models represent the quest for routine access to space; astronaut gear, spacesuit gloves, and parts of the Hubble Space Telescope convey the challenges of living and working in space; the suit worn by space tourist Dennis Tito and a model *Ares* launch vehicle suggest future prospects for commercial spaceflight and heading to the Moon.

Museum visitors can also experience aspects of spaceflight through interactive computer kiosks: serving as mission control's flight director to keep a shuttle mission on track, equipping a new module for the space station, manipulating and assembling space station elements, and matching visitors' interests to jobs in the spaceflight work force. The historic artifacts and decision-making electronics are engaging opportunities for visitors to explore the achievements and challenges of human spaceflight.[192]

2013 aerial view of the solid rocket booster replicas at the Kennedy Space Center Visitor Complex during construction of the space shuttle Atlantis exhibit and attraction. (NASA/Kim Shiflett photo)

Kennedy Space Center Visitor Complex

The Kennedy Space Center Visitor Complex is the main staging area for visitors to NASA's John F. Kennedy Space Center (KSC). Located on Cape Canaveral, KSC and adjacent Cape Canaveral Air Force Station share their grounds with Merritt Island National Wildlife Refuge. The visitor complex is an outgrowth of the early 1960s, when self-guided car tours were permitted between 1 and 4 p.m. on Sundays through Cape Canaveral's restricted government grounds. In response to public demand, a permanent visitor complex opened in 1967, just as NASA prepared to launch the first astronauts to the Moon.[193]

Less than an hour's drive from Walt Disney World in Orlando, the 70-acre visitor complex has become one of central Florida's most popular tourist destinations, now attracting more than 1.5 million visitors a year from around the world. Managed by the Delaware North Companies Parks & Resorts, Inc. since 1995, revenues from admission tickets, food purchases and merchandise allow the complex to be self-supporting, without the need for government funding.[194] It features an extensive rocket garden, IMAX films, live shows, hands-on activities, the Astronaut Memorial (Space Mirror Memorial), and behind-the-scenes tours designed to give its visitors an educational and entertaining space program experience.[195]

Guided tours of KSC depart from the visitor complex at frequent intervals and are included with admission. The tours take visitors to the Vehicle Assembly Building where the space

Art panel tribute to space shuttle Atlantis. *(NASA/Amy Lombardo)*

shuttle and other rockets were fully assembled prior to launch, the crawler platforms that slowly transported them several miles out to the launch pads, views of the launch platforms, the shuttle landing facility, and the Apollo / Saturn V Center that houses a restored *Saturn* V launch vehicle and features other exhibits related to the *Apollo* program.[196]

The visitor complex offers several youth education programs including Camp Kennedy Space Center, Overnight Adventures, annual programs for homeschoolers, Boy Scouts and Girl Scouts, field trips and special programs for youth groups.[197] The center's NASA Educator Resource Center provides expertise and facilities to help educators access and use science, mathematics, and technology instructional products. These products are based on NASA's unique mission and are aligned with the national and state standards. Educational materials include videos, slides, lesson plans, publications, lunar and meteorite samples. The resource center offers four innovative supplementary educational resources for teachers of grades K-12. Activity guides are intended to challenge students through a series of problem-solving, cooperative learning and exploratory activities.[198]

Opened to the public in June 2013, the center piece of the visitor complex is the $100 million space shuttle Atlantis attraction, a museum

Inside the "Space Shuttle Atlantis" facility at the Kennedy Space Center Visitor Complex in Florida. (NASA photo)

dedicated to the space shuttle program featuring the retired shuttle *Atlantis*. Outside, full-size replicas of the shuttle's external fuel tank and solid rocket boosters stand sentry at the entrance, requiring visitors to walk underneath the 184 foot tall stack. Inside, the shuttle sits atop two steel columns, but gives the impression it's floating in space, tilted at a 43-degree angle with landing gear down. The pay load doors are open, just as they were in space. Visitors have a 360-degree view.[199] Visitors can walk around the edge of the shuttle along an elevated platform as well as walk underneath on the lower level.

To complement the orbiter, the attraction incorporates a breathtaking 3-D IMAX film with space footage, 167 exhibits and 60 interactive and high tech experiences.[200] Twenty-one simulators allow guests to sit at a console and try to land the shuttle on Earth, dock it to the International Space Station or maneuver its robotic arm—which was used to deploy equipment from the payload bay.[201]

The new Atlantis attraction seamlessly integrates with the Shuttle Launch Experience which was previously installed in 2007. This $60 million attraction puts guests through the sights, sounds, and sensations of a space shuttle launch. Former shuttle commander and current NASA Administrator Charles F. Bolden narrates the simulation and hosts the prerecorded show. The circular ramp way exiting the simulation is lined with panels representing each mission flown during the shuttle program.[202]

Art panel tribute to space shuttle Endeavour *which includes Crew-designed patches from Endeavour's maiden voyage through its final mission are shown ascending toward the stars. (NASA/Amy Lombardo)*

California Science Center

More than 18 million visitors have toured the California Science Center since it opened in 1998 and the center now welcomes 1.4 million guests a year.[203] It has received numerous awards, and was named one of the top 10 science centers in the nation for children and their families by *Parents* magazine.[204] The center is a public-private partnership between the state of California and the nonprofit California Science Center Foundation.

Located in Los Angeles, California near the Los Angeles Memorial Coliseum and Sports Arena, the center features extensive exhibits and educational programming, much of it focused on the history of flight and space exploration. Among many other things, visitors to the center can see the 1902 glider the Wright brothers used to achieve controlled flight, the *Apollo-Soyuz* capsule that docked with Russia's *Soyuz* space craft in July 1975, the *Gemini* 11 capsule flown into space by Pete Conrad and Dick Gordon in September 1966, the *Mercury-Redstone* 2 capsule ridden into space by a chimpanzee named Ham, and the Apollo spacesuit worn by pilot Thomas Mattingly on 1972's Apollo 16 mission.[205]

NASA awarded the decommissioned shuttle *Endeavour* to the center. The shuttle was built to replace the ill-fated space shuttle *Challenger*.[206] NASA's fifth orbiter began flight operations in 1992, when it was launched to

Space shuttle Endeavour *atop its 747 carrier aircraft above the Golden Gate Bridge in California. (NASA photo)*

The space shuttle Endeavour *is parked temporarily outside the Forum in Inglewood for a celebration as it heads to its new home at the California Science Center in Los Angeles. (NASA/Bill Ingalls photo)*

repair the *Intelsat* VI communications satellite. The job required four spacewalks, including an unprecedented three-person spacewalk, and an 8-hour spacewalk that remains the longest spacewalk in history. The orbiter completed 25 missions into space, including the first service mission to the Hubble Space Telescope and the first mission to add a U.S. component to the International Space Station.[207]

In October 2012, *Endeavour* went on public display in a temporary pavilion with a companion exhibit featuring images and artifacts related to the shuttle program. Its permanent home is planned for the future Samuel Oschin Air and Space Center, projected to open in 2018. The museum is planning to mount the shuttle vertically with an external tank and pair of solid rocket boosters in the shuttle stack configuration. One payload door will be open to reveal a demo payload inside.

The addition of the space shuttle also supports the goals of the center's 25-year master plan, which includes building an entirely new gallery devoted to aeronautics and space exploration. "The *Endeavour* will provide an educational platform for the public to celebrate California's long time leadership in science, technology, mathematics and engineering. We are confident that it will serve to motivate and inspire millions of young people to dream about possibilities and will attract and engage the next generation of California's and our nation's workforce in these fields," Science Center President Jeffrey N. Rudolph said.[208]

The space shuttle Enterprise *is ferried on a barge past the Statue of Liberty on its way to the USS Intrepid Museum in New York. (NASA photo)*

Intrepid Sea, Air & Space Museum

The Intrepid Sea, Air & Space Museum mission is to honor America's heroes, and educate and inspire the public. It is dedicated to promoting the awareness and understanding of history, science and service through its collections, exhibitions and programming.[209] Located in New York City harbor, it has welcomed more than 10 million visitors since opening in 1982, and now receives more than 915,000 visitors a year. The museum is located on the aircraft carrier *Intrepid* (CVS-11). In 1943, *Intrepid* was commissioned and served proudly in World War II. She went on to serve as one of NASA's primary recovery vessels, and did three tours of duty off Vietnam as well as submarine surveillance in the North Atlantic during the Cold War. Today, she is a national historic landmark.

The museum features a wide range of interactive exhibits and events providing a snapshot of heroism, education, and excitement. They include historical re-creations, to new interactive displays. Visitors also can ride in an A-6 Cockpit Simulator, visit the Virtual Flight Zone, and tour the inside of the Growler Submarine. More than 50,000 school children participate in the museum's educational programs every year. These programs cover every age group and include special initiatives such as character and leadership development. The museum also hosts the annual Fleet Week celebration in honor of America's military personnel.

The institution's educational programming received a major boost when the space shuttle *Enterprise* was delivered to the museum in June 2012.

May, 2012. Space shuttle Enterprise *is lowered onto a specialized truck bed so the prototype spacecraft can be moved into a hangar at John F. Kennedy International Airport in preparation for display at the Intrepid Sea, Air and Space Museum in New York. (NASA/Kim Shiflett photo)*

There is a strong historical connection between the *Intrepid* and the American space program. The ship served as the NASA recovery vessel in the 1960's for some of the earliest manned space flights. On May 24, 1962, helicopters from *Intrepid* picked up astronaut Scott Carpenter, commander of the 2nd manned orbital flight, as part of the *Mercury* 7 Mission. Then on March 23, 1965, *Intrepid* helicopters picked up *Gemini* 3 astronauts John Young and Virgin 'Gus' Grissom and also recovered their two-person capsule, "The Unsinkable Molly Brown."[210]

The *Enterprise* was originally put on temporary display under a protective tent on the ship's flight deck until the effects of Hurricane Sandy prompted officials to build a new steel constructed, climate controlled pavilion in 2013. The pavilion includes 17 dynamic, content rich exhibit zones enhanced by original artifacts, photographs, and films. New features immerse visitors of all ages in the sights, sounds, and stories of the history of NASA's shuttle program and of *Enterprise*'s role in the program.[211]

Houston Space Center exhibit will display the shuttle Independence atop one of the original Boeing 747 Shuttle Carrier Aircraft. (NASA illustration)

Space Center Houston

Located in Houston, Texas, Space Center Houston is the official visitor center of the Lyndon B. Johnson Space Center (JSC), NASA's center for human spaceflight activities, including mission control and astronaut training. Space Center Houston is operated by the nonprofit Manned Spaceflight Educational Foundation Incorporated.

The center has cultivated a vast array of exhibits that include the stories, tributes and artifacts from every era of space exploration. Three theaters immerse and educate visitors with a variety of short films and real time updates on current NASA missions. A space shuttle launch simulation, mockups of mission control and the International Space Station are also highlights. Tram tours of the JSC campus include access to the astronauts training facility and the original mission control room that was used during the *Apollo* program.

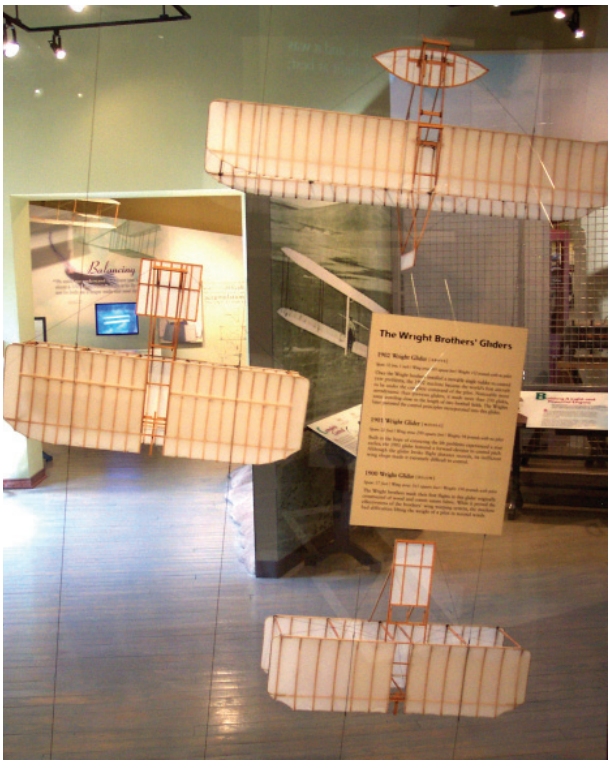
Access to some of the more notable space artifacts and hardware include the *Mercury* 9 capsule, *Gemini* 5 capsule, *Apollo* 17 command module, lunar rover vehicle trainer, *Skylab* trainer mock-up, and *Saturn* V rocket. The center's most recent acquisition includes a full-scale replica of a space shuttle that accommodates visitor access into its interior. The replica was previously on display at the Kennedy Space Center Visitor Complex in Florida. The shuttle, formerly known as *Explorer*, was transferred to Space Center Houston in June 2012 and prior to Kennedy Space Center Visitor Complex receiving the retired shuttle *Atlantis*. *Explorer* was recently renamed *Independence* through a statewide contest in Texas soliciting public input. The center is currently planning a $12 million, six-story attraction that will include placement of *Independence* atop NASA 905, one of the two original Boeing 747 shuttle carrier aircrafts. These jumbo jets shuttled the shuttles to Kennedy Space Center. This jet also shuttled the retired orbiters around the country to their final locations for museum display. Visitors will be able to access the carrier aircraft as well as the shuttle when the facility is open to the public in 2015.[212]

Recognition of the U.S. Space Program within the National Park System

While there are no national park units that are specifically dedicated to the nation's space program, the NPS does manage a unit that has strong historical connections to the space program—the Dayton Aviation Heritage National Historical Park in Dayton, Ohio.[213] The park is located in a National Aviation Heritage Area that stretches across eight counties in southwestern Ohio. It is dedicated to preserving and protecting the memories and accomplishments of Orville and Wilbur Wright, who are credited with inventing and building the world's first successful airplane and making the first controlled, powered and sustained heavier-than-air human flight on Dec. 17, 1903.[214]

There are four National Historic Landmarks in the park: The Wright Cycle Company building, Paul Laurence Dunbar State Memorial house, the Huffman Prairie Flying Field, and the 1905 *Wright Flyer* III—the brothers' first practical airplane.[215] The Dunbar house is in the Dunbar Historic District in the park.[216] Together these sites help tell the story of the lives and legacies of Wilbur and Orville Wright, allowing the public to retrace the historic events that eventually led to commercial airline flights and paved the way for space flight.

This park is a cooperative effort between the National Park Service and five partners, including: Dayton History, the Ohio Historical Society, Aviation Trail, Inc., the Wright Family Foundation, and Wright-Patterson Air Force Base. The park is also a member of the National Aviation Heritage Area which also incorporates two other national venues: the National Aviation Hall of Fame and



Wright Brothers' gliders exhibit at Dayton Aviation Heritage National Historical Park.

the National Museum of the U.S. Air Force (USAF).[217]

The USAF's national museum is of particular interest to this special resource study. It primarily features exhibits dedicated to the history of military flight. Here, 1.3 million visitors a year[218] can see and learn about early fighter planes like the 1909 *Wright Military Flyer*, or World War I's notorious *Fokker* triplane, which was made famous by ace pilot Manfred von Richthofen, who was popularly known as the Red Baron. Visitors can also explore technologically advanced Cold War-era fighters, long-range bombers, reconnaissance planes and the world's only permanent public display of a *B-2* stealth bomber.[219]

The museum also features a Missile and Space Gallery. Opened to the public in 2004, it is housed in a silo-like structure that stands 140 feet high. Visitors can view missiles such as the

Titan I and II and *Jupiter* from ground level or can take in an aerial view from an elevated platform that hugs the inside circumference of the gallery. As part of the museum's ongoing expansion efforts, the gallery also features a portion of the museum's space collection, including the *Apollo* 15 command module, *Mercury* and *Gemini* capsules, rocket engines, satellites and balloon gondolas.[220]

The museum also recently began a multimillion-dollar expansion of its 1.2 million square feet of exhibit space by adding a new building devoted to presenting the story of the Air Force's significant involvement in space. In May 2001, for example, Air Force Museum Foundation received a $10 million pledge—the single largest dollar gift in its history—from the Lockheed Martin Corporation to help construct a 200,000-square-foot building to house the museum's Space Gallery, Presidential Aircraft Gallery and a Global Reach Gallery featuring cargo and tanker aircraft. The facility will provide educational opportunities in collaboration with other educational organizations.[221]

The USAF was an important partner to NASA throughout *Columbia*'s career, and the duration of NASA's shuttle program. In addition to contributing infrastructure and multifaceted operational support, the Air Force provided NASA with many highly skilled shuttle astronauts. It was also deeply involved in determining the orbiters' design and capabilities.[222]

In 2009, then-Secretary of the Air Force Michael Donley asked NASA to recognize the agencies' "vital and historically significant partnership" by donating one of the shuttles to the USAF museum. Donley and other Air Force officials felt the acquisition was required in order to represent the USAF/NASA partnership and the contributions of the shuttle orbiter program to national defense.[223]

Ultimately, NASA decided to send the retired shuttles to other institutions. However, NASA did send a space shuttle nose cap assembly and crew compartment trainer to the museum. Officials there told the press and public they respected NASA's decision and would move forward with plans to expand their space-related exhibits. "The Space Gallery will be populated with exhibits featuring the *Apollo* 15 command module, *Mercury* and *Gemini* spacecraft, and a *Titan* IV space launch vehicle for future display, as well as an *X-15*, *X-24* and other assets which helped develop shuttle program technologies."[224]

As a result, NPS' existing connection to the shuttle program is indirect at best; however, space isn't a new topic to the National Park Service.

In 1980, Congress passed a Public Law 96-344, which authorized a study to determine whether it would be appropriate to create a National Historic Landmark or landmarks related to the theme of "Man in Space". In 1981, the NPS prepared a reconnaissance survey of the sites associated with the early American space program, and in 1984 it completed a national historic landmark theme study. The study identified 25 national historic landmarks and one nationally significant site listed on the National Register of Historic Places that best illustrate the "Man in Space" theme. These sites included:

- The John F. Kennedy Space Center in Florida, which in cooperation with Cape Canaveral Air Force Station supports major NASA launches.
- The Lyndon B. Johnson Space Center in Houston, Texas, which managed the American Manned Space Program and pioneered the research and development of manned spacecraft.
- The Jet Propulsion Laboratory in Pasadena, California, which in the 1960s became

NASA's primary center for the exploration of the moon, planets and solar system.

- The Langley Research Center in Hampton, Virginia, which was NASA's oldest center and featured a complex of wind tunnels as well as labs supporting research into space structures and materials.
- The George C. Marshall Space Flight Center in Huntsville, Alabama, which was focused on developing rocket and spacecraft technology, built on the work of Dr. Werner von Braun.
- The Goddard Space Flight Center in Greenbelt, Maryland, which worked with unmanned meteorological and communications satellites.

These sites, among others, are where critical breakthroughs took place allowing America's space program to overcome barriers to spaceflight, which led to the first landing of a man on the moon.

These sites, among others, are where critical breakthroughs took place allowing America's space program to overcome barriers to spaceflight, which led to the first landing of a man on the moon. The theme represented by these sites starts in 1915 with the formal beginnings of America's technological base for flight, extends to 1972 with the conclusion of man's successful exploration of the moon, and includes the unmanned scientific exploration of the Earth, planets, and solar system.

The "Man in Space" sites were vast, encompassing wind tunnels, rocket engine and development test facilities, launch complexes, training facilities, spacecraft and hardware test facilities, mission control and tracking centers, and other support facilities throughout the United States. In addition to the 26 sites, the study discusses 18 other installations that played an important role in the early American space program and/or have value for interpreting the history of the program to the public. Other space museums and facilities that provide interpretive and educational opportunities related to the exploration of space are also briefly described.

The main focus of the study was how best to tell the overall "Man in Space" story through education and preservation of the 26 "Man in Space" sites. At the time, NASA, the USAF, the U.S. Army, and the Smithsonian Institution, which are responsible for these sites, raised a number of concerns, including:

- Securing funding to support interpretation and preservation of "Man in Space" sites.
- How to create management arrangements to effectively protect significant resources while minimizing potential conflicts with other agency programs.
- Provision of interpretation and visitor use, recognizing the need to maintain security and safety.
- Creating definitions of preservation to allow for reasonable modifications to accommodate technological changes or demolition after adequate documentation, and requirements for compliance with the National Historic Preservation Act without unnecessary delays in implementing new missions and projects.

One of Congress' requests was for the study to prioritize the 26 "Man in Space" sites for permanent preservation, display, and interpretation based on historic significance, ease of public access, amount of current visitation, and immediate and long-term costs. The sites were evaluated and ranked according to their educational value and potential visitor use and grouped according to their preservation potential. Each site's significance was judged on its ability to represent the "Man in Space" theme, accessibility to the public and potential visitation.

Four alternatives were identified as ways of preserving and managing the 26 sites while providing educational and interpretive opportunities to the public. The report

discusses the impacts of these four alternatives on management and funding, interpretation and visitor use, and site preservation.

Alternative 1 (1981 baseline conditions) would allow for each agency to continue managing the resources under current authorities. Interpretation would continue to focus on existing and future programs rather than the "Man in Space" theme, and resource preservation would probably continue to be a low priority.

Alternative 2 would expand the role of each agency in preserving and interpreting the 26 sites. The emphasis would be on interpreting the "Man in Space" theme through off-site media; visitor access to the sites would not be stressed.

Alternative 3 would establish a new foundation or commission to coordinate and direct preservation and interpretive programs for the sites nationwide. More emphasis would be placed on providing on-site interpretation, and site preservation would receive more attention.

Alternative 4 envisions a leading role for the NPS. Under option A of this alternative an America in Space National Historical Park would be established, focusing on key sites at Cape Canaveral Air Force Station and the Kennedy Space Center. Other "Man in Space" sites would become affiliated areas of the national park system. Under option B, all 26 sites would become affiliated areas, and the NPS would provide interpretive, technical, and funding assistance rather than direct management of the sites.[225]

Congress took no further action to establish a new unit of the national park system to represent the "Man in Space" theme. Each agency continues to manage, interpret, and preserve resources under their current authorities.

Suitability Findings

The national park system does not include a park specifically set aside to tell *Columbia*'s story, although the U.S. Space Program is commemorated in a limited way at the Dayton Aviation Heritage National Historical Park in Dayton, Ohio.

There are a number of existing memorials to *Columbia* and her STS-107 crew and they vary widely in size, cost and level of effort to create or maintain. Some include honorary naming, as is the case with NASA's Columbia Scientific Balloon Facility in Palestine, Texas as well as other public streets, buildings, parks, asteroids, satellites, and landscape features on Earth and on Mars. Others, like the Astronaut Memorial at the Kennedy Space Center Visitor Complex, which has been formally recognized by Congress as the national memorial honoring astronauts who die in the line of duty or the Columbia memorial at Arlington National Cemetery are more extensive and serve annually as national destinations and tributes to *Columbia's* fallen heroes.

The decommissioned shuttles *Atlantis*, *Discovery*, and *Endeavour*, the shuttle prototype *Enterprise*, and other shuttle artifacts coupled with the extensive museum facilities and educational programs that accompany them, provide the public with distinct and rich opportunities to reflect on the meaning of the *Columbia*'s mission and tragic final flight. They also offer educational programs that can teach children and adults about the role the U.S. Space Program has played in the nation's history and development.

Of special note, the location of the recently opened Space Shuttle Atlantis exhibit and the national memorial honoring fallen astronauts at the Kennedy Space Center Visitor Complex are in a venue that also provides visitors with

At the Astronauts Memorial, Kennedy Space Center Visitor Complex, guests pay tribute to the crews of Apollo *1 and space shuttles* Challenger *and* Columbia*, as well as other NASA colleagues who lost their lives while furthering the cause of exploration and discovery, during NASA's Day of Remembrance observance Jan. 29, 2009. (NASA/Kim Shiflett photo)*

unparalleled opportunities for learning about and visiting some of the most significant artifacts, structures, and sites related to the U.S. Space Program. The Kennedy Space Center is also the repository of *Columbia*'s recovered wreckage.

In assessing a comparison of each study site with the vast array of other memorials at the federal, state, and local levels commemorating space shuttle *Columbia* and her STS-107 crew, it was found that the national perspective of this event is richly represented by other institutions. Therefore, none of the study sites qualify as a suitable addition to the national park system. These sites seem better suited as local initiatives where each community would have the freedom to commemorate *Columbia* in their own way, as well as their unique role in responding to this nationally significant event.

Study Conclusion

Previous page: *NASA T-38 jet aircraft are flying in a "Missing Man Formation" to conclude the memorial service for the crew of* Columbia *STS-107. (NASA photo)*

Special Resource Study Findings

The study team analyzed five sites to determine if they met the criteria for new national parklands as specified under Public Law 110-229, which authorized the special resource study. While the loss of space shuttle *Columbia* over East Texas is considered a nationally significant event of exceptional importance to the nation and a number of study sites have a direct association with this tragedy, none of the sites meet the suitability criteria for establishing a new unit of the national park system. A national memorial has already been designated by Congress to honor astronauts who die in the line of duty. The national perspective of this event is also richly represented by a vast array of other federal, state, and local museums and memorials commemorating *Columbia* and her STS-107 crew. As a result of the negative suitability findings, the study team did not evaluate the criteria for feasibility or the need for NPS management in detail. There was no basis for further consideration of new unit potential, the study process was concluded and no federal action is proposed.

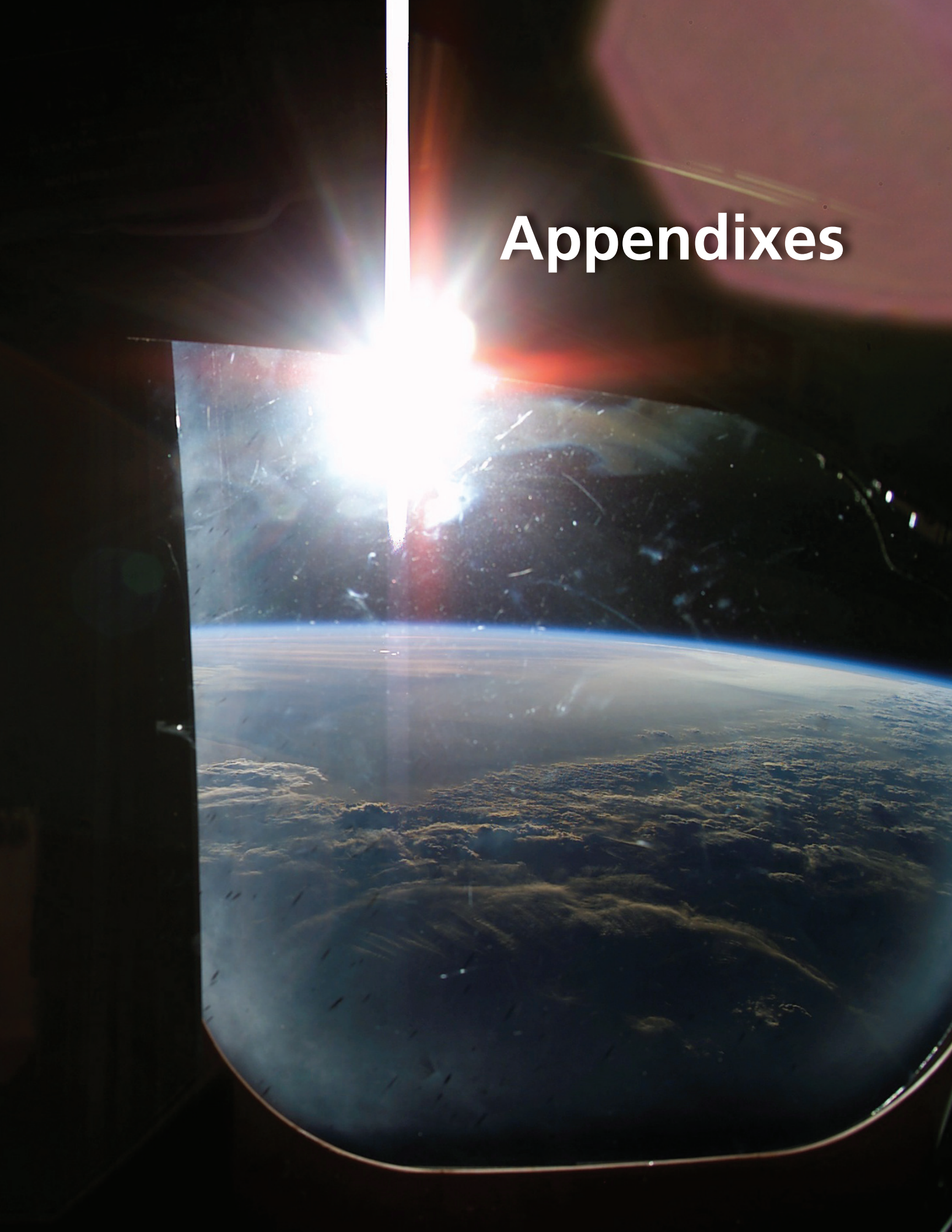
Consultation And Coordination

During September 2009, scoping meetings were held with local community members in the East Texas region. NASA's community liaison Peggy Wooten, Congressman Louis Gohmert's district director Jonna Fitzgerald, and Evelyn Husband Thompson, the widow of Commander Rick Husband also participated. The primary purpose of the meetings was to gain a better understanding of why their communities were identified in the legislation authorizing the special resource study, to gather background information, and to review site conditions. Other goals of the trip included meeting with local representatives of the U.S. Fish and Wildlife Service (USFWS) and The Conservation Fund to discuss their request to include the Neches River National Wildlife Refuge as an additional study site. A total of five meetings were held in four counties, attended by a total of 48 participants.

A second series of meetings were held in June 2010. This trip was specifically designed to introduce research historians from University of Houston's Center for Public History and the Organization of American Historians to key community leaders in East Texas, and to help the historians locate additional sources for their research. Eight meetings were held in four counties, attended by a total of 50 participants.

A newsletter was developed and published to the PEPC website during the winter of 2010. Fourteen individuals provided comments, mostly supporting the establishment of a national park in Sabine County.

No further public meetings were scheduled once it was determined that none of the study sites met the criteria for new parklands.



Appendixes

Previous page: *One of the STS-107 crew members aboard the space shuttle* Columbia *used a digital still camera to capture a sunrise from the crew cabin during flight day seven. (NASA photo)*

A. Special Resource Study Legislation

Congress requested completion of this special resource study under the Consolidated Natural Resources Projects Omnibus Authorization Act of 2008, which was signed into law (P.L. 110-229) by President Bush on May 8, 2008. Below is the relevant passage from the act.

Public Law 110-229

Sec. 324. Space Shuttle Columbia Study.

(a) Definitions.–In this section:

(1) Memorial.–The term ``memorial'' means a memorial to the Space Shuttle *Columbia* that is subject to the study in subsection (b).

(2) Secretary.–The term ``Secretary'' means the Secretary of the Interior, acting through the Director of the National Park Service.

(b) Study of Suitability and Feasibility of Establishing Memorials to the Space Shuttle *Columbia*.–

(1) In general.–Not later than 3 years after the date on which funds are made available, the Secretary shall conduct a special resource study to determine the feasibility and suitability of establishing a memorial as a unit or units of the National Park System to the Space Shuttle *Columbia* on land in the State of Texas described in paragraph (2) on which large debris from the Shuttle was recovered.

(2) Description of land.–The parcels of land referred to in paragraph (1) are–

(A) the parcel of land owned by the Fredonia Corporation, located at the southeast corner of the intersection of East Hospital Street and North Fredonia Street, Nacogdoches, Texas;

(B) the parcel of land owned by Temple Inland Inc., 10 acres of a 61-acre tract bounded by State Highway 83 and Bayou Bend Road, Hemphill, Texas;

(C) the parcel of land owned by the city of Lufkin, Texas, located at City Hall Park, 301 Charlton Street, Lufkin, Texas; and

(D) the parcel of land owned by San Augustine County, Texas, located at 1109 Oaklawn Street, San Augustine, Texas.

(3) Additional sites.–The Secretary may recommend to Congress additional sites in the State of Texas relating to the Space Shuttle *Columbia* for establishment as memorials to the Space Shuttle *Columbia*.

B. National Park Service Management Policies 2006

1.3 Criteria for Inclusion

Congress declared in the National Park System General Authorities Act of 1970 that areas comprising the national park system are cumulative expressions of a single national heritage. Potential additions to the national park system should therefore contribute in their own special way to a system that fully represents the broad spectrum of natural and cultural resources that characterize our nation. The National Park Service is responsible for conducting professional studies of potential additions to the national park system when specifically authorized by an act of Congress, and for making recommendations to the Secretary of the Interior, the President, and Congress. Several laws outline criteria for units of the national park system and for additions to the National Wild and Scenic Rivers System and the National Trails System.

To receive a favorable recommendation from the Service, a proposed addition to the national park system must (1) possess nationally significant natural or cultural resources, (2) be a suitable addition to the system, (3) be a feasible addition to the system, and (4) require direct National Park Service management instead of protection by other public agencies or the private sector. These criteria are designed to ensure that the national park system includes only the most outstanding examples of the nation's natural and cultural resources. These criteria also recognize that there are other management alternatives for preserving the nation's outstanding resources.

1.3.1 National Significance

National Park Service professionals, in consultation with subject-matter experts, scholars, and scientists, will determine whether a resource is nationally significant. An area will be considered nationally significant if it meets all of the following criteria:

- It is an outstanding example of a particular type of resource.
- It possesses exceptional value or quality in illustrating or interpreting the natural or cultural themes of our nation's heritage.
- It offers superlative opportunities for public enjoyment or for scientific study.
- It retains a high degree of integrity as a true, accurate, and relatively unspoiled example of a resource.
- National significance for cultural resources will be evaluated by applying the National Historic Landmarks criteria contained in 36 CFR Part 65 (Code of Federal Regulations).

1.3.2 Suitability

An area is considered suitable for addition to the national park system if it represents a natural or cultural resource type that is not already adequately represented in the national park system, or is not comparably represented and protected for public enjoyment by other federal agencies; tribal, state, or local governments; or the private sector.

Adequacy of representation is determined on a case-by-case basis by comparing the potential addition to other comparably managed areas representing the same resource type, while considering differences or similarities in the character, quality, quantity, or combination of resource values. The

comparative analysis also addresses rarity of the resources, interpretive and educational potential, and similar resources already protected in the national park system or in other public or private ownership. The comparison results in a determination of whether the proposed new area would expand, enhance, or duplicate resource protection or visitor use opportunities found in other comparably managed areas.

1.3.3 Feasibility

To be feasible as a new unit of the national park system, an area must be (1) of sufficient size and appropriate configuration to ensure sustainable resource protection and visitor enjoyment (taking into account current and potential impacts from sources beyond proposed park boundaries), and (2) capable of efficient administration by the Service at a reasonable cost.

In evaluating feasibility, the Service considers a variety of factors for a study area, such as the following:

- size
- boundary configurations
- current and potential uses of the study area and surrounding lands
- landownership patterns
- public enjoyment potential
- costs associated with acquisition, development, restoration, and operation
- access
- current and potential threats to the resources
- existing degradation of resources
- staffing requirements
- local planning and zoning
- the level of local and general public support (including landowners)
- the economic/socioeconomic impacts of designation as a unit of the national park system

The feasibility evaluation also considers the ability of the National Park Service to undertake new management responsibilities in light of current and projected availability of funding and personnel.

An overall evaluation of feasibility will be made after taking into account all of the above factors. However, evaluations may sometimes identify concerns or conditions, rather than simply reach a yes or no conclusion. For example, some new areas may be feasible additions to the national park system only if landowners are willing to sell, or the boundary encompasses specific areas necessary for visitor access, or state or local governments will provide appropriate assurances that adjacent land uses will remain compatible with the study area's resources and values.

1.3.4 Direct National Park Service Management

There are many excellent examples of the successful management of important natural and cultural resources by other public agencies, private conservation organizations, and individuals. The National Park Service applauds these accomplishments and actively encourages the expansion of conservation activities by state, local, and private entities and by other federal agencies. Unless direct National Park Service management of a studied area is identified as the clearly superior alternative, the Service

will recommend that one or more of these other entities assume a lead management role, and that the area not receive national park system status.

Studies will evaluate an appropriate range of management alternatives and will identify which alternative or combination of alternatives would, in the professional judgment of the Director, be most effective and efficient in protecting significant resources and providing opportunities for appropriate public enjoyment. Alternatives for National Park Service management will not be developed for study areas that fail to meet any one of the four criteria for inclusion listed in section 1.3.

In cases where a study area's resources meet criteria for national significance but do not meet other criteria for inclusion in the national park system, the Service may instead recommend an alternative status, such as "affiliated area." To be eligible for affiliated area status, the area's resources must (1) meet the same standards for significance and suitability that apply to units of the national park system; (2) require some special recognition or technical assistance beyond what is available through existing National Park Service programs; (3) be managed in accordance with the policies and standards that apply to units of the national park system; and (4) be assured of sustained resource protection, as documented in a formal agreement between the Service and the nonfederal management entity. Designation as a "heritage area" is another option that may be recommended. Heritage areas have a nationally important, distinctive assemblage of resources that is best managed for conservation, recreation, education, and continued use through partnerships among public and private entities at the local or regional level. Either of these two alternatives (and others as well) would recognize an area's importance to the nation without requiring or implying management by the National Park Service.

C. Endnotes

1. The Global Positioning System (GPS) is a satellite-based navigation system that provides location and time information in all weather, anywhere there is an unobstructed line of sight to three or more GPS satellites. The system is maintained by the United States government and is freely accessible by anyone with a GPS receiver. (It is of interesting note that space technology was used to record the recovered shuttle debris on Earth.)
2. See http://www.crgsc.org. Soon after the disaster, HUES and the GIS services of FRI merged into a single entity, The Columbia Regional Geospatial Service Center (CRGSC).
3. See USDA Forest Service, *Fire and Aviation Management Briefing Paper* (March 3, 2003).
4. "Firm selected to design Nacogdoches' Columbia memorial," the *Oxford Press*, http://www.oxfordpress.com/news/content/coxnet/tx/shuttle/year_later/story18.html, (last accessed November 4, 2011).
5. Byron Starr, *Finding Heroes: The Search for Columbia's Astronauts* (Vancouver, BC: Liaison Press, 2006). See also Sabine County Columbia Memorial Committee, *Columbia STS-107 Memorial*, Sabine County, Texas (2006).
6. Patricia Huffman Smith NASA Museum "Remembering Columbia", http://www.nasacolumbiamuseum.com/index.html (last accessed January 30, 2014)
7. Patricia Huffman Smith NASA Museum "Remembering Columbia", http://www.nasacolumbiamuseum.com/about.html , (last accessed January 16, 2014)
8. North Neches River National Wildlife Refuge Establishment Proposal, March 2005
9. Personal communications with P.R. Blackwell, Director, Columbia Regional Geospatial Service Center, (June 10, 2011)
10. Edwin Diamond, *The Rise and Fall of the Space Age* (Garden City, NY: Doubleday and Company, Inc., 1964), 1-13. Diamond, writing even before the moon landings, compared the space program to Kwakiutl Indian "potlatch" ceremony, whereby two contending chiefs would compete, with the two men throwing increasingly valuable possessions into a blazing fire until one man reached his limit. As Diamond pointed out, "viewing the hot fires that consume million-dollar—and million-ruble—rockets in this decade" seemed to some to offer striking parallels, as each of the two Cold War powers felt compelled to repeat and improve upon the other's accomplishments.
11. Stephen J. Dick, "Exploration, Discovery, and Culture: NASA's Role in History," published in *NASA's First 50 Years: Historical Perspectives*, Stephen J. Dick, editor (Washington, D.C.: NASA SP-2010-4704, 2010), p. 595. For a more complete discussion of the Space Race and its political dimension, see Walter McDougall, *The Heavens and the Earth: A Political History of the Space Age* (New York, NY: Basic Books, 1985).
12. William David Compton, *Where No Man Has Gone Before* (Washington, D.C.: NASA SP-4214), pp. 269-270. Compton suggests that the Apollo program "produced two spacecraft ideally adapted to their function but without sufficient margin for growth to advance the exploration of the moon" because of the end-of-decade goal; any more substantial spacecraft would have required additional engineering and testing, and thus additional development time.
13. John M. Logsdon, in *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, MA: MIT Press, 1970) quotes Eisenhower's first science adviser, James R. Killian, Jr., to sum up the subject nicely: "Many thoughtful citizens are convinced that the really exciting discoveries in space can be realized better by instruments than by man." For a more extensive discussion of the human vs. robot debate, see Howard E. McCurdy, "Observations on the Robotic Versus Human Issue in Spaceflight," Slava Gerovitch, "Human-Machine Issues in the Soviet Space Program, and David A. Mindell, "Human and Machine in the History of Spaceflight," in *Critical Issues in the History of Spaceflight*, edited by Roger D. Launius and Howard E. McCurdy (Washington, DC: NASA SP-2006-4702, 2006), pp. 73-164.
14. A subtext for the shift from space exploration to space utility was suggested in the *Columbia Accident Investigation Board Report*: "With the end looming for the *Apollo* moon exploration program, NASA unsuccessfully attempted to get approval for an equally ambitious (and expensive) space exploration program. Most of the proposed programs started with space stations in low-Earth orbit and included a reliable, economical, medium-lift vehicle to travel safely to and from low-Earth orbit. After many failed attempts, and finally agreeing to what would be untenable compromises, NASA gained approval from the Nixon Administration to develop, on a fixed budget, only the transport vehicle. Because the Administration did not approve a low-Earth-orbit station, NASA had to create a mission for the vehicle. To satisfy the Administration's requirement that the system be economically justifiable, the vehicle had to capture essentially all space launch business, and to do that, it had to meet wide-ranging requirements." See Columbia Accident Investigation Board, *Columbia Accident Investigation Board Report*, Volume 1, Washington DC: U.S. Government Printing Office, 2003, 11.
15. T.A. Heppenheimer, *History of the Space Shuttle, Volume 1: The Space Shuttle Decision, 1965-1972*, (Washington, D.C.: Smithsonian Institution Press, 2002), 412-413; *Columbia Accident Investigation Board Report*, Volume 1, 22.
16. Michael Cabbage and William Harwood, *Comm Check. . . The Final Flight of Shuttle Columbia* (New York: Free Press, 2004), 199-213. In the aftermath of the *Challenger* disaster, Boston College sociology professor Diane Vaughan offered a critical analysis of NASA organizational culture in her book, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1996). Vaughan served as a consultant for the Columbia Accident Investigation Board, authoring a chapter in the board's final report.
17. "NSTS 1988 News Reference Manual," published online, NASA, http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/ (accessed October 8, 2010).

18. Heppenheimer, *The Space Shuttle Decision, 1965-1972*, 213-215. See also Kenneth W. Iliff and Curtis L. Peebles, *From Runway to Orbit: Reflections of a NASA Engineer* (Washington, D.C.: NASA, 2004) 137-138. Iliff argued that "both NASA and the DOD were looking at the shuttle as being the only game in town," and that they therefore loaded it with too many operational requirements in an effort to do everything with one vehicle, ending up with a "complex and ungainly design" not because of engineering failures but because it was "the only design that would meet the operational requirements."
19. John Noble Wilford, "The Industrialization of Space: Why Business is Wary," *New York Times*, 22 March 1981, online at Proquest Historical Newspapers. See also *The Space Shuttle Operator's Manual*, Revised Edition (New York: Ballantine Books, 1988). For a discussion of payload specialist duties on STS-107, see Cabbage and Harwood, *Comm Check . . . The Final Flight of Shuttle Columbia.*
20. Tom Buckley, "NASA's Tom Paine—Is This a Job for a Prudent Man?" *New York Times*, 8 June 1969.
21. Ibid.
22. Moshe Farjoun, "History and Policy at the Space Shuttle Program," published in *Organization at the Limit: Lessons from the Columbia Disaster*, edited by William H. Starbuck and Moshe Farjoun (Malden, MA: Blackwell Publishing, 2005), 24.
23. Heppenheimer, *The Space Shuttle Decision, 1965-1972*, 232-235.
24. Ibid., 207-216.
25. Dennis R. Jenkins, *Space Shuttle: The History of the National Space Transportation System, The First 100 Missions* (Stillwater, MN: Voyageur Press, 2000), 101-102.
26. Heppenheimer, *Development of the Space Shuttle, 1972-1981*, 344.
27. Ibid., 255-260. Heppenheimer discussed the arcane minutia of the budgetary projection process and the flight rate question in detail in a chapter entitled "Economics and the Shuttle." At various times, the agency suggested that it might fly as many as fifty-seven flights a year; the ever-skeptical OMB, however, predicted much lower rates of 15-25 flights per year and found that the economics of the shuttle made sense only at the higher end of that scale. NASA achieved its highest flight rate in the twelve months prior to the *Challenger* disaster, and the Rogers Commission which investigated it concluded that the attempt to increase the flight rate contributed to safety failures. (The most shuttle flights that NASA accomplished in one year were eight in 1985. Between 1981 and 2005 the shuttle averaged less than five flights per year. See T*he Space Shuttle Program—Accomplishments of the Space Shuttle Program*, online,) http://www.libraryindex.com/pages/2823/Space-Shuttle-Program-ACCOMPLISHMENTS-SPACE-SHUTTLE-PROGRAM.html.)
28. Ibid.
29. Kerry Mark Joels and Gregory P. Kennedy, *The Space Shuttle Operator's Manual*, Revised Edition (New York: Ballantine Books, 1988), 1.5.
30. Iliff and Peebles, *From Runway to Orbit*, 137-138. Aerodynamic flight, according to Iliff, was "really the tough nut to crack in terms of a reusable vehicle," because it involved flying at never-before-seen speeds in the upper atmosphere.
31. Heppenheimer, *Development of the Space Shuttle, 1972-1981*, 387-388.
32. Ibid., 387-391.
33. Ibid., 387-391.
34. "All About Astronauts," published online, NASA, http://www.nasa.gov/audience/foreducators/k-4/features/F_All_About_Astronauts.html (accessed October 1, 2010).
35. Cabbage and Harwood, writing in *Comm Check*, offered an extensive discussion of the political and diplomatic maneuvering that led to Ramon's flight (pp. 27-32). Among other things, the Israel Space Agency wanted its representative to, in the words of Director Aby Har-Even, not "just be another tourist in space," a barely-disguised reference to Sultan Salman Abdulaziz Al-Saud, who flew aboard *Discovery* in 1985. Al-Saud was ostensibly along for the launch of a communications satellite, but had no actual duties on the flight.
36. Kenneth W. Iliff & Curtis L. Peebles, *From Runway to Orbit: Reflections of a NASA Engineer* (Washington, D.C.: NASA, SP 2004-4109, 2004), 153-187.
37. Ibid.
38. Columbia Accident Investigation Board, *Columbia Accident Investigation Board Report*, Volume 1, 23.
39. Cabbage and Harwood, *Comm Check . . . The Final Flight of Shuttle* Columbia, 226-228.
40. "Space Shuttle: Extended Duration Missions," published online, NASA, http://www.nasa.gov/mission_pages/shuttle/launch/extend_duration.html, and "Mission Archives: STS-80," published online, NASA, http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/archives/sts-80.html (both accessed October 1, 2010).
41. T.A. Heppenheimer, *History of the Space Shuttle, Vol. 2: Development of the Shuttle, 1972-1981* (Washington, D.C.: Smithsonian Institution Press, 2002), 125-131.
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53. "Frequently Asked Questions: Astronauts," published online, NASA, http://www.nasa.gov/centers/kennedy/about/information/astronaut_faq.html#4 (accessed July 20, 2010).
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56. Cabbage and Harwood, *Comm Check . . . The Final Flight of Shuttle Columbia*, 27-51. See also *Columbia Accident Investigation Board Report*, Volume 1, 29; "Astronaut Biographies," published online, NASA, http://www.jsc.nasa.gov/Bios/index.html (accessed July 22, 2010).
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59. For an extensive biography of Ilan Ramon, see Cabbage and Harwood, *Comm Check . . . The Final Flight of Shuttle Columbia*, 29-32. For general details of all shuttle crews and missions, see "Space Shuttle Flights by Orbiter," published online, NASA, http://www.nasa.gov/mission_pages/shuttle/launch/orbiter_flights.html (accessed September 27, 2010). Individual biographies for both current and former astronauts are available online, "Astronaut Biographies," NASA, http://www.jsc.nasa.gov/Bios/index.html (accessed September 27, 2010).
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63. Frederick D. Gregory, "Making Human Spaceflight as Safe as Possible," published in *Looking Backward, Looking Forward: Forty Years of U.S. Human Spaceflight Symposium*, Stephen J. Garber, ed. (Washington D.C.: NASA, SP-2002-4107, 2002), 75.
64. Brooks, *et al., Chariots for Apollo*, 223-224 & 239-240. Eventually NASA hit upon the contingency of filling the spacecraft with a mixed atmosphere of nitrogen and oxygen during ground tests and at launch; as the spacecraft flew upward, it gradually vented this launch atmosphere, simultaneously reducing cabin pressure and replacing the nitrogen present at launch with pure oxygen, which was not dangerous at the low cabin pressures used in space.
65. Ibid., 217-220.
66. Compton, *Where No Man Has Gone Before*, 386-393.
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68. *Ibid*., 172-179. As Lewis points out, the actual circumstances surrounding the deaths of the *Challenger* crew remain in serious dispute, with NASA unwilling to release the crew autopsies and speculation that the astronauts remained conscious for the full period between the break-up of the orbiter and the unsurvivable impact with the ocean. The author speculates that the crew might have survived had their module included some sort of emergency escape or parachute system but that the space agency did not wish to design such a system because it would have required a costly, time-consuming redesign of the orbiter.
69. Iliff and Peebles, *From Runway to Orbit*, 277.
70. Ibid., 137-138. See also Lewis, *The Voyages of Columbia*, which includes pictures of the tile damage taken by the astronauts.
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