

MISSION TO JUPITER:

A History of the Galileo Project

by Michael Meltzer

National Aeronautics and Space Administration
NASA History Division
Washington, DC

2007

NASA SP-2007-4231

Library of Congress Cataloging-in-Publication Data

Meltzer, Michael, 1946-

A Mission to Jupiter: A History of the Galileo Project / by Michael Meltzer.

p. cm.

1. Galileo Project. 2. Jupiter (Planet)—Exploration. 3. Jupiter probes. 4. Space flight to Jupiter. I. Title.

QB661.M48 2005

629.43'545—dc22

2005027890

(SP-2007-4231)

CONTENTS

LIST OF FIGURES	v
LIST OF TABLES	xiii
PREFACE	xv
FOREWORD	xvii
ACKNOWLEDGMENTS	xix
INTRODUCTION	xxi
1 The Importance of the Galileo Project.....	1
2 From Conception to Congressional Approval.....	9
3 The Struggle To Launch Galileo: Technical Difficulties and Political Opposition.....	37
4 The <i>Challenger</i> Accident and Its Impact on the Galileo Mission.....	71
5 The Galileo Spacecraft.....	107
6 Galileo Deployment, the Inner Solar System Tour, and the Asteroid Belt.....	149
7 The High-Gain Antenna Failure: A Disappointment and a Challenge.....	171
8 Jupiter Approach and Arrival.....	187
9 The Orbiter Tour.....	223
10 Profiles of Selected People Important to the Mission.....	283
11 Conclusion.....	299
Acronyms and Abbreviations.....	301
Index.....	305
NASA History Series.....	311

List of Figures

FIGURE	PAGE	
Cover Page	The planet Jupiter. (PIA03451)	
Table of Contents	Another view of Jupiter. (PIA02873)	iii
Introduction	Galileo the man and Galileo the spacecraft. (NASA GPN-2000-000672), (Library of Congress 3a10555u)	xxi
Chapter 1	Sources of volcanic plumes near Prometheus. (PIA02505)	1
Chapter 2	The United States Capitol. (5a50935u)	9
Chapter 3	Two scientists working on Galileo in its early stages.	37
3.1	The ΔV -EGA trajectory employed an Earth gravity-assist to place Galileo on a Jupiter trajectory. (Folder 23, Box 2 of 6, JPL 14)	56
Chapter 4	The crew of <i>Challenger</i> STS 51-L. (S85-44253)	71
4.1	Booster rocket breach. At 58.778 seconds into powered flight, a large flame plume was seen just above the right-hand booster engine exhaust nozzle. (Johnson Space Center image number S8725373, 28 January 1986)	74
4.2	Liquid-oxygen tank rupture. The luminous glow at the top is attributed to the rupture of the liquid-oxygen tank. Liquid oxygen and hydrogen mixed and engulfed <i>Challenger</i> in a fiery flow of escaping liquid propellant. (Johnson Space Center number S87-25390, 28 January 1986)	76
4.3	The VEEGA trajectory. Galileo saved fuel by getting gravity-assists from Venus and Earth. (Image number P-48182)	84
4.4	Joint Environment Simulator test. Booster motor sections needed to be rigorously tested under conditions approximating actual use. (Image number 8772121)	89
4.5	Launch of Galileo: liftoff of the Space Shuttle Atlantis, carrying the Galileo spacecraft and its Inertial Upper Stage. (STS34(S)025)	105

FIGURE	PAGE
Chapter 5 The Galileo spacecraft. (S85-44253)	107
5.1 The Galileo spacecraft consisted of three major parts: the Atmospheric Probe and the spun and despun sections of the Orbiter, each of which had specific tasks to perform. (Adapted from JPL image no. 230-1235)	109
5.2 Galileo's despun section receives its cabling.	112
5.3 Cross section of Galileo's spin bearing assembly showing slip-ring and rotary transformer assemblies. (JPL image 230-957Bc)	113
5.4 The Probe deceleration and descent modules. (JSC digital image collection, NASA photo number S89-44175)	116
5.5 Probe heatshield ablation. The forward heatshield, which was made of carbon-phenolic, accounted for about one-half of the Galileo Probe's total mass before entry (as shown in the left half of the figure). More than one-half of the heat shield's mass was ablated during the entry period. The right half of the figure shows the final heatshield shape (in black) as determined from sensors within the heatshield. The ablated material is shown in grey. (NASA Ames photo number ACD96-0313-13)	117
5.6 Probe science instruments. (Adapted from JPL image number 230-900)	123
5.7 Jupiter's net radiation fluxes. The net flux radiometer experiment measured the difference between upward and downward energy flow ("net flux") at the wavelengths of visible sunlight, as well as at the wavelengths of thermal infrared radiation, as a function of depth in Jupiter's atmosphere. The sudden rise in solar net flux followed by an abrupt dropoff is probably caused by an ammonia ice cloud layer. (NASA Ames photo number ACD96-0313-6)	128
5.8 The Galileo Orbiter. Fields-and-particles instruments were mounted on the spun section (including the long science boom); remote sensing experiments were mounted on the Orbiter's stable despun section (at the bottom of the spacecraft drawing). (Adapted from JPL image number P-31284)	130
5.9a Jupiter's magnetosphere, a region of intense magnetic fields and rapidly moving charged particles. The small black circle at the center shows the relative size of Jupiter. Also depicted are lines of Jupiter's magnetic field. (Adapted from JPL image number PIA-03476)	133
5.9b Parts of a planet's magnetosphere. Deflected solar-wind particles flow around a magnetosphere. Note the magnetosphere's typically elongated, rather than spherical, shape. The planet's bow shock is the interface	

FIGURE	PAGE
<p>between the region of space influenced by the planet's magnetic field and the region of the undisturbed, interplanetary solar wind. (Figure drawn by NASA History Office from the Web site: http://www2.jpl.nasa.gov/galileo/messenger/oldmess/Earth3.html)</p>	134
5.10 The energetic particles detector (EPD) included two telescope systems: the low-energy magnetospheric measurements system (LEMMS) and the composition measurement system. These determined particle charges, energies, and species. (JPL image no. 230-1027A)	134
5.11 The plasma subsystem measured energy and mass per unit charge of plasma particles and was able to identify particular chemical species.	138
5.12 NIMS was especially useful for studying gaseous chemical species and reflections from solid matter. The cone on the left was a radiative cooler. (JPL image 382-2165A)	143
5.13 Photopolarimeter radiometer. (Image number 23-1158A)	145
5.14 The Orbiter's SSI. (JPL image number 352-8284)	148
5.15 Cutaway schematic of the SSI. Shows principal optical components, charge-coupled device detector, particle radiation shield, and front aperture. (JPL image 230-537)	148
Chapter 6 The Galileo spacecraft about to be released from the bay of <i>Atlantis</i> .	149
6.1 The deployed Galileo spacecraft and Inertial Upper Stage booster rocket. Note the two circular Sun shields installed to protect the spacecraft's sensitive equipment. (Image number S89-42940)	150
6.2 Solar wind–bow shock–magnetosphere interaction for a planet such as Earth. Venus's bow shock occurs nearly on the planet's surface.	155
6.3 The Gaspra asteroid as seen by the approaching Galileo spacecraft. The images show Gaspra growing progressively larger in the field of view of Galileo's SSI camera. The earliest view (upper left) was taken 164,000 kilometers (102,000 miles) from Gaspra, while the latest (lower right) was taken 16,000 kilometers (10,000 miles) away. (NASA image number PIA00079)	162
6.4 Highest resolution picture of Gaspra, constructed as a mosaic of two images taken by the Galileo spacecraft from 5,300 kilometers (3,300 miles) away, 10 minutes before closest approach on 29 October 1991. The large concavity on	

FIGURE	PAGE
the lower right limb is about 6 kilometers (3.7 miles) across, while the prominent crater on the left is about 1.5 kilometers (1 mile) in diameter. A striking feature of Gaspra's surface is the presence of more than 600 small craters, 100 to 500 meters (330 to 1,650 feet) in diameter. (NASA image number PIA00118)	163
6.5 The geocorona, shown here in a photograph taken with an ultraviolet camera, is a halo of low-density hydrogen around Earth that absorbs sunlight and emits "Lyman- α " radiation. (NASA image number AS16-123-19650)	165
6.6 The geocorona and its geotail. As the atomic hydrogen in the geocorona is exposed to sunlight, the hydrogen emits radiation. This process results in a force that sweeps much of the hydrogen in the direction opposite to that of the Sun, creating a geotail.	165
6.7 The asteroids Ida (left) and Gaspra (right). Gaspra was imaged on 29 October 1991 at a range of 5,300 kilometers (3,300 miles). Ida was imaged on 28 August 1993 from a range of 3,000 to 3,800 kilometers (1,900 to 2,400 miles). The surfaces of Ida and Gaspra contain many small craters, evidence of numerous collisions. The fact that craters are more abundant on Ida suggests that it is older than Gaspra. (NASA image number PIA00332)	167
6.8 Dactyl, satellite of the asteroid Ida. The little moon is egg-shaped and only about 1.6 kilometers (1 mile) across. The large crater is about 300 meters (1,000 feet) across. This image was taken on 28 August 1993 at a distance of 3,900 kilometers (2,400 miles) from the moon. (NASA image number PIA0029)	168
Chapter 7 An artist's conception of the Galileo spacecraft approaching Jupiter.	171
7.1 The unfurled high-gain antenna. (Adapted from JPL image number 230-893B)	172
7.2 HGA's supporting ribs did not fully deploy. The HGA was not able to send usable data in its partially opened state.	174
7.3 A blowup view of the HGA in its closed, or "stowed," configuration illustrates the suspected misalignment of its restraint pins. Rather than fitting into the centers of their housings, the pins might have been bent so as to hang up on the edges of the housings, thus preventing deployment of the antenna. Note: "LGA Assembly" at the top of the figure refers to the low-gain antenna assembly that was eventually used in place of the HGA.	176
Chapter 8 An image of Jupiter and one of its moons captured by the Galileo spacecraft as it neared the planet.	187
8.1 The Galileo trajectory from launch to Jupiter arrival. This drawing charts Galileo's flightpath to Jupiter through its three planetary gravity-assists and	

FIGURE	PAGE
two asteroid encounters. Gravity-assists included those from Venus (February 1990) and from Earth (December 1990 and December 1992). Encounters with the asteroids Gaspra and Ida are also depicted. Galileo arrived at Jupiter on 7 December 1995. (NASA photo number S89-44173)	188
8.2 Comet Shoemaker-Levy 9 fragment W impact with Jupiter. These four images of Jupiter and the luminous night-side impact of fragment W of comet Shoemaker-Levy 9 were taken by the Galileo spacecraft on 22 July 1994, when it was 238 million kilometers (148 million miles) from Jupiter. The images were taken at intervals of $2\frac{1}{3}$ seconds using a green filter (visible light). The first image, taken at an equivalent time to 8:06:10 Greenwich mean time (1:06 a.m. Pacific daylight time, or PDT), shows no impact. In the next three images, a point of light appears, brightens so much as to saturate its picture element, and then fades again, 7 seconds after the first picture. (NASA image number PIA00139)	191
8.3 An artist's concept of the Galileo Probe inside its aeroshell being released from the mother ship, the Galileo Orbiter, prior to arrival at Jupiter. (NASA photo number ACD95-0229)	194
8.4 Arrival Day events. Notice the two different trajectories of the Probe and Orbiter. (Adapted from image number P-45516A)	203
8.5 Probe entry and descent into the Jovian atmosphere. (NASA photo number ACD96-0313-4)	204
8.6 Atmospheric Probe parachute deployment sequence and separation of deceleration module components from descent module. After the high-speed entry phase during which the atmosphere slowed down the Probe's speed, a mortar deployed a small drogue parachute, the drogue chute opened, the aft cover of the deceleration module was released, the drogue parachute pulled the aft cover off and deployed the main parachute, and the forward heatshield was dropped. (NASA photo number AC89-0146-2)	205
8.7 Orbiter's first 11 orbits around Jupiter. Notice that the apojoive of the first orbit is over 250 Jupiter radii (RJ) away from the planet. (Adapted from JPL image number P45516B)	209
8.8 Jupiter's expected cloud layers, along with the clouds actually observed at the Probe entry site. (NASA image number ACD96-0313-7)	212
8.9 The Jovian atmospheric composition provides a "tracer" for planetary history. (NASA photo number ACD96-0313-9)	214

FIGURE	PAGE
<p>8.10 A mosaic of Jupiter's equatorial region, photographed in the near-infrared and showing Jupiter's main visible cloud deck. The smallest resolved features are tens of kilometers in size. The dark hotspot near the center is a hole in the equatorial cloud layer and resembles the Probe's entry site. Circulation patterns and composition measurements suggest that dry air is converging and sinking over these holes, maintaining their cloud-free appearance. The bright oval in the upper right of the mosaic and the other, smaller, bright features are examples of moist air upwellings resulting in condensation. (NASA photo number PIA01198)</p>	219
<p>Chapter 9 Lava flowing from a volcano on the surface of Jupiter.</p>	223
<p>9.1 "Flower petal" plot of the Prime Mission Orbiter tour, depicting close encounters with satellites. Note the eccentricity of the first orbit as compared to the others. Due to a solar conjunction, the spacecraft did not have a close encounter with any satellites on its fifth orbit. (Adapted from JPL image number P45516B)</p>	232
<p>9.2 Solar conjunction occurs during the Galileo mission when the Sun lies directly between Jupiter and Earth. The Sun is a strong source of electromagnetic activity, and it wreaks havoc with the spacecraft's radio signal, essentially reducing the spacecraft's data-transmission rate to Earth to almost zero for the two and a half weeks spanning the conjunction. Mission planners and telemetry engineers define this problem time as occurring when the Sun-Earth-Craft (SEC) angle is less than 7 degrees, although a relatively "quiet" Sun can allow data to be successfully transmitted to Earth at SEC angles as small as 3 to 5 degrees. During Galileo's primary mission, solar conjunction periods occurred from 11 to 28 December 1995 and 11 to 28 January 1997. During the Galileo Europa Mission (GEM), solar conjunctions occurred from 14 February 1998 to 4 March 1998 and from 22 March 1999 to 10 April 1999. A Galileo Millennium Mission (GMM) solar conjunction period ran from 28 April 2000 to 17 May 2000.</p>	233
<p>9.3 Europa's surface is covered with water ice. Straight and curved low ridges form the boundaries of ice fragments that resemble those seen in Earth's polar regions during springtime thaws. The white and blue colors outline areas that have been blanketed by a fine dust of ice particles. The unblanketed surface has a reddish-brown color that has been painted by mineral contaminants carried and spread by water vapor released from below the crust when it was disrupted. The original color of the icy surface probably was a deep blue seen in large areas elsewhere on the Moon. The colors in this picture have been enhanced for visibility. (NASA image number PIA01127)</p>	234

FIGURE	PAGE
9.4 A comparison of the size of Europa’s iceberglike surface structures with features of Earth’s San Francisco Bay area. Both images show areas of equal size, 34 by 42 kilometers (21 by 26 miles), and resolution, 54 meters (59 yards). North is to the top of the picture. Europa’s crustal plates, ranging up to 13 kilometers (8 miles) across, have been broken apart and “rafted” into new positions, superficially resembling the disruption of pack ice on polar seas during spring thaws on Earth. The size and geometry of Europa’s features suggest that motion was enabled by water underneath the ice rafts. (JPL image number PIA00597)	260
9.5 Jupiter’s inner satellites and ring components. (NASA image number PIA01627)	277
9.6 Thebe, Amalthea, and Metis (left to right), taken in January 2000 by Galileo’s solid state imaging camera. The images resolve surface features as small as 2 kilometers (1.2 miles). The prominent impact crater on Thebe is about 40 kilometers across. The large white region near the south pole of Amalthea is the brightest patch of surface material seen anywhere on these three moons. (JPL image number PIA02531)	279
9.7 Bright streak on Amalthea. Galileo’s solid state imaging camera obtained the left image in August 1999 and the right in November 1999. The images show features as small as 3.8 kilometers (2.4 miles) across. The bright linear streak in the top left of the images is about 50 kilometers (30 miles) long. The large impact crater near the right-hand edge of the images is about 40 kilometers (25 miles) across. Two ridges, tall enough to cast shadows, extend from the top of the crater in a V shape resembling two rabbit ears. (JPL image number PIA02532)	280
Chapter 10 Project Galileo mission control.	283
Chapter 11 Artist’s concept of the Galileo spacecraft burning up in Jupiter’s atmosphere.	299
11.1 The demise of Galileo.	300

List of Tables

TABLE	PAGE
2.1 Milestones leading to Galileo mission approval.	10
3.1 Planned Probe investigations of Jupiter's atmosphere.	39
3.2 Planned Orbiter investigations of Jupiter and its satellites.	39
3.3 Chronology of Galileo development: 1978 to 1986.	43
4.1 Impacts of <i>Challenger</i> on the Space Shuttle Program and the Galileo spacecraft.	91
4.2 Potential asteroid opportunities.	94
4.3 Impacts of <i>Challenger</i> on the Galileo mission and spacecraft.	103
5.1 Atmospheric Probe instrumentation.	122
5.2 Orbiter fields-and-particles instruments.	131
5.3 Orbiter remote sensing equipment.	142
8.1 Timeline of Atmospheric Probe events.	206
9.1 Overview of Galileo's Prime Mission.	231
9.2 Prime Mission satellite tour. Includes the naming convention for Jupiter orbits and dates of closest approach to the designated satellite on each orbit.	233
9.3 Galileo Europa Mission key events.	235
9.4 GMM activities. During GMM, the spacecraft conducted a study of the Jovian magnetosphere–solar wind interaction in conjunction with the Cassini spacecraft (which was passing by Jupiter on its way to Saturn) and with Earth-based telescopes.	238
9.5 Io encounters.	240
9.6 Io statistics.	243
9.7 Europa data.	253
9.8 GEM Europa encounters.	257
9.9 Ganymede statistics.	267
9.10 Ganymede encounters.	269
9.11 Callisto encounters.	274
9.12 Callisto data.	275
9.13 Jupiter's inner moons.	278
10.1 Galileo project managers.	285

Preface

The Galileo Project: Commitment, Struggle, and Ultimate Success

I am glad to see that someone has followed through and done a really comprehensive and workman-like job capturing the history of the Galileo project. This book goes all the way back to the initiation of the project, when it was more or less just a thought in a few peoples' minds, and traces the whole evolution from there. I got a great deal out of reading it.

I have a vested interest in the Galileo project—I was deeply involved in it for over a decade. A lot of people know about the mission and its terrific science return, but they don't know about the struggle putting the project together, getting it started, and keeping it going through all of the reprogramming and restructuring. One of the arguments that we used with people on Capitol Hill to keep the program alive through delays in the congressional budgeting process was that Galileo would be a nonthreatening manifestation of our country's technological capabilities, and this would send a powerful message to the rest of the world. It did just that.

Galileo meant a lot to the United States, but it also meant a lot to our space science community, because at the time that we were going through the development of Galileo, it was the only major deep space project. There were Earth satellite launches going on, but nothing to the planets. It was Galileo that really helped NASA and the U.S. space science community maintain viability during a period of extreme drought in program development. A lot of capability would have disappeared over the course of the 10 years that Galileo was in development.

The commitment that individuals made to Galileo was extraordinary. Many individuals committed a third or more of their professional lifetimes to executing this project. Over the years, situations developed so many times where it looked like there was just no way out for the project, but we always managed to come up with a solution. The number of times we managed to pull the fat out of the fire was truly remarkable.

The Galileo project was complex in that it required funding for science instrument and spacecraft development from numerous sources, including NASA and its Centers, the Department of Energy, U.S. universities, and the Europeans (especially the Germans). Just how the pieces of the fabric were woven together into what turned out to be a very successful program—one that required an investment of almost two decades of preparatory and execution work to bring about—is an interesting story. Revisiting the program from a historical point of view is what motivated me to read this book. I think that people who are interested in the space program, its science achievements, and its contribution to technology in general will really appreciate this history. It's comprehensive, it's complete, and it seems to me to be pretty even-handed. I'm very appreciative of what Michael has done.

—John Casani, First Galileo Project Manager

Foreword

We Are All Standing on the Bridge of Starship *Enterprise*

This book details the history of the Galileo mission. Galileo had political ups and downs, technical challenges and hurdles, and was a multigenerational task. We had people starting the mission on advisory committees and senior management jobs who have now passed on. Many people went through parts of Galileo in stages of their careers. I have friends who still mark their anniversaries and the birthdates of their children in terms of, “That was when we were on the beginning stages of prelaunch preparation,” or, “It was during our first Europa encounter when that happened.” The Galileo team felt much more as a family than a pure professional enterprise. People worked together for long periods of time, through good times and bad, to accomplish this thing not just for them, but for everybody.

The Galileo mission to Jupiter was part of the grand sweep of solar system exploration. You can view planetary exploration as a human endeavor—a wave sweeping outward from Earth. We went to the close-in places first—the Moon, Venus, and Mars. The outer solar system was the next big frontier, and it was an order of magnitude more difficult to explore. The distances are truly staggering, and the problems of developing spacecraft that could survive on their own for long periods of time were major challenges.

The early explorations of the outer solar system were performed by relatively fast-trajectory spaceships, like the Pioneers and Voyagers. They and Galileo were major steps forward in being able to develop reliable craft that would operate for decades, continue to send data back without failing, and be smart enough to take care of themselves out of communication with Earth. At Jupiter, the time available to send a radio signal is typically 45 minutes, and another 45 minutes before you get an answer back. You are well beyond being able to do the types of things that can be done in Earth orbit.

NASA’s outer solar system missions helped turn that region into a known place, rather than just the realm of astronomers. The outer solar system became someplace that can be talked about and thought about in geological and geophysical terms. The person on the street and kids in school can say, “Hey, I saw a picture of a moon of Jupiter the other day and it had volcanoes on it.”

We planned the Galileo mission in that context. The scientific advisory committees to NASA and the U.S. government laid out an exploration strategy of fast reconnaissance missions followed by missions such as Galileo, in which we orbited planets and did more detailed studies. There was a leapfrogging characteristic to this type of exploration. The missions take so long to plan and execute that the next wave of exploration must be prepared even before the current one can be launched. We began work on Galileo in 1972 in its infant form, and we really got to work on it in 1974 with detailed studies, even before Voyager was launched in 1977.

On Galileo, we combined orbital and in situ exploration strategies. We believed that if we were going through so much effort and so many resources to get there, we ought to not only study the planet, its satellites, and magnetic fields, but that we also should understand the chemistry of the atmosphere in detail with an entry probe that actually went into the atmosphere, grabbed a sample, analyzed it, and sent the data back to the mother ship before burning up in the atmosphere. This was very ambitious.

We had a strategic plan that said we were going to go orbit Jupiter, get into its atmosphere, and then inform that plan with tactics derived from Voyager results. It is a good example of the way exploration progresses. You learn things that lead to new questions you want to answer, and so forth. We were preparing to follow up and understand Jupiter's miniature planetary system at a very detailed level, even as Voyager was continuing on from Jupiter to Saturn, opening up the rest of the outer solar system.

People frequently ask, "Why should the average person be interested in what's going on in the Jupiter system?" There are answers to that on all levels, ranging from the visibility of high technology to developing new things that have spinoffs to enhancing national prestige to satisfying pure curiosity. But really, it is all about changing the way we look at the universe and the world. We want to know how planets tick and understand the processes that control us here on Earth—everything from geophysics to climatology to global warming. The universe is effectively a laboratory waiting for us to study these things.

Most of the people who have worked on Galileo over the years probably regard their biggest contribution as having changed the textbooks. Kids today learn about such things as the moons of Jupiter, and they know what they're talking about. To them, the planets become not just dots in the sky that you can barely see with a telescope. The planets become real places, and kids know their characteristics.

There is always a tension in the national debate about how much robotic exploration (such as Galileo) we should do versus so-called human exploration (such as Apollo). This misses the point! What we call robotic exploration is in fact human exploration. The crews sitting in the control room at Jet Propulsion Laboratory as well as everyone out there who can log on to the Internet can take a look at what's going on. So, in effect, we are all standing on the bridge of Starship *Enterprise*.

It is important to note that Galileo was an international mission. Science is, by its nature, international. We had people contribute from countries all over the European community and other countries as well. This was one of the first missions in which the analysis of data more or less continued around the clock, around the globe. We'd wake up in the morning and hear that one of our colleagues in Berlin had processed some images overnight and brought new data to the table—and we could look at it immediately, while they had a chance to sleep.

The intellectual children, grandchildren, and great-grandchildren of the people who worked on Galileo have now spread through the crews operating the Cassini spacecraft at Saturn and the MER Rovers, Spirit and Opportunity, on the surface of Mars. It is an ongoing spirit of exploration and, to me, that's really the bottom line of what Galileo was all about. It is important to record the history of these types of things, both because of the intrinsic interest that the public has and because there are always lessons to be learned. I sure hope people will read this book and get that feeling from it.

Acknowledgments

So many people gave me valuable input for this book. I want to thank them for their time and interest in this project. Some of these people include:

Torrence V. Johnson, who related with eloquence how decisions were made and operations were carried out on the mission.

John Casani, whose project leader perspectives on the mission's importance and on the political battles that had to be fought were hugely important for my book. Also, thank you to the mission's other project managers: Dick Spehalski, Bill O'Neil, Bob Mitchell, Jim Erickson, Eilene Theilig, and Claudia Alexander, all of whom gave me valuable insights on what Galileo was all about.

Thanks go out to the mission engineers and technicians at Jet Propulsion Laboratory (JPL), especially Nagin Cox, who is indeed a poet when she talks about Galileo, Gerry Snyder, Duane Bindschadler, Brad Compton, Gregory C. Levanas, Theodore Iskendarian, and various members of the Galileo mission support crew; experts from Ames on the Probe, including Charlie Sobbeck, Ed Tischler, and Joel Sperans; and Krishan K. Khurana of UCLA. Also, thanks to Dick Malow, a former congressional committee staff director; Allan J. McDonald of Thiokol Propulsion; Carl Fromm for his help and encouragement; Julie Cooper for patient help in finding graphics for the book; and Craig Waff for sharing his extensive research on the Galileo mission. In addition, a special thanks goes to the staff of JPL Archives, especially Russell Castonguay, who was incredibly helpful in locating long-buried letters and documents.

At NASA Headquarters, the History Division staff, in particular, former NASA Chief Historian Roger Launius and the current NASA Chief Historian Steven Dick, deserve much credit for their support and oversight. Archivists Colin Fries and Jane Odom helped a great deal by finding and organizing essential archival material. Steve Garber oversaw the production process. Interns Liz Suckow, Jennifer Chu, Giny Cheong, and Gabriel Okolski all helped tremendously in obtaining and organizing images.

Also at NASA Headquarters, the talented professionals in the Office of Printing and Design deserve much credit. Lisa Jirousek and Dyana Weis carefully copyedited the manuscript, designers Cathy Wilson and Smahan Upson laid out the manuscript in a very attractive manner, printing specialists Jeffrey McLean and Henry Spencer handled this crucial last step, and supervisors Steven Johnson and Gregory Treese managed the whole process.

And finally, a thank you to my wife, Naisa Kaufman, for her talented and tough manuscript editing.

*"All truths are easy to understand once they are discovered.
The point is to discover them."*

—Galileo Galilei

Introduction

MEETING THE GRAND CHALLENGE

IN AN ADDRESS TO THE U.S. SENATE SUBCOMMITTEE ON Science, Technology, and Space, author James Michener asserted that "it is extremely difficult to keep a human life or the life of a nation moving forward with enough energy and commitment to lift it into the next cycle of experience . . . There are moments in history when challenges occur of such a compelling nature that to miss them is to miss the whole meaning of an epoch. Space is such a challenge."¹

The Galileo mission to Jupiter successfully explored a vast new frontier, had a major impact on planetary science, and provided invaluable lessons for the design of subsequent space vehicles. In accomplishing these things, Galileo met the challenge of "such a compelling nature" that Michener envisioned. The impact of the mission was felt by those who worked on it, the country that supported it, and the people from other parts of the world who were deeply impressed by it. In the words of John Casani, the original Project Manager of the mission, "Galileo was a way of demonstrating . . . just what U.S. technology was capable of doing."² An engineer on the Galileo team expressed more personal sentiments when she said, "I had never been a part of something with such great scope . . . To know that the whole world was watching and hoping with us that this would work. We were doing something for all mankind . . . I'd walk outside at night and look up at Jupiter, and think, my ship's up there."³

¹ James A. Michener, "Space Exploration: Military and Non-Military Advantages" (speech delivered before the U.S. Senate Subcommittee on Science, Technology, and Space, Washington, DC, 1 February 1979). Published in *Vital Speeches of the Day* (Southold, NY: City News Publishing Company, 15 July 1979).

² John Casani interview, tape-recorded telephone conversation, 29 May 2001.

³ Nagin Cox interview, tape-recorded telephone conversation, 15 May 2001.

Like other grand voyages of discovery, Galileo altered the way we view our surroundings (in this case, our planetary surroundings). It is thus fitting that this mission to the Jovian system was named after a man whose own astronomical observations radically challenged the way that people of his time viewed their universe. The discoveries of both Galileo the man and Galileo the spacecraft brought us new perceptions of our planetary system, made our lives richer and more interesting, and breathed new vitality into our quest to understand ourselves and our universe.