Sustaining the Global Positioning System

Earl M. Peabody
Editor

Space Science, Exploration and Policies Series

Novinka

SPACE SCIENCE, EXPLORATION AND POLICIES SE

SUSTAINING THE GLOBAL POSITIONING SYSTEM

EARL M. PEABODY
EDITOR

Nova Science Publishers, Inc.
New York

For permission to use material from this book please contact us:
Telephone 631-231-7269; Fax 631-231-8175
Web Site: http://www.novapublishers.com

NOTICE TO THE READER

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Sustaining the global positioning system / editor, Earl M. Peabody.
p. cm.
Includes index.
ISBN 978-1-60741-006-5 (softcover)
1. Global Positioning System. I. Peabody, Earl M.
G109.5.S87 2009
623.89'3--dc22

2009038417

Published by Nova Science Publishers, Inc. † New York

SPACE SCIENCE, EXPLORATION AND POLICIES SERIES

SUSTAINING THE GLOBAL POSITIONING SYSTEM

SPACE SCIENCE, EXPLORATION AND POLICIES SERIES

Progress in Dark Matter Research
J. Val Blain
(Editor)
2005. ISBN 1-59454-248-1

Space Science: New Research
Nick S. Maravell
(Editor)
2006. ISBN 1-60021-005-8

Space Policy and Exploration
William N. Callmers (Editor)
2008. ISBN 978-1-60456-448-8

Space Commercialization and the Development of Space Law from a Chinese Legal Perspective
Yun Zhao
2009. ISBN 978-1-60692-244-6

Space Commercialization and the Development of Space Lawfrom a Chinese Legal Perspective
Yun Zhao
2009. ISBN 978-1-60876-874-5
(Online Book)

Space Exploration Research
John H. Denis and Paul D. Aldridge
(Editors)
2009. ISBN: 978-1-60692-264-4

Space Exploration Research
John H. Denis and Paul D. Aldridge
(Editors)
2009. ISBN: 978-1-61668-212-5
(Online Book)

Next Generation of Human Space Flight Systems
Alfred T. Chesley (Editor)
2009. ISBN 978-1-60692-726-7

Nutritional Biochemistry of Space Flight
Scott M. Smith, Sara R. Zwart, Vickie Kloeris and Martina Heer
2009. ISBN 978-1-60741-641-8

Environmental Satellites: Weather and Environmental Information Systems
Vincent L. Webber (Editor)
2009. ISBN 978-1-60692-984-1

Smaller Satellites Operations Near Geostationary Orbit
Matthew T. Erdner
2009. ISBN 978-1-60741-181-9

Black Holes and Galaxy Formation
Adonis D. Wachter and Raphael J. Propst
(Editors)
2010. ISBN: 978-1-60741-703-3

Dark Energy: Theories, Developments, and Implications
Karl Lefebvre and Raoul Garcia (Editors)
2010. ISBN: 978-1-61668-271-2

Dark Energy: Theories, Developments, and Implications
Karl Lefebvre and Raoul Garcia (Editors)
2010. ISBN: 978-1-61668-889-9
(Online Book)

Future U.S. Space Launch Capabilities
Franz Lojdahl (Editor)
2010. ISBN: 978-1-60741-384-4

The International Space Station
David E. Jamison (Editor)
2010. ISBN: 978-1-60692-322-1

Global Positioning Systems
Viggo Asphaug and Elias Sørensen (Editors)
2010. ISBN: 978-1-60741-012-6

Astrobiology: Physical Origin, Biological Evolution and Spatial Distribution
Simon Hegedűs and Jakob Csonka (Editors)
2010. ISBN: 978-1-60741-290-8

Space Tourism Issues
Elias Wikborg (Editor)
2010. ISBN: 978-1-60741-353-0

Exploring the Final Frontier : Issues, Plans and Funding for NASA
Dillon S. Maguire (Editor)
2010. ISBN: 978-1-60876-080-0

Primordial Space
Bernd Schmeikal
2010. ISBN: 978-1-60876-781-6

Sustaining the Global Positioning System
Earl M. Peabody (Editor)
2010. ISBN: 978-1-60741-006-5

Analytical Methods for the Formation of Dark Matter Haloes in the Universe
Nicos Hiotelis
2010. ISBN: 978-1-60876-473-0

Space Material Sciences
A.I. Feonychev
2010. ISBN: 978-1-61668-236-1

Space Material Sciences
A.I. Feonychev
2010. ISBN: 978-1-61668-477-8
(Online Book)

Commercial Space Transportation
Jocelyn S. Gunther (Editor)
2010. ISBN: 978-1-61668-707-6

Commercial Space Transportation
Jocelyn S. Gunther (Editor)
2010. ISBN: 978-1-61668-795-3
(Online Book)

Future of U.S. Human Spaceflight: Background and Issues
Derek A. Warren and Bridget D. Conway (Editors)
2010. ISBN: 978-1-61668-774-8

Future of U.S. Human Spaceflight: Background and Issues
Derek A. Warren and Bridget D. Conway (Editors)
2010. ISBN: 978-1-61668-876-9
(Online Book)

How Did We All Begin: Where is God in All That?
Calvin S. Kalman
2010. ISBN:978-1-61668-364-1

PREFACE

This book explores the significant challenges in sustaining and upgrading The Global Positioning System (GPS). The GPS provides positioning, navigation, and timing data to users worldwide, and has become essential to U.S. national security and a key tool in an expanding array of public service and commercial applications at home and abroad. GPS is integrated into nearly every facet of U.S. military operations, and the number of civil users is increasing. Other countries are now developing their own independent global navigation satellite systems that could offer capabilities that are comparable, if not superior to GPS. The U.S. government, which plans to invest more than $5.8 billion from 2009 through 2013 in the GPS space and ground control segments currently under development, provides GPS service free of charge. The Department of Defense (DoD) develops and operates GPS, and an interdepartmental committee manages the U.S. space-based positioning, navigation and timing infrastructure, which includes GPS. This book looks at the global economic and national security importance of GPS, the ongoing GPS modernization effort and the international efforts to develop new systems.

Chapter 1 - The Global Positioning System (GPS), which provides positioning, navigation, and timing data to users worldwide, has become essential to U.S. national security and a key tool in an expanding array of public service and commercial applications at home and abroad. The United States provides GPS data free of charge. The Air Force, which is responsible for GPS acquisition, is in the process of modernizing GPS.

In light of the importance of GPS, the modernization effort, and international efforts to develop new systems, GAO was asked to undertake a broad review of GPS. Specifically, GAO assessed progress in (1) acquiring GPS satellites, (2) acquiring the ground control and user equipment necessary to leverage GPS

satellite capabilities, and evaluated (3) coordination among federal agencies and other organizations to ensure GPS missions can be accomplished. To carry out this assessment, GAO's efforts included reviewing and analyzing program documentation, conducting its own analysis of Air Force satellite data, and interviewing key military and civilian officials.

Chapter 2 - This chapter is edited and excerpted testimony Mr. Chet Huber, before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives, on May 7, 2009.

Chapter 3 - This chapter is edited and excerpted testimony Lieutenant General Larry James, before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives, on May 7, 2009.

Chapter 4 - This chapter is edited and excerpted testimony Major General Neil McCasland, before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives, on May 7, 2009.

Chapter 5 - This chapter is edited and excerpted testimony Mr. F. Michael Swiek, before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives, on May 7, 2009.

Chapter 6 - This chapter is edited and excerpted testimony Karen Van Dyke, before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, House of Representatives, on May 7, 2009.

CONTENTS

In: Sustaining the Global Positioning System ISBN: 978-1-60741-006-5
Editors: Earl M. Peabody

Chapter 1

GLOBAL POSITIONING SYSTEM: SIGNIFICANT CHALLENGES IN SUSTAINING AND UPGRADING WIDELY USED CAPABILITIES

Government Accountability Office

WHY GAO DID THIS STUDY

The Global Positioning System (GPS), which provides positioning, navigation, and timing data to users worldwide, has become essential to U.S. national security and a key tool in an expanding array of public service and commercial applications at home and abroad. The United States provides GPS data free of charge. The Air Force, which is responsible for GPS acquisition, is in the process of modernizing GPS.

In light of the importance of GPS, the modernization effort, and international efforts to develop new systems, GAO was asked to undertake a broad review of GPS. Specifically, GAO assessed progress in (1) acquiring GPS satellites, (2) acquiring the ground control and user equipment necessary to leverage GPS satellite capabilities, and evaluated (3) coordination among federal agencies and other organizations to ensure GPS missions can be accomplished. To carry out this assessment, GAO's efforts included reviewing and analyzing program documentation, conducting its own analysis of Air Force satellite data, and interviewing key military and civilian officials.

WHAT GAO RECOMMENDS

GAO's recommendations include that the Secretary of Defense appoint a single authority to oversee development of GPS space, ground control, and user equipment assets, to ensure they are synchronized, well executed, and potential disruptions are minimized. DOD concurred with our recommendations.

WHAT GAO FOUND

It is uncertain whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption. If not, some military operations and some civilian users could be adversely affected.

- In recent years, the Air Force has struggled to successfully build GPS satellites within cost and schedule goals; it encountered significant technical problems that still threaten its delivery schedule; and it struggled with a different contractor. As a result, the current IIF satellite program has overrun its original cost estimate by about $870 million and the launch of its first satellite has been delayed to November 2009—almost 3 years late.
- Further, while the Air Force is structuring the new GPS IIIA program to prevent mistakes made on the IIF program, the Air Force is aiming to deploy the next generation of GPS satellites 3 years faster than the IIF satellites. GAO's analysis found that this schedule is optimistic, given the program's late start, past trends in space acquisitions, and challenges facing the new contractor. Of particular concern is leadership for GPS acquisition, as GAO and other studies have found the lack of a single point of authority for space programs and frequent turnover in program managers have hampered requirements setting, funding stability, and resource allocation.
- If the Air Force does not meet its schedule goals for development of GPS IIIA satellites, there will be an increased likelihood that in 2010, as old satellites begin to fail, the overall GPS constellation will fall below the number of satellites required to provide the level of GPS service that the U.S. government commits to. Such a gap in capability could have wide-ranging impacts on all GPS users, though there are measures the Air Force and others can take to plan for and minimize these impacts.

In addition to risks facing the acquisition of new GPS satellites, the Air Force has not been fully successful in synchronizing the acquisition and development of the next generation of GPS satellites with the ground control and user equipment, thereby delaying the ability of military users to fully utilize new GPS satellite capabilities. Diffuse leadership has been a contributing factor, given that there is no single authority responsible for synchronizing all procurements and fielding related to GPS, and funding has been diverted from ground programs to pay for problems in the space segment.

DOD and others involved in ensuring GPS can serve communities beyond the military have taken prudent steps to manage requirements and coordinate among the many organizations involved with GPS. However, GAO identified challenges to ensuring civilian requirements and ensuring GPS compatibility with other new, potentially competing global space-based positioning, navigation, and timing systems.

ABBREVIATIONS

AEP	Architecture Evolution Plan
DASS	Distress Alerting Satellite System
DOD	Department of Defense
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
IFOR	Interagency Forum for Operational Requirements
JCIDS	Joint Capabilities Integration and Development System
L2C	second civil signal
L5	third civil signal
M-code	Military Code
NASA	National Aeronautics and Space Administration
OCS	Operational Control Segment
OCX	Next Generation Control Segment
OSD	Office of the Secretary of Defense
PDOP	position dilution of precision
PNT	Positioning, Navigation, and Timing
SLR	Satellite Laser Ranging
TSPR	Total System Performance Responsibility

April 30, 2009

The Honorable John Tierney
Chairman
The Honorable Jeff Flake Ranking Member
Subcommittee on National Security and Foreign Affairs
Committee on Oversight and Government Reform
House of Representatives

The Global Positioning System (GPS)—a space-based satellite system that provides positioning, navigation, and timing data to users worldwide—has become essential to U.S. national security and a key component in economic growth, transportation safety, homeland security, and critical national infrastructure in the United States and abroad. GPS is integrated into nearly every facet of U.S. military operations, and the number of civil users is increasing. Other countries are now developing their own independent global navigation satellite systems that could offer capabilities that are comparable, if not superior to GPS.

The U.S. government, which plans to invest more than $5.8 billion from 2009 through 2013 in the GPS space and ground control segments currently under development, provides GPS service free of charge. The Department of Defense (DOD) develops and operates GPS, and an interdepartmental committee—co-chaired by DOD and the Department of Transportation—manages the U.S. space-based positioning, navigation, and timing infrastructure, which includes GPS. DOD also provides most of the funding for GPS.

The Air Force, which is responsible for GPS acquisition, is in the process of modernizing GPS to enhance its performance, accuracy, and integrity. The modernization effort includes GPS IIF and IIIA, two satellite acquisition programs currently underway that are to provide new space- based capabilities and replenish the satellite constellation; the ground control segment hardware and software; and user equipment for processing modernized GPS capabilities.

In light of the global economic and national security importance of GPS, the ongoing GPS modernization effort, and the international efforts to develop new systems, you asked us to undertake a broad review of the program and efforts to replenish and upgrade capability. Specifically, we assessed progress in (1) acquiring GPS satellites, (2) acquiring the ground control and user equipment necessary to leverage GPS satellite capabilities, and (3) coordinating among federal agencies and other organizations to ensure broader GPS missions can be accomplished.

To assess the acquisition of satellite, ground control, and user equipment, we interviewed Office of the Secretary of Defense (OSD) and DOD officials from offices that manage and oversee the GPS program. We also reviewed and analyzed program plans and documentation related to cost, schedule, requirements, program direction, and satellite constellation sustainment, and compared programmatic data to GAO's criteria compiled over the last 12 years for best practices in system development.[1] We also conducted our own analysis, based on data provided by the Air Force, to assess the implications of potential schedule delays we identified in our assessment of the satellite acquisition. To assess coordination among federal agencies and the broader GPS community, we interviewed OSD and DOD officials from offices that manage and oversee the GPS program, officials from the military services, officials from the Department of Transportation and other civil departments and agencies, and officials at the U.S. Department of State and at various European space organizations. We also analyzed how civil departments and agencies coordinate with DOD on GPS civil requirements, and how the U.S. government coordinates with foreign countries. Additional information on our scope and methodology is in appendix I. We conducted this performance audit from October 2007 to April 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

RESULTS IN BRIEF

It is uncertain whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption. If not, some military operations and some civilian users could be adversely affected.

- Under the IIF program, the Air Force had difficulty in successfully building GPS satellites within cost and schedule goals; it encountered significant technical problems which still threaten its delivery schedule; and it faced challenges with a different contractor for the IIF program. These problems were compounded by an acquisition strategy that relaxed oversight and quality inspections as well as multiple contractor mergers and moves, and the addition of new requirements late in the development

cycle. As a result, the IIF program has overrun its original cost estimate of $729 million by about $870 million and the launch of the first IIF satellite has been delayed to November 2009—almost 3 years late.

- Further, while the Air Force is structuring the new GPS IIIA program to prevent mistakes made on the IIF program, the Air Force is aiming to deploy the GPS IIIA satellites 3 years faster than the IIF satellites. We believe the IIIA schedule is optimistic given the program's late start, past trends in space acquisitions, and challenges facing the new contractor. Of particular concern is leadership for GPS acquisition, as GAO and other studies have found the lack of a single point of authority for space programs and frequent turnover in program managers have hampered requirements setting, funding stability, and resource allocation.
- If the Air Force does not meet its schedule goals for development of GPS IIIA satellites, there will be an increased likelihood that in 2010, as old satellites begin to fail, the overall GPS constellation will fall below the number of satellites required to provide the level of GPS service that the U.S. government is committed to providing. Such a gap in capability could have wide-ranging impacts on all GPS users, though there are measures the Air Force and others can take to plan for and minimize these impacts.

Moreover, the Air Force has not been fully successful in synchronizing the acquisition and development of the next generation of GPS satellites with the ground control and user equipment, thereby delaying the ability of military users to utilize new GPS satellite capabilities. For example, a modernized military signal will be available for operations on GPS satellites over a decade before user equipment will be fielded that can take strategic advantage of it. The signal is designed to improve resistance to jamming of GPS. Also, because leadership for acquisitions across the space community is fragmented, there is no single authority responsible for synchronizing all procurements and fielding related to GPS.

Lastly, DOD and others involved in ensuring GPS can serve communities beyond the military have taken prudent steps to manage requirements and coordinate among the many organizations involved with GPS. However, we identified challenges in the areas of ensuring civilian requirements can be met and ensuring GPS compatibility with other new, potentially competing global space-based positioning, navigation, and timing systems.

Because of (1) the criticality of the GPS system to the military, various economic sectors, and the international community and (2) schedule risks in the

current program, we are recommending that the Secretary of Defense appoint a single authority to oversee the development of the GPS system, including DOD space, ground control, and user equipment assets, to ensure that the program is well executed and resourced and that potential disruptions are minimized. The appointee should have authority to ensure DOD space, ground control, and user equipment are synchronized to the maximum extent practicable; and coordinate with the existing positioning, navigation, and timing infrastructure to assess and minimize potential service disruptions in the event that the satellite constellation was to decrease in size for an extended period of time. After a review of a draft of this report, DOD concurred with our recommendations and provided some additional comments. The full text of DOD's comments may be found in appendix IV.

BACKGROUND

GPS is a global positioning, navigation, and timing network consisting of space, ground control, and user equipment segments that support the broadcasts of military and civil GPS signals. These signals each include positioning and timing information, which enables users with GPS receivers to determine their position, velocity, and time, 24 hours a day, in all weather, worldwide. GPS is used by all branches of the military to guide troops' movements, integrated logistics support and battlespace situational awareness, and communications network synchronization. In addition, bombs and missiles are guided to their targets by GPS signals and GPS is used to locate military personnel in distress. Early in the development of GPS, the scope was expanded to include complementary civil capabilities.

Over time, GPS has become a ubiquitous infrastructure underpinning major sections of the economy, including telecommunications, electrical power distribution, banking and finance, transportation, environmental and natural resources management, agriculture, and emergency services in addition to the array of military operations it services. For instance, civil agencies, commercial firms, and individuals use GPS to accurately navigate from one point to another. Commercial firms use GPS to route their vehicles, as do maritime industries and mass transit systems. In addition to navigation, civil departments and agencies and commercial firms use GPS and GPS augmentations[2] to provide high-accuracy, three-dimensional positioning information in real time for use in surveying and mapping. The aviation community worldwide uses GPS and GPS augmentations