Navipedia—The GNSS Wiki

A Reference for Global Navigation Satellite Systems

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Satellite navigation is progressing at such a rapid pace that it is difficult to keep track of the latest evolutions, satellite launches, technologies or even systems and signals. With Navipedia, the European Space Agency has introduced a common online entry point for GNSS know-how. As with all media-wiki products, any registered user can comment, propose modification to an existing article, suggest a new topic or submit a draft article. However, Navipedia has something many other wikis don't: a robust content management and control process managed by an editorial team of knowledgeable GNSS professionals to ensure that the website always remains updated and reliable.

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In the last 30 years, satellite navigation applications have grown in number and kind, entire new systems have emerged, and existing systems have modernized.

The current international scenario includes the modernization of the first completed GNSS systems, the U.S. Global Positioning System and Russia's GLONASS.

New satellite navigation systems are emerging, too: Europe's Galileo and China's Compass/BeiDou, as well as satellite-based augmentation and regional satellite systems, including the European Geostationary Navigation Overlay Service (EGNOS), the U.S. Wide Area Augmentation System (WAAS), Japan's Multi-functional Transport Satellite Satellite-based Augmentation System (MSAS) and Quasi-Zenith Satellite System (QZSS), and India's GPS- and Geo-Augmented Navigation (GAGAN) system.

With so many systems and modernization activities under way, program participants and interested observers alike may find it difficult to keep track of the latest evolutions, satellite launches, technologies or even systems and signals. This rapid pace of development means books and articles on GNSS are rapidly overtaken by events, and many times incorrect and outdated information is scattered all over the Internet.

Recognizing that satellite navigation has become a keystone for European development and services to its citizens,

the European Space Agency (ESA) has introduced Navipedia, an electronic repository of knowledge on GNSS systems, applications, receivers and fundamentals. This activity has also been supported by the United Nations Office for Outer Space Affairs (UNOOSA).

Navipedia — the GNSS wiki — is a free, web-based collaborative GNSS encyclopedia for the public that is written and continuously reviewed by experts in the field. As such, it provides an accessible, extensive, and updated source of reference materials.

The initial version of Navipedia was produced with contributions from GMV, a technological business group with international presence. ESA contracted with their GNSS experts for the production and revision of articles. Initial contributors also came from the University Polytechnic of Catalonia, others European universities, and an ESA internal team of navigation experts.

Today, more than 400 articles — classified basic, medium and advanced — are available at <www.navipedia.org>. These cover the fundamental principles of satellite navigation, how receivers operate, satellite navigation systems in current or future operation around the globe, and GNSS-related services and applications. From the outset, a major effort has been devoted to providing a complete list of dedicated articles on GNSS fundamentals, so as to support from the very beginning GNSS education and universities.

Navipedia is intended to grow with the collaboration of the GNSS community and to serve as a GNSS reference for users at all levels, from GNSS institutions and industry to academics to curious members of the public. Now, Navipedia is ready for the entire GNSS community to join in and contribute their own knowledge.

Navipedia's Design and Structure

Navipedia was conceived from the beginning to become a collaborative GNSS encyclopedia. It is built on a web-based software platform, MediaWiki, a free open-source software package written in PHP, originally developed for use on Wikipedia. It is hosted in a repository server and is the first freely accessible technical ESA wiki open to the public.

Navipedia adopts the collaborative principle of wiki products — anyone can comment, propose modification to an existing article, suggest a new topic, or submit a draft article. The design of the platform considers usability aspects such as learnability and efficiency as well as complete and correct content.

With these objectives in mind, the wiki format was adopted to comply with the required flexibility, readability and collaborative-enabled approach. In fact, users have become so used to wiki formats that Navipedia's design provides an easy entry point.

In the wiki-world, the main precedent and reference is obviously Wikipedia. However, within the broad-spectrum subject matter of Wikipedia not all topics are covered with the same level of depth and when it comes to highly specialized articles, information is often missing or even unclear.

As a consequence, specialized wikis have started to pop-up in the past few years. Skybrary <www.skybrary.aero>, for example, covers aviation safety and is offered as "the single point reference for the aviation safety knowledge." Another example is Intypedia <www.intypedia.com>, which covers information security.

Thus, certain complex topics — such as GNSS — clearly need special treatment, while still maintaining complementarity among all wikis. In fact, all of Navipedia's contents are validated by GNSS professionals from ESA, universities, and industry — re-enforcing the utility of Navipedia for educational purposes and the general public as well. Articles are classified as basic, medium, or advanced level, covering in this way a wide spectrum of potential user backgrounds and interests.

As a result, Navipedia is a complement to Wikipedia in that it provides more detailed information on GNSS — for example, descriptions of algorithms and topical discussions such as GNSS system interoperability. Also, Navipe-

Why a GNSS Wiki?

The proliferation and modernization of global navigation satellite systems, regional systems, and augmentations appears to be accelerating.

GPS and GLONASS have achieved full operational capabilities with their satellite constellations and are now modernizing. Europe's Galileo system has placed its first four permanent satellites in orbit, and China's Compass/Beidou will soon cover Asia and the Pacific region, before building toward full global capability later on.

Satellite-based augmentation systems (SBAS) have emerged as a complement to GNSS through the use of geostationary satellites that broadcast correction data, integrity messages, and/or additional ranging signals. Although the initial target application for SBAS was civil aviation safety-critical systems, other domains are already using SBAS as a way to improve accuracy and provide integrity.

SBAS adds to regional accuracy and robustness and include the EGNOS system in Europe, the WAAS in the United States, MSAS in Japan, SDCM in Russia, GAGAN in India and SNAS in China.

SBAS feasibility studies such as the SACCSA study in South America are under way in other parts of the world as well, including Malaysia, South Africa, and the Caribbean.

Furthermore, regional navigation satellite systems play an important role, enhancing and complementing GNSS performance in a various regions. QZSS in Japan, IRNSS in India and Beidou in China are examples.

At the same time, GNSS signals are becoming more robust and more accurate with improved availability, integrity and continuity. GNSS is using additional frequencies, modulations, coding schemes, and performance enabled by technology evolution, such as improvements in atomic clocks.

And then there are the applications, a true revolution nowadays.

GNSS applications play a crucial role in aviation, maritime, road, scientific, space, surveying, precise time reference, public security, atmospheric sensing, financial transactions and stock markets – just to name a few.

In other words, when it comes to satellite navigation, the flow of information is pushing at the limits of the media designed to handle it – hence, the need for a resource such as Navipedia.

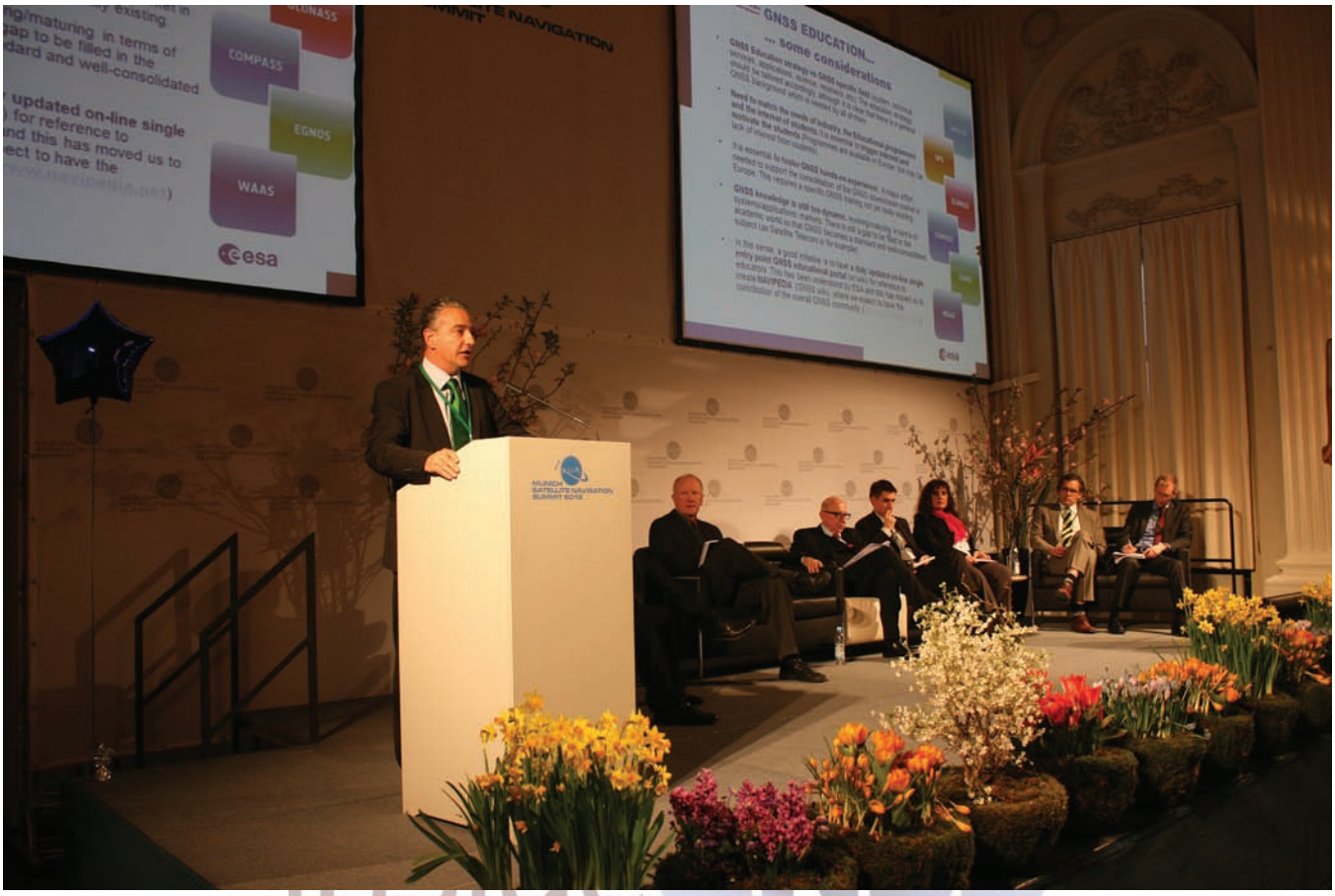

Photo by Munich Satellite Navigation Summit

Javier Ventura-Traveset introduces Navipedia at the Munich Satellite Navigation Summit on March 14, 2012. He is responsible for managing Navipedia's development as well as GNSS education activities for ESA.

"Considering the extremely dynamic nature of the GNSS world today, we decided that having a duly updated single entry point GNSS wiki could be extremely beneficial for the entire GNSS community."

Gunter Hein, ESA, at the introduction of Navipedia, Munich Satellite Navigation Summit 2012

dia's information is more trustworthy because GNSS experts review it. Another important point intellectual property rights are taken very seriously by Navipedia, which uses only information in the public domain.

Organization of Navipedia Content

As with wikis in general, Navipedia is organized into key subject sections.

The Global Navigation Satellite Systems. This category describes the existing and developing GNSS and includes regular updates on the operational status and evolution roadmap for Galileo, GPS, GLONASS and COMPASS.

At a minimum, Navipedia viewers will find the signal plan, architecture, ground segment, space segment, user segment, receivers, services, performances as well as future and evolutions for each of the GNSSes. This information is usually provided by the system operators on their web sites, at conferences, and through the general media.

In addition, specific pages highlight anything unique to each system — for example, the computation of satellite coordinates, which varies for Galileo, GPS, and GLONASS; descriptions of the reference frames used by each system, and the Galileo integrity concept.

When available, a dedicated page is created for each navigation message to provide the users with a description and pointer to the applicable Signal In Space Interface Control Documents (SIS ICD).

Satellite Based Augmentation Systems. This category includes EGNOS, WAAS, Japan's Multi-technology Satellite Augmentation System (MSAS), and other SBASes currently under consideration.

As with the GNSS category, the articles cover the fundamentals of SBAS and structural segments. In addition, this section includes information about the EGNOS Data Service (EDAS), SISNET, description of message formats, and pointers to the applicable SIS ICD.

Furthermore, SBAS articles describe the integrity concept, existing standards and main standardization bodies as well as interoperability aspects.

Finally, information on other SBAS is compiled from publicly available

information on Russia's System of Differential Correction and Monitoring (SDCM), China's Satellite Navigation Augmentation System (SNAS), and GAGAN, as well as commercial systems such as StarFire, and SACCSA (Solución de Aumentación para Caribe, Centro y Sudamérica), the SBAS initiative in South/Central America and the Caribbean, as well as Malaysian and African initiatives.

Regional Navigation Satellite Systems. This category provides information on the existing regional systems the Indian Regional Navigation Satellite System (IRNSS), QZSS, and BeiDou-1 including their signal plans.

GNSS fundamentals. This section introduces the basic concepts: how to compute a navigation solution, different reference systems, signals characteristics, generation of observables, positioning models and data processing, just to name a few.

More than 180 articles cover highly specialized GNSS topics, from information on coordinates transforms, detailed description of the Galileo AltBOC signal modulation, Advanced Receiver Autonomous Integrity Monitoring (ARAIM), pole tide and shift of earth rotation axis, NeQuick Ionospheric Model, cycle slips detection with three-frequency signals, precise point positioning (PPP) standards and GNSS compatibility and interoperability considerations.

To date, the main contributors to this section are university-level students and professors. Navipedia strongly encourages contributions and keys findings from students, formally recognizing their contribution in their associated Navipedia articles.

GNSS Receivers. This category covers the parts of a receiver and how they work. The main receiver blocks are antenna, front end, baseband processing, and application processing.

Articles linked to these blocks describe functionalities, expected performances and most commonly used techniques.

Differences among receivers from the various satellite navigation systems are presented and discussed in more than 20 pages that go into precise details, such as the detailed mathematical model of lock detectors or state diagrams of typical receiver operations.

GNSS applications. Because there are so many applications for GNSS receivers – clearly not limited to the simple computation of a position — they are broken out into their own category.

It is a large category, indeed, covering a wide range of areas such as location-based services, civil navigation, surveying and mapping, autonomous, scientific, space, military, maritime, road, agriculture and public security — just to name a few.

Most of the application-oriented articles are classified as "basic," that is, the reader does not have to have any specialized GNSS background.

This area makes interesting reading for anyone looking for articles on, for example, innovative ideas related to geocaching and gaming.

Inside Navipedia. At the top of every page on the Navipedia website is a *hotlink* to an invitation to join as a registered user. This links to five simple questions —email address, name, job function and organization, and country.

Once a viewer submits an application, he or she will instantly receive an email acknowledgment and password. Registration is free.

Most of the home page (**Figure 1**) contains color-coded buttons for the categories just discussed — one for each of the various GNSSes, augmentation and regional systems, GNSS fundamentals, receivers and applications.

On the right-hand side are ESA news headlines and a quick reference section that includes a useful list of acronyms used by the satellite navigation community.

Furthermore, Navipedia also aggregates links to external pages (such as the official pages of each of the systems), GNSS-specialized educational tools, and relevant documentation.

The left sidebar (**Figure 2**), which appears on each internal page of the website, gives the user a number of tools and controls:

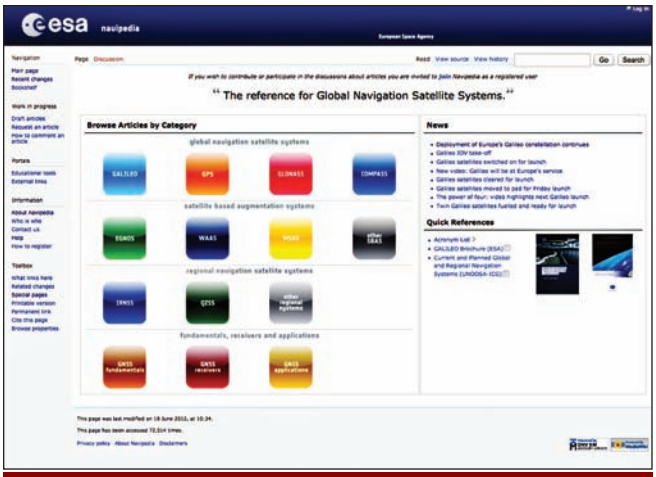

FIGURE 1 The Home Page of Navipedia – <www.navipedia.org >

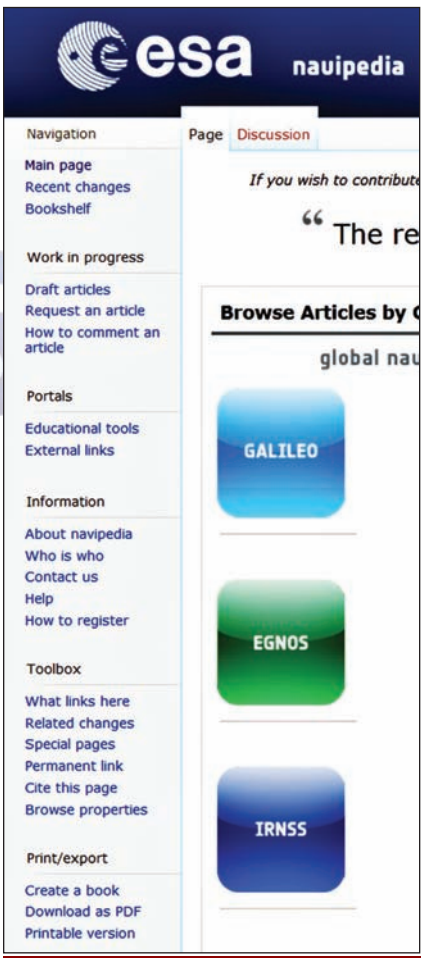

FIGURE 2 Sidebar detail.

- Navigation: including quick links to the main page, recent changes and the bookshelf, the beginning of a collection that will provide searchable access to articles, papers, books and brochures available online
- Work in progress: the location of draft articles, requests for articles, and instructions on how registered users may comment on posted articles
- Portals: pointing to ESA educational software tools and the respective links for accessing them, as well as external links to all of the official GNSS websites
- Information: about Navipedia, its history, the people behind the idea and its development, and information on how to contact the Navipedia team
- Toolbox: links to the "back end" of the wiki and tools to support navigation and usability of the site.

Navipedia: Article Example

Figure 3 provides an excerpt of the Galileo Architecture article.

Every article starts with a short abstract and a list of contents with the direct links to each section. On the right hand side, a box gathers related information such as category —Galileo, in this case — title, editor information, level of the article, and the year of publication.

As for any wiki-based platform, the format is standardized, enabling website users to follow the links highlighted in the text with a different color just by clicking on them.

The top bar includes the discussion tab, where registered users can provide comments to the article and view the history of the past modifications.

The Mediawiki software includes a useful search engine that has been incorporated into the website in order to search for a given topic within Navipedia.

The Navipedia Community

In addition to a continuing participation by its founders, the European Space Agency and UNOOSA, Navipedia also seeks new partnerships with academic institutions that would like to contribute actively to the project.

Navipedia already hosts portals for GNSS-related educational tools and external links to several GNSS entities and institutions and would like to include more. The team also welcomes GNSS professionals, users, and the public to join the community and continue to extend the set of references.

The list of potential Navipedia users is long — from GNSS institutions and agencies to individual professionals and technicians, service providers to university students and educators and, indeed, anyone who uses GNSS now or in the future.

This group has very different needs: some are more interested in a high-level description of the concepts without being submerged in mathematical equations while others are more interested in practical techniques and their actual performance.

In order to cover these different needs, all articles in Navipedia have been categorized in three levels: Basic, Medium, and Advanced. The first aims at the general public without technical knowledge of GNSS, the second at those seeking detailed technical information, and the third at scholars and GNSS professionals seeking more detailed technical knowledge on specific aspects of GNSS technology.

All pages are accessible to all users, but this labeling of the articles may be useful as a guideline.

The article classification system helps readers decide how to use Navipedia content.

Three different types of users are supported in Navipedia.

- *Readers* are unregistered users who have read-only access to all pages.
- *Contributors* are registered users who can participate in discussions, suggest modifications to articles, comment on, contribute to or propose new articles.
- *Reviewers* are registered users with approval and administrator's privileges.

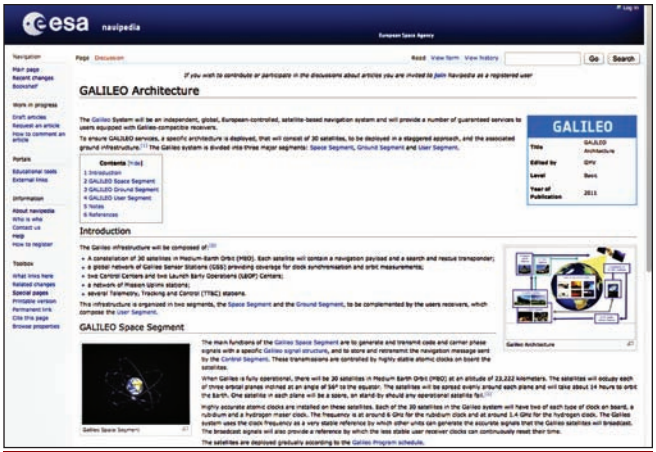

FIGURE 3 Galileo architecture

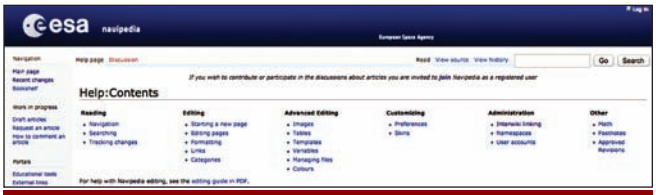

FIGURE 4 Help on Navipedia

How to Contribute to Navipedia?

Anyone can contribute to Navipedia, using a process described on the website. Contributions range from providing comments, suggestions, proposing new content (either updates to sections, articles, or new articles) and participating in discussions about the articles.

In order to contribute, users need to register to Navipedia (free of charge). Anyone can register from any of the pages in Navipedia by clicking the "join" link in the upper part of the page, as illustrated in the following figure.

The next step to becoming a registered Navipedia user is to fill out a form with some basic information, as shown in the figure below.

From that point onwards, the user receives a password by e-mail and is able to log in to Navipedia. Logged

users have access to the "edit" tab and are able to join discussions on articles and topics – unregistered users are only allowed to read the discussions, not participating.

For people who are not familiar with editing the contents of a wiki-platform, Navipedia provides an extensive help manual, accessible from the left hand side column on every page. For example, **Figure 4** is a screenshot from the website that illustrates how to edit an article on Navipedia.

Registered users are able to keep track of changes in a given page or to follow modifications and updates on a given topic.

Summary

Navipedia is a common entry point for GNSS know-how that enables users to access updated information on the existing GNSS Systems, applications, receivers and fundamentals.

Navipedia adopts the concept of Media-wiki products— anyone can comment, propose modification to an existing article, suggest a new topic or submit a draft article.

However, an important difference distinguishes Navipedia from other wikis: a robust content management and control process ensures the required quality, reliability and consistency of stored GNSS information.

Today, Navipedia is fully operational and evolutions are already being planned to increase its access to users, such as the development of applications to be hosted in smartphones. Navipedia is available on social media, too: Facebook <http://www.facebook.com/Navipedia.net> and LinkedIn (search for Navipedia in "Groups").

Even though GMV is currently contractually responsible for the maintenance of Navipedia, all contributions from the GNSS community will be welcomed.

The Navipedia team is open to develop new partnerships to increase collaborations and extend Navipedia portals for the use of the GNSS community and the general public. Contributions can be made through the official Navipedia site where anyone can register as a user: www.navipedia.org.

Anyone can contact the editors and the content managers by submitting questions about editorial content, ideas for new articles, and quality assurance concerns to <navipedia@esa.int>.

The final objective is that together with the GNSS community we achieve and maintain a truly reliable and updated web-based, world-reference GNSS encyclopedia.

Authors

Teresa Ferreira has been working in receiver and navigation-related technologies and applications since she joined GMV in 2004. Her degrees are in telecommunications and GNSS.

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Timo Kouwenhoven works at DNV knowledge management advisory services. He designed and developed the "Single Points of Knowledge" service that builds web-based platforms for critical content. His projects include navipedia.org for ESA and skybrary.aero for Eurocontrol. He has degrees in technical information systems and cooperative systems.

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Dr Javier Ventura-Traveset has worked at the European Space Agency since 1989, where he has been involved in a large number of space programs. He has been EGNOS System Manager, EGNOS Mission Manager, and EGNOS Principal System Engineer and has more than 20 years of experience in the GNSS field. He had the vision for the creation of Navipedia and has managed the project for ESA. He is the recipient of several awards, the co-inventor of SISNET, and has published more than 200 publications in the field.

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Dr. Günter W. Hein serves as the editor of the Working Papers column. He is head of the Galileo Operations and Evolution department of the European Space Agency. Previously, he was a full professor and director of the Institute of Geodesy and Navigation at the Universität der Bundeswehr München. In 2002, he received the Johannes Kepler Award from the U.S. Institute of Navigation (ION) for "sustained and significant contributions" to satellite navigation. He is one of the CBOC inventors. IG