46
Review paper I Прегледни научни рад
DOI 10.7251/STP2215476N
ISSN 2566-4484

Zvonimir Nevistić, University of Zagreb, znevistic@geof.hr
Željko Bačić, University of Zagreb, zbacic@geof.hr

USER NEEDS ASSESSMENT FOR THE ESTABLISHMENT OF SPATIAL DATA INFRASTRUCTURE OF CELESTIAL BODIES

Abstract

Large amounts of data are collected on space bodies, and all data is available to all users free of charge through various archives and portals. When searching for data, especially non-space scientists, often have problems because the archives are tailored to meet only space experts needs. Prior knowledge about missions is necessary to search data and use archives. Large amounts of data, and the interest of the public impose the need to develop Spatial Data Infrastructure of Celestial Bodies to enable efficient use and exchange of data. In this paper user needs assessment, in the form of global survey, for the purpose of establishing SDICB was con-ducted. The results will serve as a basis for establishing guidelines for the implantation of the SDICB concept.

Keywords: Archives, Space Data, SDICB, User Needs Assessment

ПРОЦЈЕНА ПОТРЕБА КОРИСНИКА ЗА УСПОСТАВУ ИНФРАСТРУКТУРЕ ПРОСТОРНИХ ПОДАТАКА НЕБЕСКИХ ТИЈЕЛА

Сажетак

У данашње вријеме свим корисницима бесплатно су доступне велике количине података о свемирским тијелима путем разних архива и портала. Приликом претраживања тих скупова података, корисници изван домене свемирских истраживања често наилазе на проблеме јер су архиве прилагођени потребама свемирских стручњака. За претраживање података потребно је претходно знање о мисијама. Велике количине података као и повећани интерес јавности за податке свемирских истраживања намећу потребу развоја инфраструктуре просторних података небеских тијела (ИППНТ) како би се омогућило учинковито кориштење и размјена података. У овом раду проведена је процјена потреба корисника, у облику глобалне анкете, која ће послужити као основа за доношење смјерница приликом успоставе IPPNT-a.

Кључне ријечи: Архиве, Свемирски подаци, ИППНТ, Процјена потреба корисника

1. INTRODUCTION

The digital age we live in today has made it possible to have large amounts of information easily accessible through various web services. With the development of technology, a number of tools have been developed to support and dis-tribute spatial information, which is often one of the most important elements in decision-making in many disciplines. Although spatial information is easily available today, there is often the problem of finding adequate and consistent information for different needs, and the large amount of data that has appeared over the past few years does not facilitate their search [1]. This fact has triggered the development of the Spatial Data Infrastructure (SDI) concept, which solves the problem of finding spatial data and reducing their redundancy [2] and enables better data management, which can bring economic and environmental benefits. The SDI concept connects existing spatial data into a single network, and to be successfully implemented, it is necessary to harmonize existing data sets and standardize their quality [3]. The implementation of this concept pro-vides a basis for searching spatial data, their assessment and different application at all levels of society and facilitates integration with other data sets, which opens new innovative business opportunities, significant resource savings, pro-motes sustainable development, better environmental management, and social stability [4, 5].

As space exploration has intensified over the past decade and numerous scientific studies of planets and other celestial bodies have been launched, the interest of a wide range of users in this type of data has increased. Space research data are of particular interest and importance because their interpretation provides a better understanding of the Earth and its dynamics and provides answers to cur-rent and important questions, such as the impact of global warming [6], provides a better understanding of the solar system and is used to mitigate dangers of life on Earth and contribute to the development of science in general in terms of new technologies, engineering, and mathematics. Data collected by numerous space missions of different agencies are given to users for use through various space data portals and archives. Access to this data is free for all users. As the archived data are not suitable for direct use, the data is accompanied by metadata to facilitate their use for a wide range of users [7]. The primary purpose of these archives was the long-term storage of data for space scientists and their research, so the archives are tailored to their needs. With the increase in the number of multidisciplinary missions, the number of scientists who want to access this data has also increased. At the same time, the interest of scientists from other fields as well as the public has also increased. For such groups of users, searching the archives is a great challenge because prior knowledge about the missions that collected the data is needed to successfully obtain the data of interest. The biggest problems of existing archives are also the visibility, accessibility, understanding and interpretation of data as well as users' expectations for interactive services that will help them research, discover, filter, and visualize data before downloading [8, 9].

Because of the mentioned increase in the amount and diversity of data and public interest in the use of data, there is a need for a Spatial Data Infrastructure of Celestial Bodies (SDICB) as an extended concept of traditional terrestrial SDI, which should address the challenges of collecting, managing, finding, and using space research data. As one of the first step for the establishment and implementation of this concept, it is necessary, among other things, to investigate what data is collected and to what extent, how data is currently distributed and analyze the needs and requirements of users. In this paper, a User Needs Assessment (UNA) was conducted for the purpose of establishing such an infrastructure, and the results of the assessment, in the form of user needs and requirements, will serve as a basis for establishing guidelines for IPPNT concept implantation which will improve the availability of space research data.

2. DATA ARCHIVES OF SPACE RESEARCH

Space spatial data are all data with a spatial component collected by direct or remote observations on space bodies in the solar system. The first space body for which data was collected is the Moon. Mapping of the Moon began in early 1600s with the invention of the telescope [10]. Until the 1900s, when the first space missions were launched, telescopes, placed on the Earth's surface, were used to observe space bodies. In 1964, the American spacecraft Ranger VII collected over 4,000 telescopic images of the Moon. These images were used to create the first catalog of space data collected by remote sensing techniques. Since then, many missions, primarily from the United States but also from other countries, have been involved in mapping the Earth's Moon, Mars and other planets and their satellites, as well as observing other, smaller space bodies. What has been most explored on space bodies from the beginning until today are the geo-logical features.

The biggest difference in the use of space spatial data from those collected on Earth is their shape and size. International Astronomical Union (IAU) defined, for almost all major bodies in our solar system, geodetic parameters, which allows mapping of their surface as well as new opportunities for research of these bodies. The definition of coordinate systems on space bodies forms the basis (standards) for all other interoperable initiatives in space science, which relate to the collected spatial data.

Although the collection of data (especially those with a spatial component) in the space community has progressed rapidly, there are still no adequate ways to store this data and distribute it to users. One of the main problems is the fact that the space scientific community is extremely decentralized, and each organization has its own archives and data sources, but also the standards and formats they use. The main goal is to develop standards that would enable the interoperability of these data between different communities and that would create the foundations for the establishment of a SDICB. Space data is available to everyone, in its full extant, but the big problem is finding and interpreting it. Therefore, it is necessary to create spatial data that will satisfy all users (development of policies, standards, etc.) and that will be easy to find, share and interpret (metadata).

Data in the planetary community mostly come from the instruments of certain missions, and there are several different portals for finding those data. The largest archive of space data, which includes all data collected by missions under the jurisdiction of NASA, and other space organizations, is the Planetary Data System (PDS). PDS consists of several nodes (access points), each of which has a separate interface, which makes finding this data not easy. The purpose of this archive is to make the data publicly available to everyone, scientists, engineers, and other users. However, the problem arises in the fact that certain data of interest to users is difficult to find and there is no adequate metadata for its interpretation. In addition to the PDS, there are other access points such as ESA's Planetary Science Archive (PSA), but also many other mission portals where mission managers distribute data to users for use.

All of this points to many shortcomings in accessing, finding, and retrieving space data, especially for users outside space communities and the public. Space research is interdisciplinary research and not only space but also scientists of other professions are interested in it. Space exploration can give us a better understanding of our planet, so the data collected by space missions should be easily, efficiently, and understandably available to everyone. The analysis of archives and related services for finding space data from the perspective of non-space sciences leads to numerous shortcomings in the methods of their storage and distribution. Some of these shortcomings are: dispersion of data due to the large number of access points, incomprehensibility of data caused by inadequate metadata, incomprehensible data formats that cannot be used in standard processing tools, the need for some prior knowledge to successfully find data, poor search and data filtering options that gives too many of the same or similar results, inability to search the data on the map and visualize the data before down-loading, and poor supporting documentation and instructions for using the archive. All the above indicates that the archives are outdated and that it takes too much effort and time to search for the data. Archives and related services are not designed to be user centric. It is necessary to create approaches that would be more user-friendly and that would simplify data retrieval. Given the growth and large investments in space missions and technologies, these problems must be resolved as soon as possible, and one of the solutions to these problems is the establishment of a SDICB following the example of terrestrial SDI initiatives.

3. IMPROVING THE AVAILABILITY OF SPACE RESEARCH DATA

To improve the availability of space research data, a number of initiatives have been launched to make it easier for users to search and download data of interest. The motivation to support common, interoperable data formats and standards is not only to improve access to products but also to solve the problem of distributing increasing amounts of data. Within the space community, terabytes of data are available for planets, satellites, and other celestial objects [11]. For this rea-son, there is a need to adopt standardized formats and delivery methods to users.

Most of the space data collected by NASA, but also by other, non-US space missions, is stored in the PDS format / standard (PDS3/4) [12]. Most of the data is archived in the original (raw) form of the instrument which was used to collect the data. Unfortunately, the PDS format, although well documented with a focus on long-term availability in archives, is not widely recognized in spatial data mapping and analysis applications (such as GIS tools). Two formats that are recommended for use when collecting and archiving space mission data are GeoTIFF and GeoJPEG2000 [11]. Another format that is imposed and often used within the astronomical community and is also recommended for the space data is Geo-TIFS. These formats are compatible with PDS standards and are supported

by a large number of open-source software tools and catalogs. Although GeoTIFS format is widely used in astronomical observations, it is rarely used in the space community, but there are initiatives to spread FITS standards to support geospatial markings in space research. The use of this format could provide uninterrupted data exchange in the community and potentially homogenize data collection and visualization methods [13].

The U.S. Geological Survey's Center for Astrogeology (USGS ASC) is the main institution for software support of cartographic data processing for NASA's re-search missions and programs. ASC has developed Integrated Software for Imaging and Spectrometers (ISIS) which is a specialized tool for image processing and working with space data [14]. ISIS3 (third version of the software) is compatible with several different widely spread formats, but processing is only possible in a specialized custom image format. In 2006 and 2007, the PDS and ISIS3 format were added to the GDAL (Geospatial Data Abstraction Library) to improve interoperability with other applications and tools. By adding these formats to GDAL, conversion and direct use within numerous applications and software for GIS and spatial data processing is enabled.

In the domain of web service, the consortium that defines standards is Open Geo-spatial Consortium (OGC). OGC define standards such as WMS (Web Map Service), WMTS (Web Map Tiles Service), WFS (Web Feature Services) and others for web mapping and data visualization and retrieval. Several space missions support WMS / WFS standards. This allows users to search and visualize spatial databases projected on a map in JPEG or PNG format. The WMTS service is also used in some missions, but it is not as flexible as the previous two and cannot generate images at any scale, therefore, it is recommended to use WMS and WFS services when distributing space research data [11].

The IAU defines the specifications of reference systems used in the space community, and the use of which is recommended, to harmonize the use of spatial reference on all data. What IAU do not define are standards for digital mapping such as cartographic signs, attribute and symbol features, metadata, etc. It is recommended to use the digital cartographic standard for symbolization of USGS geological maps [15]. This will make easier to read and understand space maps. In addition to the reference systems, the IAU also publishes a journal of planetary nomenclature, whose wide application unifies the names used for geographical features on space bodies.

Many initiatives to improve the availability of space data have been launched through volunteer communities and various private organizations. One of these initiatives is MPASIT, which provides recommendations for the development of a comprehensive planetary spatial data infrastructure. Europlanet initiative aims to connect the European space community and project of geological mapping of Mars, Mercury and the Moon was also launched within it. The VESPA initiative deals with the availability and distribution of space data from various scientific domains. Several initiatives address the standardization of space data archiving such as PlanetServer, Open Planetary initiative provides an online framework to help collaborate between different institutions in planetary mapping, and CARTO initiative is focused on web solutions for spatial visualization and data analysis of space research data.

As already mentioned, one of the solutions to the problem of rapid increase in the amount of space research data is the establishment of an efficient spatial data infrastructure (SDI) – SDICB. The SDICB will allow standardized collection, management, and retrieval of spatial data from space exploration. The existing archives, given their objectives and method of implementation, currently do not meet the main principles of the SDI. SDI must serve the wider community whose members do not need to be spatial data experts and who do not understand the intricacies of storing, retrieving, and using spatial data. Archives are technology-oriented and need to focus on simplifying data access and improving data usability. The main reasons why SDICB is needed is that its establishment would keep all data in one place, will avoid du-plication of data, harmonize the formats, and achieve their interoperability, simplify access and downloading. Using these datasets would reduce the number of difficult-to-understand data access tools and allow other users outside the space community to access and use the data [16, 17].

To establish such a user-oriented concept, it is necessary to conduct a user needs assessment which will analyze the requirements and needs of users who will use new ways of accessing space data in the future. By implementing such a concept, that would meet the needs of a wide range of users, the data would not remain unused i.e., the currently inefficient management of this valuable data set will be avoided. Similar as terrestrial SDI initiatives, SDICB should be a set of agreed standards, institutional cooperation agreements and policies to describe the framework within spatial data from space exploration will be collected and organized so that they are easily accessible and usable for a wide range of user.

4. USER NEEDS ASSESSMENT

The main goal of SDICB is to provide space research data to a large number of different user groups, regardless of their knowledge and skills about spatial or space data. Therefore, the development of such an initiative focuses on the needs of users to develop an effective and sustainable SDI. By focusing on user needs SDICB will reach its full potential in the context of spatial data sharing. Given the current non-existence of the concept, a user-based approach is applicable as this assessment must be considered at the very beginning of the establishment. The main feature of this approach is that user requirements need to be researched first and that they form the basis of SDI development. In this approach, users are a separate component in the development and implementation of the initiative [18]. Users require easy access to data, metadata, and services, and each request must be met for the satisfactorily function of SDI. In this approach, the survey is the best tool for gathering information on user needs because it can be distributed to many addresses and gain insight into different user needs through open and closed questions. The disadvantages of this approach are the reduction of the ability to comment on specific needs and the possibility to not obtaining sufficient input data to conduct the analysis.

The chosen approach for user needs assessment in this research, as a tool for collecting input data, i.e., identifying user needs and requirements, which will later be used for conducting a guideline for the establishment of SDICB is a global survey.

4.1. CONDUCTED RESEARCH

For the purpose of the research, two global surveys created for two different user groups were sent. The first group of users consists of scientists and individuals who use space data and archives in their work (SD users). The second group of users are scientists, researchers, and students in the field of spatial data interest-ed in space data (GI users). Therefore, two separate global surveys were conduct-ed, each of the surveys was sent to a specific group of users, and the synthesis of the obtained results from both surveys will be used to create guidelines for establishing SDICB based on user needs. In compiling the surveys, efforts were made to consider the different theoretical views of such research. Each individual question is a separate input for final analysis, and the questions are grouped according to the definition of SDI, i.e., efforts were made to cover all relevant components necessary to obtain an adequate assessment of user needs.

The first survey, for SD users, consists of a total of 39 questions and was sent to a group of users who use spatial data archives in their work and research and are not experts in the field of spatial data. The survey was divided into three groups of questions. The first group of questions refers to general information about the user, and the goal is to collect information on whether they use archives in their work, for how long and for what purpose. The second group of questions is about the use of data archives. In this group of questions, the aim was to examine which archives users use most often and to gain insight into general opinions of users about archives such as whether they think that archives are tailored to a specific group of users, how much time they spent searching data, are they satisfied with distribution and retrieval of data, are there adequate metadata, what problems they encounter and are the data understandable. The third group of questions refers to the assessment of user needs. All individual components of SDI are considered, and user had to evaluate for each component whether it should be added or improved to make access to data more efficient. A total of 21 responses to the first survey were received.

The second survey was sent to a group of GI users who are not experts in the field of space sciences but in the field of spatial data and have used SDI portals in their work or education. As these users do not use space data archives, to access the survey, they had to solve a given task to get acquainted with the way archives work and how to access data. The task for these users was to use the PDS archive and try to find and retrieve any data collected by observing Mars or Mercury, which is spatially defined. It was necessary to find and download vector or tabu-lar data with a spatial reference in one of the offered formats. They needed to find data formats that are usable in standard GIS tools. Products such as carto-graphic maps or ortho-mosaics are not accepted as a successfully completed task. The purpose of this task is to examine whether an expert in the field of spatial data can find data of interest using tools and services within the PDS. Also, part of the task was to download the relevant metadata, and users had to independently investigate metadata and try to understand what downloaded data present and investigate can they use the data for further analysis in one of the GIS tools. De-pending on successfully completed task, the survey consisted of a total of 31 questions for those who managed to find data of interest, and 25 questions for users who failed to find data. Questions were divided into three groups of questions. The first group of questions is related to basic information about users, their field of work, level of education and familiarity with

the concept of SDI. The second group of questions is separated depending on success in solving the task. If the user successfully completed the task, they answered questions about which portal they used, which tools, how much time they spent on searching the data and about the experiences when using the archive. If the user did not successfully complete the task, the questions were about which portal they used, how much time they spent trying to find data, and about the experiences when using the archive. The third group of questions refers to the assessment of user needs. All individual components of SDI are considered, and user had to evaluate for each component whether it should be added or improved to make access to data more efficient. A total of 65 responses to the first survey were received.

Both surveys were conducted during December 2021 and were open for 14 days. Most of the questions in both surveys were closed-ended where users chose be-tween pre-offered answers. While such questions may not explore every user preference in detail, they provide a valuable source of information and are more commonly used in surveys because users are more likely to be willing to answer this type of question than open-ended questions.

4.2. RESULTS

Responses to the Survey came from 18 different countries (4 continents) which satisfies the condition that the survey is global. Since two surveys were sent, different groups of users were included. The majority of the total survey participants (56%) are employed at a university or a research center, and the most of user have level of education of Doctor of Science. Of the total number of users, as can be seen in Graph 1, 72% are familiar with the concept of SDI, and 94% users have used GIS tools for data analysis and processing of data in their work so far.

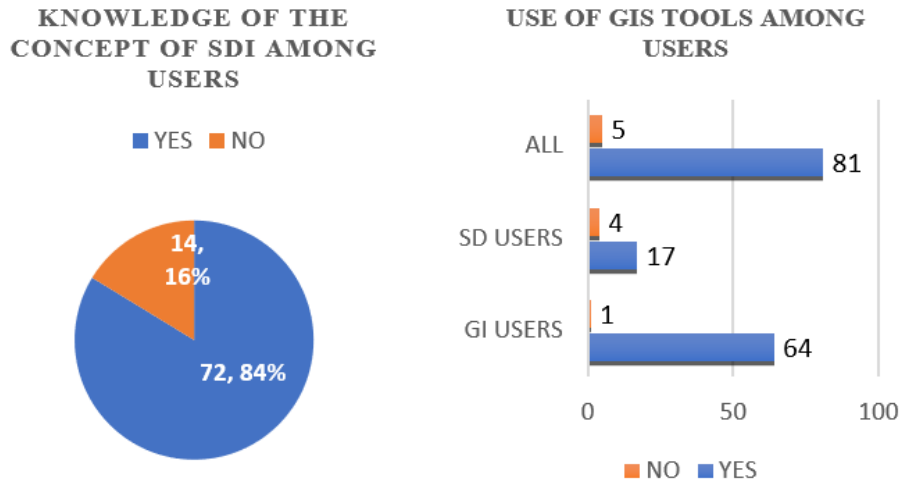

Figure 1. *Knowledge of the concept of SDI (left) and GIS tools (right) among survey users*

All SP users of survey use space research data in their work, and 90% of them use archives to download data. Graph 2 shows the role of the organization in which they are employed regarding the use of space data. Most respondents are end users of the data, followed by users who use this data for educational purposes. Also, of all SP users, 48% have been working for more than 10 years with space data, while no one has been working in this domain for less than 1 year. Most users use the archives several times a week, and Graph 2 shows that most users use the PDS archive in their work. After PDS, the most used portals are JMars / JMoon and Astropedia by USGS.

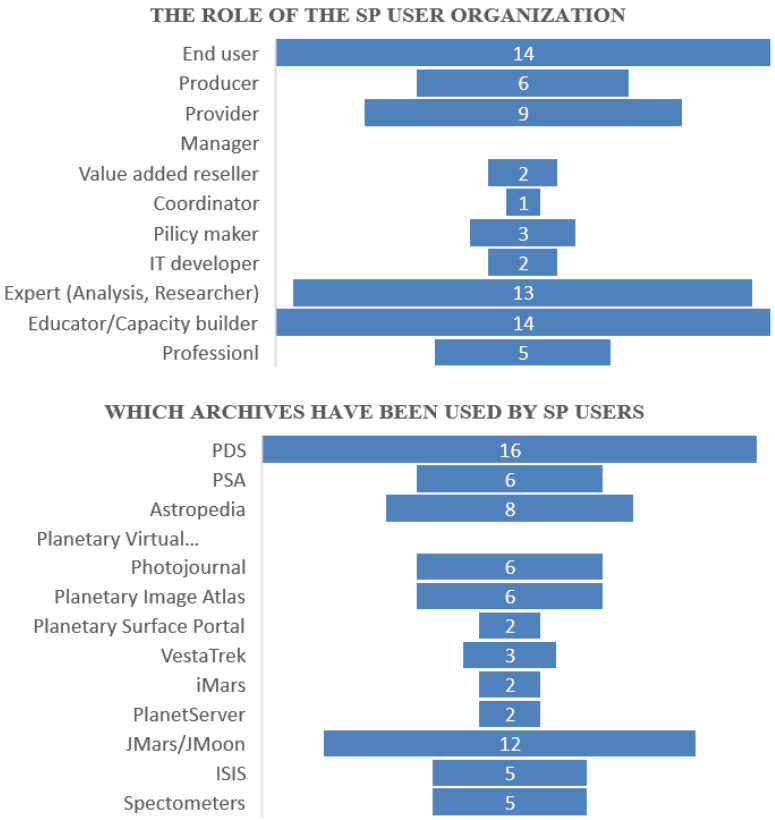

Figure 2. *The role of organization regarding the use of space data in which SP users are employed (up) and archives SP user used so far in their work (down)*

The second part of the survey gives us an insight into the experience of using archives. Among SP users, only 5% do not think that the archives are partially or completely adapted for scientists in the field of space research, and as the biggest shortcoming they state, “the need for prior knowledge for using the archives” and “lack of data visualization”. All SP users indicated that they encounter some problems in finding data, and as can be seen in Graph 3, most users state that they need more than one hour to find data of interest. Most of SP users (81%) believe that data is always open and accessible to everyone, and the most common access they use to download the data is direct access through archives.

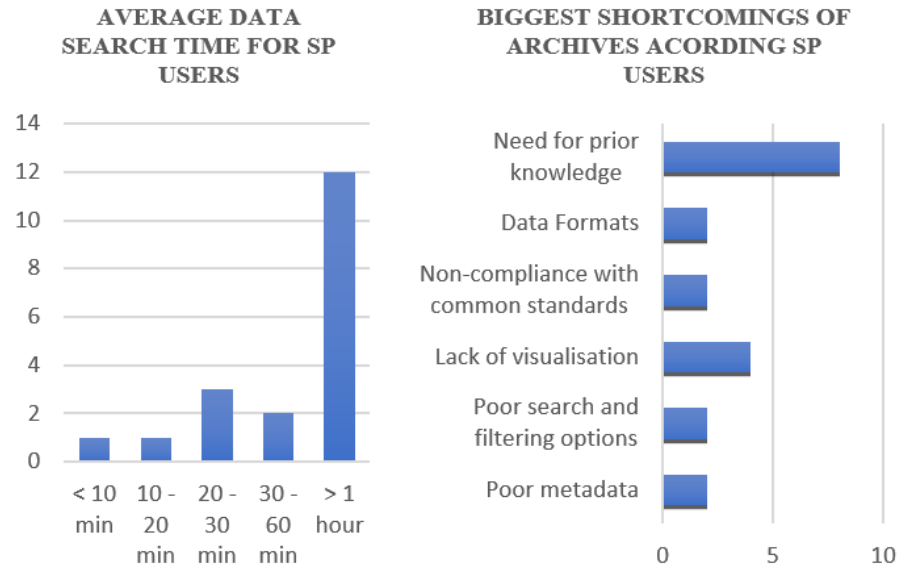

Figure 3. *Average search time for data by SP users (left) and shortcomings of archives (right)*

Among the GI users, the task was successfully completed by 60% of them. Most users used the PDS archive to search the data, and a total of 62% of users used some other available additional tools and services. Only 2 users spent less than 30 minutes to find the data, while most users, as shown in Graph 4, needed more than 1 hour and even up to several hours. The most of users (58%) also used additional resources and tutorials (e.g. YouTube) in order to achieve the required results.

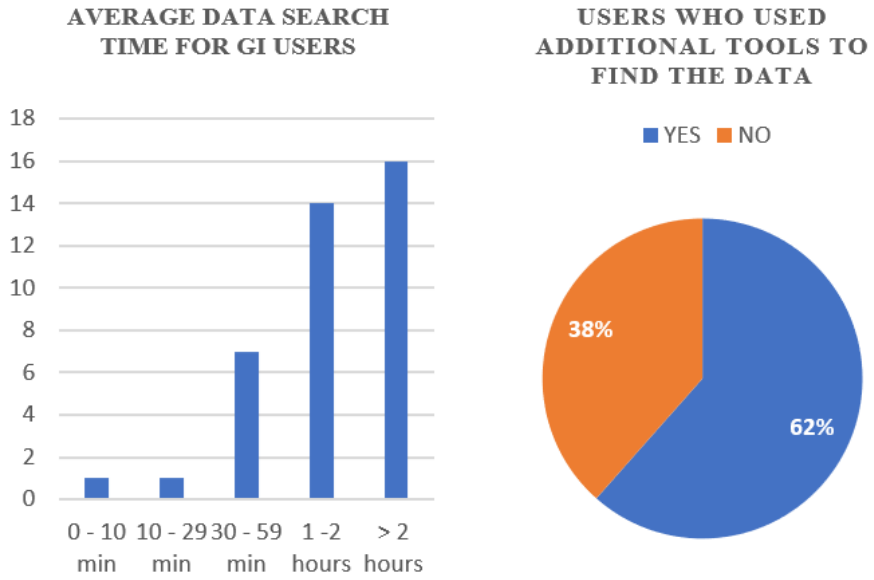

Figure 4. *Average data search time (left) and the use of additional search tools (right) among GI users*

In the third part of the UNS, user requests for improved archives that would enable better search and retrieval of space research data were examined. Some aspects of the improvement were examined in both user groups, while some specific ones were only examined among SP user groups due to previous experiences in the use of archives. The results of both surveys were combined, and requests for improvement were obtained in joint graphs.

Graph 5 shows that over 80% of respondents believe that archives are not user-friendly, not intuitive, and not easy to use. More than 90% of them believe that the tools currently available do not facilitate data retrieval and that the data should be tailored and accessible to everyone, not just space science users.

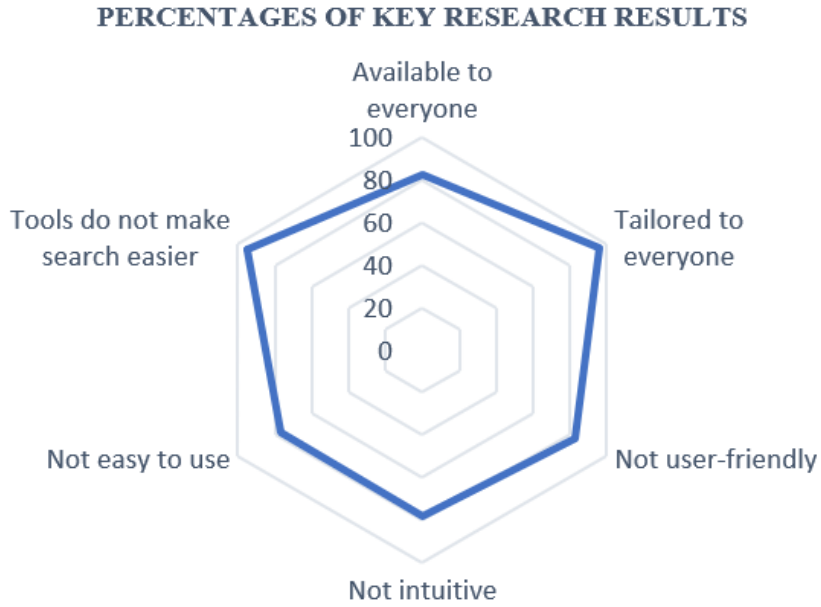

Figure 5. *Percentages of key research results in use of space data archives by both group of users*

Graph 6 shows the results of the analysis in the range of grades from one to five (grade one is considered not to need changes, and grade five that major changes are needed) depending on how users think that change is needed for each examine component, and each of these components are the basic parts of the future SDICB concept. The graph shows that all components were rated higher than three, which indicates the fact that it is necessary to introduce changes in all of them. The highest ratings, i.e., the biggest need for changes expressed by users, are needed for the user interface (4.31) and the establishment of a single metadata catalog (4.05). Users stated that better methods of data visualization are need-ed (4.09), as well as search (3.76) and data filtering (3.98) options. Also, the need to introduce new standards that are globally open and accepted is graded 3.84 by users, and the change in metadata was graded 3.39. In terms of data formats, this component was only evaluated by SP users as GI users were pre-set by task which formats to download. The need to change the format was graded with 3.52.

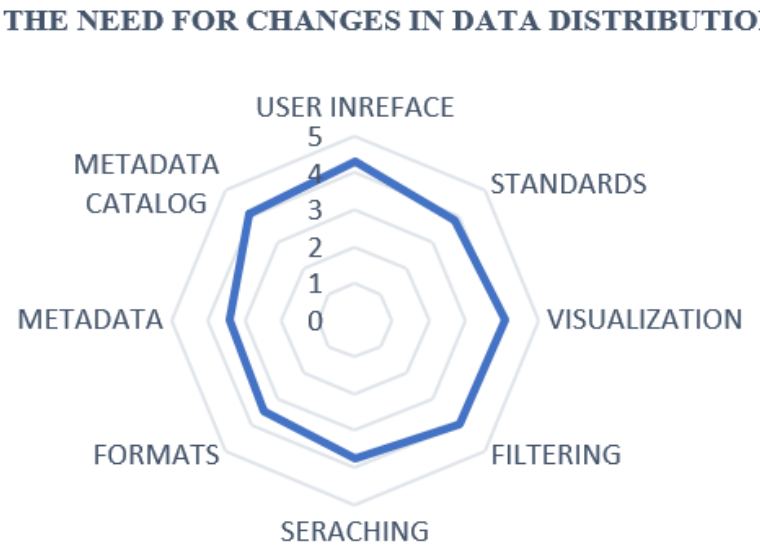

Figure 6. *The need for changes in data distribution graded by users*

Graphs 7 show that only 54% of GI users, who successfully solved the task, understood the data, i.e., that the metadata was clearly defined according to them. Regarding the data format, only 29% of SP users believe that the formats are satisfactory, and 62% users encounter the problem of data loss during the transformation into other formats. Also, only 33% of respondents believe that the data are fully usable.

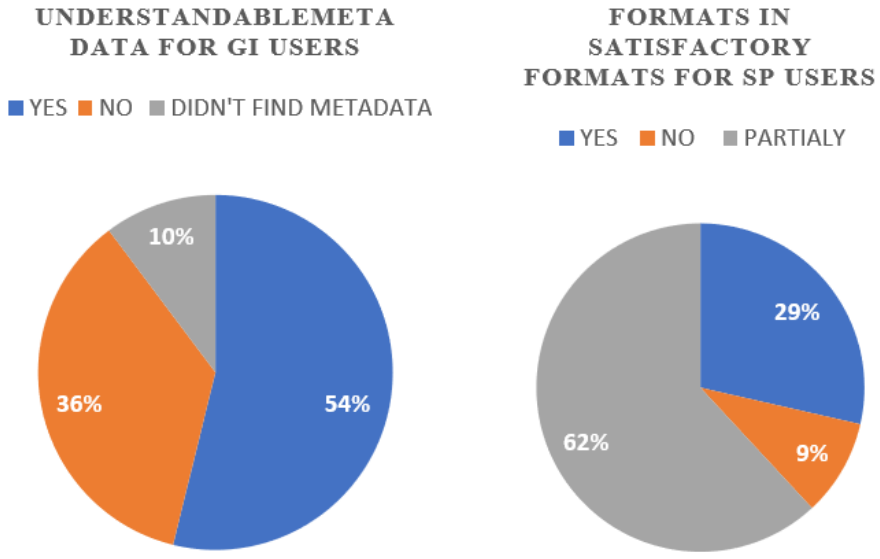

Figure 7. *Understandable metadata for GI users (left) and satisfaction with data formats for SP users (right)*

Finally, Graph 8 shows the user's opinion on what the SDICB users' domain should be. Among all users 82% of them believe that the data should be available to everyone, not just space scientists, and only 5% of users believe that the cur-rent situation is satisfactory, and that archives should serve only the space community.

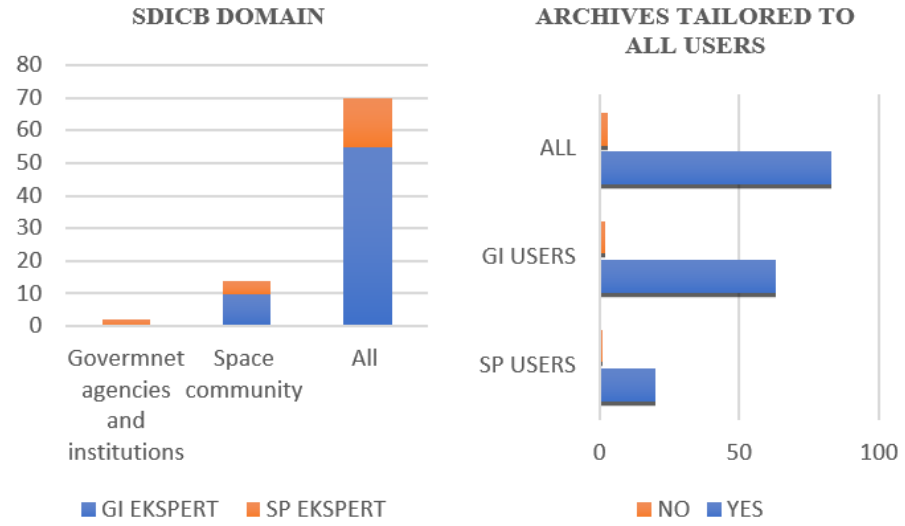

Figure 8. *User thoughts on the SDICB domain (left) and customizing the archive for all users (right)*

4.3. DISCUSSION

The conducted UNA provides a detailed insight into the user experience when using existing methods of access to space data, but also about the needs of users for more efficient use and exploitation of space research data. The analysis covered almost all aspects of one SDI concept (except policies) and collected input data to establish guidelines based on which the SDICB should be implemented. Relevant answers were received from current users of the archives, but also from other users who could use these archives in the future. The research shows that the PDS archive is the most used, but that its use requires certain prior knowledge such as knowledge of the missions that collected data, but also knowledge about time when data is collected, and about professional labels used in documenting data. The average time required to find data is over an hour for all user groups, and users often encounter various problems in the data search. Data is open and accessible to everyone, but there are too many tools and services to search for it, and there is a problem of data scattering and users' lack of knowledge about which tool to use to find data of interest. Over 80% of respondents believe that archives are not user-friendly, not intuitive, and not easy to use. More than 90% of them believe that the tools do not facilitate the search for data and that the data should be tailored to everyone, not just users in the field of space science. Users assessed that the need for changes is necessary in almost all aspects and that the current ways of distributing metadata, their content, data formats, but also the ways of searching data and user interface are not at a satisfactory level.

5. CONCLUSION

The increased interest in space research data that has emerged over the past few years has raised questions about access to this data for all groups of users. Cur-rent ways of archiving data are tailored to the space community, while other user groups face many problems when searching and downloading data. The best solution to this problem is to establish an SDICB concept that would allow all users easy access to data and enable better management and exploitation of space re-search data. So far, several initiatives have been launched to improve the availability of this data, and by accepting the recommendations of these initiatives in the framework of the implementation of the SDICB, the data would become interoperable, understandable, and usable for all user groups. The SDICB should be user-oriented, so the needs of different user groups were assessed as part of this research. A global survey for user needs assessment was conducted, which included users of space data and archives and experts in the field of spatial data. A total of 86 responses were received and from the results of the survey it is evident that requests of users for changes are permeated in all components of the SDICB initiative. For example, users feel that current solutions are not user-

friendly, are not intuitive and easy to use, and that the tools do not simplify data retrieval. According to users, searching methods for this data should be tailored to all user groups. To enable this needs it is necessary to introduce a change in the way of storing and distributing metadata, introduce understandable and generally accepted standards and data formats and improve data search, filtering, and visualization options. The obtained results will serve as input for the establishment of guidelines based on which the SDICB concept will be implemented.

LITERATURE

[1] W. Li, S. Wang, V. Bhatia, "PolarHub: A large-scale web crawling engine for OGC service discovery in cyberinfrastructure," *Computers Environment and Urban Systems*, vol. 59, pp. 195-207, 2016.

[2] Y. Hu, W. Li, "Spatial Data Infrastructures", in *The Geographic Information Science & Technology Body of Knowledge*, John P. Wilson, ed., 2017. Available: http://gistbok.ucgis.org/bok-topics/spatial-data-infrastructures [March 04, 2022].

[3] S. Ključanin, V. Poslončec-Petrić, Ž. Bačić, *Osnove infrastrukture prostornih podataka*, Sarajevo, Dobra knjiga, 2018, pp.9-35.

[4] V. Cetl, "Infrastrukture prostornih podataka", *Ekscentar*, vol 6. (6), pp.36–38., 2004.

[5] A. Rajabifard, I. P. Williamson, "Spatial data infrastructures: concept, SDI hierarchy and future directions", in Proc. *GEOMATICS'80 Conference*, 2001.

[6] D. Breuer, J. L. Grenfell, M. Grot, E. Hauber, H. Hussmann, J. Jänchen, M. Knapmeyer, J. Oberst, F. Sohl, T. Spohn, K. Stephan, R. Wagner, F. Wagner, M. Wählisch, "Landolt-Börnstein - Group VI Astronomy and Astrophysics, Astronomy, Astrophysics, and Cosmology" in *Solar System*, vol 4B, J.E. Trümper, ed., 2009, pp.560-630.

[7] Mapping and Planetary Spatial Infrastructure Team, "Mapping and Planetary Spatial Data Infrastructure Roadmap 2019 – 2023", MAPSIT, 2019, Available: https://www.lpi.usra.edu/mapsit/roadmap/MAPSIT-Roadmap-2019-06-19.pdf [March 09, 2022].

[8] R. M. Borden, B. W. Bishop, "Assessing Planetary Data Access and Use", in Proc. 4th Planetary Data Workshop, LPI Contribution No. 2151, 2019.

[9] T. M. Hare, A. P. Rossi, A. Frigeri, C. Marmo, "Interoperability in planetary research for geospatial data analysis", *Planetary and Space Science*, Vol. 150, pp.36–42., 2018.

[10] T. M. Hare, L. Keszthelyi, L. R. Gaddis, "Online Planetary Data and Services at USGS Astrogeology, Astrogeology Science Center", in Proc. 45th Lunar and Planetary Science Conference, ID 2487, 2014.

[11] T. M. Hare, A. P. Rossi, A. Frigeri, C. Marmo, "Interoperability in Planetary Research for Geospatial Data Analysis", *Planet. Space Sci*, Vol 150, pp.26-42., 2018.

[12] T. Morgan, M. Banks, "NASA's Planetary Data System Status and Future Plans", Report to the Planetary Advisory Council, NASA, 2018, Available: https://www.lpi.usra.edu/pac/presentations/0218/Morgan.pdf [March 05, 2022]

[13] C. Marmo, T. M. Hare, S. Erard, B. Cecconi, F. Costard, F. Schmidt, A. Rossi, "FITS Format for Planetary Surfaces: Bridging the Gap Between FITS World Coordinate Systems and Geographical Information Systems", in Proc. *Lunar Planet Science Conference LXXVIII*, ID 1870, 2016.

[14] L. Keszthelyi, T. Becker, T, Titus, S. Sides, L. Gaddis, T. Hare, R. Kirk, K. Edmundson, J. Anderson, "Utilizing the Integrated Software for Imagers and Spectrometers (ISIS) to Support Future Missions", in Proc. *Lunar Planetary Science Conference XLV*, ID 1686, 2014.

[15] J. A. Skinner, T. M. Hare, C. M. Fortezzo, M. A. Hunter, "Planetary Geologic Mapping Handbook", U.S. Geological Survey. Astrogeology Science Center, 2014, Available: https://planetarymapping.wr.usgs.gov/Page/view/Guidelines [March 02, 2022]

[16] J. R. Laura, T. M. Hare, L. R. Gaddis, R. L. Fergason, J. A. Skinner, J.J. Hagerty, B. A. Archinal, "Towards a Planetary Spatial Data Infrastructure", *ISPRS International Journal of Geoinformatics*, vol.6(6), 181, 2017.

[17] J. R. Laura, M. Bland, R. L. Fergaso, T. M. Hare, B. A. Archinal, "Framework for the Development of Planetary Spatial Data Infrastructures: A Europa Case Study", *Earth and Space Science*, vol. 5, pp.486-502, 2018.

[18] S. Hennig, M. Belgui, "User-centric SDI: Addressing users' requirements in third generation SDI. The example of nature-SDIplus", in Proc. *Geoforum Perspektiv 10*, 2011.