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Research Article

Exploring the Dimensions of Global Navigation Satellite System: An Opportunity Window for Academia and Industry in Pakistan

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Abstract: This research contribution highlights the role of academia and industry in Pakistan to cope with the mushrooming applications and technology of Global Navigation Satellite Systems (GNSS). The Global Positioning System (GPS) of U.S is fully operational, and the GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (GLONASS) of Russia has got the latest up-gradation. The modern navigation constellations like Galileo of European Union and Beidou of China are in the process of development along with some regional navigation systems, like QZSS of Japan and GAGAN by India. This opportunity window triggers the techno-academic giants to develop the human resource for this burgeoning field of GNSS and to contribute in GNSS market for the sustainable growth and development. This paper performs the SWOT analysis about the prevalent GNSS conditions in Pakistan and foresees the prospective application areas of GNSS technology in Pakistan. It show cases the architecture of GNSS and highlights the basic principle of Positioning, Navigation and Timing (PNT) using GNSS signals. Also, it presents a broad framework and policy to develop a "GNSS Technology Centre" in Pakistan at Institute of Space Technology (IST), Islamabad, under the umbrella of the pioneers in this field like United Nations and the other developed countries.

Keywords: Global Navigation Satellite System (GNSS), academia, industry, GPS

1. INTRODUCTION

The quest of knowing the position and location is as old as the history of human conscious. The ancient man peeped into the space and looked into stars and constellations for his positioning information. The old inventions like compass and sextant were the daily tools of travelers and voyagers. The industrial revolution and the technological advancement changed the whole application scenarios, and the need of position and time became very essential like some other scientific gadgets. The marine and aviation technology developed at the very higher pace and demanded for more accurate positioning information. The gyroscopic and Inertial Measurement Units (IMUs) based positioning methods solved that partial problem but dead reckoning and severe weather conditions demanded for some other types of all weather, global and precise positioning and navigation system. The hi-tech expedition all over the globe after the Second World War triggered the development of sophisticated gadgets with high precision and positioning demands. The civil applications of timings and positioning were also emerged and the need of position information triggered the scientific community for some navigation system in the backdrop of human expedition of spacecrafts and space flights. The modern man followed the thoughts of ancient man and peeped into the space again for the precise and all weather global navigation system and came up with the idea of satellite based global navigation system that can provide the positioning

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and timing information to all the users, all over the globe at all time with high accuracy and precision. This constellation of navigation satellite system is termed as Global Navigation Satellite System.

Global Navigation Satellite System consists of a *space segment* having a group of satellites at the height of nearly 20,000 km and above, *control segment* having the monitoring and control stations to monitor/control/update the constellation of satellites and finally the *user segment*; consisting of receivers to give Position, Velocity and Time (PVT) of the static and mobile user all over the globe, at all time using at least four satellites of the constellation in view [1].

The Global Positioning System (GPS) of U.S is fully functional Global Navigation Satellite System since 1994 and providing Positioning, Navigation and Timing (PNT) information globally to all users at all times. It has gone to the modernization level too with the inclusion of new technology and more frequency signals. The GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (GLONASS) by former Soviet Union was fully operational since 1995 but suspended and partially operated after collapse of USSR and now has got the latest up-gradation and is fully operational since 2010 by Russia. European Union is developing its own modern navigation constellation named as Galileo that is expected to be fully functional by 2020. On the eastern side, China is also in this race to develop its own GNSS named as Beidou/Compass by the year 2020 to join the GNSS community of technology and to get the market share too. Some regional navigation systems are also in the development phase like the QZSS by Japan and the GAGAN by India [2].

The gurus of navigation community predict that the year 2020 when GPS, GLONASS, GALILEO, and COMPASS will be fully operational and interoperable, four times more satellites will be available for navigation, positioning, and timing, providing more types of signals, broadcasted on more frequencies. This will create the system of global navigation satellite systems, resulting in improvement and increase of services, applications and users too. This scenario promises more reliability, accuracy, availability and integrity in the GNSS solutions and applications. The year 2020 predicts more than 100 navigation satellites hovering over the globe for providing enormous applications, and this opportunity window calls for the concrete steps from the techno-academicians to invest in this navigation paradigm and get their share and contributions in the coming decades [3].

Global Positioning System has become a clichéd terminology due to its applications in navigators and cellular technology. The modern cell phones and vehicles are equipped with GPS chipsets, but the applications are far beyond these two basic concepts and have wide applications in many terrestrial, civil, air, marine and space domains. At present, the civil applications have out marked the military applications. The wide range of applications and the promises of the prospective global navigation systems have paved the way for the development of strong market for GNSS receivers, and this market is growing at an enormous rate, and the prevailing market trends call for enthusiastic contributors to participate in this development phase and garner the fruits at the end of this endeavor.

United Nations has declared GNSS as a special technology for the sustainable development, especially in developing nations. In 1999, according to the 54/68 resolution of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), the UN General assembly endorsed the "Vienna Declaration: Space Millennium for Human Development" that called for action to improve and enhance the access and compatibility of space-based navigation and positioning systems [4].

In the developing countries like Pakistan, the academic, scientific and market-based bounties of GNSS proliferation are quite unknown, and it is the need of time to invest academically and technologically in this field for achieving the benefits and applications of this emerging paradigm. This paper proposes a policy document for establishing a GNSS Technology Centre at Pakistan with the help of United Nations and the developed countries. The technology and applications of this promising field have been reviewed to investigate the status of GNSS technology and expertise in Pakistan and pop-up with the idea of creating a centre of excellence to abreast with the upcoming demands of this field. The

SWOT analysis for this issue has been carried out and a road map for the establishment of such a centre in Pakistan has been presented with the notion of University-Industry collaborations [5-10]. The blue print for the GNSS technology center is presented while discussing the basic principle and structure of GNSS, hi-tech advancements, International GNSS market trends and applications. The proposed centre is envisaged to act as the hub of the GNSS related activities at Pakistan.

Section II and III of this research contribution provide the basic structure and principle of GNSS while highlighting the space, control, user and augmentation segment. The GNSS applications with respect to terrestrial, air, marine and space are briefly described in Section IV for developing the premise for establishing the GNSS technology center. To support the same argument, section V analysis the International market trends of GNSS technology and applications. The existing contributing status of academia, industry and public research organizations in Pakistan, especially in creating the awareness and acquiring the technology and applications of GNSS are addressed in section VI. The prospective application areas are addressed in section VII and finally, the road map for establishing the GNSS technology centre at IST is presented in Section VIII. The Paper concludes with recommendations and future vision.

2. GNSS ARCHITECTURE

The Global Navigation Satellite System has a well defined structure, initially designed by US and USSR and then is being followed by the systems like Galileo and Beidou. The basic segments like space, control, user and augmentation are discussed in next lines. The reference architecture [11] is about the GPS as it is only the fully operational at this moment with maximum information too. The structure of the signal transmitted by the navigation satellites is also discussed to understand the basic principle of navigation positioning and timing. The interested readers may refer to [1.11] for details about the history, function and principle of GNSS.

2.1. Space Segment

The space segment consists of medium Earth orbit satellites at the height of approximately 20000 Km and above. In case of GPS, there are 24 satellites in six planes at an inclination of 55 degrees with four satellites in each plane. These satellites are equipped with different satellite subsystems and most importantly the precise atomic clock and navigational payload.

2.2. Control Segment

Monitoring and Control segment is for attitude and orbit control of navigation satellites along with telemetry and telecommand. It performs the functions like orbit and clock corrections, signal monitoring, navigation message transmission and satellite health information.

2.3. User Segment

User segment includes the GNSS receivers that varies from application to application and it process the received radio frequency signal from the navigation satellite and find the user position using the principle of Triliteration.

2.4. Augmentation Segment

Augmentation system includes additional components like geostationary satellites or pseudolites for improved positioning and navigation. Salient examples are Differential GPS, Local Area GPS, Wide Area GPS, Wide Area Augmentation System, Global Differential GPS by NASA, Multifunction Satellite Augmentation System by Japan and EGNOS (European Global Navigation Overlay System) by European Union.

3. GNSS PRINCIPLE

Navigation, positioning and timing are the main outputs of any GNSS, and it is achieved by the processing of signals transmitted by the constellation of satellites. The constellation design and the choice of frequency, modulation and coding make this technology as a superb master piece for applications beyond imagination. This section discusses the basic structure of GPS signal, the principle of triangulation and main sources of errors in the navigation solution [11,12].

3.1. GNSS Signal Structure

GNSS signal particularly the GPS signal is transmitted by the navigation satellites on two carrier frequencies, L1 of 1575.42 MHz and L2 of 1227.60 MHz. L1 has two signals; one for the civil user and second for the authorized Department of Defense (DOD) while L2 is dedicated for defense users only. Each signal consists of three components, carrier phase, ranging Code and the navigation data.

3.2. Positioning by Triliteration

Triliteration is the basic principle behind the calculation of positioning information by any GNSS receiver. The GNSS signal is equipped with navigation message and observation data. Receiver uses the Navigation message to identify the position of visible satellites and uses the pseudorange and time difference between the transmitted signal and the received signal from the at least four satellites to determine the receiver position and clock bias. Another method of estimation is by using the phase measurements that are more precise than the code measurements.

3.3. GNSS Errors

GNSS provides positioning and timing information using the radio frequency signal broadcasted from the navigation satellites. The common errors encountered in GNSS positioning are related with clock errors of satellite and user segment, orbit errors, atmospheric errors, including ionospheric and tropospheric errors, noise related with receivers and errors like multipath.

4. APPLICATION PARADIGM OF GNSS

The application paradigm [12] of GNSS is vast and beyond the imaginations. The positioning, Navigation and timing information with high precision, reliability and interoperability options have convinced the GNSS gurus to see the next decade with new applications. The proliferation of global navigation satellite systems and the promises of modern systems have shifted the application paradigm from military to civil domains with mind blowing applications in the areas of civil, aerospace, maritime and aviation sectors. The civil applications encapsulate the wide domain from the personal navigators to the field of geodesy, civil engineering, urban planning, communication, environmental protection and control, agri-management, disaster management, transport and rail management, emergency & rescue and vessel management system. The Earth observation satellites and formation flights are using this technology for attitude and orbit determination, and the unmanned air vehicles and missiles are getting guidance and control by the GNSS technology. The e-commerce and electronic banking are also under the influence of GNSS timing facility.

5. GNSS MARKET TRENDS

The GNSS market is on the rise progressively. This growth will pick up the pace in the next decade as new satellite based navigation systems are in the development phase like Galileo and Beidou. Market evolution is depicted in the Fig. 1 as a total annual global income for GNSS and Fig. 2 shows the contribution of different regions in Global Annual Net Product Turnovers [13].

In 2012, The European GNSS Supervisory Authority (GSA) presented the forecasted analysis of GNSS, especially the Galileo market for the four sectors namely the location based services in communication sector, road navigation, agriculture sector and aviation industry. The GSA estimates that global GNSS market will rise to 250 billion euro [14] in the year 2020 as shown in Fig. 3.

6. GNSS STATUS IN PAKISTAN

This section discusses the prevailing status of GNSS technology and its applications in three major areas of academia, industry and public research organizations at Pakistan. The present condition in all the above mentioned sectors is quite depressing, but the potentials are there for upholding this technology.

6.1. Academia

The basic academic requirements for the GNSS technology and applications are related with Space Technology, Geodesy, Communications and Electronics Engineering. It also involves signal

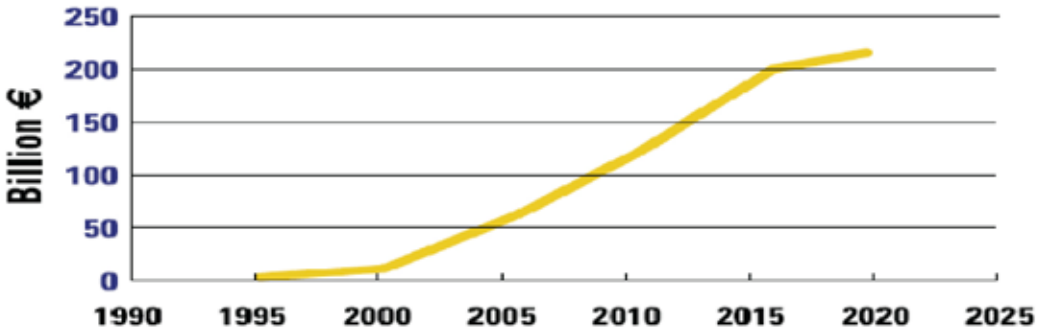

Fig. 1 Total annual global income for GNSS [13].

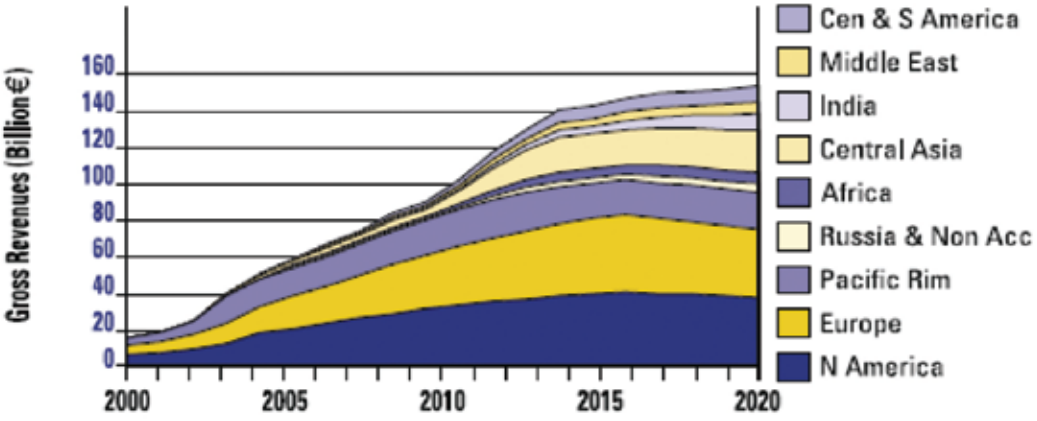

Fig. 2 Region-wise gross revenue [13].

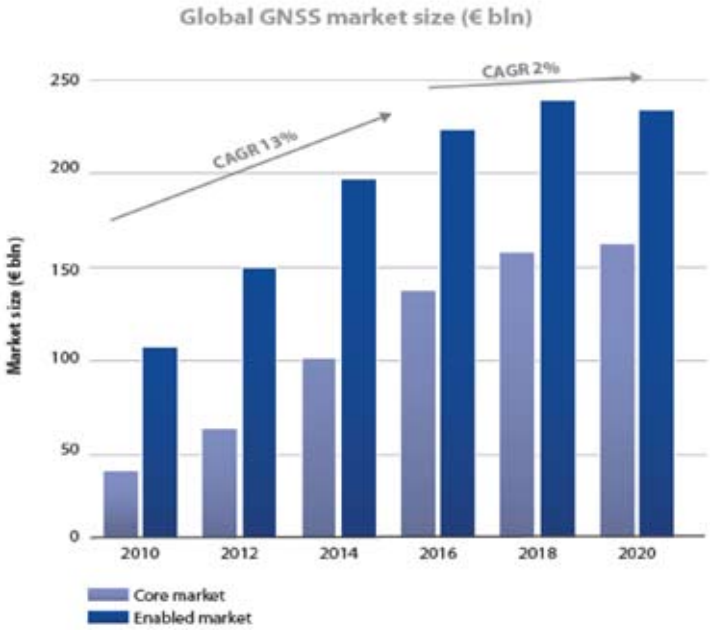

Fig. 3 Global GNSS market [14].

processing and computer sciences too as the tools to implement different applications. It has been found that there is no exclusive undergraduate or postgraduate degree program related with GNSS that is being offered at any University of Pakistan. Only a single course partially related with GNSS is offered at Senior UG/PG level at some universities.

The Engineering universities at Pakistan are offering the general curriculums that can be helpful in materializing GNSS technology but there is no specific course for GNSS. Following Universities have some programs related with Space Sciences and Technology but no exclusive Major Program is offered that is related with GNSS and its applications:

- Institute of Space Technology, Islamabad, Pakistan
- Institute of Geographical Information Systems, NUST, Islamabad, Pakistan
- University of Punjab, Lahore, Pakistan
- Karachi University, Karachi, Pakistan
- Air University, Islamabad, Pakistan
- Bahria University, Islamabad, Pakistan

6.2. Industry

Industry plays a vital role in shaping and promoting the technology but at Pakistan, there is no major public or Private Industry that is dealing with GNSS and its applications. There are only some small companies that are working for digital maps and navigators marketing. Some government companies and organizations like Survey of Pakistan, Civil Aviation Authority and PIA are the users but not the developer of the technology and applications. In contrast to this, the annual revenue from the GNSS market in the world market can be accessed from the Fig. 4 for the last decade [13]

6.3. Public Research Organizations

Public Research organizations and defense related organizations are using GNSS technology for their classified projects but without any aid from the local industry and academia. There are very few specialists of this particular field and most of them are using the allied knowledge and experience to implement for their specific projects. Some of the public research organizations that are using this technology in Pakistan are SUPARCO, NESCOM, Military, Aeronautical Complex, Scaled Aviation Private Industries Ltd, Pakistan Ordinance Factory, Integrated Dynamics and SATUMA UAV systems. Recently, SUPARCO has signed one agreement with China to develop GNSS technology applications in Pakistan [15].

7. PROSPECTIVE GNSS APPLICATION SECTORS IN PAKISTAN

GNSS applications are increasing with the progress in the field of nanotechnology and nanomaterials, and a broad distribution is shown in Fig. 5 that depicts the world GNSS users according to different application areas [16].In contrast to the world GNSS users, the existing application areas in Pakistan are quite less as shown in the Fig. 6.

The author has outlined the different areas in which the GNSS application can be applied at Pakistan as shown in Table 1.

Table 1 Prospective GNSS application areas in Pakistan.

Telecommunication	Location-based Services
Railways	Water Management
Transportation	Environment Pollution
Aviation	Surveying
Shipping and Ports	Maritime
Construction	Defense
Energy Sector	Military
Emergency	Rescue and Safety
Mining	GIS
	Urban Planning

8. IST GNSS TECHNOLOGY CENTRE

The global GNSS market trends, the upgrading of GPS, the growth of new satellite navigation systems like Galileo and Beidou, the existing and envisaged applications of GNSS technology, the world academic and industrial pursuits to develop GNSS technology and applications; prompt the authors to present a concept of "GNSS Technology Center"

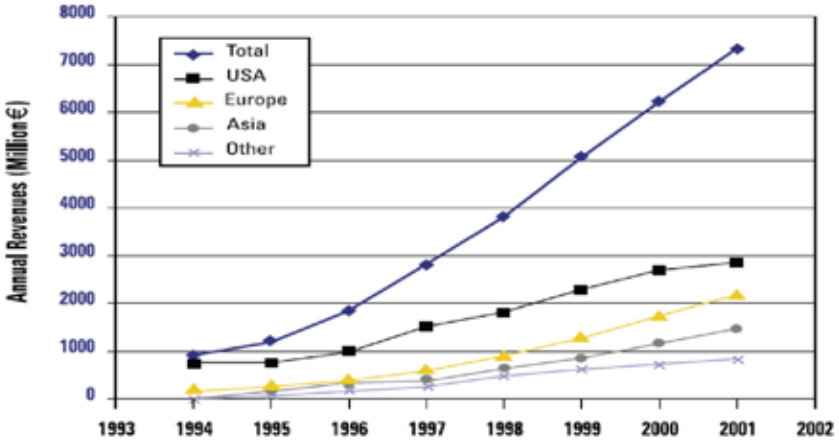

Fig. 4 Annual revenue of GNSS market for the last decade [13].

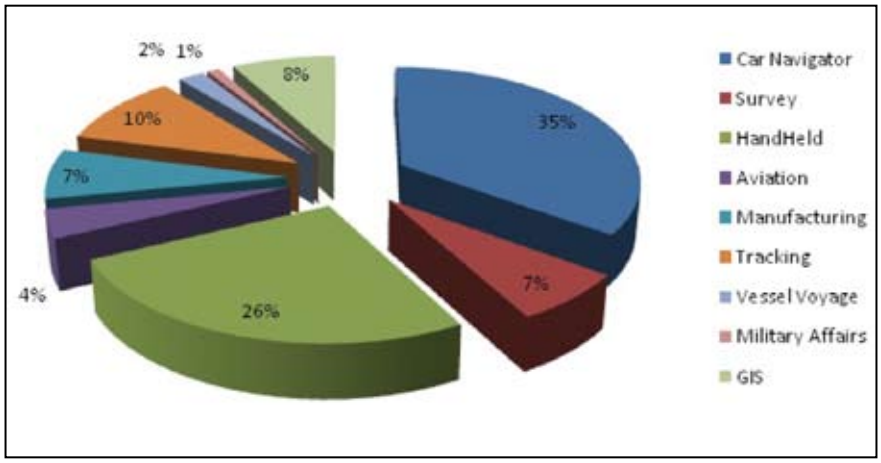

Fig. 5 Worldwide GNSS application areas [16].

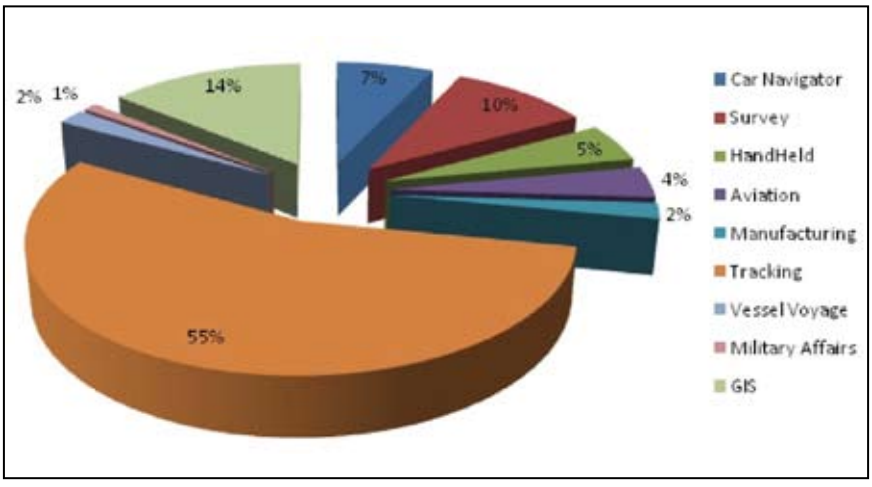

Fig. 6 GNSS market and users in Pakistan [16].

at Institute of Space Technology(IST), Islamabad, Pakistan. IST is a Public University and providing Space related Bachelors and Masters engineering degrees. It has been contributing in developing the aerospace and communication systems human resource for private enterprises and especially for the National R&D organizations for the last ten years. The choice of IST has come after the SWOT analysis and feasibility study of this centre as IST has some uniqueness linked with its programs of study, location, affiliation with National Space Agency of Pakistan, its proximity with satellite ground station, its association with public research and development organizations, its GIS centre at Karachi, Pakistan and its international linkages with the worldwide space academia and industry. In this background, it is proposed to develop the "GNSS Technology Centre" at Institute of Space Technology, IST, and Islamabad to create awareness about GNSS and to cater for the technological needs of this field. This centre is envisaged to develop the human resource in the field of GNSS and to act as a liaison between the worldwide GNSS gurus and the local GNSS architects. It is believed to act as a platform for knowledge sharing and innovation by mutual collaborations and International linkages.

8.1. Proposed Structure of GNSS Centre

The proposed centre [17] will act as an incubation centre for GNSS technology under the patronage of Pakistan Academy of Science, Higher Education Commission and Pakistan Engineering Council. The academic activities will be performed at Institute of Space technology, Islamabad, Pakistan and the affiliated public research organization will be the national space agency of Pakistan, i.e., Space and Upper Atmosphere Space Research Commission (SUPARCO), with its technical supports of satellite ground stations, satellite control stations and satellite development centers. The public and private industry like Telecom, Survey of Pakistan, R&D, Transportation Sector, Agriculture Sector, Environment, Tourism, emergency and rescue, Energy and Water Resources, industry related with Maps and Navigators; will coordinate and collaborate with IST to develop their applications and technology related with GNSS. The organizational structure of the proposed GNSS technology centre at IST is shown in Fig. 7.

8.2. United Nations Support and Collaboration

International Committee on Global Navigation Satellite Systems (ICG) [19] is concerned with the cooperation for satellite navigation systems applications, compatibility, services, reliability and interoperability, especially for the developing countries. United Nations Office for Outer Space Affairs (UNOOSA) [3] works for capacity building in the field of space science and technology with the special focus to GNSS technology and applications. The UNOOSA has developed various regional GNSS development centers like in Morocco,

Fig. 7 Organizational structure for the proposed GNSS Technology Center.

Nigeria, India, Brazil and Mexico. United Nations, especially the ICG and UNOOSA can be the real partner and guide in developing a GNSS centre at Pakistan as it is included in their charter to develop such centers in the developing countries.

8.3. International Academic Collaboration

Some academic role models can be followed or their consultancy can be hired for the initial development phase. It may include the Politecnico Di Torino, Italy or the Beihang University China under the APSCO [20]. As a reference for academia related with GNSS, the following universities of the world are offering specialized GNSS programs [18]. There are many other universities in Australia, the Netherlands, Canada and US offering trainings and research concerning GNSS.

i. **Politecnico di Torino, Italy*:*** Master on Navigation and Related Applications

ii. **University of Nottingham, UK:** GRACE Institute (GNSS Research and Applications Centre of Excellence).

iii. **University of Maine, USA:** GPS, Geodesy and Application Program (GPS – GAP); Asynchronous Internet Education

iv. **ISAE, France:** Master of Science in Global Navigation Satellite System (GNSS)

v. **Beihang University, China:** Master degree program on GNSS which cooperated with Asia- Pacific Space Cooperation Organization (APSCO)

8.4. GNSS Technology Center

The Fig. 7 presents the broad structure of IST GNSS centre on the theme of University, Industry and Public research organization collaboration under the Patronage of higher education and science centers and with the collaboration of International linkages.

8.5. Modus Operandi of GNSS Technology Center

Authors have drafted the following road map for the development of the GNSS technology center at Institute of Space Technology, Pakistan. It has been divided into three phases namely as Design, Development and Specialization phase. The brief outline of each phase is presented in next lines.

Phase I: Design Phase

The basic theme behind the design phase is to develop the user requirements and perform the market study to analyze the potentials of users and professionals. The second main task is to develop the infrastructure for executing the GNSS research. The main functions include the followings:

- Development of GNSS centre and GNSS team
- GNSS market survey and analysis for identifying the potential GNSS Target Groups
- Developing the GNSS Lab and procurement of GNSS software and simulators
- Interaction with Clients and Users to develop User Requirements in-order to design the vision for GNSS Technology Centre
- Interactions with Industry, public research organizations and academia to gather the useful input and potentials to frame out the mission statement of the GNSS centre
- The GNSS human resource and facilities will be developed through International Linkage
- Developing / Collecting, and to maintain the database for the satellite data of Pakistan

Phase II: Development Phase

Development phase involves developing the human resource and platform for sharing the GNSS technology and to develop the alliances with international academia and industry. In this phase, different BS/MS programs, diploma courses, summer schools, workshops and specialized Masters Program will be developed. The main tasks include the followings:

- Offer trainings / short Courses / Diploma on GNSS for human resource development in the area of GNSS. These trainings can be extended to the developing countries too
- GNSS centre will arrange International Workshop and Conferences with the collaboration of international agencies and academia to provide the platform for the local researchers and professionals to share the technology.
- A specialized BS program on GNSS technology and applications will be initiated at IST

- The GNSS Technology Center will offer specialized Masters in GNSS and Related applications at IST
- The GNSS Centre will act as a hub between the national and international GNSS professionals and will collaborate with GNSS organizations for GNSS knowledge sharing, innovation and applications.

Phase III: Specialization Phase

The specialization phase of GNSS Centre will develop the following specialized areas in collaboration with local / International Industry, academia and Public research Organizations.

- Development of Software and Hardware Receivers
- GNSS for Rescue, Emergency and Safety
- GNSS for Location Based Services in collaboration with Telecommunication sector
- GNSS applications for environmental protection and agriculture management
- GNSS applications in the field of geodesy and surveying
- GNSS applications for construction management, transportation management and control
- GNSS applications in the field of Urban planning
- GNSS for Military and Space Applications

9. CONCLUSION AND ECOMMENDATIONS

The growing trends of GNSS constellations and the mushrooming of its application areas demand for a strong policy and vision to comprehend the technology and to participate in the world's knowledge economy. The authors have overviewed the GNSS technology, applications, market and have surveyed the contribution of academia, industry and public organizations in Pakistan. The critical analysis of the prevailing conditions of GNSS knowledge and technology in Pakistan demands for the creation of a GNSS Technology Centre at the Institute of Space Technology, Islamabad, Pakistan with the collaboration of the United Nations and the developed countries in order to create a win-win research and development (R&D) ecosystem with the collaboration of academia, public research organization and the public and private industry.

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11. REFERENCES

1. Parkinson B., J. J. Spilker. *Global Positioning System: theory and applications,* Vol. I. American Institute of Aeronautics, Reston, VA, USA (1996).
2. Giorgi, G. *GNSS Carrier Phase-based Attitude Determination*. PhD thesis, Delft University of Technology, Deft, The Netherlands (2011).
3. UNOOSA official website, http://www.oosa.unvienna.org/, (accessed March 12, 2012).
4. Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999 (United Nations publication, Sales No. E.00.I.3), chap. I, resolution 1, sect. I, para. 1 (e) (ii), and chap. II, Para. 409 (d) (i).
5. Kwon, K. The co-evolution of universities' academic research and knowledge-transfer activities: the case of South Korea. *Science and Public Policy* 38(6): 493–503 (2011).
6. Schmoch, U., F. Laville, P. Patel, & R. Frietsch. *Linking Technology Areas to Industrial Sectors*. Final Report to the European Commission, D G Research (2003).
7. Abramo, G., C. A. D'Angelo, & F. Di Costa. University–industry research collaboration: A model to assess university capability. *Higher Education* 62(2): 163–181 (2011).
8. Crespo, M., & H. Dridi. Intensification of university–industry relationships and its impact on academic research. *Higher Education* 54: 61–84 (2007).
9. Manjarre´s, L., A. Gutierrez, A. Carrion, & J. Vega. The effects of university–industry relationships and academic research on scientific performance: Synergy or substitution? *Research in Higher Education* 50(8): 795–811 (2009).
10. Turk-Bicakci, L., & S. Brint. University–industry collaboration: Patterns of growth for low and middle level performers. *Higher Education* 49: 61–89 (2005).
11. Hofmann-Wellenhof, B., H. Lichtenegger, J. Collins. *Global Positioning System. Theory and Practice*, 5th ed., Springer-Verlag, Wien, New York (2001).
12. Lectures attended by the First Author at Politecnico Di Torino Italy in Masters of Navigation and

Related applications (2006–07).
13. http://www.galileo-services.eu/library/library.html, (accessed Jan 20, 2012).
14. European GNSS Agency, GNSS Market 2012 report http://www.gsa.europa.eu, (accessed Jul 25, 2012)
15. National space agency of Pakistan, SUPARCO, www.suparco.gov, (accessed Oct 15, 2012).
16. Jamal, S. Z. Implications and stake holders of GNSS in Pakistan. In: *UN/IAF International Workshop on "GNSS Applications for Human Benefit and Development"*, 24–25 September, 2010, Prague, Czech Republic.
17. Naqvi, N. A. The Paradigm of Global Navigation Satellite Systems: Role of Education Sector in Creating Awareness about GNSS Technology and Applications. In: *International Conference of Aerospace Sciences and Engineering*, ICASE 2009, August 19-21 2009.
18 http://spacegeneration.org/, (accessed Jan 20, 2012).
19. ICG ,http://www.oosa.unvienna.org/oosa/en/SAP/gnss/icg.html, (accessed March 15, 2012).
20. http://www.apsco.int/, (accessed March 15, 2012).