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A Proposal for the Fundamental Structure of South American (GPS Aided) Geo Augmented Navigation System – Space Weather Integrated Monitoring and Surveillance Systems(SAGANS-SWIMS)

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Abstract—This particular paper is all about the introductory details of the theoretical and technical structure of the South American GPS Augmented Navigation System – Space Weather Integrated Monitoring and Surveillance Systems(SAGANS-SWIMS) which will undoubtedly be the most robust navigation, communication, surveillance and weather monitoring systems in the entire continent of Latin America, which will cater to the diversified requirements of people in various sectors such as agriculture, Science, engineering and technology, communication, navigation, education, militaries and defense systems, governmental policies regarding the best utilization of natural resources.

Keywords— SAGANS – SWIMS – South American GPS Augmented Navigation System – Space Weather Integrated Monitoring and Surveillance Systems, Space Sandwich, Deep Space Segmentation, GEES segmentation.

I. INTRODUCTION

Most of the countries in the Latin American Continent possess their own unique and distinct space satellites on Communication, Earth Observation, Science, Technology and Education. It is worth-noting that all the countries that had their space satellites launched, possess their own unique strategic goals in the space arena in the continent, thereby collaborating with space agencies in either Asia (China, India etc), ESA[1], CNES (FRANCE) , NASA etc. The following table provides the number of satellites for each country which mostly are launched, some of them are yet to be launched at the earliest. Paraguay still needs to launch a satellite of its own. The main areas explored are the Communications, Earth observation, Science, Technology and Education. Every country in the continent of Latin America is equipped with their own unique state-of-the-art facilities regarding their space missions. Brazil tops the list in all the three areas[2] having its own space program [3], AEB (BRAZILIAN SPACE AGENCY)[4] and

INPE [5] (NATIONAL INSTITUTE FOR SPACE RESEARCH) are two premier space research organizations that drive Brazil ahead in the South American continent in the Space sector [6], followed by Argentina which are the largest economies in the continent. Brazil (collaborating with China – CBERS , in terms of Earth Resource satellites) and Argentina have the maximum number of satellites – combined as well as in each specific area individually. Peru launched a satellite which is dedicated to different applications [7]. Peru had been very active in developing programs like INCA at UCH, and with nano-satellite and pico-satellite technology in different universities [8]. Aerospace technology is achieving new frontiers in the country at a good pace [9] [10] [11] [12] [13] [14]. In this connection, proposals were made regarding small satellite network for the Peruvian region [15] and the nanosatellite ‘Chasqui 1’ was launched with the help of Russia [16]. Colombia entered the space race in the continent with the formation of Colombian Space Commission [17] [18]. The small landlocked country ‘Bolivia’ had only one satellite to its credit, as aerospace technology is being promoted in the country [19][20]. Bolivia even had formed its own space agency and launched a satellite mainly for communication purposes. Ecuador, being a small country to the north of Peru is very active in space and has a Civilian Space Agency whose director is Cdr. Ronnie Nader who is the only astronaut of that country [21]. The Bolivarian Republic of Venezuela also entered the South American Space race [22]. Of course, there are many challenges and opportunities in the space and aerospace arena in the Latin American Continent [23]. Since, every country in the continent has its own space program, Argentina with the Support of Brazil had put forward a proposal for a common space agency for entire continent [24]. Many sites provide good details of the various space missions of the countries of the world (of which some examples are

provided)<https://eoportal.org/web/eoportal/home> ,
https://space.skyrocket.de/directories/sat_c.htm
<http://www.earth-observation-directory.com/missions/>
and the basic details are outlined in these sites, along with the specific purposes accomplished by those missions.

TABLE I. NUMBER OF SATELLITES LAUNCHED BY EACH COUNTRY IN LATIN AMERICA

A. NUMBER OF SATELLITES			
B. COUNTRY	1) COMMUNICATIONS	2) EARTH OBSERVATION	3) SCIENCE, TECHNOLOGY AND EDUCATION
Brazil	21	14 (series)	13
Argentina	12	8 (series)	14
Peru	-	1	4
Chile	-	1	3
Ecuador	-	-	3
Colombia	-	-	3
Bolivia	1	-	-
Venezuela	1	2	-
Uruguay	-	-	1

* (Courtesy: https://space.skyrocket.de/directories/sat_c.htm)

II. METHODOLOGY

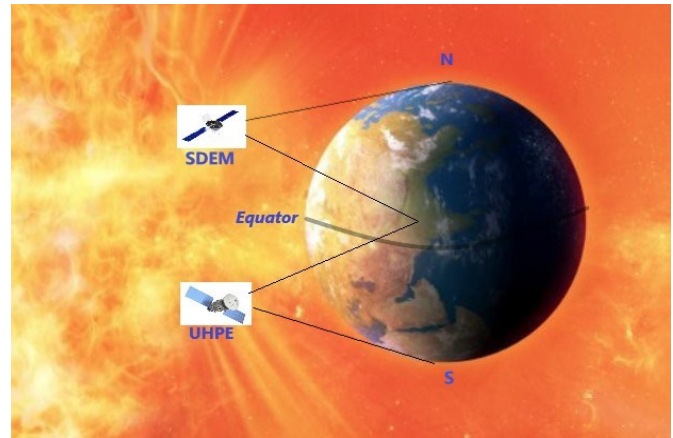
The SAGANS-SWIMS is but a unique project in this regard in terms of integrating the various fields like communication, navigation, earth observation etc., for which every country relies heavily upon technologically, especially in the continent of South America. The continent needs autonomy in the space and aerospace sectors [25]. The detailed review of various space activities in the continent are described in a good paper by Bruno Victorino et al., [26]. At this crucial juncture, SAGANS – SWIMS will play a much significant role by integrating the Communication, Earth Observation, Science, Technology and Education fields, in the areas such as airborne mapping, ocean floor mapping, agriculture, application of Civil engineering like structural deformations, Vehicle and way-point navigation, Transit systems in transportation, earthquake and seismic studies, disaster warning systems, natural resources monitoring, marine seismic surveying, precision farming, open pit mining, Oil and natural gas monitoring in the coastal regions of the continent in a more sophisticated manner. Indeed SAGANS-SWIMS can be a new beginning for a South American Space Era [27].

The fundamental technical structure of SAGANS-SWIMS is as follows:

A. SPACE SANDWICH (SPACE SEGMENTATION) :

This segmentation has two parts, completely handled by SWIMS.

1) *Deep Space segmentation or Gravitational Equilibrium of Earth Sun (GEES) segmentation*: This deep space segment will be purely handled by SWIMS (Space weather Integrated Monitoring and Surveillance Systems) , which is a separate module of SAGANS-SWIMS. This segment will collect the data from two space satellite missions – SDEM (Sun Dynamics Explorer Mission) and UHPE (Ultra High Energy Particle). These two space satellite missions will station themselves at 1.5 million km from the Earth in a symmetrical way, to the east and to the west of the Earth and will be strictly parallel to the equatorial plane of the Earth, thereby the two spacecrafts will get a good picture of the solar wind interaction with the magnetic field of the Earth at the polar regions. Both the spacecrafts will be at the GEES (Gravitational Equilibrium of the Earth Sun) east-west points, parallel to the equatorial plane of the Earth as shown in the figure below.



2) *Magnetically Turbulent Space (Zone of) Earth Segmentation (MTSE) segmentation*: This Space Zone of the Earth is magnetically active and turbulent all the time and is technically known as Magnetosphere of the Earth which is spread typically up-to an altitude of 60,000 km from the Earth's crust. This Space-zone is active even during quiet geomagnetic disturbance periods. Therefore, a spacecraft known as MEE (Magnetosphere Earth Explorer) will perform a polar orbit revolution around the Earth perpendicular to the equator passing through the Latin American Continent. This Spacecraft (satellite) will monitor the magnetosphere region orbiting at an altitude of 56000 km from the Earth' s surface by getting the data from UHPE and SDEM regarding the energetic charged particle influx and its interaction with the Earth's magnetic field lines, the compressing of the field lines by the

solar wind, measuring the change in the Earth's magnetic field etc.

B. ATMOSPHERE SANDWICH (ATMOSPHERE SEGMENTATION):

This segmentation also has two parts:

1) *Upper Atmosphere segmentation – UAS:*
This zone consists of most of the magnetosphere – ionosphere region from the equatorial and polar perspective to monitor the space weather conditions at the Earth's equator and the polar regions in the magnetosphere-ionosphere zone. In addition the polar and equatorial magnetosphere-ionosphere currents are measured which are much important to understand the various anomalies and instabilities like Rayleigh-Taylor, Kelvin Helmholtz etc in the ionosphere and the magnetosphere connection. The Lorentz force along with the electromagnetic energy density is also measured at the polar regions. In this connection, two spacecrafts FALCON EXPLORER (Polar) and EAGLE EXPLORER (equatorial) will orbit in the magnetosphere-ionosphere region in the polar and equatorial zones at an altitude of 42000 km from the earth's surface. Equatorial electrojets are given special importance in order to understand the equatorial magnetosphere-ionosphere dynamics.

2) *Lower Atmosphere segmentation – LAS:* A series of four major space satellite missions need to be launched which will orbit in the lower atmosphere, from thermosphere, ionosphere to the stratosphere-ionosphere boundary region at varying altitudes. The outline is as follows:

a) *GEO-SAT Constellation –* The GEO-SAT constellation is a series of Earth Observation satellite missions four in number, which will mainly serve the purpose of communication and navigation purposes and airline communication purposes, by integrating the data from the satellites in the GEES segmentation, MTSE segmentation and UAS. These satellites will orbit at a height of 24000 km above the surface of the earth.

b) *TERNO-SAT constellation (Terrestrial Network of OBSERVATION Satellites constellation) –* The TERNOSAT series of four satellites will orbit the Earth at an altitude of 16000 km above the Earth's surface, will serve the purpose of land mapping, precision farming, forest and natural resources monitoring, agricultural land monitoring, Structural deformations in dams, huge constructions like bridges, various other civil engineering applications etc.

c) *NEV-SAT Constellation (NETWORK OF ENVIRONMENTAL SATELLITES) –* This series of four satellites will orbit at an altitude of 8000 km above the surface of the earth, serving the purposes of Advanced disaster warning systems like earthquake studies, volcanic eruptions, Tsunamis, Open pit mining etc.

d) *HYDRO-SAT Constellation –* This constellation of four satellites will orbit the Earth at an altitude of 4000 km and

will monitor the coastal regions of the Latin American continent, pacific and atlantic ocean floor mapping along the coastal length and breadth of the continent. The river water resources, Oil and natural gas reserves etc are also closely monitored for a proper utilization of natural resources.

e) *BREEZE Constellation–* This constellation of three satellites will monitor the ozone dynamics above the continent of South America

C. TERRESTRIAL SANDWICH (TERRESTRIAL GROUND SEGMENTATION – TGS):

. This segmentation also has two parts:

1) *Terrestrial Equatorial Ground segmentation :* The ground stations will be set up near the equatorial regions in the continent to receive the data from the various constellation of satellites orbiting at various altitudes.

2) *Terrestrial Polar Ground segmentation :* The ground stations will be located at the southern most locations of Argentina and Chile to receive the data from the polar satellites of SAGANS.

D. USER SANDWICH (USER ORIENTED SEGMENTATION – UOS):

SAGANS-SWIMS is expected to cater to the diversified requirements of users from various fields – academics, scientific and technological , engineering and medical, Disaster studies, Vehicle and way-point navigation, airline communication, governments, defense systems (military, naval and air-force).

III. THE DIFFERENT PHASES OF SAGANS-SWIMS

A. Initial Phase (I- Phase):

This Phase consists of the theoretical design of the various space satellite missions, their goals studied, the various parameters which need to be measured are defined, the mathematical analysis will be done, the various technologies to be employed in the sensor and instrument development which will be mounted on the satellite.

B. Testing, Experimentation and Validation Phase (TEV - Phase) :

This phase consists of the testing, experimentation and validation of the various instruments to be mounted on the spacecraft in orbit, the software needed to operate the instruments on board.

C. Launch Phase (L- Phase) :

This phase includes the funding and various options required for the final launch of the spacecrafts and placing them in orbit which includes the strategies being employed.[30]

IV. SATELLITE OR SPACECRAFT PROPULSION SYSTEMS – FUSE – FUEL USAGE STRATEGY AND EXPERIMENTATION

The below are the various options that can be considered for spacecraft propulsion systems and only the outline is given in this paper. Many of the technologies mentioned below are either already existing or some might be in the experimental stages.

A. *Electromagnetic and Electrodynamic spacecraft propulsion system (EESP) :*

The solar energetic charged particle flux that strikes the spacecraft detectors can be utilized as a source of propulsion systems. In one sense, this is approximately equal to the “Magnetic Sail” propulsion system, but much more can be possible in this type of propulsion. There are many options like Electrodeless Plasma thruster, MPD thruster, Pulsed plasma thruster, Helicon Double layer Thruster, Pulsed inductive thruster which fall under this category.

B. *Water (based) propulsion system (WPS) :*

This also can prove to be an effective propulsion system for the satellites in orbit.

C. *Hydrazine (based) propulsion system (HPS) :*

This is a well-known spacecraft propulsion system which is currently in use by Ariane Group and others.

D. *Green Technologies (based) propulsion system :*

This is also an innovative technology by Launch companies like Ariane Groups.

E. *Superfluid helium (based) propulsion system :*

Considering the special properties of Liquid helium-3 and superfluid Helium-4, there can be some possibilities for this kind of propulsion system, and Ariane group is actively working in this area too.

V. SPACECRAFT ORBITAL DYNAMICS

This section just outlines the orbital dynamics of spacecrafts, but the details are out of scope of this paper. The orbits will be angular, Quasi-equatorial, Quasi-polar, orbiting only the length and breadth of the South American Continent and need not necessarily be Geo-stationary. (The satellite need not make a complete revolution of the Earth either in equatorial or polar orbit, but will orbit only along the horizontal and vertical size of the continent, without being Geo-stationary at all). Although this can be a radical approach, but not at all impossible, if certain important parameters are taken into account.

VI. RESULTS AND DISCUSSIONS

1. SAGANS-SWIMS is a completely new and unique project in terms of space weather, communication, navigation, Earth observation etc, which is still in its initial stages.
2. SAGANS-SWIMS can fulfill the need of common space goals and common space agency for entire South American continent as a whole.
3. The minimum and maximum operational timeline for the design, implementation and operation of SAGANS-SWIMS can approximately range from 10 – 25 years and is certain to become the most robust communication, navigation and Earth observation system in the continent by integrating the various technologies in the continent.
4. Every country in the continent of Latin America has its own space goals and SAGANS-SWIMS can fulfill these by integrating these space goals.
5. SAGANS-SWIMS will play the major role in shaping the present and future education systems in the continent in the form of SIT -classrooms (SATELLITE INTEGRATED TECHNOLOGY) from school level to University level.
6. SAGANS-SWIMS will ensure that the safety, security and integrity will never be compromised for any country in the continent under any circumstances.
7. SAGANS-SWIMS will prove to be an effective technological and friendly tool for users in various fields as well as governments and defense systems.
8. SAGANS-SWIMS will facilitate ease of trade and business for various countries inside and outside of the continent.
9. SAGANS-SWIMS will make sure the natural resources of every country are monitored, utilized properly and not fall in the hands of miscreants, by keeping a ‘Technological Eagle-eye’ on the continent.
10. SAGANS-SWIMS will play the role of an advanced disaster warning system for the entire continent, thereby lots of lives can be saved from the wrath of nature, in the form of earthquakes, Tsunamis etc.
11. SAGANS-SWIMS will be the major boost for agriculture, generating revenue for various countries in the continent in terms of trade with other continents.
12. Special focus will also be given to the coastal area monitoring of the continent in terms of marine seismic surveying, Oil and natural gas monitoring etc.
13. The data received will be real-time and be of a higher accuracy than the traditional GPS systems, which is one of the major goals of SAGANS-SWIMS.
14. The current timeline of this project is to determined yet as the project itself is undergoing a lot of refinements and scrutinizations in its initial stages.

15. The formation of Scientific research teams are currently under progress for this unique big project as of now.
16. Some technical specifications are outlined regarding this unique project. More inputs are necessary from many other scientific researchers in the Latin American continent.
17. The SAGANS-SWIMS is in favor of pico, nano, micro satellites which are cost-effective and technologically robust.
18. Although Cube-Sat technology is considered one of the best for nano satellites, still we can expect some modifications in order to improve efficiency of the satellites.
19. Since SAGANS-SWIMS is a huge project consisting of a total of 24 satellites , and the various sensors, instruments to be mounted, the project will begin with UHPE and SDEM, the spacecrafts belonging to the Deep space segmentation or the GEES Segmentation , thereby going systematically.
20. The technical structure of every space satellite mission will be dealt first and then come the sensors and the instruments to be mounted, then the orbital dynamics and Fuel usage strategy following the Initial, TEV and the Launch phase in a systematic fashion.
21. Some genuine ideas need to be materialized when it comes to important issues like partial funding, step-by step funding etc in this regard.

CONCLUSION AND FUTURE TRENDS

Brazil, Peru, Colombia, Ecuador, Bolivia, Argentina, Uruguay, etc. and some central American countries like Guatemala are some of the foremost countries to accept responsibilities especially regarding space and aerospace technologies as these nations highly recognize and realize the core importance of these advanced technologies for a prosperous society. Since SAGANS - SWIMS offers more features regarding satellites regarding vehicle and way-point navigation, airborne and seafloor mapping, precision farming, monitoring of natural resources, illegal mining, illegal activities, terrorism, smuggling, drug trafficking, forest mapping, utilities and retail industry, monitoring and advanced warning systems of natural calamities like earthquakes, Tsunamis, volcanic eruptions, cadastral surveying, structural deformations and other civil engineering applications and much more etc., the various universities in these countries can actively participate in the preparation of nano-satellites and can begin with any theme listed above like vehicle navigation, weather monitoring, precision farming , seafloor mapping etc.

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