International Multilingual Journal of Science and Technology (IMJST)
ISSN: 2528-9810
Vol. 6 Issue 12, December - 2021

Correlated T-Tests Analysis Of Predicted Orbital Altitude Datasets From Two Online Satellite Tracking Tools: Cases Study Of EUTELSAT 7B

Kufre M. Udofia
Department of Electrical/Electronic and Computer Engineering,
University of Uyo, Nigeria
kmudofia@uniuyo.edu.ng

***Abstract*— In this paper, correlated t-tests analysis of predicted orbital altitude datasets from two online satellite tracking tools is presented. The cases study satellite is EUTELSAT 7B with Norad identification number of 39163. Four different orbital altitude datasets of EUTELSAT 7B satellite were obtained from two different online satellite tracking tools. Each of the dataset has 170 altitude data items. The four datasets were combined in six different pairs and correlated t-test analysis was performed on the six pairs of the orbital altitude datasets. The results showed that the mean of the first, second and third combinations of the datasets are -0.191936649, -1.094454754 and -2.392700035 respectively, while the mean of the fourth, fifth and sixth combinations of the datasets are -0.902522257, -2.200767205 and -1.298245614 respectively. Again, the results showed that there is no significant difference between the mean of the two dataset in the first, second, third, fourth, fifth and sixth combinations of the four datasets. Essentially, the mean of the two dataset are equal in all the combinations of the four datasets.**

Keywords*— *Satellite, Correlated T-Tests, EUTELSAT 7B, Statistical Analysis, Orbital Altitude, Satellite Tracking

1. Introduction

Satellite orbital motion tracking datasets are very useful for satellite applications. Researchers and satellite applications developers use such data in their analysis [1,2, 3,4, 5,6, 7,8, 9,10, 11]. Such data as the orbital longitude, latitude and altitude are used to determine several satellite communication link parameters such as the elevation angle, the slant range, the path loss, the communication delay, the coverage range, among others [12,13,14,15,16,17,18,19,20]. The accuracy of such analysis depends on the accuracy of the input dataset. As such, determination of the accuracy of the satellite tracking dataset is essential for effective satellite application development.

Nowadays, there are several online satellite tracking tools that enable access to the predicted satellite dataset [1,2, 3,4, 5,6, 7,8]. Unfortunately, for the same timeframe, many of these tools give different data values for the same satellites. Also, they have different time intervals in their data capture. As such, evaluation of the accuracy of the dataset obtained from the different online tools is essential to know which dataset conforms to the known mean values of the orbital parameters.

In this case, the correlated t-tests analysis is essential for comparing two related dataset that can be paired [21,22,23,24,25,26,27,28,29]. In this paper, the satellite altitude datasets acquired from two different online satellite tracking tool is presented. The study utilised the correlated t-tests analysis to ascertain the relationship that exist between the mean of the two satellite altitude datasets, specifically to check if the two mean values are the same or whether there is a significant difference in the mean of the two dataset. The approach can be used to validate the applicability of any online tool generated dataset when the dataset is statically compared with a reference dataset that is known to be accurate. In any case, the correlated t-tests analysis can only be applied when the requisite conditions are satisfied.

2. Methodology

2.1 The correlated t-test procedure

In the corrected t-test analysis in this paper two orbital altitude databases are considered. Each of the two datasets consists of N data items. The data items in the two datasets are represented as $A_{x,k}$ for the first dataset and $A_{y,k}$ for the second dataset, where k = 1,2,3,…N. Then, the dataset for the difference, denoted as $D_{ay,k}$ is given as;

$$D_{ay,k} = A_{x,k} - A_{y,k} \text{ for k = 1,2,3,…N} \quad (1)$$

The mean of $D_{ay,k}$ is denoted as $\overline{D}$ where;

$$\overline{D} = \frac{\left[\sum_{k=1}^{N}(D_{ay,k})\right]}{N} \quad (2)$$

The standard deviation of $D_{ay,k}$ is denoted as S_D is given as;

$$S_D = \sqrt[2]{\left(\frac{\left[\sum_{k=1}^{N}(D_{ay,k}-\overline{D})^2\right]}{(N-1)}\right)^2} \quad (3)$$

The standard error of $\overline{D}$ is denoted as SE_D is given as;

$$SE_D = \left(\frac{S_D}{\sqrt{N}}\right) \quad (4)$$

The t-statistic denoted as t_D is given as ;

$$t_D = \frac{\overline{D}}{SE_D} \quad (5)$$

The degree of freedom, df is given as

$$df = N - 1 \quad (6)$$

For a selected significance value, α, the critical t value, denoted as $t_{Dcritical}$ is given as;

$$t_{Dcritical} = t_{(\alpha/2)} \text{ at df} \quad (7)$$

The confidence interval in respect of SE_D and α is denoted as $CI_{D\alpha}$, where;

$$CI_{D\alpha} = \left[\left(\bar{D} - \left(\left(t_{(\alpha/2)}\right)(SE_D)\right)\right), \left(\bar{D} + \left(\left(t_{(\alpha/2)}\right)(SE)\right)\right)\right] \quad (8)$$

If there is no significant difference in the mean of $A_{1,k}$ and $A_{2,k}$, then the value of t_D must be such that ;

$$\left(\bar{D} - \left(\left(t_{(\alpha/2)}\right)(SE_D)\right)\right) \leq \bar{D} \leq \left(\bar{D} + \left(\left(t_{(\alpha/2)}\right)(SE)\right)\right) \quad (9)$$

2.2 The case study datasets

In this study, four different orbital altitude datasets of EUTELSAT 7B satellite with Norad identification number of 39163 were obtained from two different online satellite tracking tools. Each of the dataset has 170 altitude data items, hence, N is 170. For the analysis, the four datasets are denoted as $AL_{1,k}$, $AL_{2,k}$, $AL_{3,k}$ and $AL_{4,k}$ and k is 1,2,3,…,170. For the correlated t-test, the datasets are considered two at a time. Then, the combination expression, ${}_WC_r$ is used to determine the number of combination of the dataset for comprehensive analysis, where;

$${}_WC_r = \frac{W!}{r!(W-r)!} \quad (10)$$

Hence, for w = 4 and r = 2, then $(4,2) = \binom{4}{2} = \frac{4!}{2!(4-2)!} = \frac{24}{2(2)} = 6$. If the datasets are generally denoted as $AL_{z,k}$ where z =1,2,3,4 and k = 1,2,3,…,170, then, the combinations of the four datasets into six different pairs are shown in Table 1.

Table 1.The combinations of the four datasets into six different pairs

	$A_{x,k}$	$A_{y,k}$
Combination Serial number	The dataset number, Z for the first dataset	The dataset number, Z for the second dataset
1	1	2
2	1	3
3	1	4
4	2	3
5	2	4
6	3	4

Datasets 1 and 2 were obtained from http://www.satellite-calculations.com while datasets 3 and 4 were obtained from https://orbit.ing-now.com/. The online satellite tracking tool at http://www.satellite-calculations.com provides hourly predicted orbital altitude for 170 consecutive hours from the time of request submission on the website. The 170 hours is about 7 days and few hours. On the other hand, the online satellite tracking tool at https://orbit.ing-now.com/ provides predicted orbital altitude for up a selected number of data points that spans over a month and about two or three data items are predicted per day. Notably, the analysis in this paper seeks to check if the difference in the sampling of the data points in the two different online tools will affect the mean of the datasets and to check also if there is significant difference in the mean of the four datasets. The graph plots of the orbital altitude for dataset 1 and 2 from satellite-calculations.com are shown in Figure 1 while those for dataset 3 and 4 from https://orbit.ing-now.com/ are shown in Figure 2.

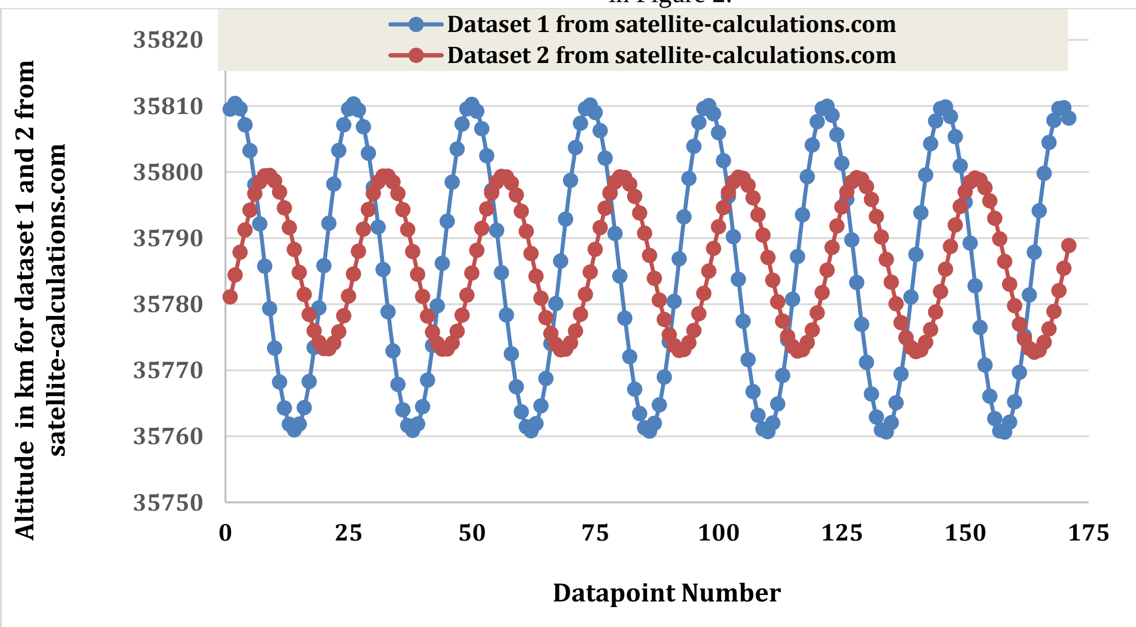

Figure 1 Orbital altitude for dataset 1 and 2 from satellite-calculations.com

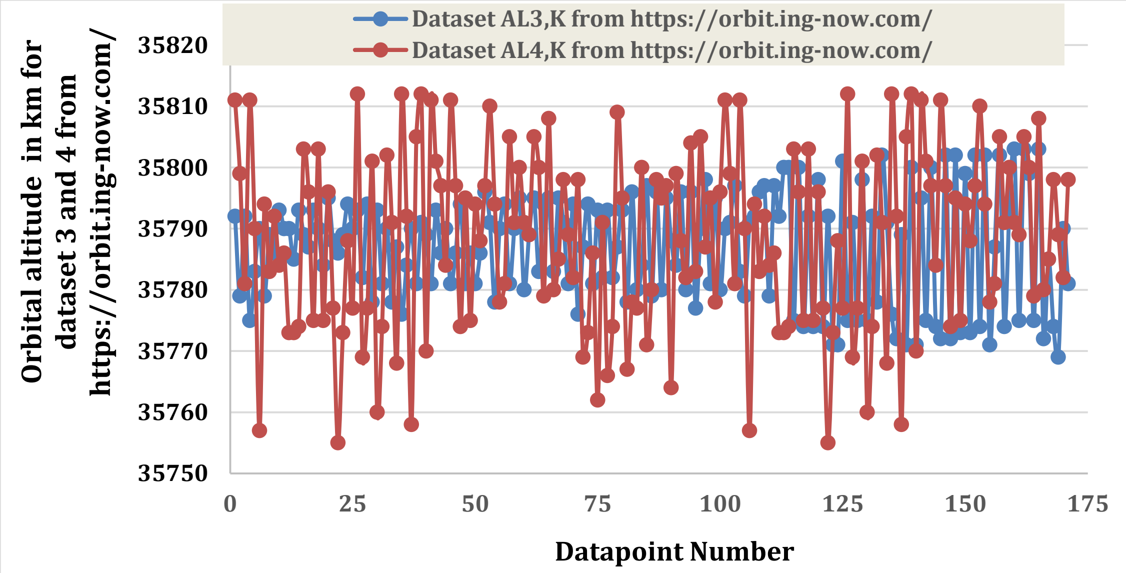

Figure 2 Orbital altitude for dataset 3 and 4 from https://orbit.ing-now.com/

3. Results and discussion

The summary of the analysis of the first, second and third combinations of the four datasets, the three combinations involve dataset 1 is presented in Table 2. The scatter line chart of the orbital Altitude difference of Dataset 1 and Dataset 2 is presented in Figure 3 while the results of the correlated t-test on orbital altitude difference of dataset 1 and dataset 2 is presented in Figure 4. Also, the scatter line chart of the orbital altitude difference of dataset 1 and dataset 3 is presented in Figure 5 while the results of the correlated t-test on orbital altitude difference of dataset 1 and dataset 3 is presented in Figure 6. Again, the scatter line chart of the orbital altitude difference of dataset 1 and dataset 4 is presented in Figure 7 while the results of the correlated t-test on orbital altitude difference of dataset 1 and dataset 4 is presented in Figure 8. The results in Table 2 show that the mean of the first, second and third combinations of the datasets are -0.191936649, -1.094454754 and -2.392700035 respectively. Again, the results in Table 2 and Figure 4, Figure 6 and Figure 8 show that there is no significant difference between the mean of the two dataset in the the first, second and third combinations of the four datasets. Essentially, the mean of the two dataset are equal in the first, second and third combinations of the four datasets.

Table 2. The summary of the analysis of the first, second and third combinations of the four datasets, the three combinations involve dataset 1

	Dataset 1 and 2 (both from satellite-calculations.com)	**Dataset 1 and 3** (Dataset 1 from satellite-calculations.com and Dataset 3 from https://orbit.ing-now.com/)	**Dataset 1 and 4** (Dataset 1 from satellite-calculations.com and Dataset 4 from https://orbit.ing-now.com/)
Mean $\bar{D}$	-0.191936649	-1.094454754	-2.392700035
Standard deviation, S_D	21.11000329	20.82652609	23.17774172
t-statistic, t_D	-0.119	-0.687	-1.350
t_critical, $t_{(\alpha/2)}$	1.962	1.962	1.962
Confidence interval, $CI_{D\alpha}$ (upper)	3.167300350	3.124768030	3.477539462
Confidence interval, $CI_{D\alpha}$ (lower)	-3.167300350	-3.124768030	-3.477539462
Remark	There is no significant difference between the mean of the two dataset. Essentially, the mean of the two dataset are equal.	There is no significant difference between the mean of the two dataset. Essentially, the mean of the two dataset are equal.	There is no significant difference between the mean of the two dataset. Essentially, the mean of the two dataset are equal.

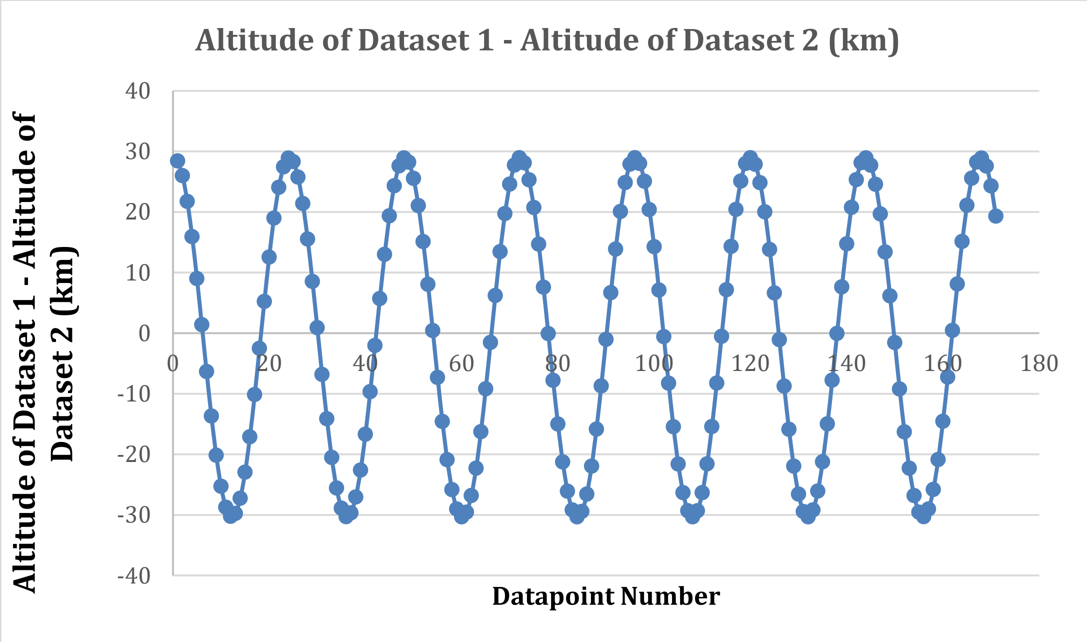

Figure 3 Scatter line chart of the orbital Altitude difference of Dataset 1 and Dataset 2

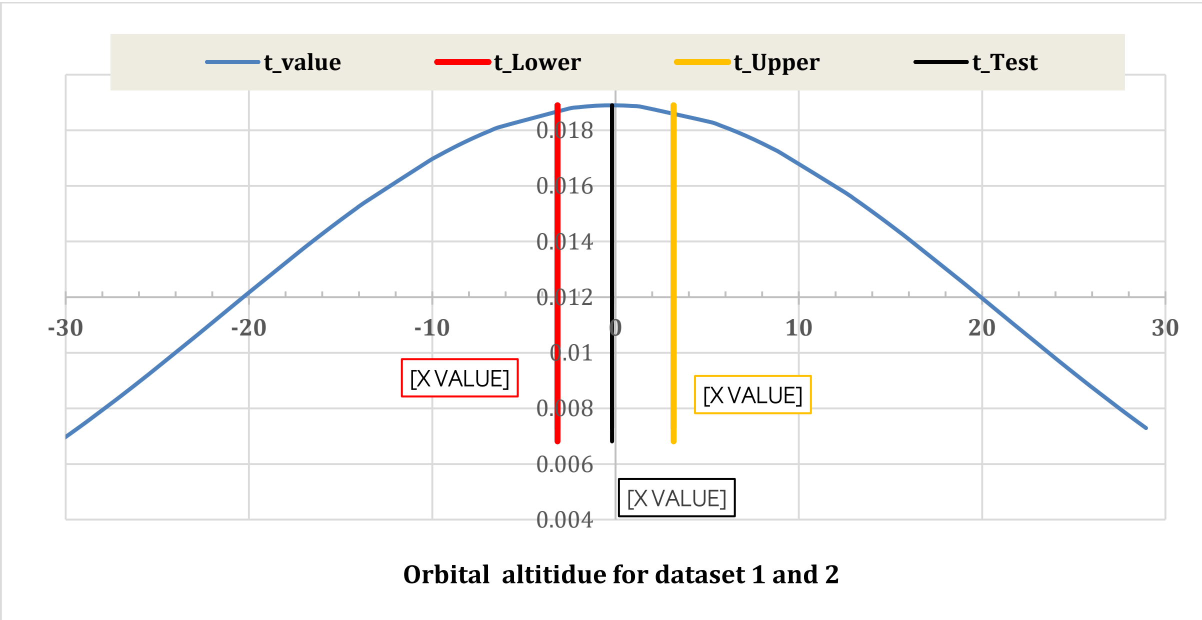

Figure 4 Results of the correlated t-test on orbital Altitude difference of Dataset 1 and Dataset 2

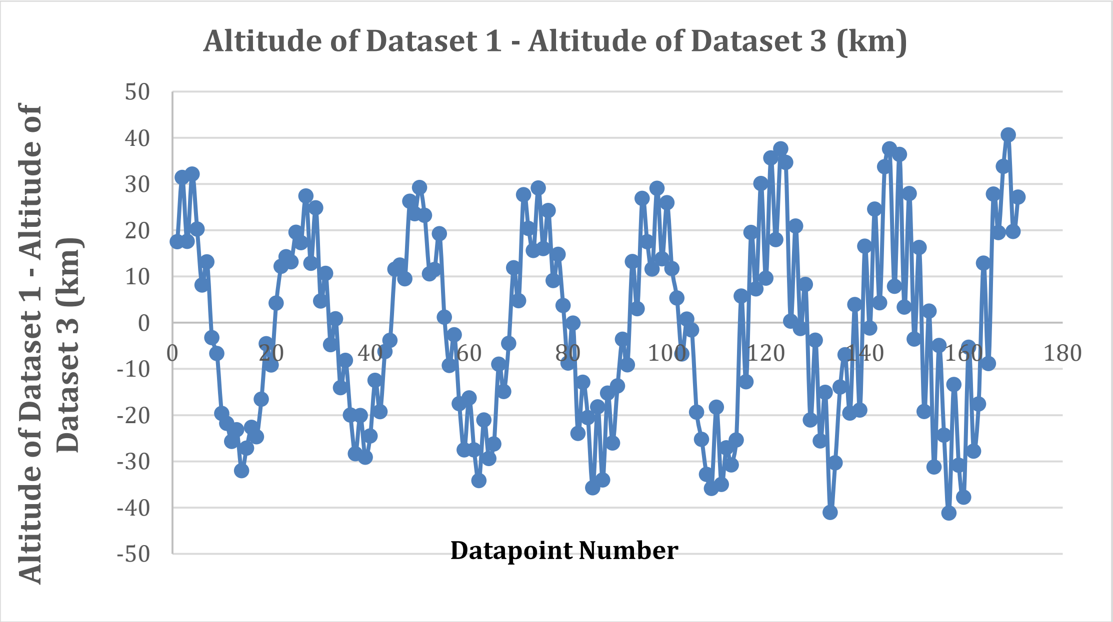

Figure 5 Scatter line chart of the orbital Altitude difference of Dataset 1 and Dataset 3

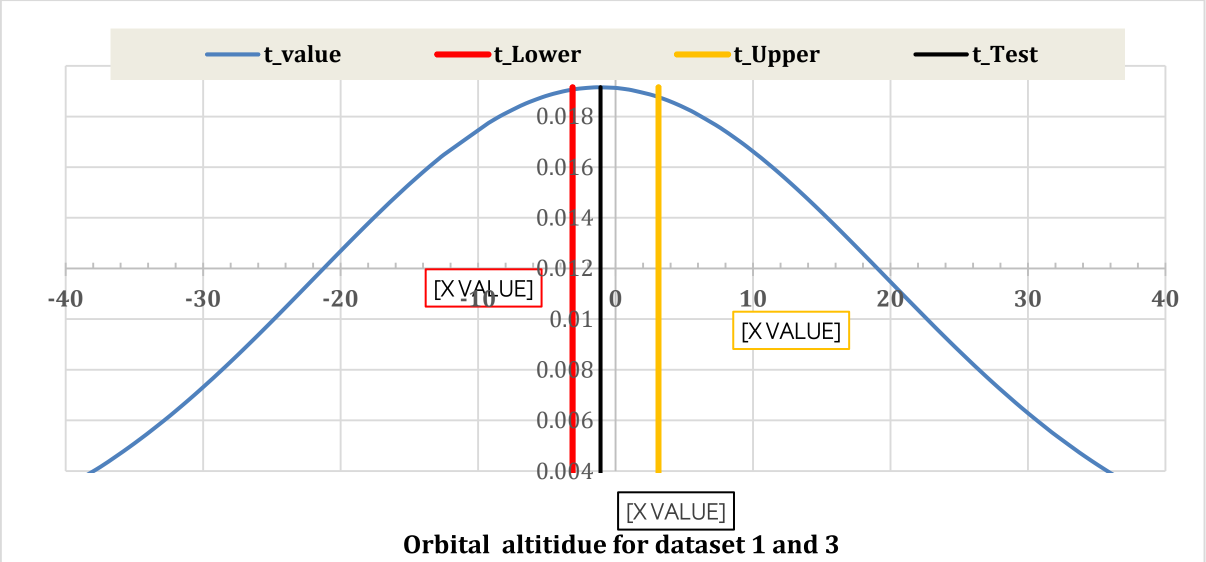

Figure 6 Results of the correlated t-test on orbital Altitude difference of Dataset 1 and Dataset 3

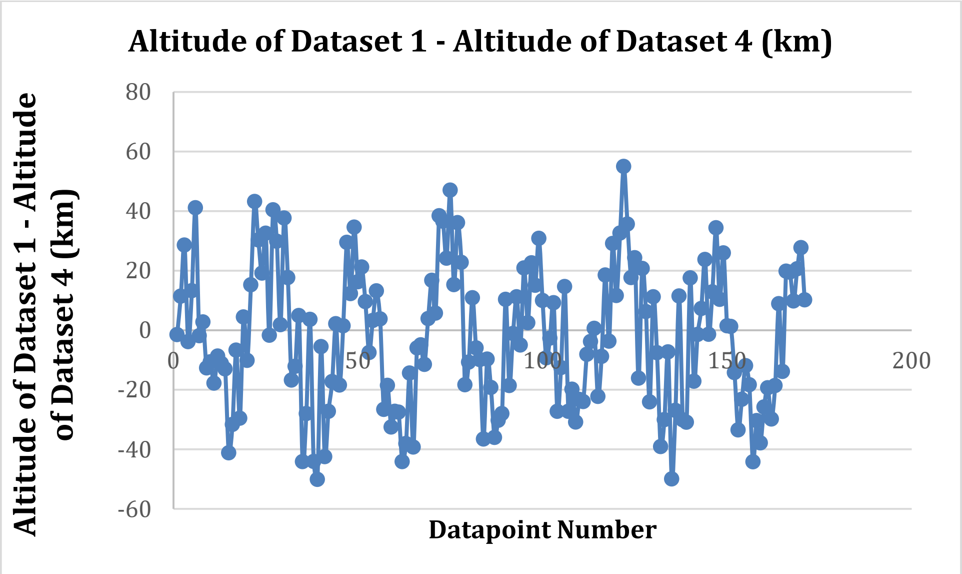

Figure 7 Scatter line chart of the orbital Altitude difference of Dataset 1 and Dataset 4

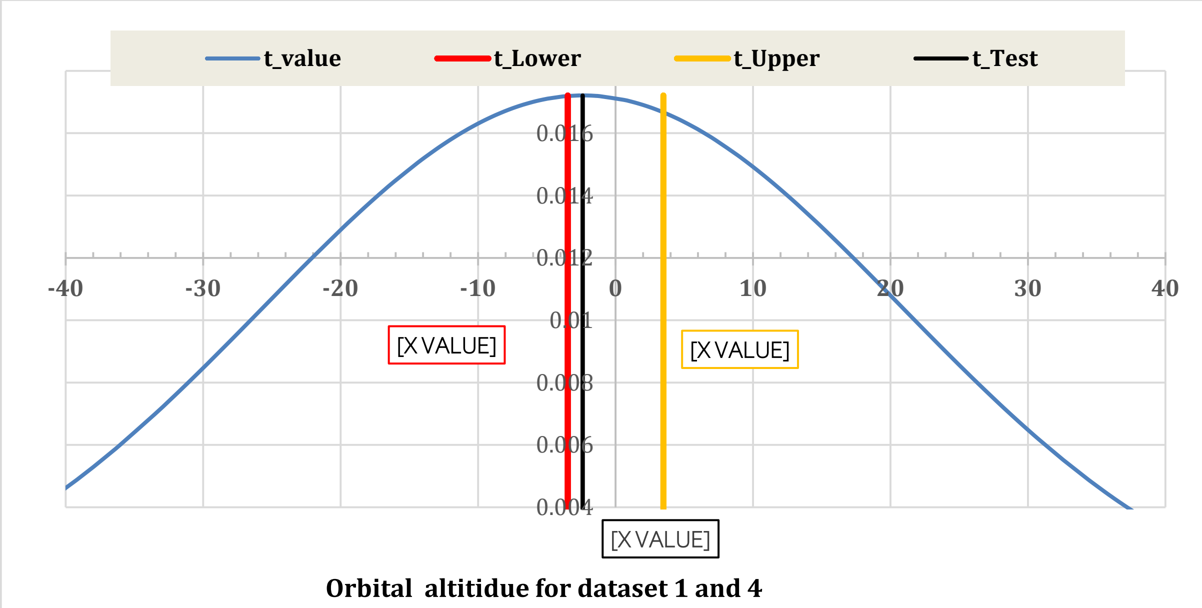

Figure 8 Results of the correlated t-test on orbital Altitude difference of Dataset 1 and Dataset 4

The summary of the analysis of the fourth and fifth combinations of the four datasets, with both combinations involve dataset 2 is presented in Table 3. The scatter line chart of the orbital altitude difference of dataset 2 and dataset 3 is presented in Figure 9 while the results of the correlated t-test on orbital altitude difference of dataset 2 and dataset 3 is presented in Figure 10. Also, the scatter line chart of the orbital altitude difference of dataset 2 and dataset 4 is presented in Figure 11 while the results of the correlated t-test on orbital altitude difference of dataset 2 and dataset 4 is presented in Figure 12. The results in Table 3 show that the mean of the the fourth and fifth combinations of the datasets are -0.902522257 and -2.200767205 respectively. Again, the results in Table 3 , Figure 10 and Figure 12 show that there is no significant difference between the mean of the two dataset in the the fourth and fifth combinations of the four datasets. Essentially, the mean of the two dataset are equal in the fourth and fifth combinations of the four datasets.

Table 3. The summary of the analysis of the fourth and fifth combinations of the four datasets, both combinations involve dataset 2

	Dataset 2 and 3 (Dataset 2 from satellite-calculations.com and Dataset 3 from https://orbit.ing-now.com/)	**Dataset 2 and 4** (Dataset 2 from satellite-calculations.com and Dataset 4 from https://orbit.ing-now.com/)
Mean $\bar{D}$	-0.902522257	-2.200767205
Standard deviation, S_D	13.08002775	17.8262131
t-statistic, t_D	-0.902	-1.614
t_critical, $t_{(\alpha/2)}$	1.962	1.962
Confidence interval, $CI_{D\alpha}$ (upper)	1.962499764	2.674607399
Confidence interval, $CI_{D\alpha}$ (lower)	-1.962499764	-2.674607399
Remark	There is no significant difference between the mean of the two dataset. Essentially, the mean of the two dataset are equal.	There is no significant difference between the mean of the two dataset. Essentially, the mean of the two dataset are equal.

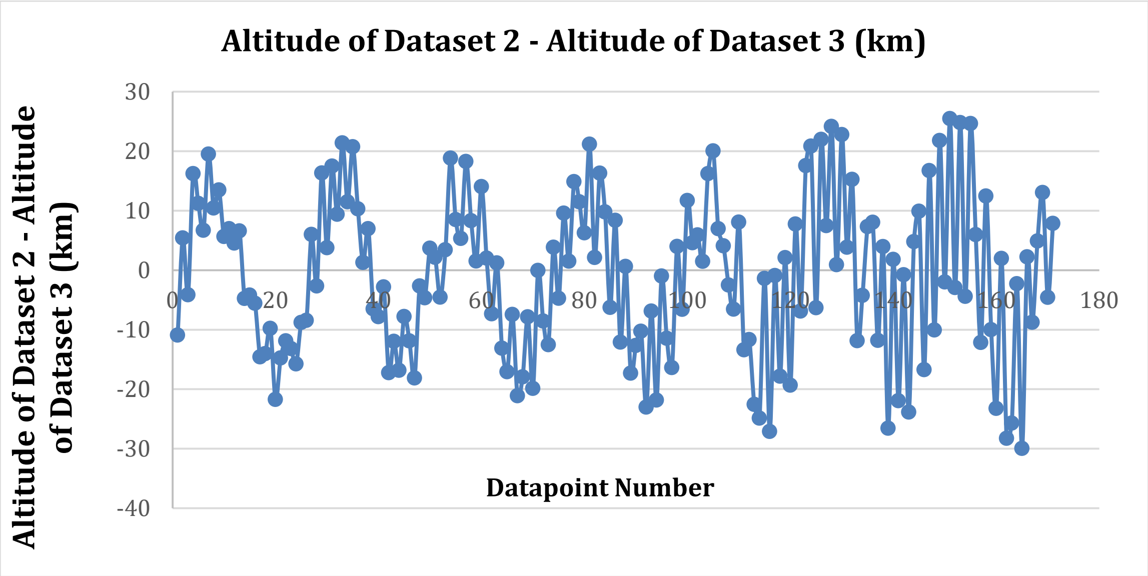

Figure 9 Scatter line chart of the orbital Altitude difference of Dataset 2 and Dataset 3

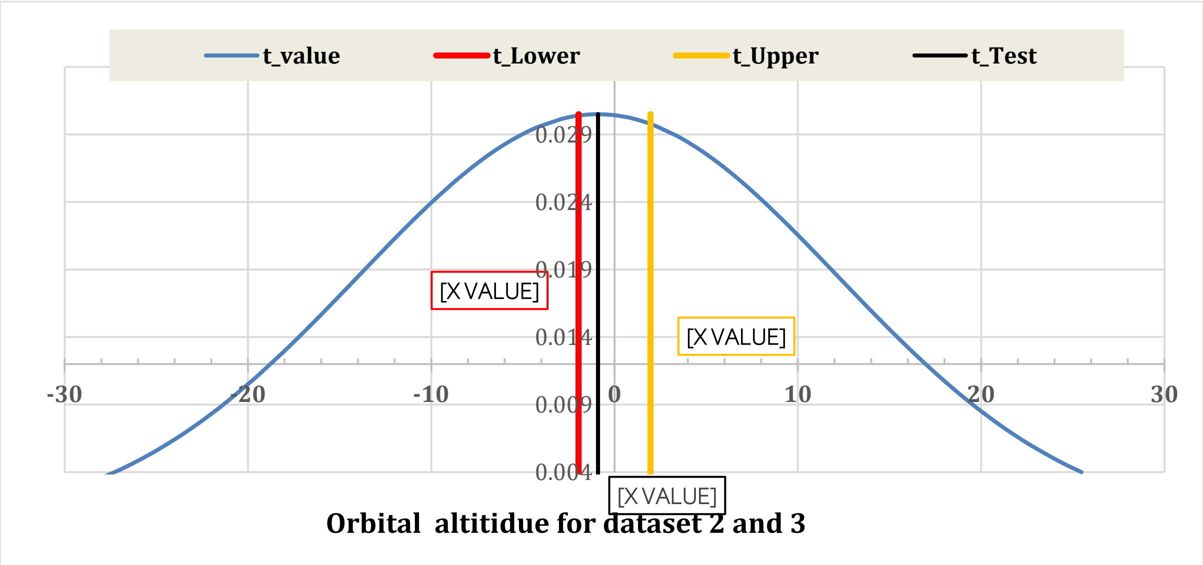

Figure 10 Results of the correlated t-test on orbital Altitude difference of Dataset 2 and Dataset 3

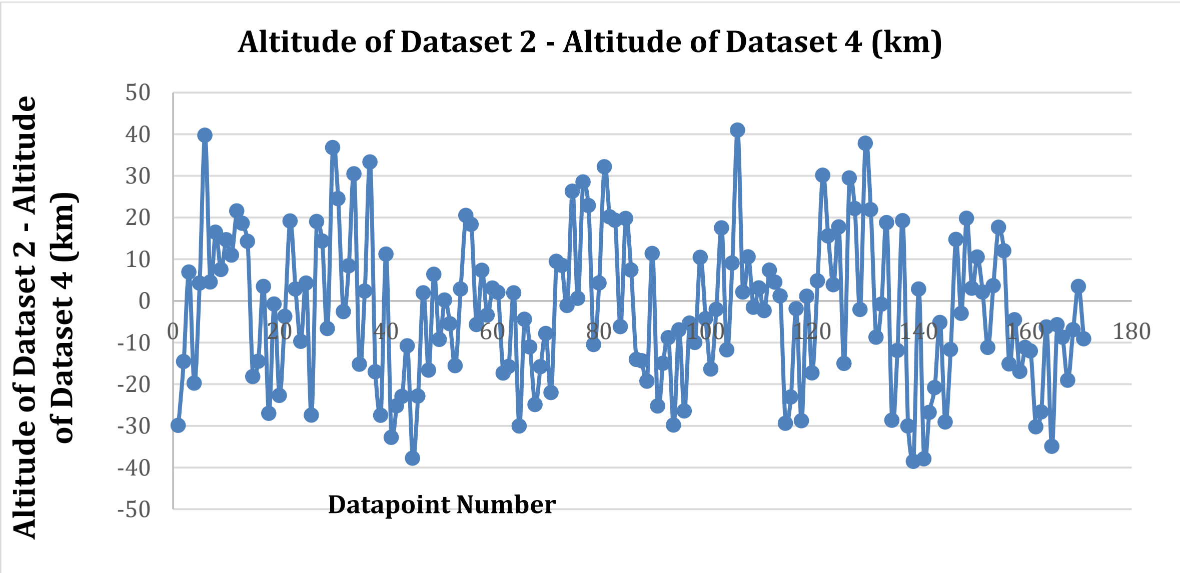

Figure 11 Scatter line chart of the orbital Altitude difference of Dataset 2 and Dataset 4

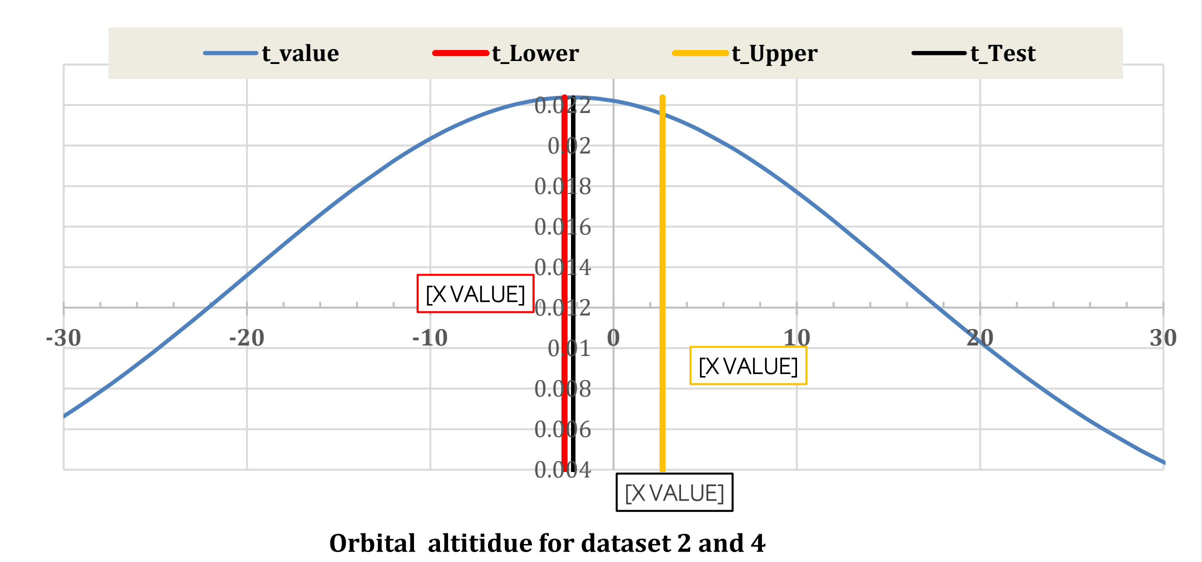

Figure 12 Results of the correlated t-test on orbital Altitude difference of Dataset 2 and Dataset 4

The summary of the analysis of the sixth combination of the four datasets which involves dataset 3 and dataset 4 is presented in Table 4. The scatter line chart of the orbital altitude difference of dataset 3 and dataset 4 is presented in Figure 13 while the results of the correlated t-test on orbital altitude difference of dataset 3 and dataset 4 is presented in Figure 14. The results in Table 4 show that the mean of the the sixth combination of the datasets is -1.298245614. Again, the results in Table 4 and Figure 14 show that there is no significant difference between the mean of the two dataset in the the fourth and fifth combinations of the four datasets. Essentially, the mean of the two dataset are equal in the sixth combination of the four datasets.

In all, despite the fact that the four datasets were captured on different dates and by two different online tools, their correlated t-test analysis showed that the datasets have the same mean.

Table 4. The summary of the analysis of the sixth combination of the four datasets, the combination involve dataset 3 and dataset 4

	Dataset 3 and 4 (both datasets from https://orbit.ing-now.com/)
Mean $\overline{D}$	-1.298245614
Standard deviation, S_D	16.94902209
t-statistic, t_D	-1.002
t_critical, $t_{(\alpha/2)}$	1.962
Confidence interval, $CI_{D\alpha}$ (upper)	2.542995511
Confidence interval, $CI_{D\alpha}$ (lower)	-2.542995511
Remark	There is no significant difference between the mean of the two dataset. Essentially, the mean of the two dataset are equal.

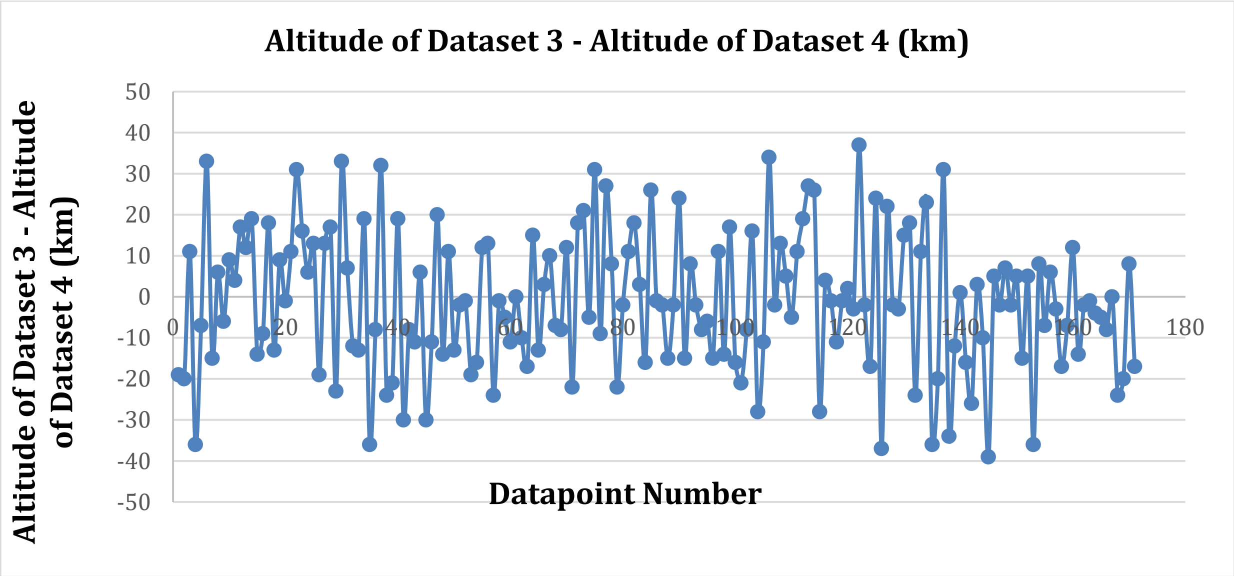

Figure 13 Scatter line chart of the orbital Altitude difference of Dataset 3 and Dataset 4

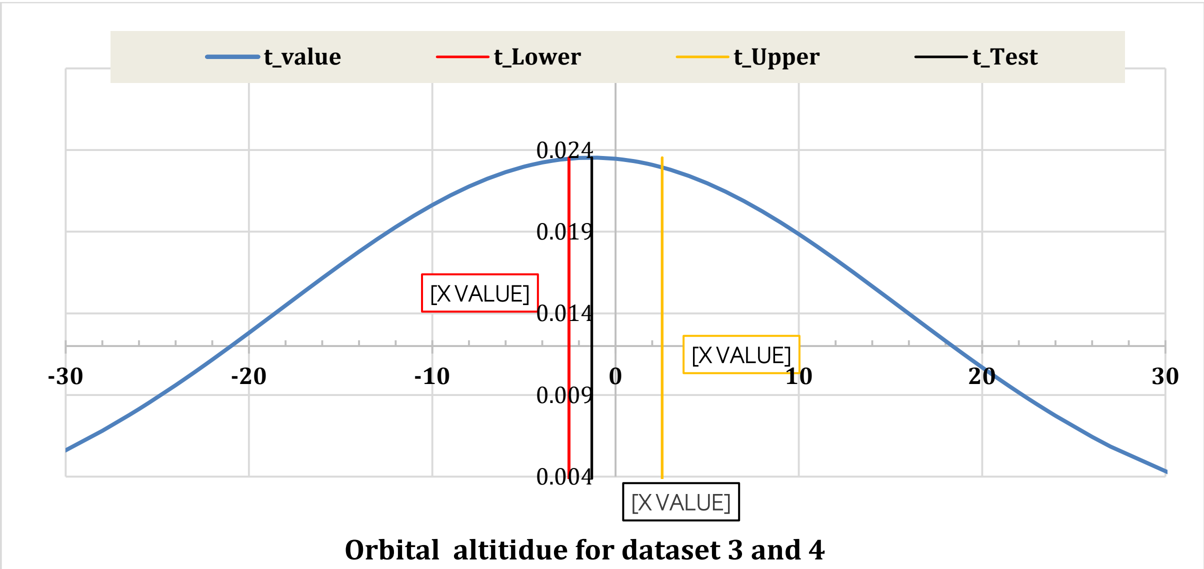

Figure 14 Results of the correlated t-test on orbital Altitude difference of Dataset 3 and Dataset 4

4. Conclusion

Correlated t-test analysis is performed on four orbital altitude datasets collected at different dates using two different online satellite tracking tools. The analysis is to establish if the predicted altitude datasets from the two tracking tools have the mean or if there is significant differences among the dataset from the same tool and datasets from the two different tools. The case study satellite in the study is the EUTELSAT 7B satellite with Norad identification number of 39163. In all, the results of the correlated t-test showed that there is no significant differences in the mean of the datasets from the different tools and the datasets collected on different dates.

References

1. Stoll, E., Letschnik, J., & Kebschull, C. (2020). II-3: Ground-based Satellite Tracking. *Nanosatellites: Space and Ground Technologies, Operations and Economics*, 471-494.
2. Griffith, N., Lu, E., Nicolls, M., Park, I., & Rosner, C. (2019). Commercial space tracking services for small satellites.
3. Montenbruck, O., & Gill, E. (2000). Satellite Tracking and ObservationModels. In *Satellite Orbits* (pp. 193-232). Springer, Berlin, Heidelberg.
4. Vuckovic, D., Rajkovic, P., Jankovic, D., & Pavic, O. (2010). Guidelines for Satellite Tracking. In *Satellite Communications* (p. 283). IntechOpen.
5. Nguyen, A. N. (2019). *Leo Satellite Orbit Determination from SDR-Based Observations*. New Mexico Institute of Mining and Technology.
6. Donaldson, D., & Storeygard, A. (2016). The view from above: Applications of satellite data in economics. *Journal of Economic Perspectives*, *30*(4), 171-98.
7. Wimberly, M. C., de Beurs, K. M., Loboda, T. V., & Pan, W. K. (2021). Satellite observations and malaria: new opportunities for research

and applications. *Trends in parasitology*, *37*(6), 525-537.
8. Derya, B. (2015). *Satellite Orbit Determination via Optical and Radar Systems* (Doctoral dissertation, MSc Thesis, İTÜ).
9. Burke, M., Driscoll, A., Lobell, D. B., & Ermon, S. (2021). Using satellite imagery to understand and promote sustainable development. *Science*, *371*(6535), eabe8628.
10. Nguyen, P., Shearer, E. J., Tran, H., Ombadi, M., Hayatbini, N., Palacios, T., ... & Sorooshian, S. (2019). The CHRS Data Portal, an easily accessible public repository for PERSIANN global satellite precipitation data. *Scientific data*, *6*(1), 1-10.
11. Feng, Z., Leung, L. R., Liu, N., Wang, J., Houze Jr, R. A., Li, J., ... & Guo, J. (2021). A global high-resolution mesoscale convective system database using satellite-derived cloud tops, surface precipitation, and tracking. *Journal of Geophysical Research: Atmospheres*, *126*(8), e2020JD034202.
12. Simeon, O. (2016). Comparative Analysis Of Rain Attenuation In Satellite Communication Link For Different Polarization Options. *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, *3*(6).
13. Kozhemyako, V. A., Ivanov, I. A., Uvaysov, S. U., & Uvaysov, R. M. (2021, November). Energy calculation of a satellite communication system. In *2021 International Conference on Electrotechnical Complexes and Systems (ICOECS)* (pp. 495-499). IEEE.
14. Utami, V. B. R., Imam, M. P. B., & Romadhona, S. (2021). Analysis the impact of sun outage and satellite orbit at performance of the telkom 3S satellite communication system. *JURNAL INFOTEL*, *13*(3), 134-142.
15. Singh, K., Nirmal, A. V., & Sharma, S. V. (2017). Link margin for wireless radio communication link. *ICTACT Journal on Communication Technology*, *8*(3).
16. Ippolito Jr, L. J. (2017). *Satellite communications systems engineering: atmospheric effects, satellite link design and system performance*. John Wiley & Sons.
17. Alqaraghuli, A. J., Abdellatif, H., & Jornet, J. M. (2021, June). Performance analysis of a dual terahertz/ka band communication system for satellite mega-constellations. In *2021 IEEE 22nd International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)* (pp. 316-322). IEEE.
18. Muñoz Tardà, C. (2018). *Study of the ground-to-Very Low Earth Orbit (VLEO) satellite communication link* (Bachelor's thesis, Universitat Politècnica de Catalunya).
19. Ramadhan, A. F., Larasati, S., & Muhammadi, P. I. (2021, July). Orbit Shifting Analysis Satellite Telkom 4 with Cowell and Encke Method Caused by Perturbation. In *2021 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT)* (pp. 6-15). IEEE.
20. Sebestyen, G., Fujikawa, S., Galassi, N., & Chuchra, A. (2018). *Low Earth Orbit Satellite Design*. Springer International Publishing.
21. Xu, M., Fralick, D., Zheng, J. Z., Wang, B., & Changyong, F. E. N. G. (2017). The differences and similarities between two-sample t-test and paired t-test. *Shanghai archives of psychiatry*, *29*(3), 184.
22. Hedberg, E. C., & Ayers, S. (2015). The power of a paired t-test with a covariate. *Social science research*, *50*, 277-291.
23. Joseph, M. A. (2019, November). Z-test for difference in two proportions, independent and paired samples t-tests, one-way anova. In *APHA's 2019 Annual Meeting and Expo (Nov. 2-Nov. 6)*. APHA.
24. Proudfoot, J. A., Lin, T., Wang, B., & Tu, X. M. (2018). Tests for paired count outcomes. *General psychiatry*, *31*(1).
25. Pietrobelli, A., Pecoraro, L., Ferruzzi, A., Heo, M., Faith, M., Zoller, T., ... & Heymsfield, S. B. (2020). Effects of COVID-19 lockdown on lifestyle behaviors in children with obesity living in Verona, Italy: a longitudinal study. *Obesity*, *28*(8), 1382-1385.
26. Kim, T. K. (2015). T test as a parametric statistic. *Korean journal of anesthesiology*, *68*(6), 540-546.
27. Imai, A., Kaneoka, K., Okubo, Y., & Shiraki, H. (2014). Effects of two types of trunk exercises on balance and athletic performance in youth soccer players. *International journal of sports physical therapy*, *9*(1), 47.
28. Bluth, K., Roberson, P. N., & Gaylord, S. A. (2015). A pilot study of a mindfulness intervention for adolescents and the potential role of self-compassion in reducing stress. *Explore*, *11*(4), 292-295.
29. Lee, K. Y., Cho, J. W., Chang, N. Y., Chae, J. M., Kang, K. H., Kim, S. C., & Cho, J. H. (2015). Accuracy of three-dimensional printing for manufacturing replica teeth. *The Korean Journal of Orthodontics*, *45*(5), 217-225.