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# Positioning Systems in Precision Farming and CORS-TR

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**Abstract:** Precision farming is known as determination of variability for soils, plants and products, planning of production due to spatial variability and application of variable rate inputs such as fertilizer, pesticide and seeds. Positioning and especially GPS is one of the important factor when determining of the variability for soils and plants, or nutrition. Determining of the position is vital for preparing of spatial variability maps of texture, or nutrients in the soils and application maps of fertilizer and/or pesticides, yield and then preparing of application maps of fertilizers a, seeds and pesticides. Accuracy and precision of the positioning affect on application of agricultural inputs directly. In this study, GPS, DGPS, RTKGPS and CORS-TR system which was developed by a project group carried out in Turkey were explained.
**Key words:** Precision farming, positioning, GPS, CORS-TR

## Hassas Tarımda Koordinat Belirleme Sistemleri ve CORS-TR

**Özet:** Hassas tarım toprak, bitki ve üründeki değişkenliklerin saptanması, bu değişkenlikleri dikkate alarak üretim planlamasının yapılması, ve değişken düzeyli girdi uygulaması olarak bilinmektedir. Hassas tarımdaki çeşitli değişkenlik tanımlamaları arasında en önemlisi konuma bağlı olarak saptanan yersel değişkenliktir. Toprak, bitki ve üründeki değişkenlikler saptanırken en önemli araçlardan birisi de GPS ve konum belirlemedir. Gerek topraktaki tekstür veya bitki besin elementlerindeki değişkenlik ve gerekse verim haritalamada yada gübre yada ilaç uygulama haritalarının hazırlanmasında ve sonrasında tarlada uygulama sırasında konum belirleme hayatidir. Konum belirlemedeki doğruluk ve hassasiyet hassas tarımda yapılacak uygulamaları doğrudan etkilemektedir. Bu çalışmada hassas tarımda kullanılan el tipi GPS, DGPS, RTKGPS ve ülkemizde yürütülen bir proje sonucu geliştirilen CORS-TR sistemi ile ilgili bilgiler verilmiştir.
**Anahtar kelimeler:** Hassas tarım, konum belirleme, GPS, CORS-TR

## INTRODUCTION

For organized societies, geographic data plays a vital role in all spatial design, planning and implementation in addition to the effective use of resources. Having up-to-date geographic bases are compulsory for kadastre and mapping work as well as the management and execution of infrastructure and superstructure efforts specifically towards achieving precision agriculture and remote farming.

Precision agriculture could be defined as the determination of variables pertaining to the soil, plants and crops, using these variables for planning the planting of crops and entering *degisken duzeyli* data. Among the variables used in precision agriculture the most vital ones are those that vary by location. GPS and positioning are important tools in determining variability in soil, plants and crops. Whether it is the texture of the soil or the variation in plant nutrition or generating fertility maps or determining pesticide and fertilizer distribution geographic positioning is critical. Precision and accuracy of position values play a direct role in precision agriculture implementation. The aim of this work is to provide information on hand held GPS, DGPS, RTKGPS devices used in precision agriculture and the CORS-TR system developed as part of a national project.

**DETERMINING POSITION USING SATELLITES**

Since the dawn of its existence mankind has always been curious about his location and how he can navigate to a desired location. (Figure 1).

**Figure 1. Determining position via satellites**

The technological solution to this problem is the use of Global Positioning Systems which are known as GPS in the USA, GLONASS in Russia (which abbreviates the same terms in Russian) and the work-in-progress Galileo of the European Union (Figure 2 and 3). Even with a basic handheld device it is possible to safely and cost effectively determine position with a precision of 10-20 meters anywhere on the planet, 24-7 without interruption.

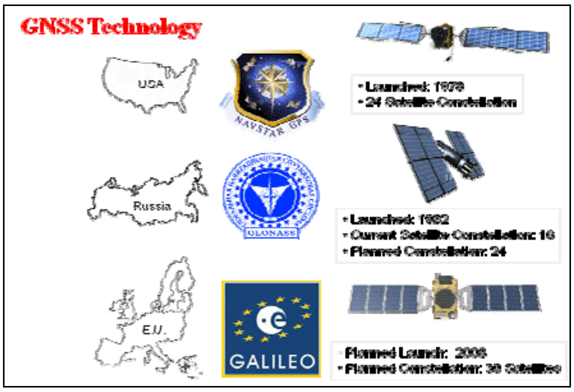



**Figure 2. GNSS technologies**

**Figure 3. Handheld global positioning device**

Global positioning systems are abbreviated as GNSS (**G**lobal **N**avigation **S**atellite **S**ystems).

In the 1960's USA developed positioning systems with the use of artificial satellites such as Transit, Timation and 621b to guide the inter-continental Polaris missiles launched from its submarines. The progress of this work paved the way for the development of a better system and thus in 1973 the Navstar GPS (**NAV**igation **S**ystem with **T**iming **A**nd **R**anging) was initiated. The system was completed and fully tested from 1979 to 1985. In 1996 the system was made accessible to civil use.

Every point on earth has a unique and uniform address (coordinate) defined by GNSS. Thus there is only one unique point corresponding to a set of coordinates and these coordinates are defined by the WGS84 datum (Figure 4).

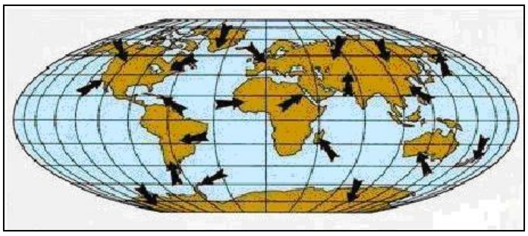


**Figure 4. WGS84 coordinate system**

Global positioning systems operate on common principles. Each one is comprised of three phases; the first of these is the ***Space Phase*** involving 24-30 artificial satellites (with their backups) in orbit some 20,250 km from earth's surface (Figure 5). In order for this system to provide uninterrupted service to every corner of earth a set number of satellites need to be positioned in a specific configuration.

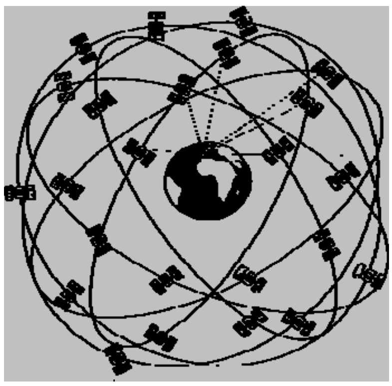


**Figure 5. GPS satellite orbits**

The satellites have on-board atomic clocks keeping standard time. Each satellite continously broadcasts the time and its position as calculated at the main control center (Figure 6 and 7).

**Figure 6. GNSS satellites**

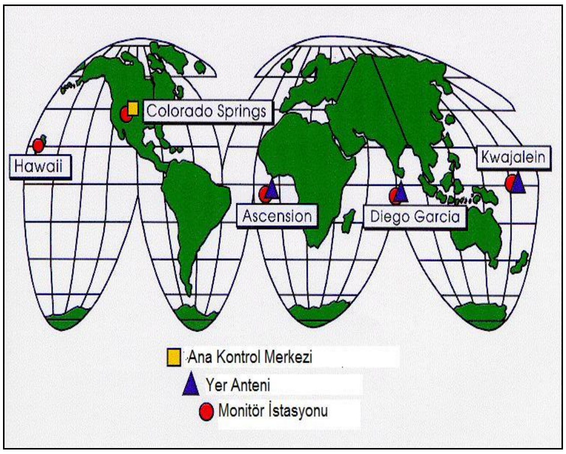



**Figure 7. GPS control stations**

***The Control Phase*** is handled by control stations placed around the globe. These stations relay the satellite data accumulated by their dish sensors to the **main control center**. The main control center analyzes this data in order to calculate corrections to satellite orbits and time stamps in order to have these updated values broadcast back to the satellites via control stations between the hours of 0-12 and 12-24.

During the ***User Phase*** handheld receivers with built in clocks and processors use satellite data picked up by their antennas to calculate their position.

Determining position with GNSS requires measuring the distance between the receiver and the satellite. A signal broadcast from the satellite at time $t_0$ will reach the receiver at time $t_1$. Thus the distance between the satellite and receiver can be calculated with the following formula.

$$D = v.(t_1 - t_0) \qquad (1)$$

The variable $v$ in the formula is the speed of electromagnetic waves broadcast by the satellite (~ 300 000 km $s^{-1}$). A signal from the satellite will reach the receiver at a very rapid time of approximately 0.033 seconds. As can be seen from the formula only the time is being measured. In order to determine coordinate values with reasonable accuracy the measured time should be accurate to within $\pm 10^{-11}$ s. For this reason satellites are fitted with atomic clocks based on cesium which are checked against the main control center time.

The distance between the satellite and receiver can be formulated in terms of the satellite coordinates *(X, Y, Z)* and receiver coordinates *(x, y, z)* as follows:

$$D = ((X-x)^2 + (Y-y)^2 + (Z-z)^2)^{1/2} + \delta t \qquad (2)$$

At this point the coordinates of the satellite are known. The goal is to determine the coordinates of the receiver. Given that the clock error $\delta t$ of the satellite and receiver is also unknown, the equation has a total of four unknowns. In order to solve for these unknowns information from four satellites must be received and expressed by the given equation. These equations can then be solved for the receiver coordinates (Figure 8 and Figure 9).

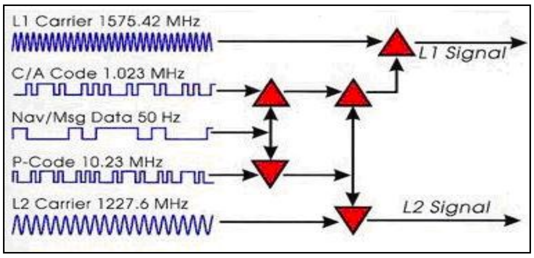



**Figure 8. GPS signals**

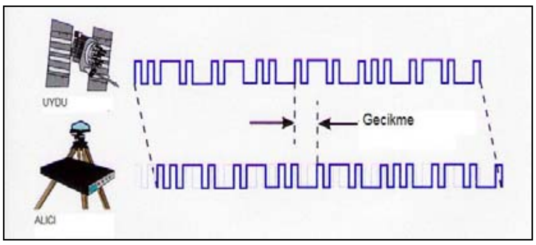



**Figure 9. Delay ($t_1$-$t_0$)**

Satellite data is broadcast using modulated signals (L1, L2, L5 vb). In terms of wavelengths the distance between the satellite and receiver can be formulated as follows:

$$D = m.\lambda + \frac{\Delta\varphi}{2\pi} \qquad (3)$$

Here,

m indicates the number of integer wavelenghts, $\Delta\varphi$ phase difference of electromagnetic waaves between satellite and receiver.

*m,* is determined by different techniques. The observation of phase difference constitutes the foundation of range determination by modulated wavelength. Information comes as coded. Codes are keys for observation. Receivers know code structure of every satellite. They generate equivalent signal of that coming from the satellite and measures the delay $t_1$-$t_0$.

Fractions of wavelengths are determined by signal processing techniques. 1% of wavelength can be measured by these techniques. By measurement of more than one wavelength, we achieve the desired accuracy (Figure 10 and Figure 11).

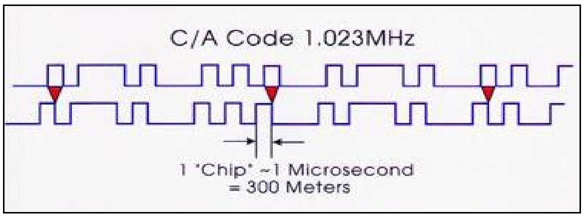



**Figure 10. 300 m chip length is used to achieve approximately 3m resolution.**

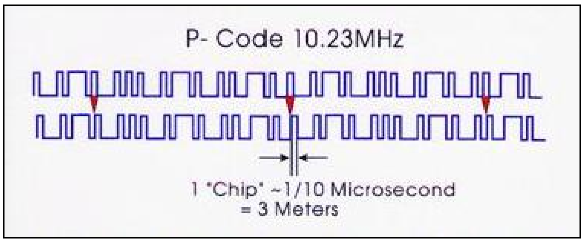



**Figure 11. 3m chip length is used to achieve approximately 30cm resolution.**

## CONTINUOUSLY OPERATING GNSS REFERENCE STATION SYSTEM (CORS)

The velocity and orientation of the satellite signals will be altered by the electron content in the ionosphere as well as the temperature, pressure, partial evaporation pressure and their gradients as tabulated in Table 1 (Figure 12 and 13).

**Table 1. GNSS positional errors**

| Type | Absolute | Relat. | Effect |
|---|---|---|---|
| Noise (Carrier) | 0.5 mm | 0.5 mm | Random |
| Reflection (Code) | <10 m | <10 | Systematic |
| Yansıma (Carrier) | <10 mm | <10 mm | Systematic |
| Satellite Orbit | 20 m | 1 ppm | Scale |
| Throposphere (0-15 km) | < 30 m | < 10 mm | Height |
| Ionosphere (70 -1000km) | < 100 m | < 50 ppm | Scale |

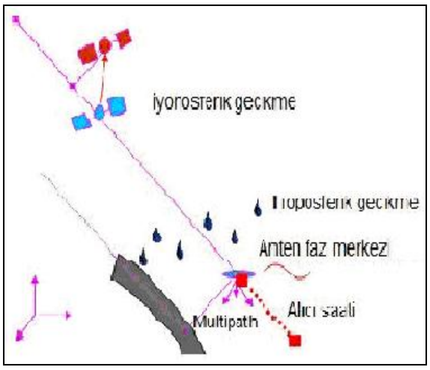



**Figure 12. Causes of error in the GNSS**

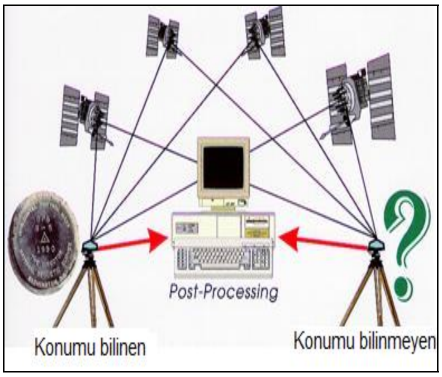



**Figure 13. Post-processing in the DGPS**

The effect of the Ionosphere and Trophosphere can be determined by mathematical models and other effects can be determined by various measurement techniques in order to increase the positional accuracy to the desired levels. For a network with 150 nodes acquiring data on two frequencies, the number of unknowns in the network equations is roughly 3,600. These can be solved quickly using various mathematical methods.

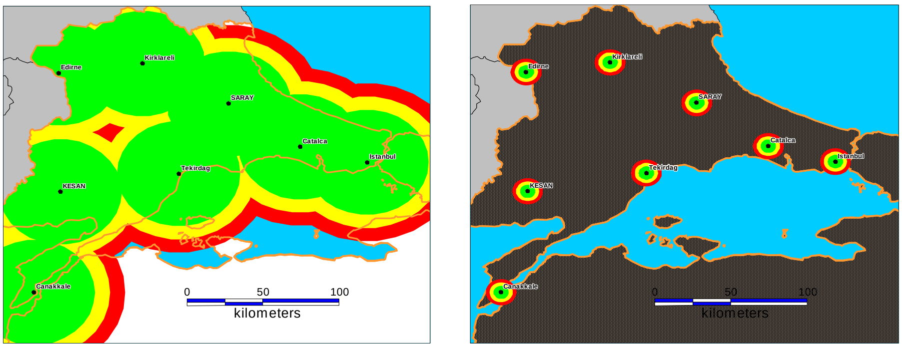
One of the most important measurement techniques for positioning is ***"differential GPS (DGPS)"***, which involves simultaneously using one receiver at a base point with known coordinates and the other at the point to be measured (Annonymous, 2003; French, 2001). Although it must be noted that the ***coordinate correction values*** are effective within a narrow 10 km radius for real time kinematic (RTK) measurements and up to 40-50 km radius for static measurements (following several hours of measurement depending on base length).

Corrections that are faster, continuous and on a wider area are referred to as **C**ontinuously **O**perating GPS Kinematic Reference **S**tations **S**ystem (***CORS)***. CORS operates through networking static reference stations distributed at 60-120 km intervals. The data collected in reference stations are processed together. Using this system coordinates of the reference stations can be determined to within several millimeters (Layer, 2008). The coordinate correction values of the difference between the accurately determined reference station coordinate values and the calculated coordinates of dynamically measured points is valid in a much larger area compared to DGPS (Figures 14 and 15).

Inside a CORS network a mobile GPS device can determine its position accurate to a centimer within several seconds. The system is operational 24 hours, 7 days a week.

In our current age, information technologies play an important role in production and related fields. **G**eo-**I**nformation **S**ystem ***(GIS***) stores spatial knowledge on computers in multiple layers, allowing for detailed analysis by relating data across the layers. This system is based on the ability to define position using a consistent coordinate system. CORS is the cutting edge technology used in achieving this goal.

CORS-TR's reference stations can use signals from GPS, GLONASS and Galileo. The satellite data picked up by the reference stations are relayed to the CORS control center. The results of data analyzed with the network principles are sent out to the roving stations (Eren ve ark, 2008).




**Şekil 14. DGPS ile CORS'un kıyaslamalı kapsama alanları**

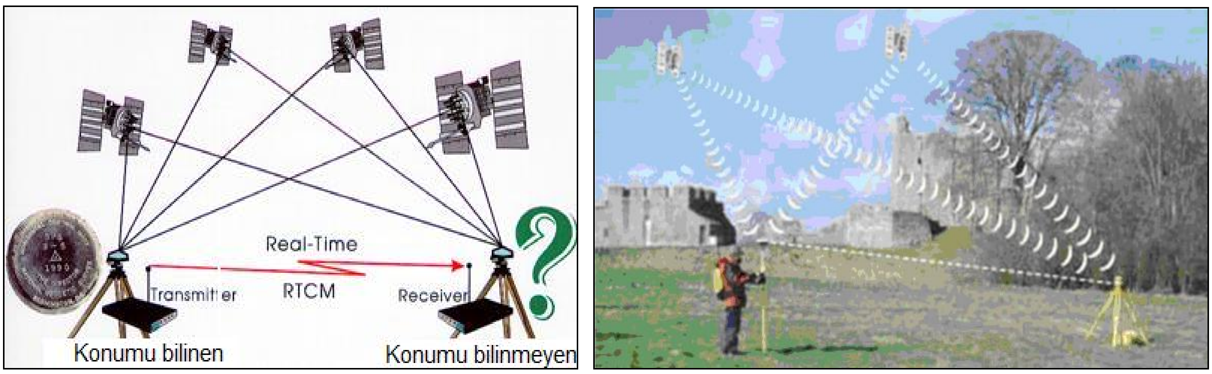



**Figure 15. By DGPS techniques, real-time kinematic observation data is transmitted to rovers by telemetry**

**CORS TR**

In order to achieve the aforementioned goal on a national scale a project titled "Creation of a National CORS System and Cellulor Datum Conversion" was undertaken by Istanbul Kultur University with the support of TUBITAK (The Scientific and Technological Research Council of Turkey). With the successful completion of the three year project, on May 1, 2009 CORS TR was made operational in Turkey and KKTC (Turkish Republic of Northern Cyprus).

The aim of the CORS-TR project was the use of state of the art technology to enable the fast, reliable and accurate entry of all geographic data as well as provide improvements in monitoring of tectonic plate movements and meteorological predictions.

A vital component of kadastre, mapping and GIS work is the determination of unique, reliable and uniform geographic position (coordinates). If this is not the case, there will be inconsistency when merging data. GPS has created a new paradigm in geographic positioning. Although GPS has been accessible since the 1990's in our country, field work is still based on old and expensive methods that require local reference stations. CORS-TR aims to replace these inefficient systems with a modern one that provides fast, cost effective and robust service. This project also provides support for the national conversion efforts between the outdated ED50 datum to the ITRFyy datum by determining conversion parameters.

General objectives of the CORS-TR project are highlighted as follows (Eren ve ark., 2009):

<u>Objective-1</u>: Very effieciently, fast and economically determining positions throughout the country in cms for 24 hours using real-time (RTK) and post processing techniques:

- *Using the CORS-TR system to determine the coordinates of geographic data and documents that are generated to provide benefit to the security and development of the country*
- *Carry out geodetic surveys (control points), terrestrial mapping, cadastral surveys, other surveys for GIS/LIS purposes of all agencies responsible for mapping and mapping information such as GDLRC and GCM.*

<u>Objective-2</u>: provide navigation support on air, land and sea with precision better than a meter,

<u>Objective-3</u>: Determination of conversion parameters to aid in the national conversion efforts of all mapping agencies (specifically the military mapping agencies TKGM and HGK) in updating maps and kadastre data from the ED50 datum to the ITRFyy datum,

<u>Objective-4</u>: Modeling of the conditions in the atmosphere and ionosphere above Turkey in order to improve meteorological predictions and aid technical research related to signal transfer and communications,

<u>Objective-5</u>: Precise and continuous monitoring of the tectonic plate movements of Turkey (which is on an earthquake belt), determination of the deformation at mm precision, thus providing assistance to research towards earthquake warning systems,

<u>Objective-6</u>: Provide support for R&D and space research in our country,

National CORS aids new projects and implementations by providing a base of geographic position data. Some examples which would benefit from the additional precision, speed and lower costs include: R&D towards earthquake warning systems; geodesic work; ionosphere and trophosphere research; precise meteorological predictions; provide data for global disasters; provide support towards the formation of regional emergency handling systems (flood, landslides, earthquakes, avalanches and storms); determination of coast lines; navigation and tracking services at sea, land and air; unmanned vehicle systems; ER support; marine structure projects; sea floor monitoring for approaching vessels; precise positioning to determine and clean sea and lake pollution sites; constant monitoring of large dams and the design of central warning centers; precise agriculture; unmanned agriculture; precise positioning for remote sensing applications; precise positioning for photogrammetric applications; positioning for archeology; engineering projects; photocoding; e-government; e-commerce and many more.

The motivation for the design of the CORS-TR project was a desire to create a low cost, continuous system for determining coordinates that is similar to implementations in several developed countries.

The project involved nearly fifty researchers from IKU, ITU, YTU, HGK and TKGM. The first phase involved a literature study and on-site analysis of existing implementations. As a result of this phase it was decided that a benchmark test involving a network comprised of triangular configurations of CORS stations with 60, 90, 120 km length sides was necessary. Thus one of the most comprehensive benchmarks in the world was conducted between the months of September and October 2006 in Trakya-Istanbul (Figure 16). This test allowed for the analysis of CORS systems, communication infrastructure and mathematical models for the datum conversion. Using the results of this test and other studies the final CORS network of 147 reference stations (spread at 80-100 km offsets) was designed (Figure 17, 18, 19).

**Figure 16. Reference stations**

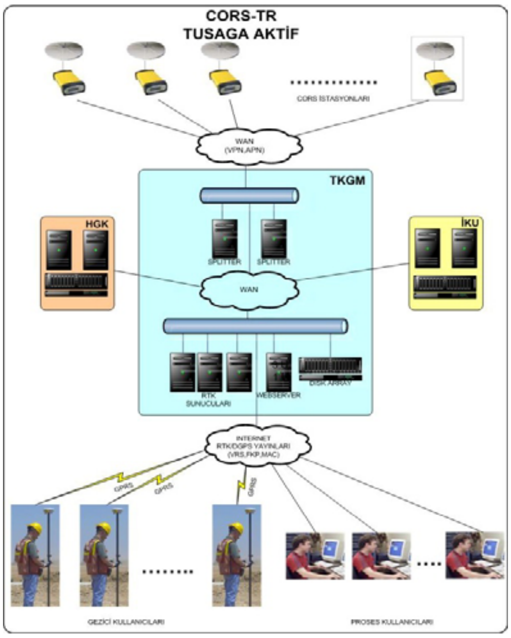



**Figure 17. CORS TR operation diagram and positioning with VRS**

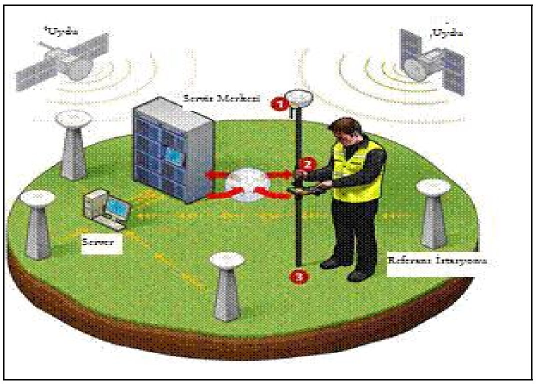


**Figure 18. Positioning with the FKP method**

**Figure 19. Positioning with CORS TR**

CORS-TR's reference stations can use signals from GPS, GLONASS and Galileo. The satellite data picked up by the reference stations are relayed to the CORS control centre. The results of data analyzed with the network principles are sent out to the roving stations (Eren vd, 2008).

Communication infrastructure for all stations and the control center make use of TT-ADSL with Turkcell EDGE as the alternative method. Using either ADSL or EDGE the reference stations send approximately 700 kbits$^{-1}$ of data to the control centre; following this the network calculations and correction values are sent out from the control center to the users via RTCM3.x. This system uses globally excepted VRS, FKP and MAC techniques.

This marks the start of a new era for mapping, cadastre and all geographic information technologies and research in Turkey. 24 hours a day, all across the country users of this system will be able to determine their coordinates to within centimeters in real-time or to within millimeters after post-processing. These coordinates, whether on land, sea or air, will be determined with greater accuracy, in less time, more cost effectively while adhering to a national standard.

In summary, geodetic control establishment required for mapping and subsequent layouts in the field shall not be carried out by old techniques any more, they will stay back in the history.

When compared to similar undertakings (in addition to having the most efficient budget) the CORS-TR project has the following features:

* *The 150 node network is the third largest in the world,*
* *Chrononologically it is the ninth implementation in the world,*
* *The first among developing countries*
* *It has been declared a model project by TUBITAK due to the following criteria: "national scope; tangible results that provide benefits to research and various project implementations; transparent use of its budget (Eren vd, 2009)"*

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