GNSS ATC Interface

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Abstract. The necessity of a navigation system, more flexible and interoperable, has become more and more important and the use of satellite system has been recognized as the main means to obtain this improvement. In the aeronautical field the GNSS has been chosen by the ICAO as fundamental component for the future CNS/ATM systems because of its peculiar characteristics that provide the necessary assistance during all flight phases. The ATC interface developed in the frame of EtoG aims to facilitate the introduction of GNSS services in Italian airspaces. The EtoG programme is a programme for researching and developing of new aeronautic applications to optimize the existing procedures and to find new technologies for the management of critical situations (safety) by using satellite navigation. The introduction of satellite navigation (GPS-EGNOS-GALILEO) allows the management of the aircraft flying phases with remarkable advantage compared to the traditional systems.

1 Introduction

Thanks to the use of the GNSS/EGNOS service and aiming at providing synthetic information to the aircraft controller with regard to the GNSS operating status, ENAV and SELEX–SI have began to develop a new prototype for the monitoring of the GNSS performance on the Italian airspace and presentation to controller. This monitoring tool will be able to provide a great operating support for all people involved in air traffic control and management (ATC/ATM). At the moment a mock-up in term of human machine interface (HMI) has been developed.

The International Civil Aviation Organisation (ICAO) has recognised a need improvements to the existing air navigation system. An ICAO Special Committee of Future Air Navigation Systems (FANS) developed a new concept expressed in terms of communication, navigation, surveillance and air traffic management (CNS/ATM). It is intended to be an evolutionary means of achieving improvements in the global air navigation system. To obtain the benefits of the CNS/ATM concept, aircraft will need to achieve accurate, repeatable and predictable navigation performance. This is referred to as Required Navigation Performance (RNP).

RNP is intended to define the requirement for the navigation performance of each individual aircraft within the airspace.

Table 1. Signal in space performance requirements.

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
Enroute	3.7 km (2.0 NM) (Note 6)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Enroute, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Nonprecision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APVI)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ per approach	10 s	$1 - 8 \times 10^{-6}$ in any 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ per approach	6 s	$1 - 8 \times 10^{-6}$ in any 15 s	0.99 to 0.99999
Category I precision approach (Note 8)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 7)	$1 - 2 \times 10^{-7}$ per approach	6 s	$1 - 8 \times 10^{-6}$ in any 15 s	0.99 to 0.99999

NOTES:—

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D, 3.2.
2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. These alert limits are:

A range of vertical limits for Category I precision approach relates to the range of vertical accuracy requirements.

3. The accuracy and time-to-alert requirements include the nominal performance of a fault-free receiver.
4. Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity (see Attachment D, 3.4).
5. A range of values is given for the availability requirements as these requirements are dependent upon the operational need which is based upon several factors including the frequency of operations, weather environments, the size and duration of the outages, availability of alternate navigation aids, radar coverage, traffic density and reversionary operational procedures. The lower values given are the minimum availabilities for which a system is considered to be practical but are not adequate to replace non-GNSS navigation aids. For en-route navigation, the higher values given are adequate for GNSS to be the only navigation aid provided in an area. For approach and departure, the higher values given are based upon the availability requirements at airports with a large amount of traffic assuming that operations to or from multiple runways are affected but reversionary operational procedures ensure the safety of the operation (see Attachment D, 3.5).
6. This requirement is more stringent than the accuracy needed for the associated RNP types but it is well within the accuracy performance achievable by GNSS.
7. A range of values is specified for Category I precision approach. The 4.0 metres (13 feet) requirement is based upon ILS specifications and represents a conservative derivation from these specifications (see Attachment D, 3.2.7).
8. GNSS performance requirements for Category II and III precision approach operations are under review and will be included at a later date.

The new concept of RNP is being applied to develop guidance standards for all phases of aircraft operations, including en route, landing and surface operations. The term RNP is applied as a descriptor for airspace, routes and procedures and can be applied to a unique approach procedure or to a large region of airspace.

This means that RNP is an airspace system function and not a navigation sensor function; the airspace requirements are satisfied independent of the methods by which they are achieved. This is quite different from the method used by regulating agencies at present which requires mandatory carriage of specified equipment for air navigation and thus constraints the optimum application and implementation of modern airborne equipment.

Tables 1 and 2 show the performance requirements of signal in space and alert limit associated to flight phases [1].

With the aim at providing a service to ATC controllers, the system shall provide the following features, with respect to the algorithm defined in [2], [3]:

- A *real time* evaluation of the GNSS availability for any virtual user who flies over the Italian airspace for all phases of flight (from Enroute to Precision approach);
- A *prediction* of the GNSS availability for any virtual user who flies over the Italian airspace for all flight phases (from En-route to Precision approach);
- To display over a particular geographical area or over a specific airways the result of the computation for the GNSS availability;

Moreover the system provides:

- Evaluation of the User Differential Range Error (UDRE) and Grid Ionospheric Vertical Error (GIVE) parameter included within the SBAS augmentation messages provided by EGNOS ATC Server

In order to evaluate the GNSS service in term of the integrity, two parameter, described in the algorithm defined in the RTCA standard document, will be used: the Vertical Protection Level (VPL) and the Horizontal Protection Level (HPL) [2].

Moreover Satellite navigation allow the ADS usage in the CTR and give to the air traffic controller a pseudo radar presentation of the air traffic equipment with ADS.

Table 2. Integrity requirements in terms of alert limit.

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APVI	40 m (130 ft)	50 m (164 ft)
APV-II	40.0 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40.0 m (130 ft)	15.0 m to 10.0 m (50 ft to 33 ft)

1. The terms APV-I and APV-II refer to two levels of GNSS approach and landing operations with vertical guidance (APV) and these terms are not necessarily intended to be used operationally.

In this way it is possible to increase safety and airport capability.

Data coming from local sensor possibly located in airport field could be taken into account for the evaluation of GNSS availability.

2 Service and Functionalities

The EtoG programme, through the GNSS ATC interface can offer advantages to three main figures:

- *Planner operator* (the person who has to manage and plan the flight within his/her region of interest)
- *Executive operator* (the person who has to directly provide to the airman the guideline for the procedure to be followed)
- *Supervisor operator* (the person who has to monitor the performance of the GNSS system at the moment and for future time)

For each operator the system has been studied to give an appropriate support based on the peculiar characteristic of the operator work. To do this, three main scenarios has been identified and characterized in order to provide a better service for the operator who shall use the system.

In addition for the supervisor operator has been developed, following the ICD provided by ESA [3], the interface for the ATC Client. The ATC Client is the primary mean to acquire data from the EGNOS system. Thanks to the development of this interface it is possible to directly compute data related to the UDRE and GIVE parameters in order to show the result to the supervisor operator. Many other information can be obtain through this connection such as almanacs, satellite status and so on. The information from the ATC Client are particularly useful for performance prediction while, for a real time evaluation this information could be refined with data from a GNSS receiver.

So, the main functionalities provided by the prototype can be summarize as follows:

- Prediction
- Real time evaluation
- Acquisition and elaboration of navigation EGNOS ATC messages

Figure 1 is shown the context diagram related to the main functionalities of the system proposed.

In the following sections the main result in term of sponsored service is presented.

2.1 Planner and Executive Operator

As anticipated before three main scenarios has been identified; in the following each scenario will be described.

This description is driven on a common base, i.e. a full functionality of the satellite navigation systems in all the conditions, and their integration with communication and

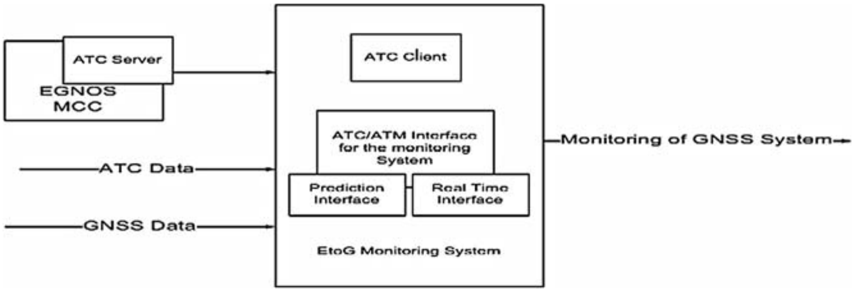

Fig. 1. EtoG tnterface – context diagram.

specific ATC/ATM systems. In particular, it's possible to identify some fundamental topics of scientific research which are strictly correlated to the full and correct definition of the applicative products:

- Interference management
- Augmentation and integrity algorithms

The EtoG project hence foresees to give a fundamental contribution to research in these research fields, beginning to study, develop, and validate at least some of the needed technologies.

2.1.1 En-route Scenario. The en route application product will optimize the air traffic flow from the controller point of view, providing information about the GNSS/SBAS performance within the Italian airspace; in particular it provides a great support for the transition areas (such as north Africa and Middle East areas). Predictive tools, matched with interface towards flow management units will allow to estimate GNSS availability along planned routes.

It is allowed the option to implement in the future the capability to manage Galileo messages too. In the following figures the interface for ACC controller (executive and planner) are presented. The first step is to configure the operating environment as shown in the following. The interfaces show different scenarios that can be set by the operator, for example the interface with the Terminal Manoeuvring Area (TMA) or Airways is presented. The scenario will be set by checking the appropriate checkbox in order to recognize the proper area of competence. Figure 2 is set the checkbox for the TMA. In a similar way it is possible to set different operating environment, such as Control Terminal Regions (CRTs), Flight Information Regions (FIRs) and so on.

In Fig. 3 the airways, within the Italian airspace are presented.

After the setting of the operating environment the ACC operator has to set if the prediction or the real time evaluation will be displayed on a particular airway or on a specific geographic area. In both cases the operator shall select the particular airway or area. The third step is to set the date and time of the evaluation (real time as well as prediction) and then he/she can display the prediction or real time evaluation by click the button *Prediction Data* or *Real Time*, respectively. Figures 4 and 5 show both elaboration.

Fig. 2 ACC interface with TMA.

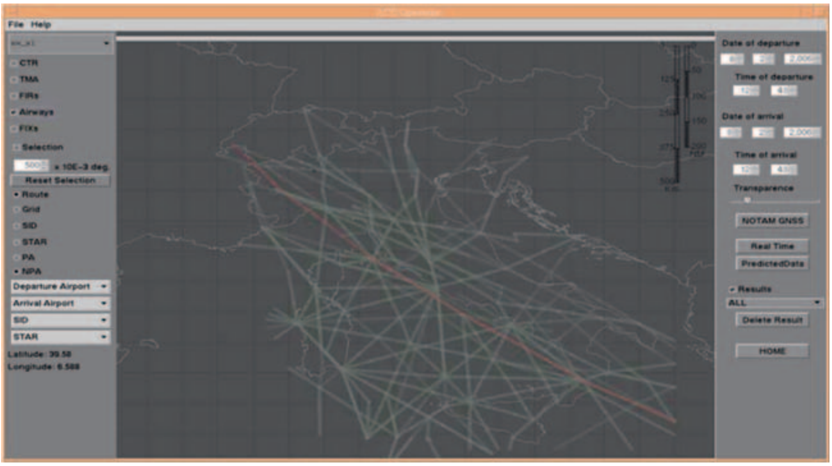

Fig. 3. ACC operator with airways.

For a better and an immediate comprehension of the interface for each type of RNP procedure is associated a given color. In this case the APV-I procedure is represented.

2.1.2 Approach Scenario. For the approaching scenario, the application product is targeted to innovation in the field of satellite navigation, allowing the integration of the satellite functionalities in conjunction with the additional capabilities typical of ADS systems.

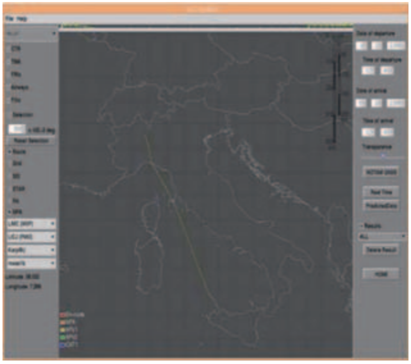

Fig. 4. Real time for a given Route.

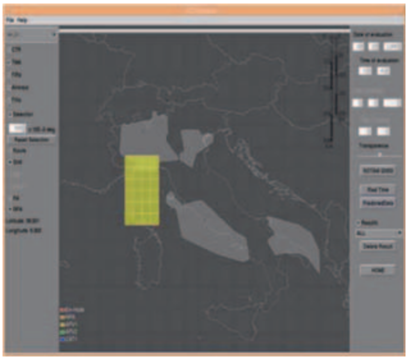

Fig. 5. Prediction in a given area.

As described above, the APP operator has to preliminary set the operating environment, the type of evaluation and the related time and data. The main difference is given by the difference area of interest between the ACC and APP operator.

Figure 6 the prediction on a particular airspace within the Naples CTR and the real time evaluation for one STandard ARrivals (STAR) and two Standard Instrumental Departures (SIDs) for the Rome CTR are presented. In the second case (Fig. 7) the operator will be able to display the distance between the aircraft and the ground (in terms of Flight Level –FL).

2.1.3 Airport Scenario. For the airport operational scenario, the application product is focused on innovation in the field of satellite navigation and its applications. This product focuses its applications to the most critical phases of the flight. Possible benefits are under investigation that local sensor could give to an EM interference analysis potentially impacting approaching procedures.

In Fig. 8 two different SID for the Malpensa Airport are shown. The picture is referred to a prediction.

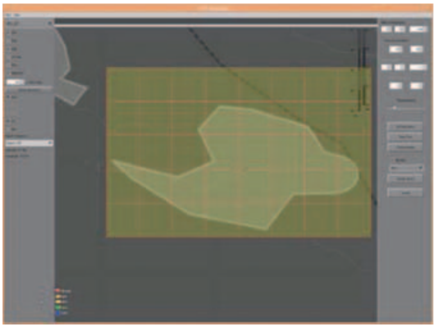

Fig. 6. A prediction in naples CTR.

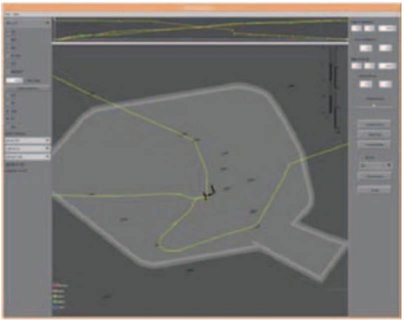

Fig. 7. A real time evaluation in Rome CTR.

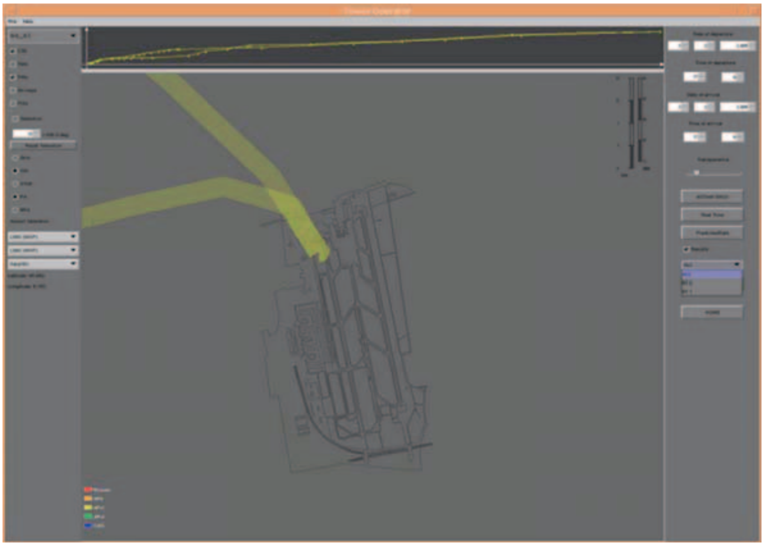

Fig. 8. A real time in airport scenario.

2.2 Supervisor Operator

For the supervisor operator has been developed, following the ICD provided by ESA [3], the interface for the ATC Client which is connected with the ATC Server in the MCC of Ciampino. Thanks to the development of this interface it is possible to predict the performance of the GNSS/SBAS system in terms of integrity parameters. Moreover it is possible to display other elaboration such as the computation of the User Differential Ranging Error and Grid Ionospheric Vertical Error parameter, the average local error, the user fix scattering and so on, as showed in the following pictures. Figure 9 are shown different elaboration in order to verify the GNSS performance of the satellite navigation aid.

The elaboration of the EGNOS-ATC-message type 6 and message type 7 provided by the EGNOS ATC Server will be useful to display the UDRE and GIVE maps in order to evaluate the GNSS behaviour within the Italian airspace.

An example of such elaboration is presented Fig. 10.

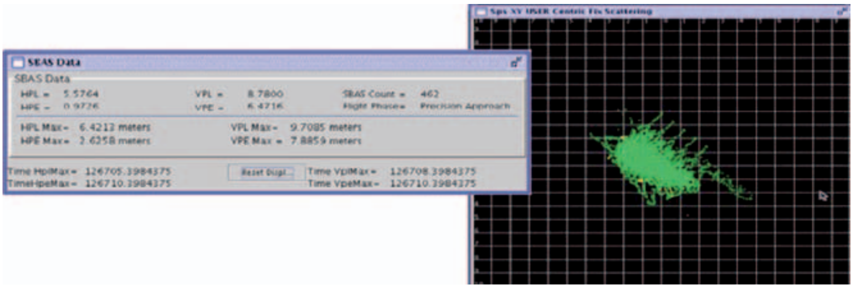

Fig. 9. User fix scattering and local error.

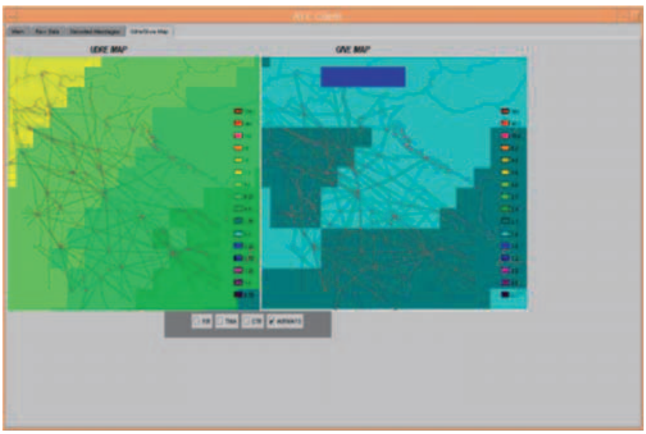

Fig. 10. UDRE and GIVE computing.

The supervisor operator can also know information provided by NANUs messages related to programmed unavailability of GNSS satellites. The unavailability notice are presented in table form or they are displayed, through a simulator, tracking their position as shown in Fig. 11.

2.3 ATC Client Interface

In the scope of EtoG programme, the "ATC Interface" between ATC Server, inside CCF of Ciampino, and the ATC Client (ENAV/SELEX-SI development) that provides data to the ATC users, has been developed following the ICD [3]. Figure 12 the EGNOS ATC block diagram is presented.

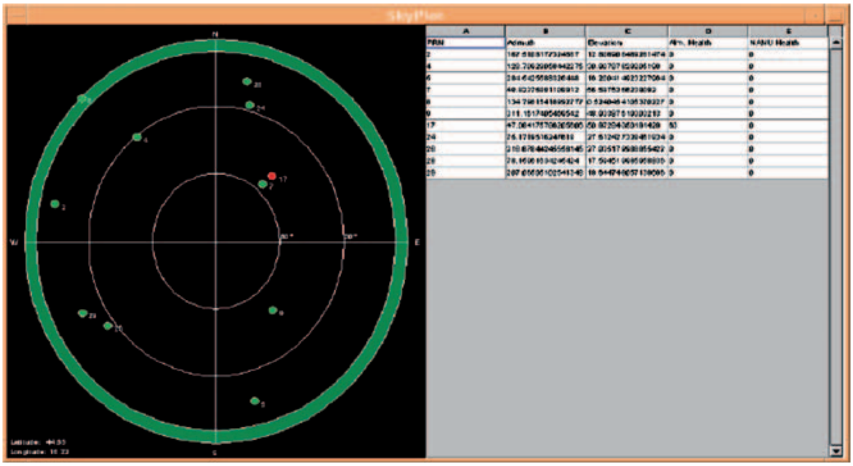

Fig. 11. NANU messages.

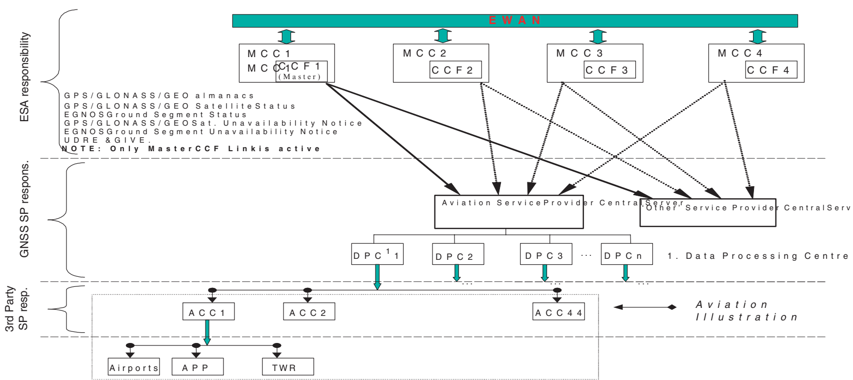

Fig. 12. EGNOS ATC block diagram.

The data sets provided by the CCF are the following:

- 0. ATC Connection Status (MT 0)
- 1. GPS/GLONASS/GEO Almanacs (MT 1)
- 2. GPS/GLONASS/GEO Satellite Status (as monitored by EGNOS) (MT 2)
- 3. EGNOS system Status (MT 3)
- 4. GPS/GLONASS/GEO Satellite Unavailability Notice (MT 4)
- 5. EGNOS Ground Segment Unavailability Notice (planned maintenance) (MT 5)
- 6. CPF processed data: UDRE (MT 6) and GIVE (MT 7)

The data are transmitted to each ATC client connected:

- for the data (1), (4) and (5) repeatedly every 30 minutes and also each time their content are updated
- for the other data (2), (3) and (6) repeatedly every 1 minute

The ATC Server provides data only when the MCC is master; in the future a procedure, described in the ICD, should be developed in order to have the automatic switching from an MCC to another when the first will be not master using a Primary ISDN link. Figure 13 the ATC Client Interface is presented.

It is possible to display the acquired data in two different modes. The *Raw data* window will display the received data without any template, as the ATC server send in broadcast this data. Another way is through the *Decoded Message* window where the received message are formatted in a proper form in order to be read. Figures 14–16 the Raw data window and some example for the Decoded message window.

ATC Client data, possibly merged with data from local sensors (receivers), local environmental conditions (orography, EM environment model) are planned to feed (joined with possible GNSS back-up data from other sources) an ATC Interface for ATC operators.

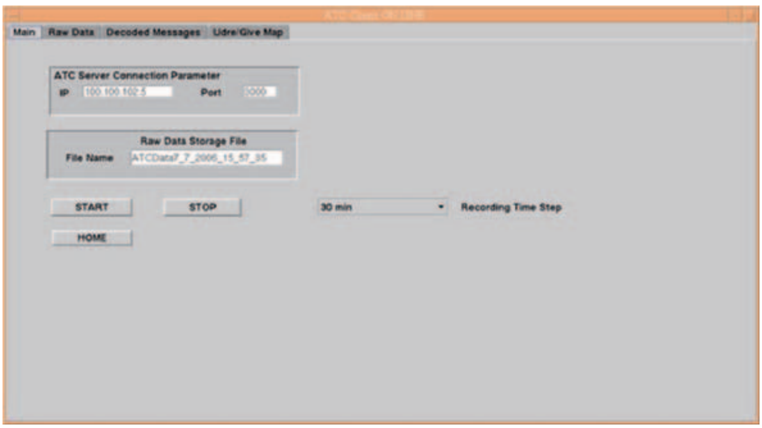

Fig. 13. ATC client interface.

Fig. 14. ATC client - raw data window.

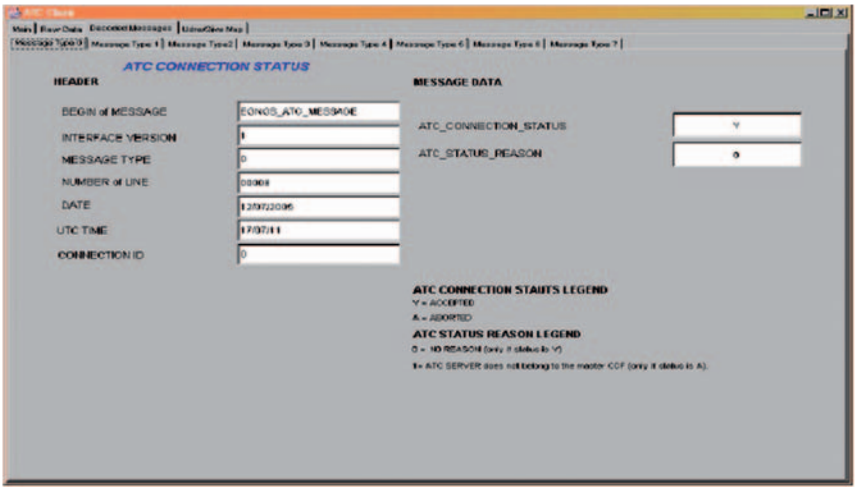

Fig. 15. ATC Client - decoded message type 0.

Moreover another functionalities is given by the possibility to provide a playback of the recorded EGNOS ATC data. In this way an operator is able to display again, in a separate window, a particular situation while the system runs. Figure 17 the ATC Client in Off Line mode is shown.

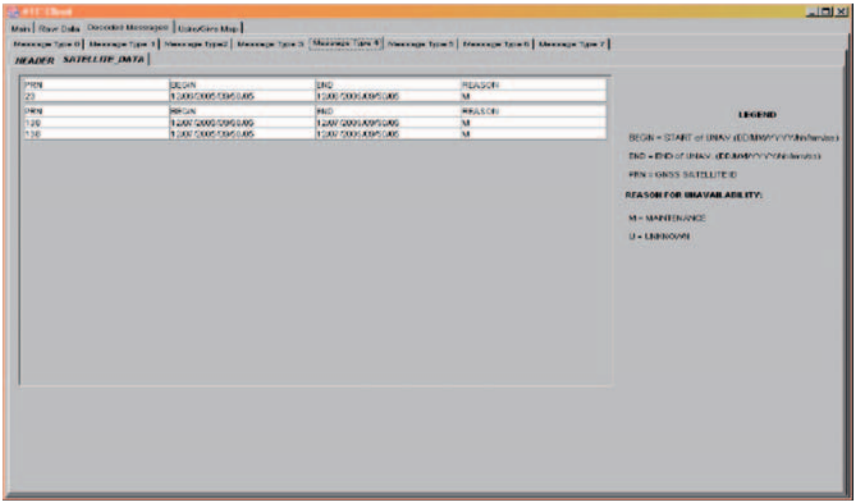

Fig. 16. Decoded message type 4.

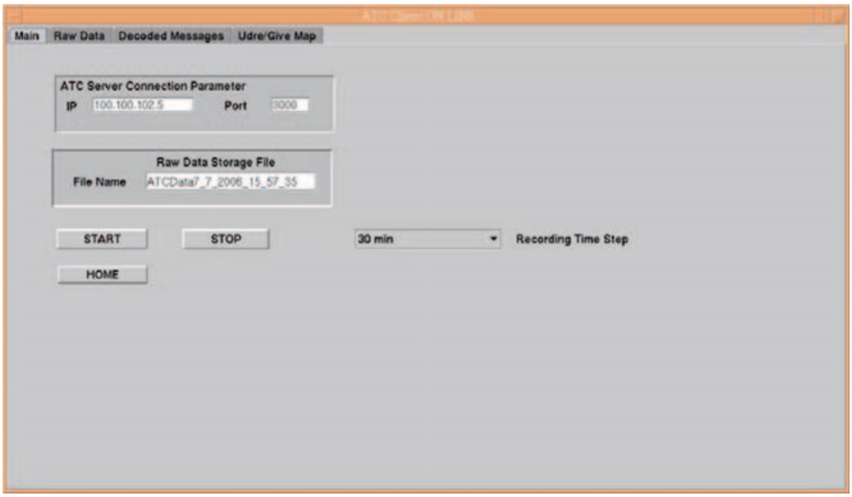

Fig. 17. ATC client for recording and playback mode.

3 Conclusion

Through the EtoG project the ENAV (National Air Navigation Service Provider) and SELEX-SI not only develop satellite application in the important field of air traffic management/control, identifying and planning innovative application products in typical operational scenarios, but also they intend to pursue important targets of research in the field of satellite navigation. More specifically, the project will aim at introducing the GNSS/SBAS applications within Italian airspace.

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