The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2025-27

Satellite Navigation Science and Technology for Africa

23 March - 9 April, 2009

SAT-SURF Suite A tool for Hands-on Training on Satellite Navigation

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Italy

SAT-SURF & SAT-SURFER Satellite Navigation Science and Technology for Africa

NavSAS Group

SAT-SURF

The Training Board for GNSS

SAT-SURFER

SW Suite for GNSS Training

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ISMB
Istituto Superiore Mario Boella

NavSAS Group

Outline

1 – Motivation

2 – Introducing NavSAS

3 – NAVKIT Educational Tool

4 – SAT-SURF Hardware Platform

5 – SAT-SURFER Software Suite

6 – SAT-SURFER Setup & Demo

7 – Questions

NavSAS Group

Motivation

SAT-SURF & SAT-SURFER Seminar

NavSAS Group

- GNSS technologies are progressively becoming a key element in many innovative wireless applications. Most location-based services and systems are in fact employing standalone GPS, GPS+EGNOS, Assisted-GPS and Differential GPS as core technologies.
- Academies and companies need to train engineers, technicians and students on these subjects.

Motivation

- Many educational offers are based on theoretical study of GNSS leaving limited space to labs and/or training on the job.
- There is a huge demand of methods allowing to help students in doing hands-on exercises.
- SAT-SURF & SAT-SURFER represent a complete tool made of HW and SW components specifically designed for R&D and education purposes:
  - ✓ **SAT-SURF** is the HW box including GPS and COM functionalities;
  - ✓ **SAT-SURFER** is the SW suite running on standard PCs, that gets and process data from SAT-SURF.

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Motivation

After a short practice with SAT-SURF & SAT-SURFER, anybody should be able to:

✓Manage SAT-SURF & SAT-SURFER;

✓Have a practical feeling on the GPS receiver capabilities and on the NAV/COM possibilities;

✓Practice with binary protocols (of different receivers) as well as NMEA one;

✓Perform data log of the most important receivers' parameters and measures;

✓Perform field measurements and data collections.

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Motto

With SAT-SURF and SAT-SURFER engineers, technicians and students learn how to practically surf with GNSS!

NavSAS Group

Outline

NavSAS Group

A Joint Research Lab on GNSS

NavSAS Group

ISMB
Istituto Superiore Mario Boella

Private Research Center

Top Technical University

GALILEO LAB

Introducing NavSAS

NavSAS is a joint research group of ***ISMB*** and ***Politecnico di Torino*** University. It operates in the satellite navigation and localization sectors.

NavSAS Group

- NavSAS is part of a cluster of 8 laboratories that are the core of ISMB, a prominent centre of applied research in wireless technologies with over 230 experts.

Introducing NavSAS

- NavSAS staff consists of 28 researchers.
- Research is focused specifically on advanced technologies for GPS / EGNOS / Galileo receivers and applications.
- NavSAS cooperates with major industrial and institutional players operating in the field.
- http://www.navsas.eu
- http://www.galileoblog.eu

NavSAS Group

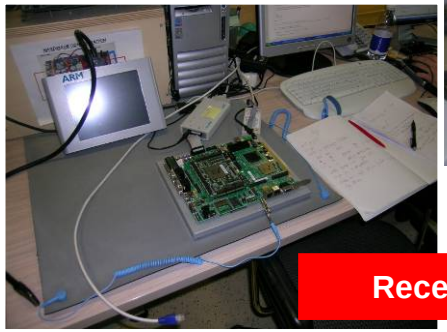
The Navigation Lab at ISMB

NavSAS Group

EGNOS monitoring station

NAV/COM integrations

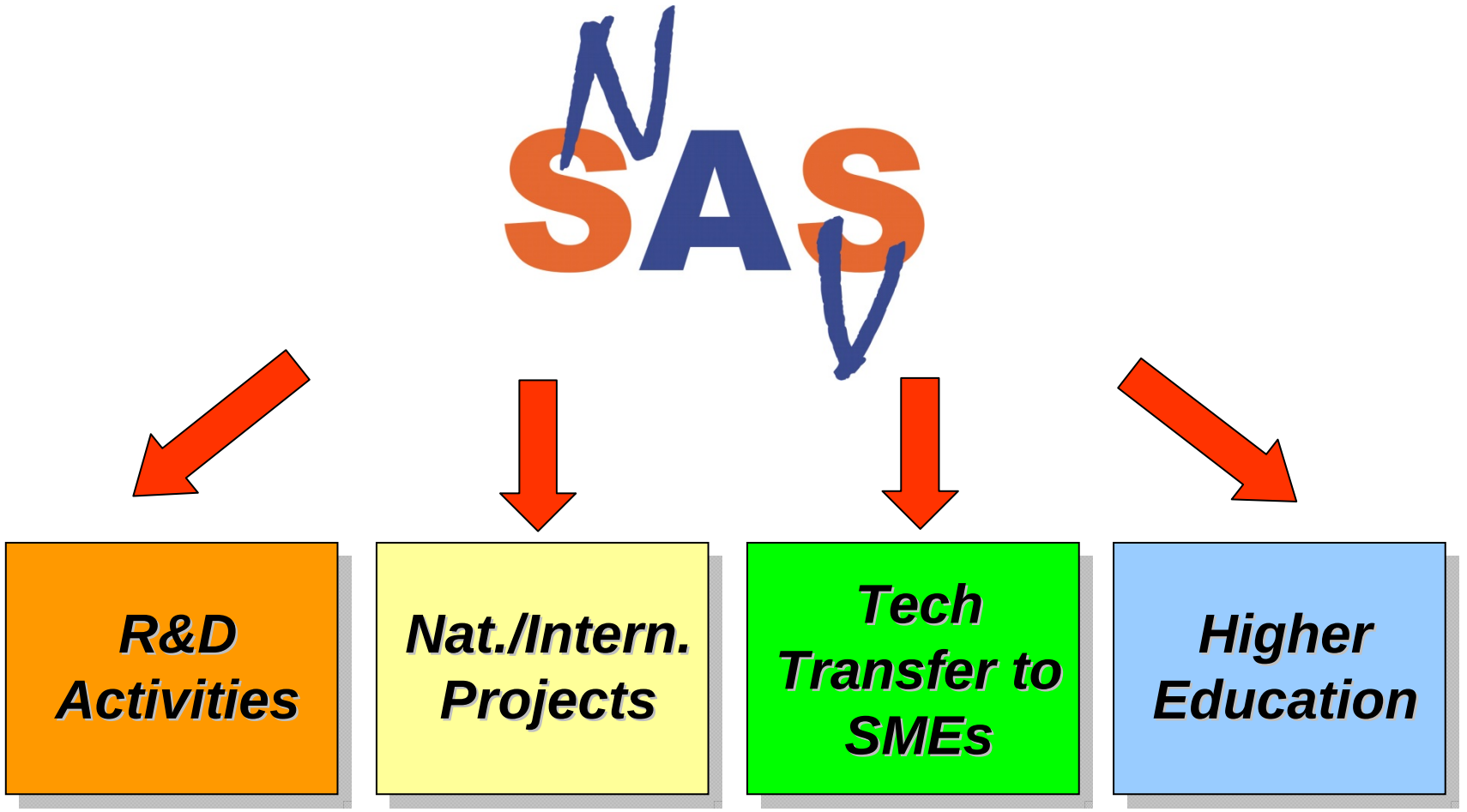
Emergency Management System



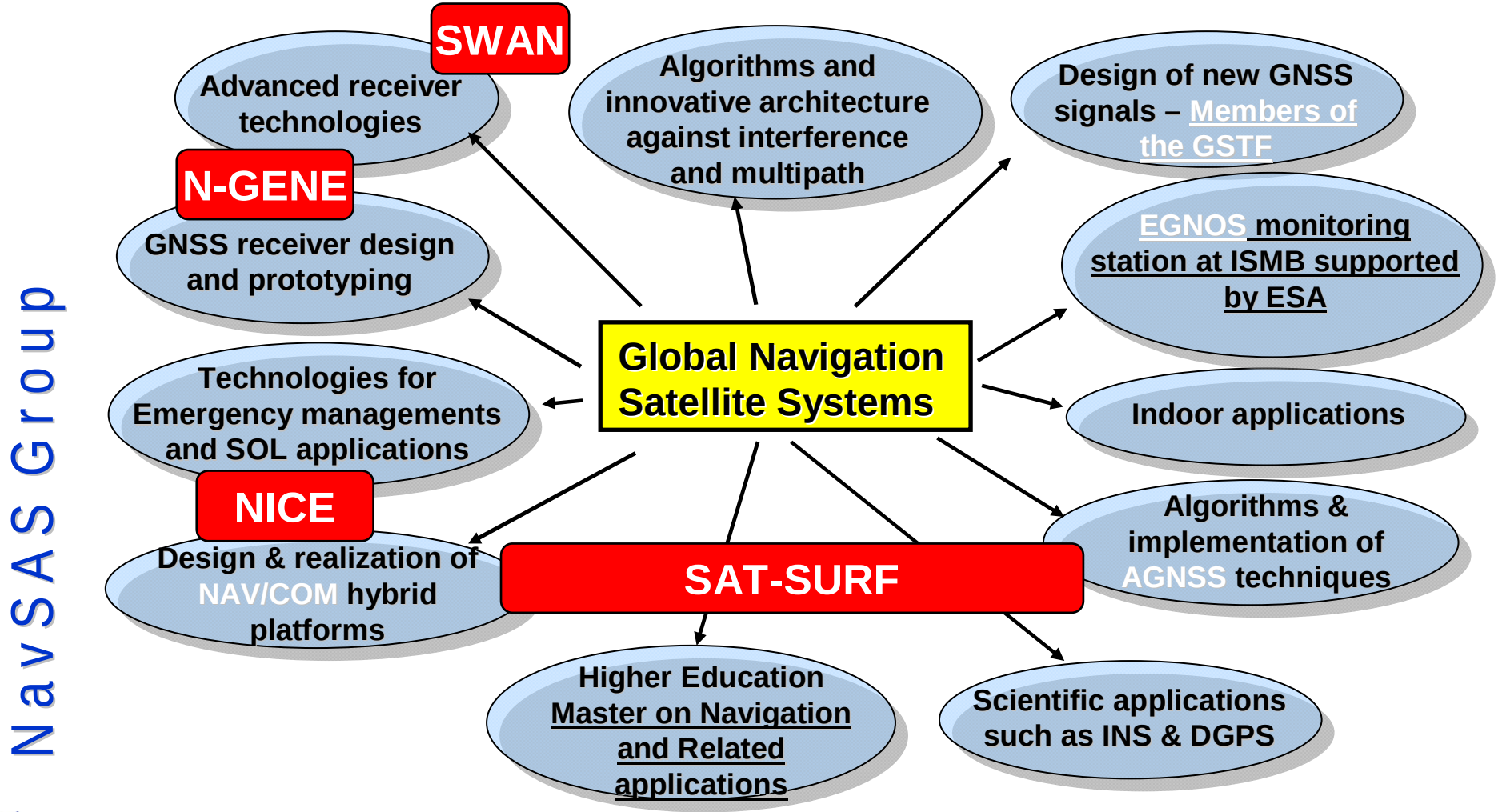
Receiver design and prototyping

The Navigation Lab at ISMB

NavSAS Group



The NavSAS Activities



National & International Projects

- In the years 2004-2008 the group was involved in 9 European projects funded by the European commission (Galileo Supervising Authority)

- Several national project funded by:
  - ✓ Piemonte Region
  - ✓ Ministry of Research
  - ✓ Italian space Agency

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Working Groups and Committee

Participation to working groups and committee:

- Galileo Signal Task Force
- Advisory Group on Receiver technologies of GSA
- CTT – Partner of the Consorzio Torino Time
- International Pseudolite working group
- CGALIES working group for E-112 (2002)
- GALILEAN Network, technology analysis of European Capabilities in the field of GNSS (2002-03)
- Chairing of several sessions at the most important International Conferences on navigation

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Research on GNSS Receivers

NavSAS started its R&D activities applying advanced signal processing strategies to GNSS receivers

Today NavSAS is developing professional and mass-market Galileo receivers with major industrial players.

NavSAS Group

R&D Activities:

- Fully SW and SDR implementations
- NAV/COM integration and data fusion
- Analysis of Innovative Galileo Signals (MBOC, AltBOC)
- Receiver core technologies: Multipath & Interference detection and mitigation and Quality Control

N-GENE Software Receiver

The first release of the **N-GENE** fully Software receiver is ready!

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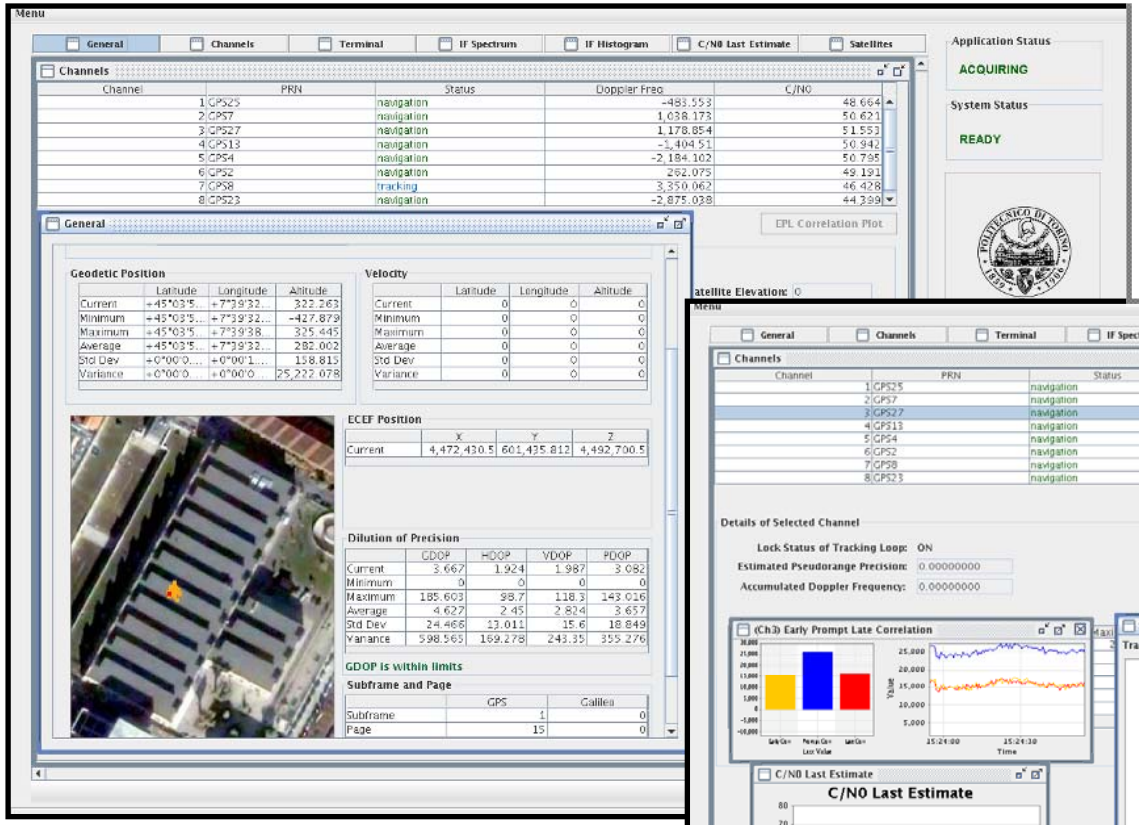
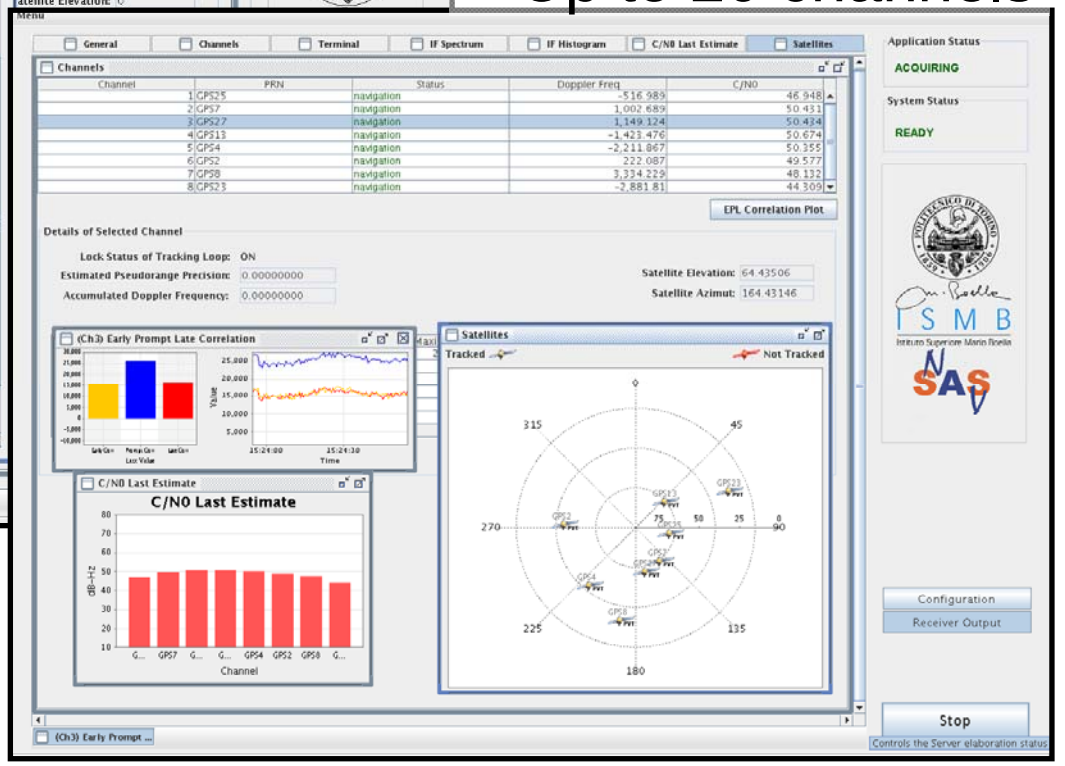
- **GPS L1**
  - ✓ 8 bits quantization
  - ✓ fs 17.5103 MHz
- **Galileo E1, GIOVE-A & GIOVE-B** signals, upgradable to Multiplexed Binary Offset Code (MBOC) easily
- **EGNOS, WAAS & A-GPS**

N-GENE Software Receiver





- Position Accuracy: r.m.s<10 m (Code)
- Up to 20 channels

Time To First Fix (cold Start) <45 s

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SWAN

- the *Base Model (BM)*: a GNSS receiver prototype, developed in SDR technology and able to represent a wide set of radio-navigation terminals;
- the *Simulation Tool (ST)*, a software tool, designed to be composed by two fundamental blocks:
  - ✓*Signal Simulation Tool (SST)*
  - ✓*Signal Analysis Tool (SAT)*
- the *Support Platform (SP)*, which produces the input signals for the Base Model and give a support during the validation and test phases.

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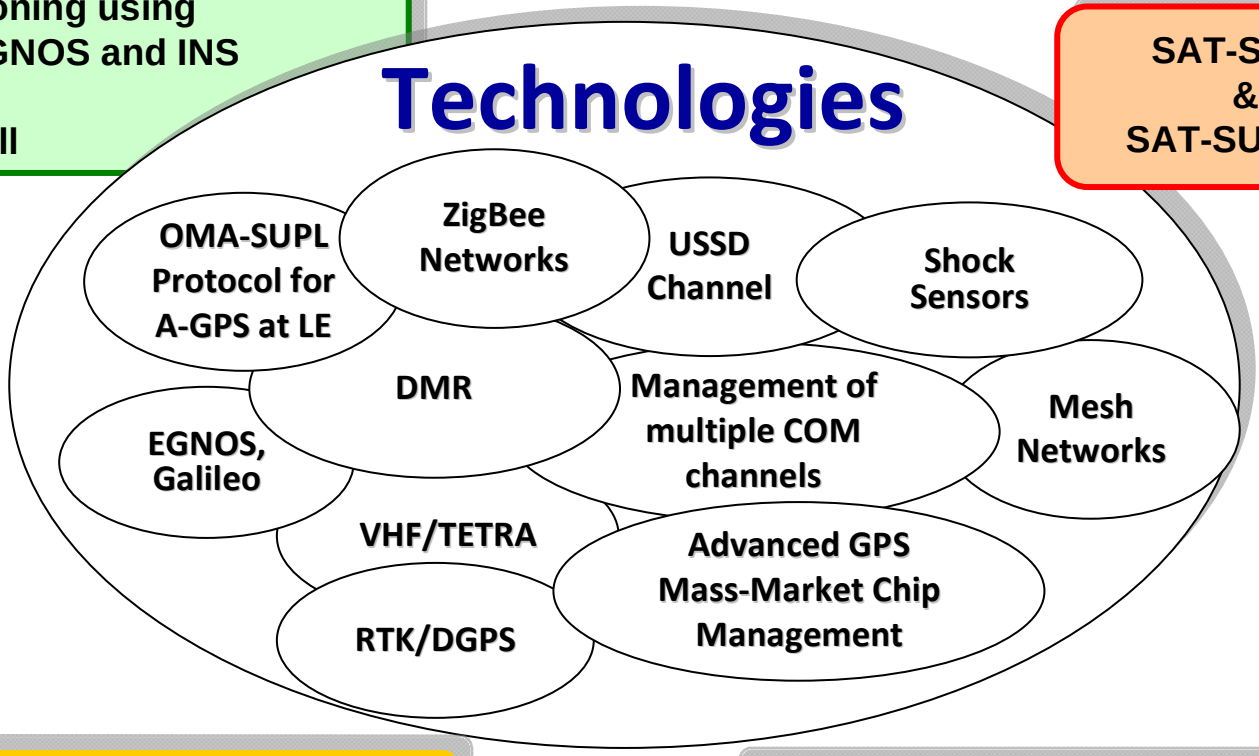
Technologies 4 Applications

Network Platform - Local Element:
- NICE- Navigation In Case of Emergency System
- Precise Positioning using RTK/DGPS, EGNOS and INS integration
- Road&Park Toll

Low Cost Mapper for Footpath Mapping

SAT-SURF & SAT-SURFER



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eCall - Emergency Call System

Satellite Based Financial Systems

NAV/COM Technology Platform

NICE is a real-time monitoring system for work-force management. Its innovative feature is the integration with professional COM system like VHF and TETRA

NICE can be then employed to control and manage in real-time:

- Civil protection agencies;
- Alpine rescue teams;
- Precise Fleet Management.

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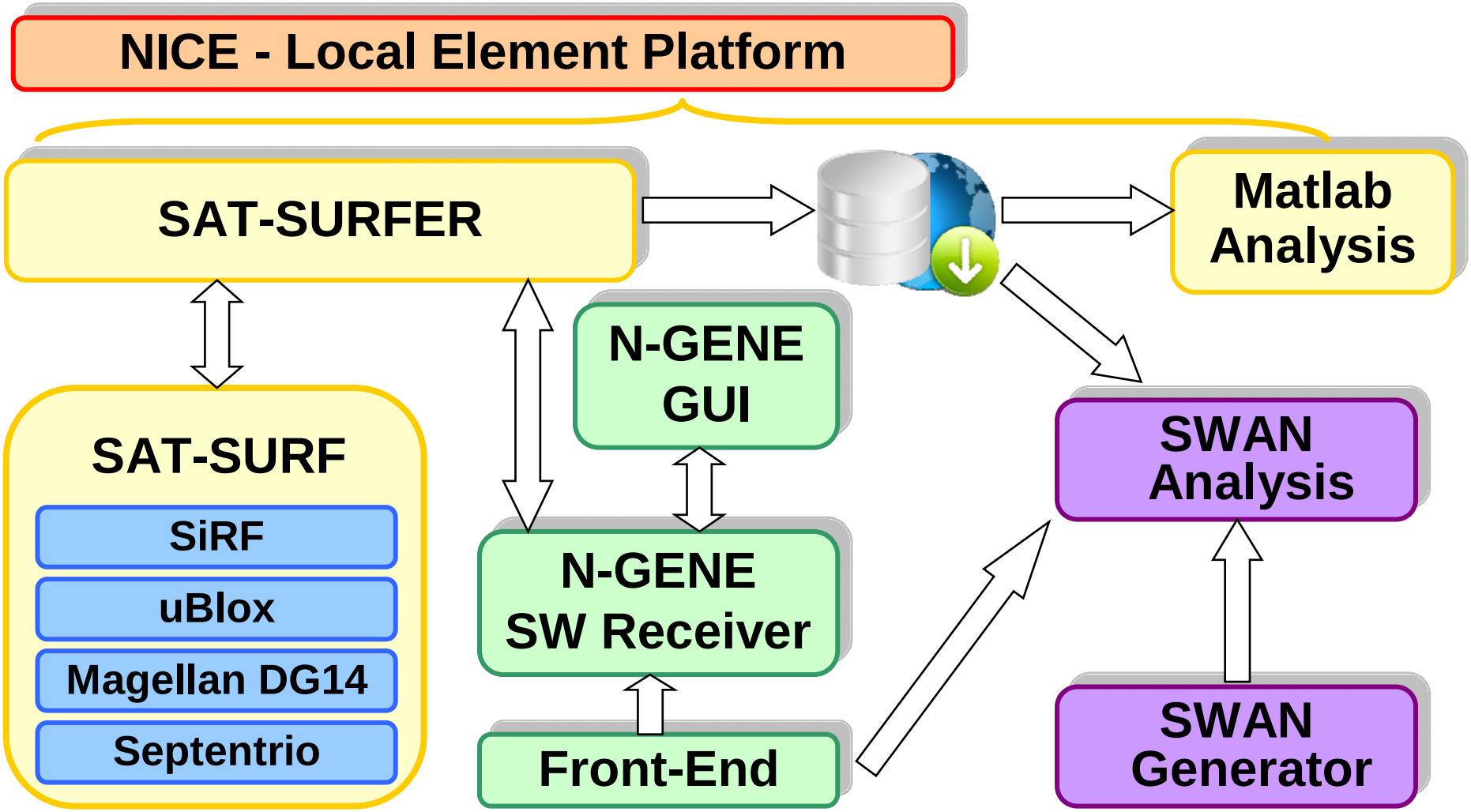
SAT-SURF & SURFER



Higher Education

The Master On Navigation & Related Applications is a joint initiative of ISMB and Politecnico di Torino with the support of

Istituto Elettrotecnico Nazionale GALILEO FERRARIS

United Nations

Office for Outer Space Affairs

The Master aims of creating specialist and technicians able to operate in the framework of the GNSS and Galileo at both core system and services level

NavSAS Partnership

Companies

- Telecom Italia
- Thales Alenia Space
- Carlo Gavazzi Space
- ST Microelectronics
- IfEN
- *SMEs*

Academia

- Italian Universities
- Uni. New South Wales @ Sidney
- Uni of CO @ Boulder
- FAF Uni. Munich
- University of Calgary

Local institution and research labs

- Alpine Rescue Team
- CSP

Institutional partners

- UN-OOSA
- ESA
- ASI
- GSA/EC

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European GNSS Supervisory Authority

ERIG
Education, Research & Innovation in GNSS

ISMB
Istituto Superiore Mario Boella

POLITECNICO DI TORINO
1859 1906

NAVKIT

Tool for self-training on satellite navigation subjects

What is NavKIT

- NAVKIT is a tool for autonomous training on satellite navigation subjects
- NAVKIT has been developed by professors and researchers of the NavSAS Group
- NAVKIT has been developed as a task of the ERIG project “Education Research and Innovation in GNSS” funded by the GNSS Supervisory Authority within the VI FP

NavSAS Group

European GNSS Supervisory Authority

ERIG
Education, Research & Innovation in GNSS

What is NavKIT

- The tool can be accessed via Web or can be installed as an application on your own PC
- It allows to learn the basic concepts of satellite navigation by means of a multimedia approach
  - ✓Videos
  - ✓Exercises fully solved step by step
  - ✓Self evaluation tests
  - ✓Frequently asked questions
- The content of the lesson is organized in order to provide technical concepts also to non specialists
- The tool is designed for students but also for technicians and professionals in need of a starting training in the field

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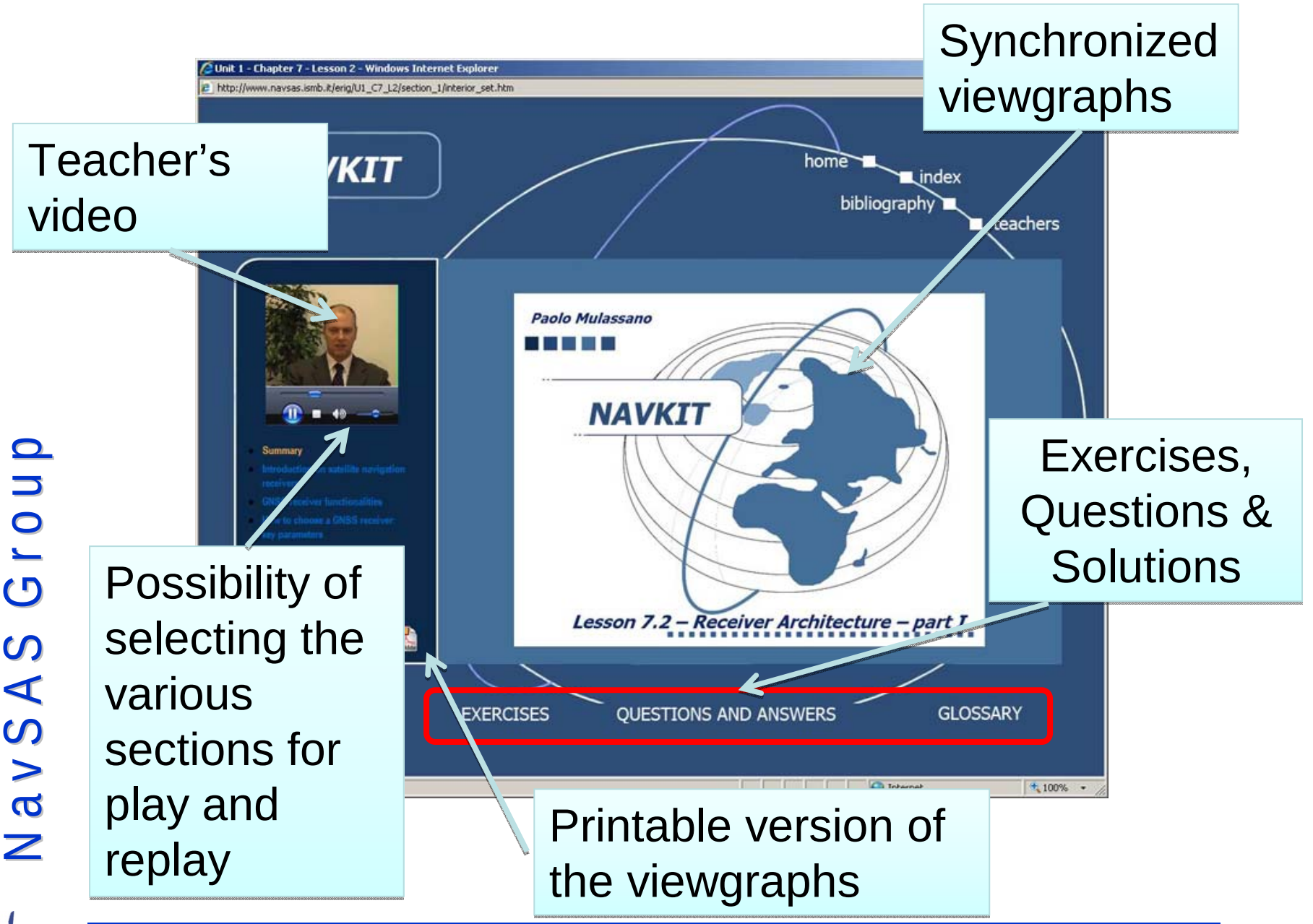
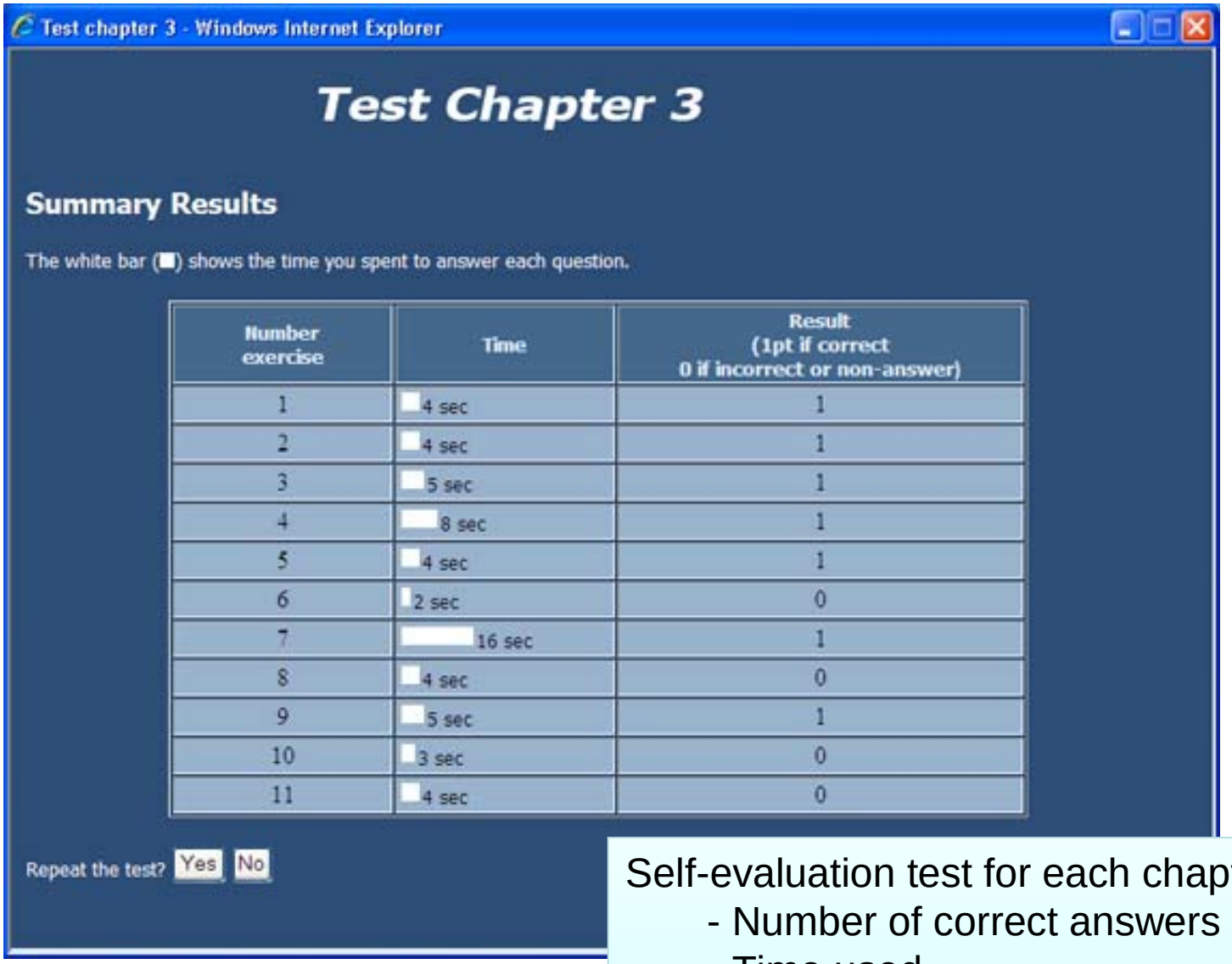

Synchronized viewgraphs
Teacher's video
Exercises, Questions & Solutions
Possibility of selecting the various sections for play and replay
Printable version of the viewgraphs
Unit 1 - Chapter 7 - Lesson 2 - Windows Internet Explorer
http://www.navsas.ismb.it/erig/U1_C7_L2/section_1/interior_set.htm
home
index
bibliography
teachers
Paolo Mulassano
NAVKIT
Lesson 7.2 – Receiver Architecture – part 1
EXERCISES
QUESTIONS AND ANSWERS
GLOSSARY
NavSAS Group



Self-evaluation test for each chapter:

- Number of correct answers
- Time used

For each wrong answer a reference to the proper section of the lessons is provided

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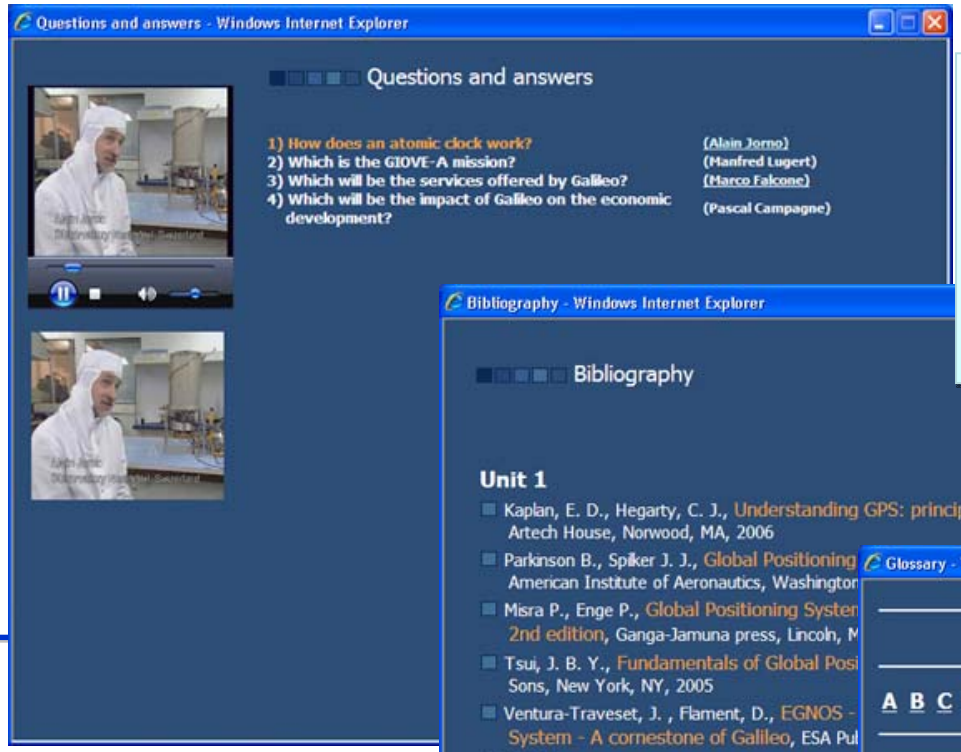

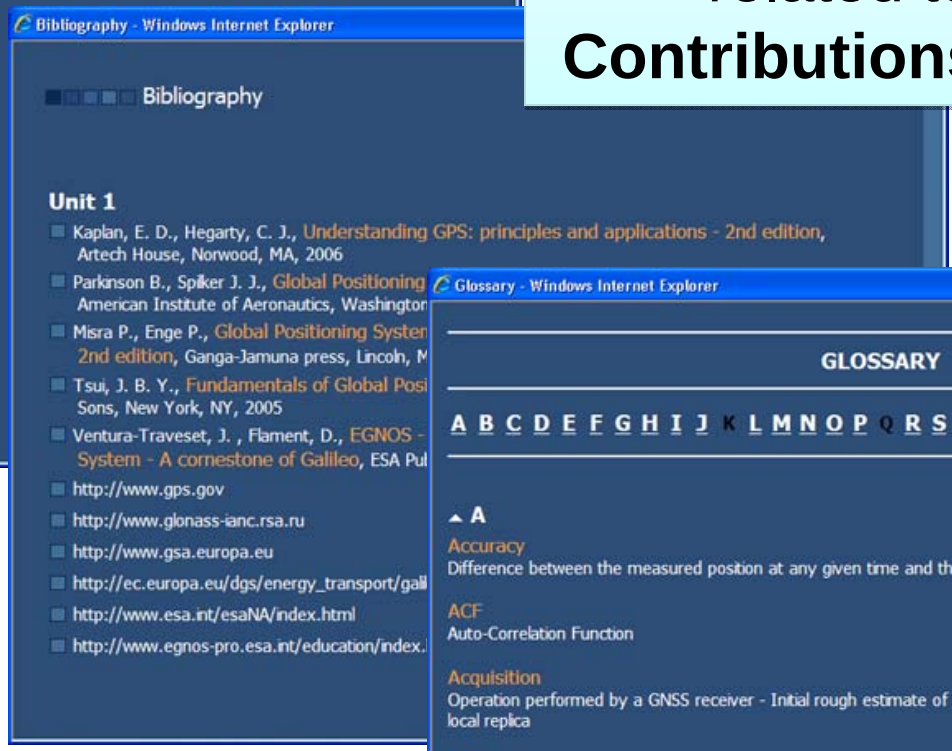

Section of question and answers on general topics related to GNSS **Contributions by experts**

Bibliography & Glossary

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How to Use NavKIT

- Single user
  - ✓Take 1-2 lessons per day
  - ✓Study of the slides and of the material suggested in the bibliography
  - ✓Analysis of the solved exercises
  - ✓Solution of the proposed exercises
  - ✓Self evaluation using the test
- Group users
  - ✓NAVKIT can be used as virtual teacher

NAVKIT

http://www.navsas.eu

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SAT-SURF Hardware Platform

4 – SAT-SURF Hardware Platform

- **a – SAT-SURF &SAT-SURFER at a glance**
- **b – Details on SAT-SURF**
- **c – SAT-SURF Architecture & Functionalities**
- **d – What you can do with SAT-SURF**
- **e – Other Information**

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SAT-SURF & SURFER at a Glance

SAT-SURF & SAT-SURFER are a complete tool made of hardware-software components specifically designed for R&D and education purposes:

- ✓ **SAT-SURF** is the HW box including GPS and COM functionalities;
- ✓ **SAT-SURFER** is the SW suite running on standard PC that gets and process data from SAT-SURF.

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Details on SAT-SURF

SAT-SURF is an HW box integrating GPS and GSM/GPRS capabilities. It includes:

- 4 alternatives of GPS receivers
- GSM/GPRS module
- GSM antenna
- GPS patch antenna
- Serial I/O port (DB25)
- MEDUSA cable (3 DB9 + power)

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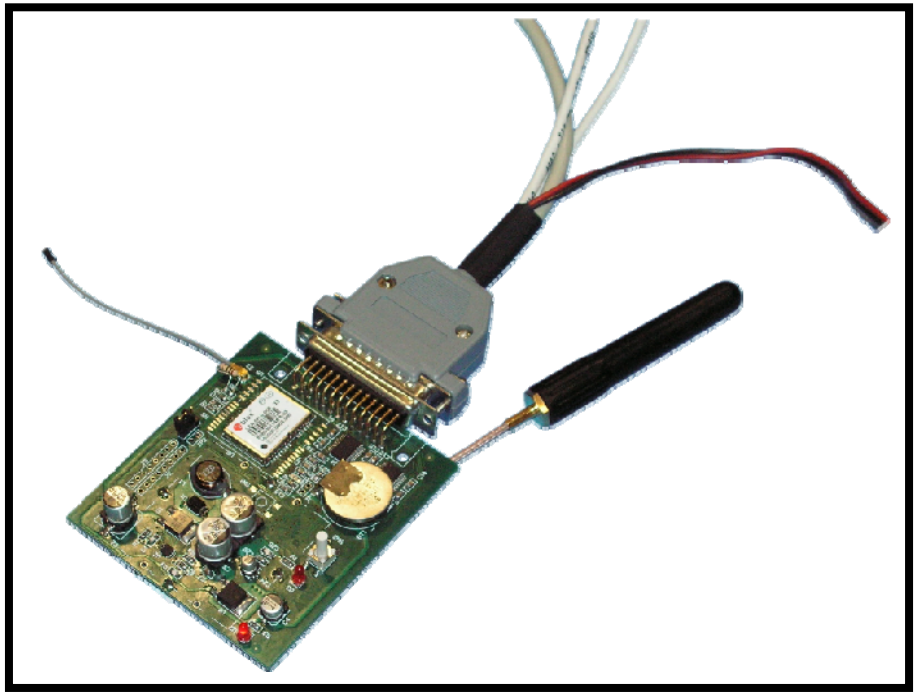
Details on SAT-SURF

- Serial ports can be connected to a standard PC
- GSM module used to implement A-GPS service (OMA-SUPL compliant) or to get differential corrections
- SAT-SURF needs external power supply: DC power supplier with voltage between 9 and 30 V. A standard automotive power connector can supply SAT-SURF for kinematics data log.



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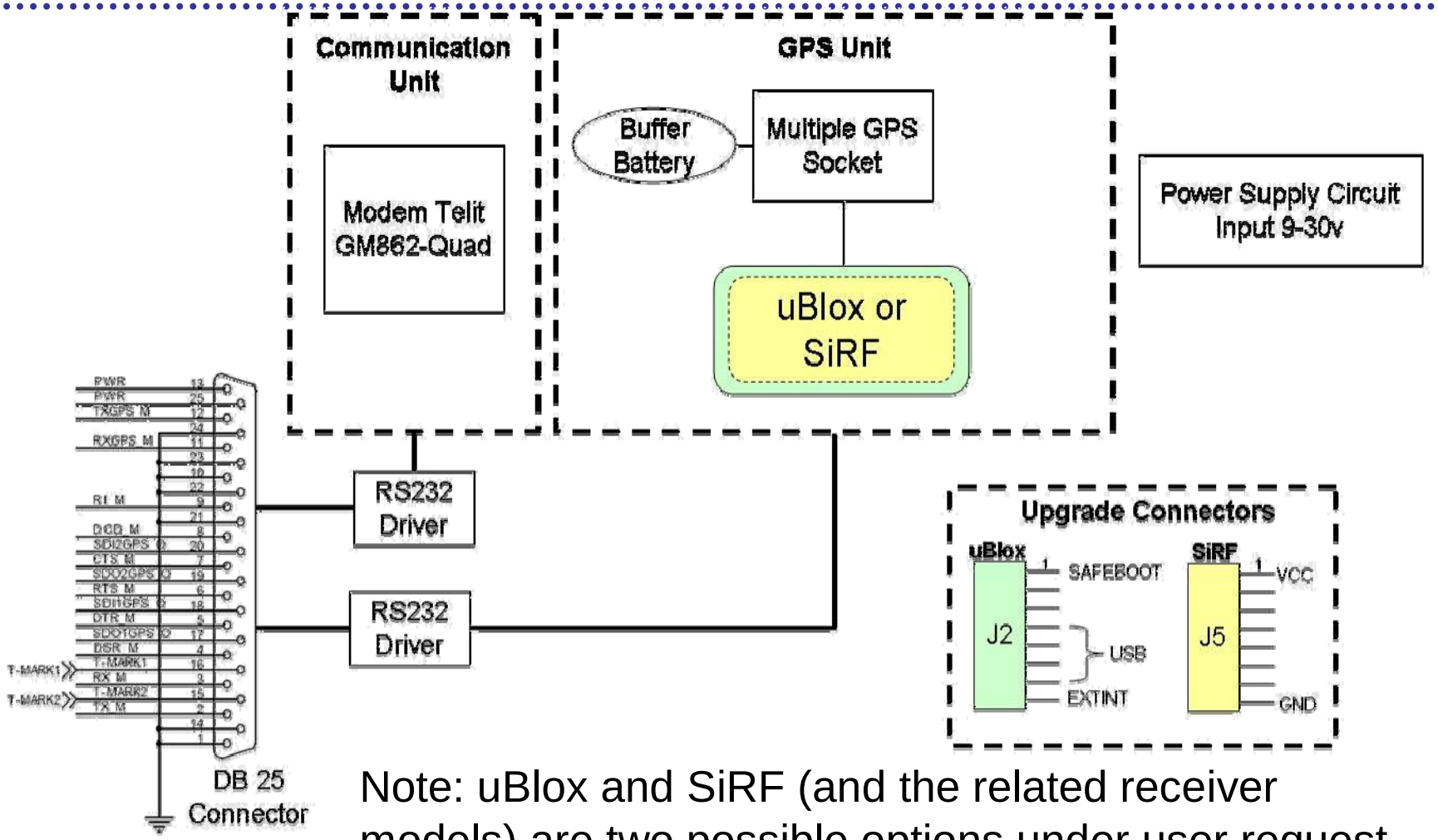
SAT-SURF Architecture

- SAT-SURF integrates **components of the shelf**
- **Flexibility**: possibility to get all the signals from each component of the chain
- SAT-SURFER SW uses the proprietary protocols of GPS modules (of different manufacturer) to get all the navigation raw measurements and not only NMEA data
- SAT-SURF has been developed for **educational** and **training purposes** on GNSS. It has been conceived with a **multiple footprint** (i.e. pinout of a GPS module) of different GPS receivers.

SAT-SURF Architecture



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Note: uBlox and SiRF (and the related receiver models) are two possible options under user request.

SAT-SURF HW Features

GPS/Galileo receivers available in SAT-SURF:

- **uBlox 5** High Sensitivity GPS module, OMA-SUPL compliant;
- **uBlox ANTARIS 4** GPS module, DGPS compliant;
- **JP13-LP** GPS module based on SiRFstarIII with low power consumption and High Sensitivity ;
- **JP15** High Sensitivity GPS module based on SiRFstarIIIx, DGPS compliant;

GSM Module:

- Telit GM862-QUAD GSM module.

SAT-SURF Capabilities

- It logs GDOP versus GPS time;
- It logs pseudoranges for each satellite versus GPS time;
- It enable testing your own PVT computation strategy using raw pseudorange measurements;
- It logs the number of satellites used for the PVT computation versus the GPS time;
- It logs the receiver position in ECEF or lat-long;
- It logs the C/N_0 for each satellite versus GPS time;
- It logs the carrier frequency ranges and Doppler shifts.

SAT-SURF Capabilities

- It enable the measure of the Time To First Fix in different environmental situations (e.g. outdoor vs light-indoor);
- It logs the ionospheric delay versus GPS time;
- It logs pseudoranges residuals (only uBlox version).

It is important to remark that such capabilities are available when using the SAT-SURFER SW suite together with SAT-SURF. The complete list of the parameters that can be logged is reported in the SAT-SURFER User Manual.

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SAT-SURFER Software Suite

5 – SAT-SURFER Software Suite

- a – SAT-SURFER at a Glance
- b – Details on SAT-SURFER
- c – SAT-SURFER Architecture & Functions
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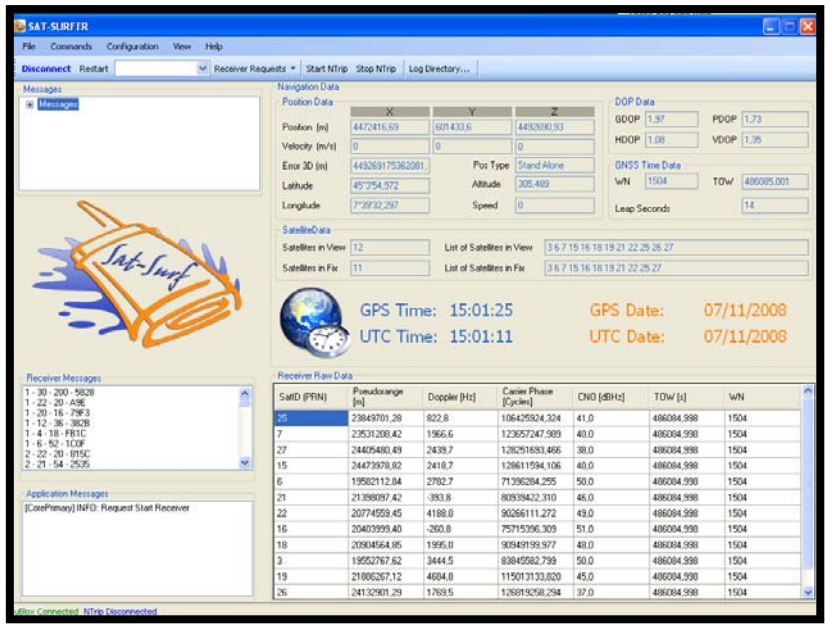
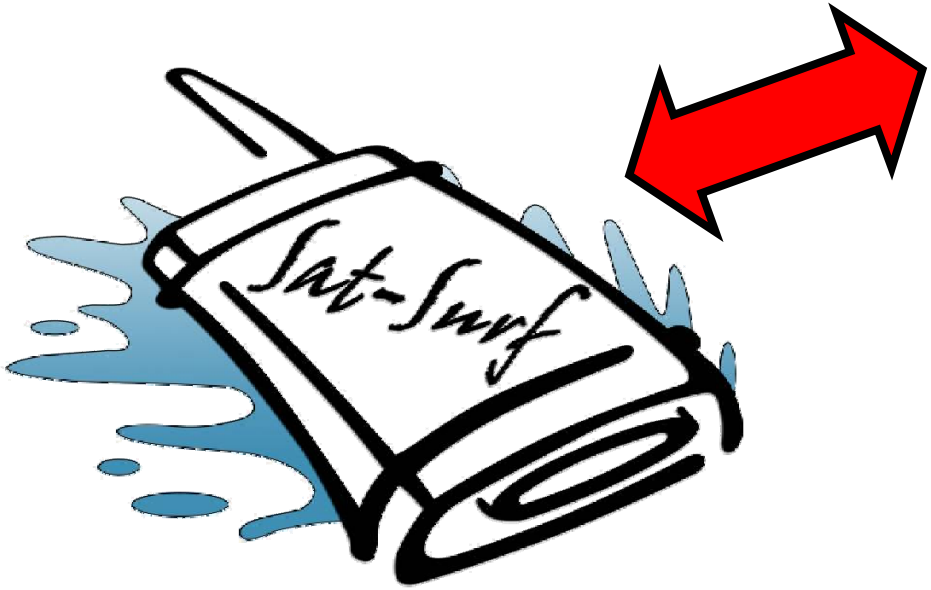
SAT-SURFER at a Glance

SAT-SURFER Software Suite

SAT-SURFER is the software running on a standard PC that gets and process data from SAT-SURF.





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Details on SAT-SURFER

- SAT-SURFER is able to “talk” to different GNSS receivers using their binary (proprietary) protocols

- Current version of SAT-SURFER can get data from four receiver families:
  - SiRF;
  - uBlox;
  - Magellan;
  - Septentrio.

Details on SAT-SURFER

- SAT-SURFER together with SAT-SURF is an Enhanced Evaluation Kit managing different kind of GPS receivers
- It is also able to provide a Communications (COM) interface through the GSM quad-band modem

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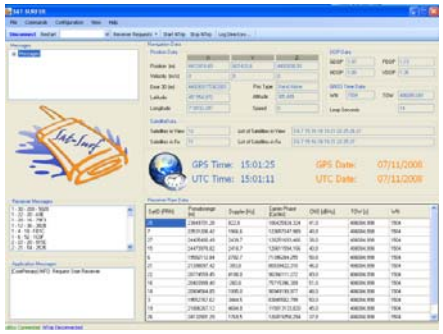
SAT-SURFER Architecture



Graphical User Interface

File Logs

Settings

Data Logger Matlab, Text, Rinex, KML

Core Application

Driver SiRF

Driver uBlox

Driver GSM Modem

Driver NTrip DGPS

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SAT-SURF HARDWARE

Other RXs

SAT-SURFER Capabilities

Log of several GPS/GSM raw parameters using the following file formats:

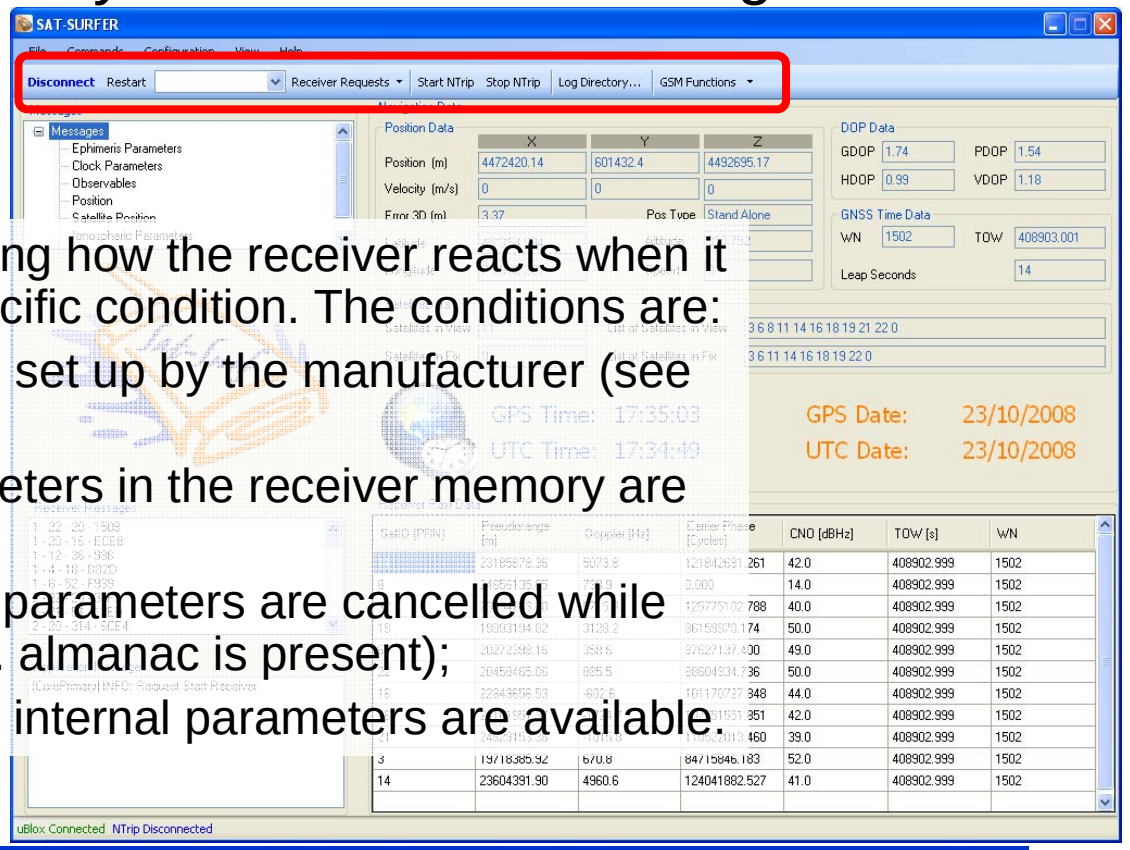
- ✓ ASCII text (.txt) file;
- ✓ MATLAB® (.mat) file;
- ✓ Microsoft Office Excel® (.xls) file;
- ✓ binary (.bin) file;
- ✓ RINEX 2 log;
- ✓ RINEX 3 log;
- ✓ Keyhole Markup Language (.kml) file.

SAT-SURFER Capabilities

- Export automatically any raw data for MATLAB® processing;
- Display of the most important raw data and positioning information in real-time;
- Possibility to decide the type of GPS receiver family (in the first release only uBlox or SiRF);
- Possibility to plot some parameters in real-time if MATLAB® is installed on the PC;
- Possibility to display the position in real-time on Google Earth™ (if it is installed on the PC);
- It allows the test of Assisted-GPS and Differential GPS functionalities and performances.

Functionalities: Toolbar

The “Connect” and “Disconnect” buttons allow to start and stop SAT-SURF on the basis of the configuration parameters specified by the user in the “Configuration” menu.



RESTART: it allows testing how the receiver reacts when it is forced to start in a specific condition. The conditions are:

- ✓ “FACTORY”, as it was set up by the manufacturer (see “COLD”);
- ✓ “COLD”, all the parameters in the receiver memory are cleared;
- ✓ “WARM”, some of the parameters are cancelled while others are available (e.g. almanac is present);
- ✓ “HOT”, all the receiver internal parameters are available.

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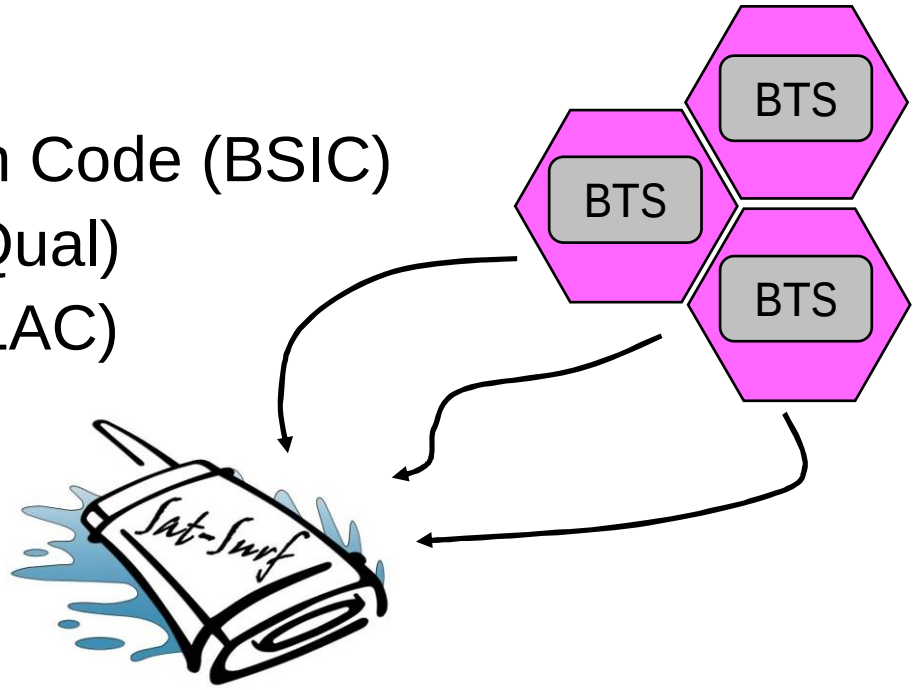
GSM Logged Parameters

- Cell type
- Base Station Identification Code (BSIC)
- Quality of Reception (RxQual)
- Localization Area Code (LAC)
- Power (dBm)
- C1 reselection parameter
- C2 reselection parameter
- Time Advance (TA)
- Assigned Radio Frequency ChaNnel (ARFCN)
- Cell Identification (Cell Id)
- Public Land Mobile Network (PLMN)



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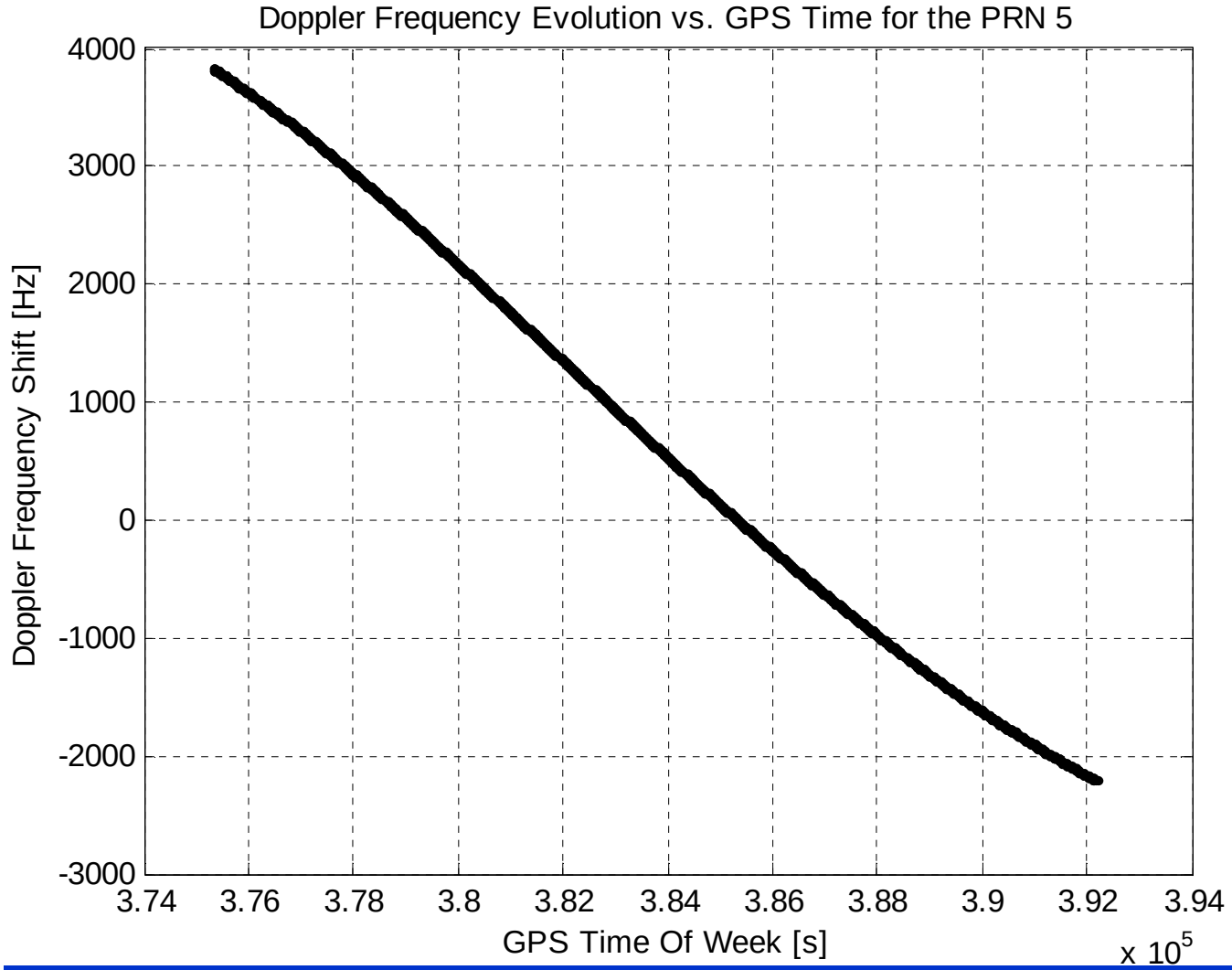
Plot Examples



Doppler frequency evolution of one satellite (PRN 5) vs. GPS time.

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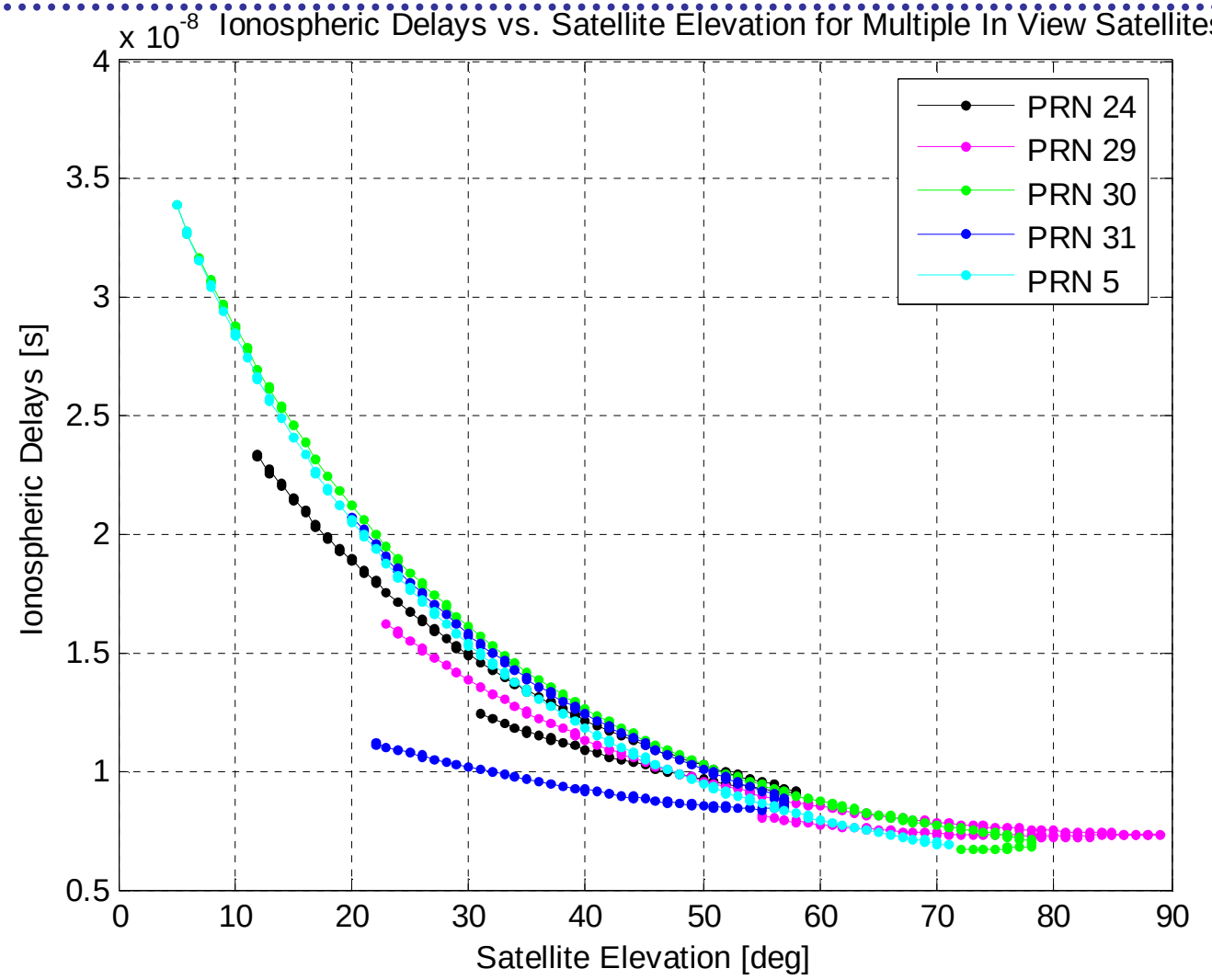
Plot Examples



Ionospheric delays evolution for 5 satellites versus elevation.

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Further Works & Evolutions

- SAT-SURF&SURFER Evolution:
  - ✓ New hardware platform with USB port etc…;
  - ✓ Software 3.0 with additional functionalities.
- Building of a **Mapper** for easy data collections and post-processing;
- Possibility to get/log data from an **IMU** synchronized with GPS data by means of SAT-SURFER;
- Addition of an advanced configuration page for each receiver;
- Addition of N-GENE support;
- Making the SURFER like an EGNOS tool;
- Addition a NavClock control for have precise timing capabilities;
- Addition of real time plot on the graphical user interface;
- Addition of a complete data-log for RTK/DGPS data;
- Addition of a multi-language support.

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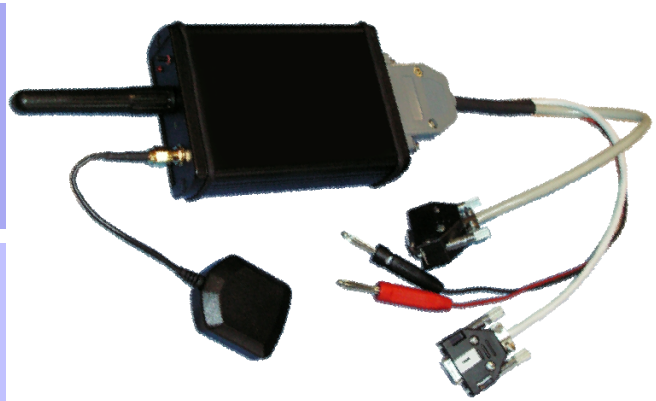
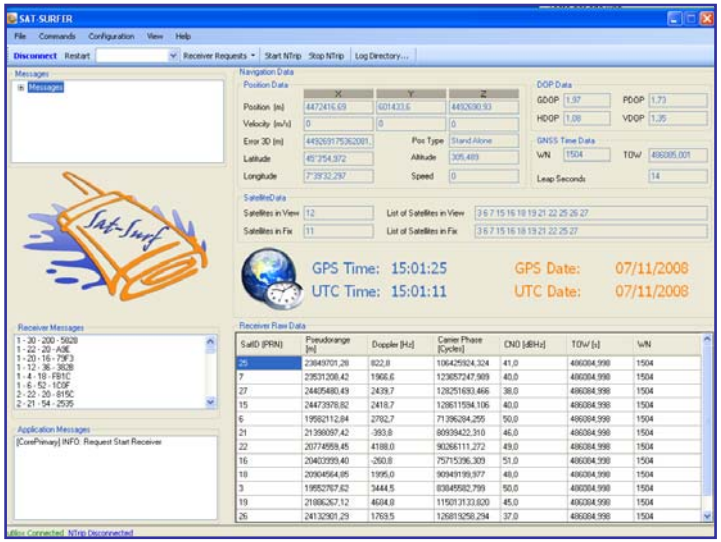
SAT-SURF & SURFER Summary

1 – Log all the raw GPS and GSM data (both binary and NMEA Protocols)



2 – Embeds different GPS modules depending on the user needs:

- uBlox Modules
- SiRF Modules



3 – Equipped with a quad-band GSM/GPRS modem for NAV/COM integration

4 – Raw data storage in the various file formats for an easy post-processing:

- ASCII, Excel® & MATLAB® files
- RINEX 2/3 Log

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SAT-SURF & SURFER Summary

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NAV/COM Integration Capabilities

SAT-SURF is made up of components of the shelf. The HW + SW tool is an innovative and complete GPS+GSM evaluation kit. It can be effectively used to test all the receiver features, Assisted-GPS strategies (OMA-SUPL compliant) and/or Differential GPS techniques.

Specific Educational Tool

SAT-SURF & SAT-SURFER is a complete educational tool. It includes several exercises with solutions for students. This is then a perfect tool for a lab dedicated to ICT technologies.

A Ready to Use Tool

SAT-SURF & SAT-SURFER is a ready-to-use tool. The tool has already been delivered to many education institutions such as Hanoi University of Technology (Vietnam), Asia Institute of Technology (Thailand) and Politecnico di Torino (Italy).

SAT-SURF & SURFER Partnership

- SAT-SURF and SAT-SURFER have been designed and developed by the NavSAS Group;
- SAT-SURF is manufactured and distributed by SAET s.r.l., a high-tech Italian SME;
- SAT-SURFER has been written by the NavSAS Group.

NavSAS Group

www.navsas.eu

www.saetsrl.com

Outline

1 – Motivation and Time Schedule

2 – Introducing NavSAS

3 – NAVKIT Educational Tool

4 – SAT-SURF Hardware Platform

5 – SAT-SURFER Software Suite

6 – SAT-SURFER Setup & Demo

7 – Questions

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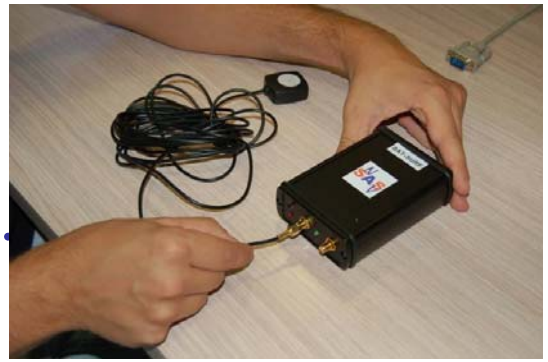
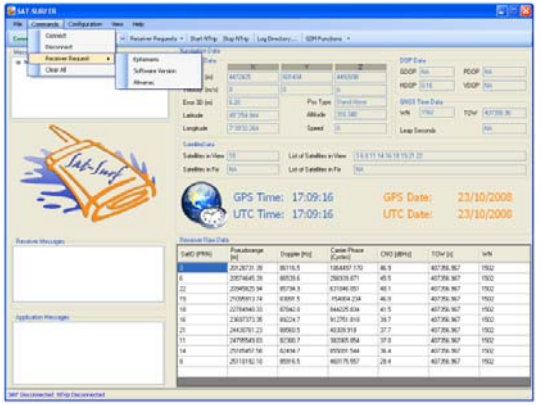
Getting Started



- Set-up the **SAT-SURF** hardware (antenna, cable connections, power supply…). Please refer to the “Getting Started” Section of the SAT-SURF User Manual.
- Place the patch **antenna** of SAT-SURF in outdoor (open sky) stationary position.
- Install on your PC the **SAT-SURFER** software tool. Perform the registration (website) and set-up the software for your first data collection. Please refer to the “Getting Started” Section of the SAT-SURFER User Manual.



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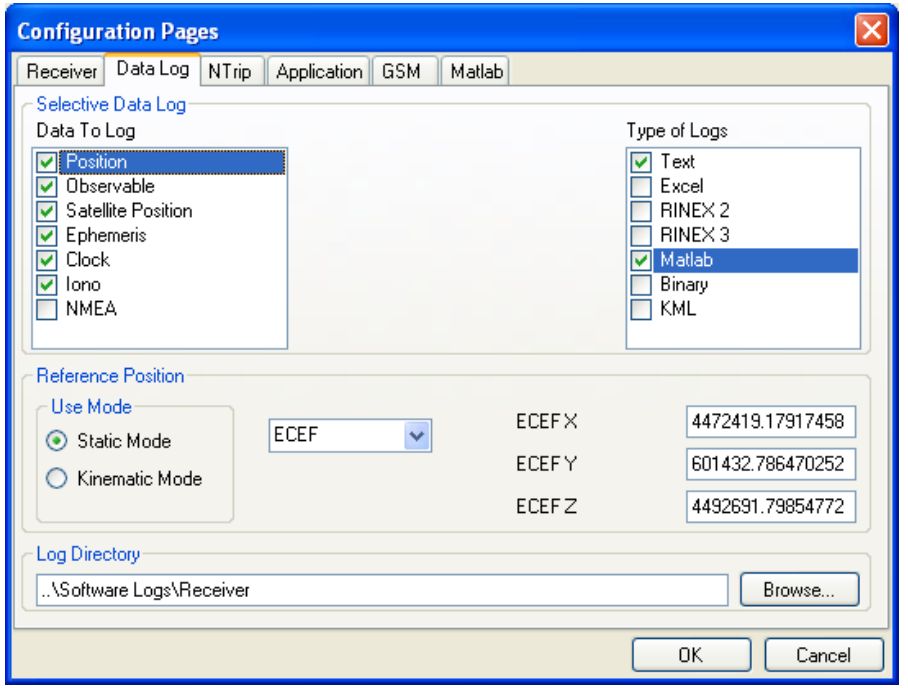
Parameters Logged by SAT-SURFER

Name	Description
Position Data	▪ Position (m), the three components ▪ Velocity, (m/s), the three components ▪ Latitude, Longitude, Altitude ▪ Error 3D ▪ Position Type, so how the RX computed the position. It can be: STANDALONE, SBAS, DGPS, RTK FIX, or RTK FLOAT. ▪ Speed, the amplitude of the velocity vector
Satellites Data	▪ Number of satellites in view ▪ Number of satellites in fix, meaning satellites used for the computation of the position, velocity, and time (PVT) ▪ List of satellites in view ▪ List of satellite in fix (satellites used in PVT computation)
GNSS Time Data	▪ Week Number (WN) ▪ Time Of Week (TOW) ▪ GPS Hours ▪ Leap Seconds
Dilution Of Precision Data	▪ GDOP ▪ PDOP ▪ HDOP ▪ VDOP

Parameters Logged by SAT-SURFER

Name	Description
Observables (per each satellite in view)	▪ Satellite Identifier (PRN) ▪ Pseudorange measurements (m) ▪ Doppler ▪ C/No ▪ Carrier phase ▪ Ephemeris parameters ▪ Clock parameters ▪ Satellite positions (Azimuth, Elevation, xs,ys,zs) ▪ Ionospheric parameters
GSM Network Parameters	▪ Cell ▪ Base Station Identification Code (BSIC) ▪ Quality of Reception (RxQual) ▪ Localization Area Code (LAC) ▪ Power (dBm) ▪ C1 reselection parameter ▪ C2 reselection parameter ▪ Time Advance (TA) ▪ Assigned Radio Frequency ChaNnel (ARFCN) ▪ Cell Identification (CellId) ▪ Public Land Mobile Network (PLMN)

Available Log File Formats



- ASCII text (.txt) file
- MATLAB® (.mat) file
- Binary file
- RINEX 2 log
- RINEX 3 log
- Microsoft Office Excel® (.xls) file
- Keyhole Markup Language (.kml) file
- NMEA file

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MATLAB® File Format

- Several `.mat` files will be created if the MATLAB® file logging is enabled (depending on the number of data to be logged).
- The filenames contains:
  - ✓ a first part related to the type of data logged (`Clk`, `Eph`, `Iono`, `Obs`, `Pos`, or `SatPos`),
  - ✓ a second part with the data and a last part with the hour of begin of the data logging.
- Example: the file `SatPos24102008_101654.mat` contains Satellite Positions (`SatPos`) collected on the 24th October 2008, starting the data collection at 10:16:54 AM.
- Each `.mat` file contains an array or a matrix of structures with the receiver parameters and/or the measures related to a precise time-stamp.

MATLAB® File Format

- Example: Satellite Positions (`SatPos`) file.
- This file contains a variable called `Pos`, that is a structure in which each field is an array containing the user position data.
- The fields of `Pos` are arrays of data.
- Each element of the arrays is a value obtained at a time instant (defined in the field 'TOW').
- The MATLAB® command `Pos.NumSatView(1)` allows to see the number of satellites in view at the first measuring instant (if available).

`Pos` structure fields		
'PosID'	'SOG'	'NumSatUsed'
'Xu'	'DGPSType'	'NumSatView'
'Yu'	'TOW'	'LeapSeconds'
'Zu'	'WN'	
'Latitude'	'HDOP'	
'Longitude'	'GDOP'	
'Altitude'	'PDOP'	
'Vx'	'VDOP'	
'Vy'	'LSatView'	
'Vz'	'LSatUsed'	

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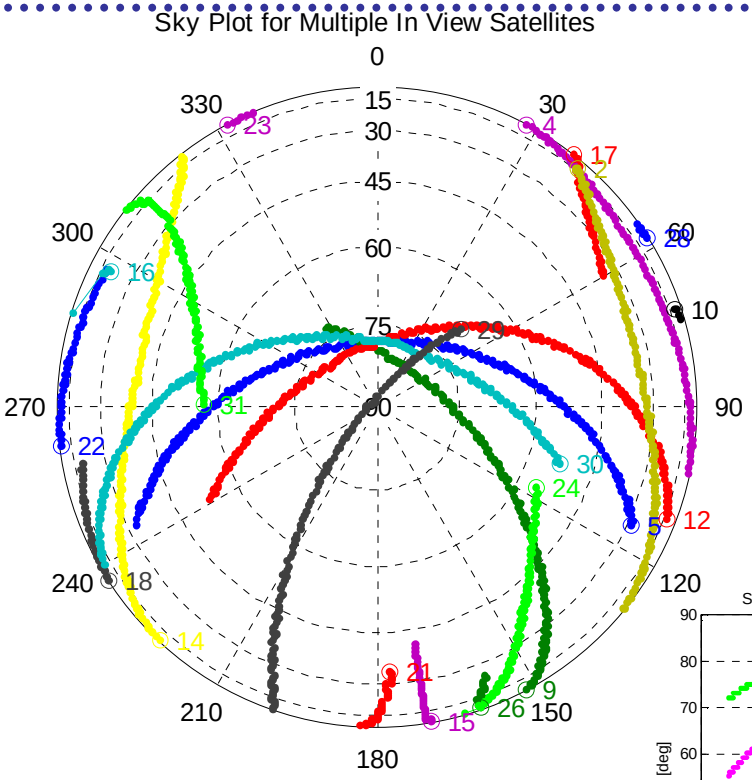
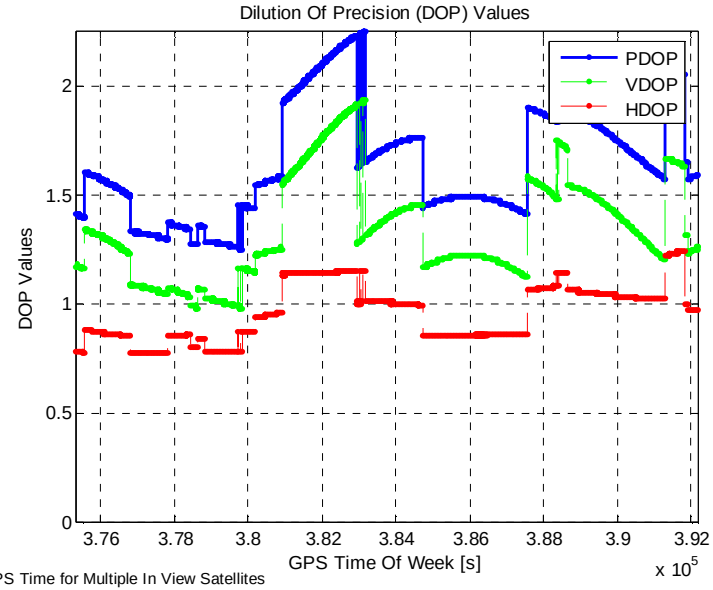
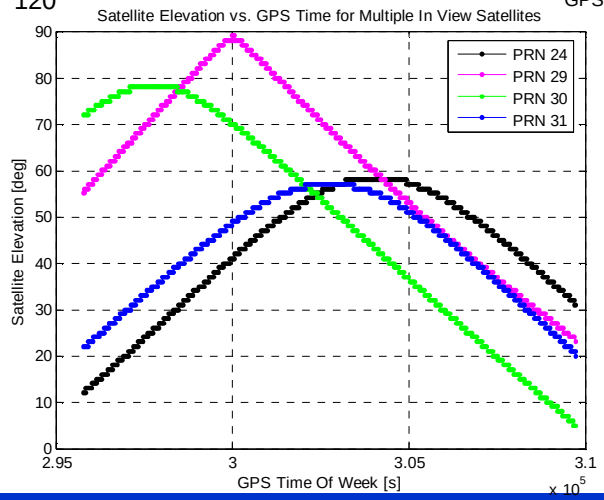
DEMO & Exercises







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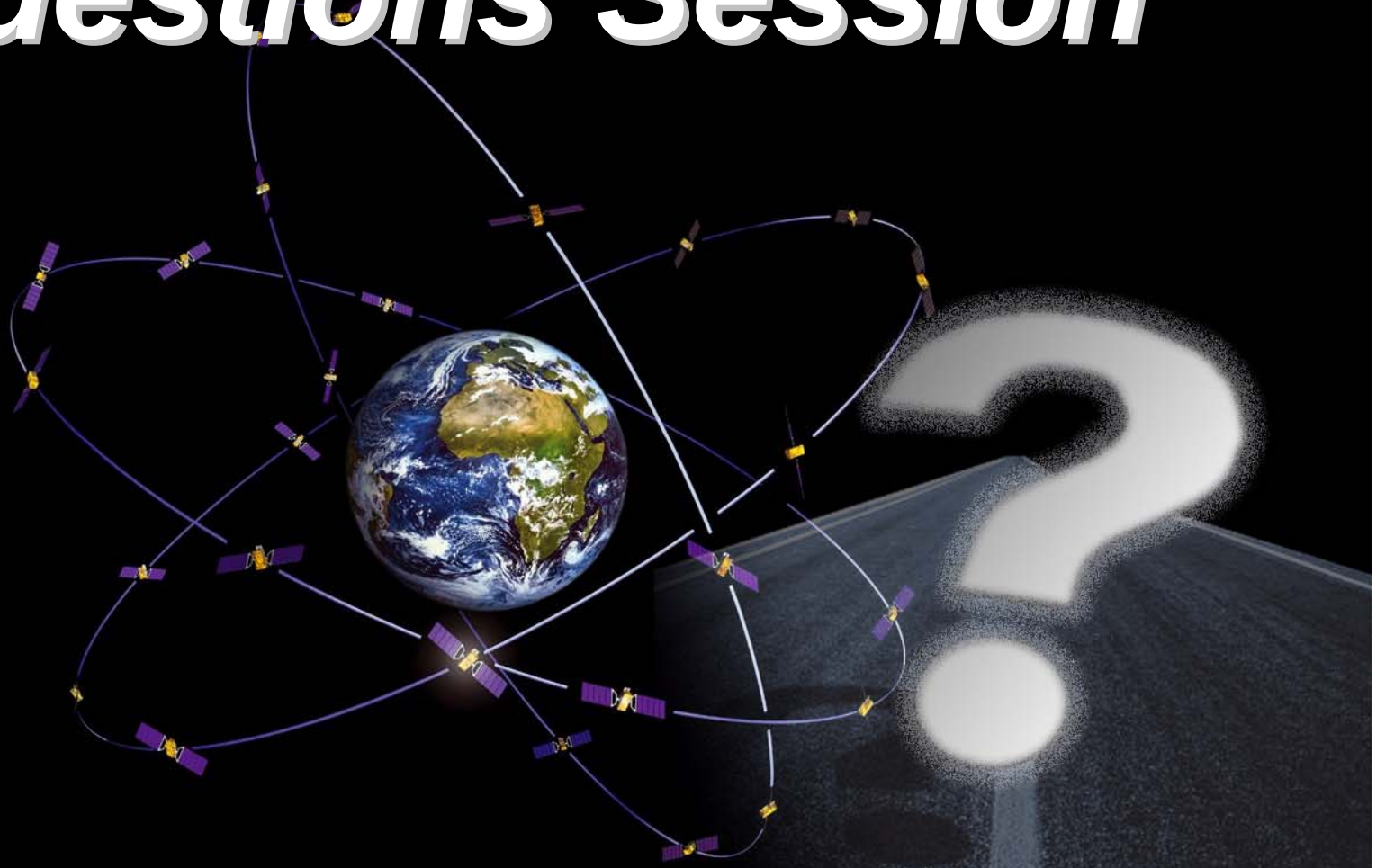
Questions Session



www.navsas.eu
www.galileoblog.eu