Satellite Navigation Science and Technology for Africa

23 March - 9 April, 2009

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

Marucco Gianluca
Istituto Superiore Mario Boella
Via Pier Carlo Boggio 61
Torino
Italy
SAT-SURF & SAT-SURFER
Satellite Navigation Science and Technology for Africa

SAT-SURF
The Training Board for GNSS

SAT-SURFER
SW Suite for GNSS Training
Lecturer

Gianluca Marucco
Researcher
E-mail: marucco@ismb.it
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
Motivation

SAT-SURF & SAT-SURFER Seminar

- 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.
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.
Motto

With SAT-SURF and SAT-SURFER engineers, technicians and students learn how to practically surf with GNSS!
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
A Joint Research Lab on GNSS
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 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.navsas.eu)
- [http://www.galileoblog.eu](http://www.galileoblog.eu)
The Navigation Lab at ISMB

NAV/SAS Group

NAV/COM integrations

EGNOS monitoring station

Emergency Management System

Receiver design and prototyping

SAT-SURF & SAT-SURFER Seminar – March 09
The Navigation Lab at ISMB

NavSAS Group

- R&D Activities
- Nat./Intern. Projects
- Tech Transfer to SMEs
- Higher Education

SAT-SURF & SAT-SURFER Seminar – March 09
The NavSAS Activities

Global Navigation Satellite Systems

- Advanced receiver technologies
- Algorithms and innovative architecture against interference and multipath
- Design of new GNSS signals – Members of the GSTF
- GNSS receiver design and prototyping
- Indoor applications
- Technologies for Emergency managements and SOL applications
- Algorithms & implementation of AGNSS techniques
- Design & realization of NAV/COM hybrid platforms
- Higher Education Master on Navigation and Related applications
- Scientific applications such as INS & DGPS
- SAT-SURF
- EGNOS monitoring station at ISMB supported by ESA
- N-GENE
- NICE
- SWAN

SAT-SURF & SAT-SURFER Seminar – March 09
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
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
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.

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!

- **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
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.
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

Technologies

OMA-SUPL Protocol for A-GPS at LE
ZigBee Networks
USSD Channel
DMR
Management of multiple COM channels
Advanced GPS Mass-Market Chip Management
Mesh Networks
VHF/TETRA
RTK/DGPS
EGNOS, Galileo

Shock Sensors

ZigBee Networks

eCall - Emergency Call System

Low Cost Mapper for Footpath Mapping

Mesh Networks

OMA-SUPL Protocol for A-GPS at LE

VHF/TETRA

RTK/DGPS

EGNOS, Galileo

DMR

Advanced GPS Mass-Market Chip Management

Management of multiple COM channels

Satellite Based Financial Systems

SAT-SURF & SAT-SURFER

NavSAS Group
**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.
SAT-SURF & SURFER Seminar – March 09

SAT-SURF & SURFER

NICE - Local Element Platform

SAT-SURFER

SAT-SURF

SiRF
uBlox
Magellan DG14
Septentrio

N-GENE SW Receiver

Front-End

N-GENE GUI

Matlab Analysis

SWAN Generator

SWAN Analysis

Matlab Analysis

Front-End

N-GENE SW Receiver

N-GENE GUI

SiRF
uBlox
Magellan DG14
Septentrio

NICE - Local Element Platform
Higher Education

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

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
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
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
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
Teacher’s video

Possibility of selecting the various sections for play and replay

Synchronized viewgraphs

Printable version of the viewgraphs

Exercises, Questions & Solutions
Every Chapter has a test. The student can check its own preparation.

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

Bibliography & Glossary
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
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
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
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.
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)
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.
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

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/N₀ 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.
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

d – What you can do with SAT-SURFER

e – Other Information
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.
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.
SAT-SURF & SAT-SURFER Seminar – March 09

NavSAS Group

SAT-SURF Hardware

Data Logger Matlab, Text, Rinex, KML

Settings

Core Application

Driver SiRF

Driver uBlox

Driver GSM Modem

Driver NTrip DGPS

File Logs

Graphical User Interface

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.
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.
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)
Plot Examples

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

Ionospheric delays evolution for 5 satellites versus elevation.
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.
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
NAV/COM Integration Capabilities

Specific Educational Tool

A Ready to Use Tool

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.

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.

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.

www.navsas.eu

www.saetsrl.com
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.
# Parameters Logged by SAT-SURFER

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
</table>
| **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

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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
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 contain:
  - 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).

<table>
<thead>
<tr>
<th>Pos structure fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>'PosID'</td>
</tr>
<tr>
<td>'SOG'</td>
</tr>
<tr>
<td>'NumSatUsed'</td>
</tr>
<tr>
<td>'Xu'</td>
</tr>
<tr>
<td>'DGPSType'</td>
</tr>
<tr>
<td>'NumSatView'</td>
</tr>
<tr>
<td>'Yu'</td>
</tr>
<tr>
<td>'TOW'</td>
</tr>
<tr>
<td>'LeapSeconds'</td>
</tr>
<tr>
<td>'Zu'</td>
</tr>
<tr>
<td>'WN'</td>
</tr>
<tr>
<td>'Latitude'</td>
</tr>
<tr>
<td>'HDOP'</td>
</tr>
<tr>
<td>'Longitude'</td>
</tr>
<tr>
<td>'GDOP'</td>
</tr>
<tr>
<td>'Altitude'</td>
</tr>
<tr>
<td>'PDOP'</td>
</tr>
<tr>
<td>'Vx'</td>
</tr>
<tr>
<td>'VDOP'</td>
</tr>
<tr>
<td>'Vy'</td>
</tr>
<tr>
<td>'LSatView'</td>
</tr>
<tr>
<td>'Vz'</td>
</tr>
<tr>
<td>'LSatUsed'</td>
</tr>
</tbody>
</table>
DEMO & Exercises

Sky Plot for Multiple In View Satellites

Satellite Elevation vs. GPS Time for Multiple In View Satellites

Dilution Of Precision (DOP) Values

PDOP
VDOP
HDOP

Satellite Elevation (deg)

GPS Time Of Week [s] × 10^5

3.76 3.78 3.8 3.82 3.84 3.86 3.88 3.9 3.92

GPS Time Of Week [s] × 10^5

0 0.5 1 1.5 2

DOP Values
Questions Session

www.navsas.eu
www.galileoblog.eu