



# New KHz capable software in Metsähovi

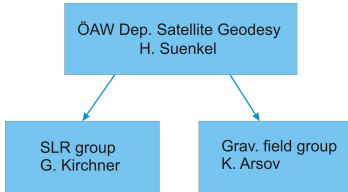
Kirčo Arsov

Finnish Geodetic Institute  
Department of Geodesy and Geodynamics  
[kirco.arsov@fgi.fi](mailto:kirco.arsov@fgi.fi)

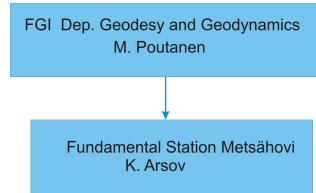
SLR Workshop Wetzell, May. 2011

# Short Bio

## Before Finland

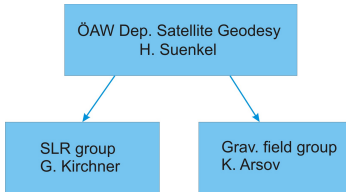


## Currently

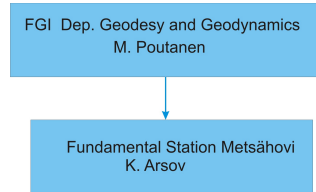


# Short Bio

## Before Finland



## Currently



**2007-cur** Responsible for Metsähovi Fundamental station in general and SLR in particular. Work concentrated on the new 2KHz SLR in Metsähovi; implementation of all the new hardware+software and fine tuning the system. Research also on Satellite Geodesy in general and Gravity from space in particular.

## Some Department Tasks

- EUREF and its realisation in Finland (EUREF-FIN), connection to the international frames
- Vertical datums, precise levelling, and new Finnish height system, participation in the creation of new European vertical datum
- Participation on IAG services (IGS, IVS, ILRS, IDS) and other international permanent geodetic networks (EPN, GGP, NGOS, GGOS ...), especially using FinnRef and the instrumentation in Metsähovi
- Promotion, education and consultation on new reference frames in Finland;

# Metsähovi Observatory

- Research unit of FGI, Department of Geodesy and Geodynamics



Photo: Jyri Näränen

# Metsähovi Observatory

- Research unit of FGI, Department of Geodesy and Geodynamics
- Located in Kirkkonummi, ca 35km west from Helsinki



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- Staff involved cca 8-10



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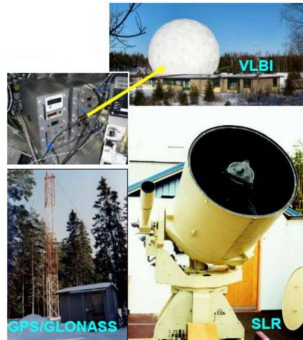
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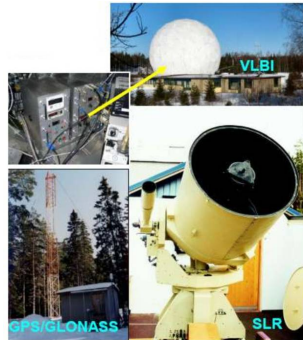


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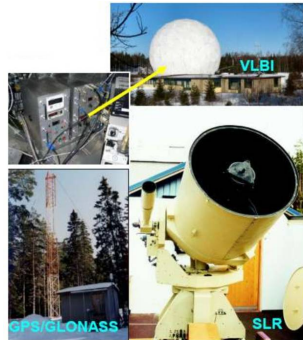
- GPS (IGS station since 1992)



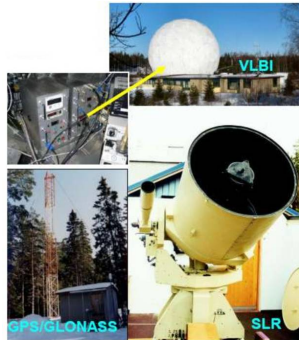
- GPS (IGS station since 1992)
- GPS/GLONASS



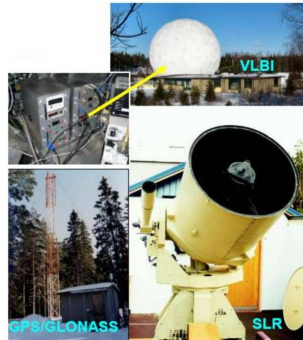
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- GPS/GLONASS
- SLR (1978-curr)
- geo-VLBI (2004- curr)

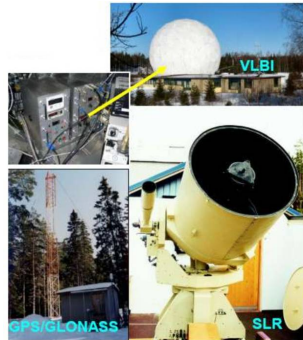


- GPS (IGS station since 1992)
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- geo-VLBI (2004- curr)
- DORIS

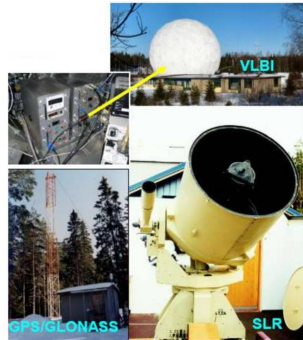




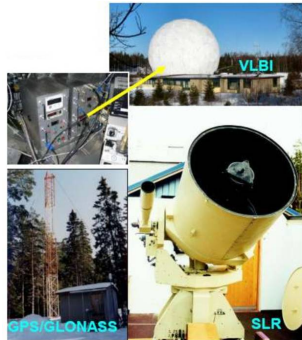
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- geo-VLBI (2004- curr)
- DORIS
- SCG



- GPS (IGS station since 1992)
- GPS/GLONASS
- SLR (1978-curr)
- geo-VLBI (2004- curr)
- DORIS
- SCG
- Abs. Gravity



- GPS (IGS station since 1992)
- GPS/GLONASS
- SLR (1978-curr)
- geo-VLBI (2004- curr)
- DORIS
- SCG
- Abs. Gravity
- Seismometer



## SLR general

- Not operational from second half of 2005
- Old 1Hz system; difficult maintenance and observations, most of equipment old and obsolete.
- Personnel change; late 2006 decision to completely renovate the system; started Apr 2007.
- New laser late 2006, HighQ 2KHz, Nd:VAN solid state laser., pulse 12.3ps 830mW, 0.425mJ @532nm.
- Purchase of A032-ET for 2KHz timing
- Graz+own fpga based RGG board for time critical tasks.
- UTC timing; GPS time + frequency receiver from CNSSYS (used frequently in VLBI);Serves also as NTP time server.
- Meteo server; Vaisala PTU200 (in the station at the moment 5 barometers present)

## SLR general

- New photodetector C-SPAD replaced the old PMT.
- Couple of pulse distributors.
- Timing signal from H. Maser.
- New encoders for the telescope together with motors, complete renovation of the telescope is undergoing.
- New room for SLR instrumentation.
- New operational software from scratch to suit the new 2KHz SLR.
- Primary telescope mirror recoated.
- Mechanical/optical solution for the separate beam path under implementation.
- Seeking funding for a new telescope and a dome to host the new SLR observatory building in the future

## 2KHz software

- Windows 7 operating system with intel i9 -> 8 threads.
- Operator knowledge only how to use mouse.
- RTOS not needed because of:
  - Windows is never later then 1 msec. Especially in loops, threads or services.
  - Running only the most necessary services.
  - All time critical tasks are programmed as windows services or threads or executed in hardware.
  - A032-ET has FIFO buffers, so no need for real-time.
  - All fpga board tasks done in FIFOs.
  - Min "idle" requirement is ToF. GOCE 1.5-2 ms.
  - Graphics is done with DirectX10 inside graphics board. Partly is programmed as video game.
  - Full GUI implementation with MFC library.

## 2KHz software

- RTOS not needed because of: (cnt.)
  - all writings to disk are done binary in threads writing big amount of data at once; ex. write everything after 5 min observing from service.
  - all interpolations, computations etc from threads.
- Writing everything new from scratch tailored to 2KHz system
  - C++ as programming language +MFC and partly Assembler.
- RGG -> fpga, hardware accelerated, couple of event timers inside, laser control, C-SPAD etc.
- Master windows computer for session planning, SLR measurement, Graphics, 1Gb LAN for time telescope and meteo server communication.
- design of our own fpga SLR controller board based on Graz DOS ISA board.

## 2KHz software

- PCI and win instead of ISA and DOS
- 150 € board with our own software
- Automatic session downloading, CPF treatment, session planning, observation etc.
- Graphics rendering, computations, display controlled by the graphics external board, no additional burden on CPU.
- Full 2KHz scenario uses only 20% of the CPU.
- Capable of 10KHz observations scenario.
- Use of LAVA PCIe for timer reading.
- User/administrator usage for preserving modifying the properties/sessions.
- 1s screenshots copied to ftp server for documentation.

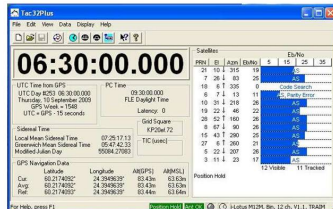
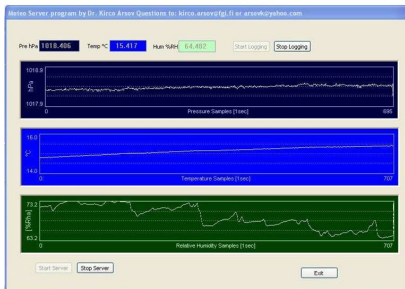


And very important...

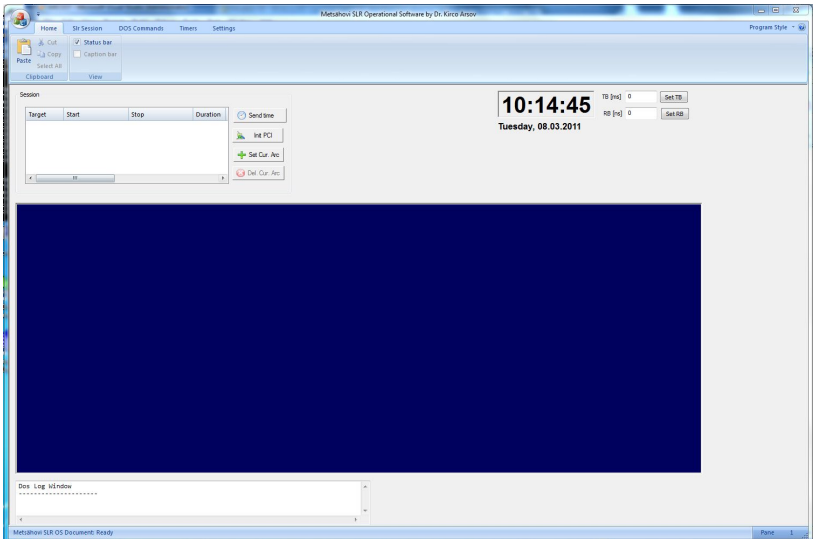
**IT IS FREE TO ANYONE INTERESTED!!**

**(GPL) licence; Code freely available to  
SLR community!**

- Own program for Meteo data and NTP
- CNSClock II for UTC offset



# SLR software



# SLR A032-ET overlapping

The screenshot displays the Metahovi SLR Operational Software interface. The main window is titled "Metahovi SLR Operational Software by Dr. Kalle Aarnio". The interface includes a menu bar with "Home", "SLR Session", "DOS Commands", "A032-ET", and "Settings". Below the menu bar are several icons for "Load FFT", "Load FFT Edit Sat.", "Delete all Satellites", "Start SLR Session", "Stop SLR Session", "Resume Session", and "Reupload Background Session".

The "Session" table is visible, showing a single session entry:

Target	Start	Stop	Duration	Pass Rise	Rise El.	Rin.
Saturn	01.09.2009 00:15:00	01.09.2009 00:45:00	00:30:00	01.09.2009 01:15:00		

Below the table are buttons for "Start ET", "Release PCI", "Set Cur. Acc.", and "Del. Cur. Acc.". The main plot area is dark blue with a yellow horizontal line and two dashed yellow lines above it, representing a signal or session data. At the bottom of the window, a status bar shows "SLR Session Finished".

On the right side of the screen, there is a vertical list of variables and their values:

- populatsAme: public
- False
- False
- False
- False
- False
- False
- False
- False
- False
- void

The taskbar at the bottom shows several open applications: "Welcome Center", "Metahovi SLR...", "Odt-Finn", "Debug", "Administrator...", "Virtual PC - L...", "Source-File", "SquidMail 1.4...", "Metahovi SLR...", and "Sessions View". The system clock shows 11:30.

# SLR ftp cpf orbits

FTP Session

FTP Connection

Ascii    FTP Site:

Binary    FTP Type:

ftp:

FTP Servers

File name	File size	Date
..		
.._cpf_090825_5051.hts		
ajisai_cpf_090910_7521.hts		
ajisai_cpf_090910_7541.jax		
ajisai_cpf_090911_7541.sgf		
andec_cpf_090911_7542.prd		

File name	File size	Date
..		
ajisai_cpf_09091...	74KB	11.09..
andec_cpf_0909...	701KB	11.09..
andep_cpf_0909...	701KB	11.09..
anderra_cpf_071...	701KB	11.09..
anderro_cpf_080...	676KB	11.09..

Successfully received a response from the server.

# SLR load cpf orbits

The screenshot displays the 'Metsähovi SLR Operational Software by Dr. Kirco Aršov' interface. The main window features a menu bar with 'Home', 'Slr Session', 'DOS Commands', 'A032-ET', and 'Settings'. Below the menu is a toolbar with icons for 'Load CPF orbits from FTP', 'Load CPF orbits', 'Edit Sat. Priorities', 'Delete all Satellites', 'View Satellites', 'Start SLR Session', 'Stop SLR Session', 'Residual Bcgrnd Session', and 'Redraw Session'. A table with columns 'Target', 'Start', 'Stop', 'Duration', 'Pass Rise', 'Rise El.', and 'Ris' is visible, along with buttons for 'Start ET', 'Int PCI', and 'Set Cur. Arc'.

An 'Open CPF Orbits' dialog box is open, showing a file explorer view of the 'CURRENT' directory. The file list includes:

Name	Date modified	Type	Size
ajisai_cpf_090911_7541.sgf			
andec_cpf_090911_7542.nrl			
andep_cpf_090911_7542.nrl			
anderra_cpf_071202_8362.nrl			
anderrp_cpf_080520_6414.nrl			
beaconc_cpf_090911_7541.sgf			
champ_cpf_090911_7542.gfz			
compass1_cpf_081204_8391.sha			
compassm1_cpf_090910_7531.sha			
envisat_cpf_090911_7541.sgf			
ers2_cpf_090911_7541.sgf			
etalon1_cpf_090911_7541.sgf			
etalon2_cpf_090911_7541.sgf			

The 'File name' field is empty, and the file type is set to 'All Files (\*.\*)'. The 'Open' button is highlighted.

At the bottom of the main window, there is a 'Dos Log window' which is currently empty.

# SLR satellites management

Metsähovi SLR Operational Software by Dr. Kirco Arsov

Home Slr Session DOS Commands A032-ET Settings

Load CPF orbits from FTP Load CPF orbits Edit Sat. Priorities Delete all Satellites View Satellites Start SLR Session Stop SLR Session Redraw Residual Bgnd Session

Session

Target	Start	Stop	Duration	Pass Rise	Rise El.	Ris
goce	11.09.2009 07:57:00	11.09.2009 08:03:00	00:06:00	11.09.2009 07:57:00		
terrasarx	11.09.2009 08:35:45	11.09.2009 08:43:45	00:08:00	11.09.2009 08:35:45		
Envisat	11.09.2009 09:36:00	11.09.2009 09:48:00	00:12:00	11.09.2009 09:36:00		
terrasarx	11.09.2009 10:09:45	11.09.2009 10:15:45	00:06:00	11.09.2009 10:09:45		
Envisat	11.09.2009 11:15:00	11.09.2009 11:30:00	00:15:00	11.09.2009 11:15:00		

Start ET

Init PCI

Satellites Priorities edit dialog

Priority	Satellite Name
<input checked="" type="checkbox"/>	01 graceb
<input checked="" type="checkbox"/>	01 gracea
<input checked="" type="checkbox"/>	02 champ
<input checked="" type="checkbox"/>	03 terrasarx
<input checked="" type="checkbox"/>	03 goce
<input checked="" type="checkbox"/>	04 envisat
<input checked="" type="checkbox"/>	05 ers2
<input checked="" type="checkbox"/>	06 jason1
<input checked="" type="checkbox"/>	07 jason2
<input type="checkbox"/>	08 oicets
<input checked="" type="checkbox"/>	09 larets
<input checked="" type="checkbox"/>	10 starlette
<input checked="" type="checkbox"/>	11 stela
<input checked="" type="checkbox"/>	12 ajisai
<input checked="" type="checkbox"/>	13 lageos2
<input checked="" type="checkbox"/>	14 lageos1
<input checked="" type="checkbox"/>	15 hearnnr

Add Sat.

OK Cancel

Double click a row to edit  
Select row(§) and hit del key to delete

# SLR residuals filter

The screenshot displays the Metsähovi SLR Operational Software interface. The main window shows a session table and a 'Residuals Filter Settings' dialog box. The session table lists targets and their scheduled times. The filter settings dialog shows two filters with parameters for bandwidth, criterion points, and use of last points. The 'Satellites View' window shows a plot of satellite activity over time, with a list of satellites on the left and a small elevation plot on the right.

**Session Table:**

Target	Start	Stop	Duration
goce	04.01.2011 08:29:00	04.01.2011 05:33:00	00:06:00
Lageos1	04.01.2011 04:30:00	04.01.2011 05:30:00	01:00:00
Lageos2	04.01.2011 09:05:00	04.01.2011 07:05:00	01:00:00
Jason1	04.01.2011 14:03:00	04.01.2011 14:21:00	00:18:00
Jason2	04.01.2011 13:06:00	04.01.2011 13:18:00	00:12:00
Stop	04.01.2011 09:46:00	04.01.2011 09:56:00	00:10:00

**Residuals Filter Settings:**

Filter 1	Filter 2
BandWidth [Hz] 5000	BandWidth [Hz] 5000
Criterion Pts 3	Criterion Pts 3
Use Last Nr Pts 2000	Use Last Nr Pts 300

**Satellites View:**

Time Axis settings: Spacing 1 0 Set

Start with 0 0 Set

Session Time Window: Start Time 03.01.2011 00:00:00, End Time 06.01.2011 15:24:00

Satellite: goce  
Date 04.01.2011 14:15:00 Azim 65.0° Elev 3.0°  
Set 04.01.2011 14:38:00 Azim 15.0° Elev 0.8°  
Arc length [kilometers] 300:03.00  
Dt [s] 300 Nr. Pts 2 Pwr 3

Plot labels: gracea, graceb, blits, goce, terrasarx, envisat, ERS2, Jason1, Jason2, Larets, Starlette, Stella, Ajisai, Lageos2, Lageos1, BeaconC, Etalon1, Etalon2.



# SLR residuals filter

SLR OS Program Settings

**Residuals Filter Settings**

Filter 1	Filter 2
BndWdth [ps] <input type="text" value="5000"/>	BndWdth [ps] <input type="text" value="5000"/>
Criterion Pts <input type="text" value="3"/>	Criterion Pts <input type="text" value="3"/>
Use Last Nr Pts <input type="text" value="2000"/>	Use Last Nr Pts <input type="text" value="300"/>

Plot Every Residual

Before apply or OK make sure the satellites wiew is opened once at least

OK Cancel Apply Help

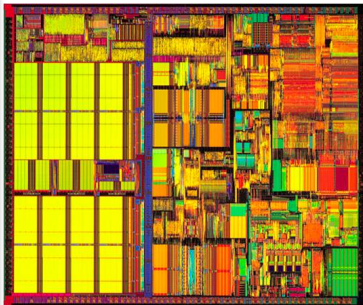
Filters  
General  
Windows  
Locations

## to do...

- PCIe FPGA implementation
- Smart satellite search, auto RB, TB determination and setting in real time
- Auto RG\_WIDTH setting
- Kalman to aid in filtering ?
- Auto session planning, real time visibility and sat plot
- Post processing module (use Graz/RIGA version for starting)
- Telescope control module
- Work on higher rates ?
- More automation
- Virtual observation animation

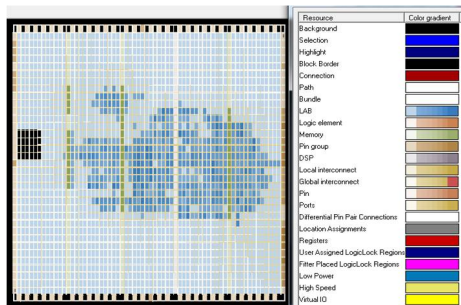
- **Field Programmable Gate Array (FPGA):**  
Executes all "instructions" in parallel.
- You write massively parallel source code for FPGA. Code is translated directly into hardware.
- You can even fit small computers on a single FPGA (Commodore-64 is popular). FPGA chips have hundreds of free I/O pins you can use for whatever you like: DDR2 busses, PCI busses, motor and robot control, switch-mode supplies, timing systems, ... SLR telescope control?

# FPGA vs CPU

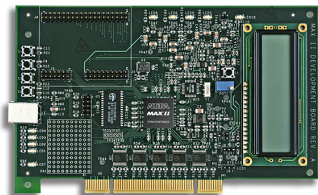
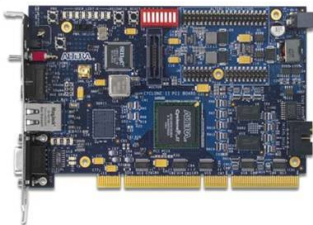


- Intel Celeron CPU  
(1 task/Cycle)

- SLR code translated onto FPGA (500++tasks/cycle?)  
Green=memory, blue=SLR logic, light blue=free



# FPGA project; Hardware used



PCI and PCI-X	PCIe 1.x/2.0/3.0
Obsolete	The standard
Already faster than SLR requires	Even faster, $\geq 250\text{MB/s/lane}$ requires
Cheap sub-\$1k evaluation kits	Kits reasonably inexpensive
Easy to design 66MHz boards	Challenging to make GHz boards
Free PCI software cores for FPGA	Only commercial cores costing $\geq \$5000/\text{license}$

**Altera PCI/PCI-X Evaluation Kit** €800 Based on a small CycloneII FPGA (EP2C35). MAXII CPLD development kit, €150 -> Open code to SLR community

Next...

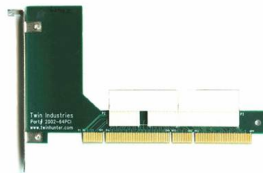
Future: Altera CycloneIII or Xilinx Spartan3 micromodules  
=€100, same SLR functionality!



OR



+



Just add water (or PCI  
card edge 😊)

## Features at glance

- Fully controlled and configured over open-standard Wishbone Interface
- Uses open-source PCI Wishbone from OpenCores.org, GNU LGPL
- SLR in pure VHDL and Verilog source code  
⇨ FPGAs from any vendor might be used
- Time critical 2KHz operations into hardware
- Uses multiple clocks derived from H-maser
- Enables use of SLR frequencies up to 10KHz
- Free le's ⇨ further extensions
- CycloneII/III FPGAs ⇨ old enough ⇨ free Altera Quartus 9.x Web Edition ☺
- Own Windows and linux driver for the board

## Functionality

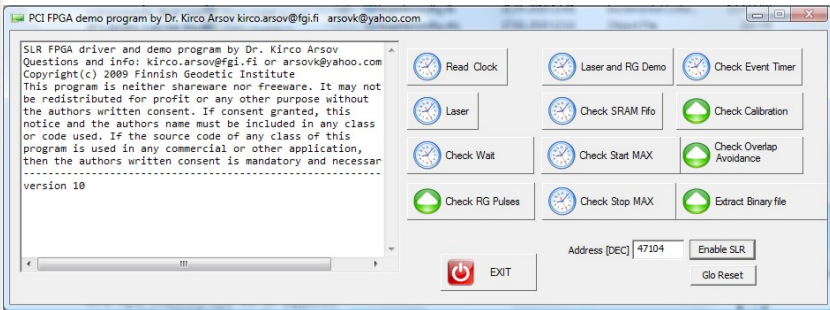
- Manage the Range Gate pulses
- Integer and fractional part of the expected RG is written in the PCI registry sent to the C-SPAD
- FIFO of 1024 points is used inside the board
- Controlling of the laser fire frequency
- user might change on-the-fly the laser frequency
- Calibration and CCD control is programmed, and is fully automatic
- Event timing with 5ns resolution
- Start as well as stop events are time-stamped and put into 1024 FIFOs



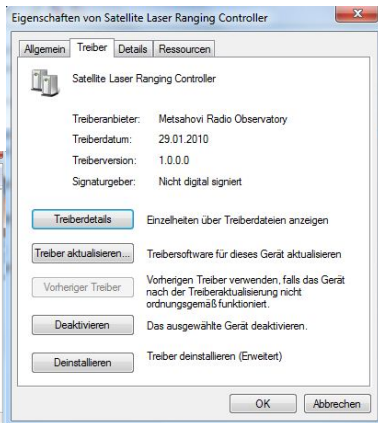
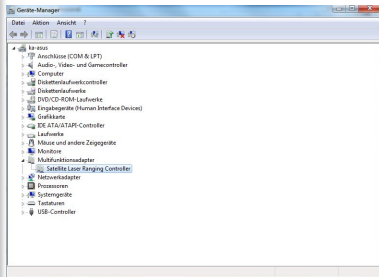
## Functionality

- Integer and fractional part, so absolute reading is possible
- Couple of counters readable, 10MHz and 200MHz
- Implemented overlapping avoidance of start and stop signals and the user might adjust on-the-fly the intervals of overlapping
- Calibration mode as well as CCD mode fully automatic
- Fully implemented into our SLR software
- Demo program to test the functionality of the board

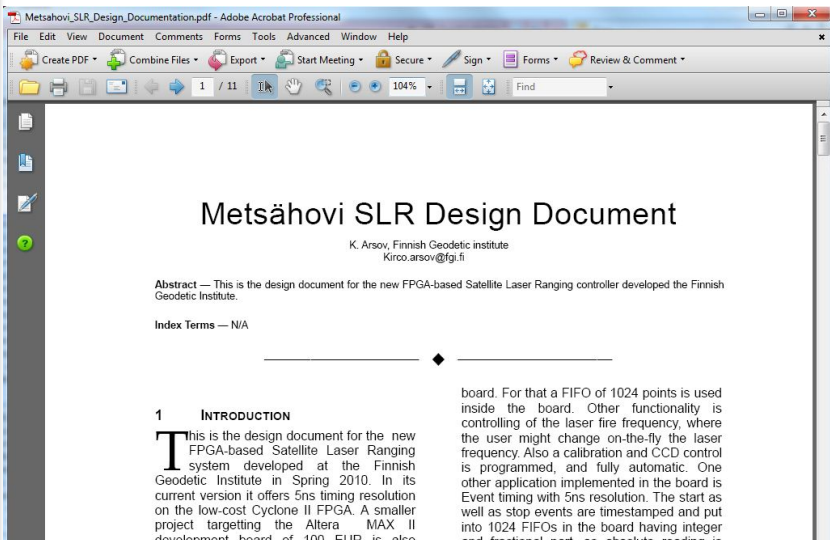
# Demo program for board functionality test



# Windows and Linux drivers programmed



# Project documentation



Metsähovi\_SLR\_Design\_Documentation.pdf - Adobe Acrobat Professional

File Edit View Document Comments Forms Tools Advanced Window Help

Create PDF Combine Files Export Start Meeting Secure Sign Forms Review & Comment

1 / 11 104% Find

## Metsähovi SLR Design Document

K. Arsov, Finnish Geodetic institute  
Kirco.arsov@fgi.fi

**Abstract** — This is the design document for the new FPGA-based Satellite Laser Ranging controller developed the Finnish Geodetic Institute.

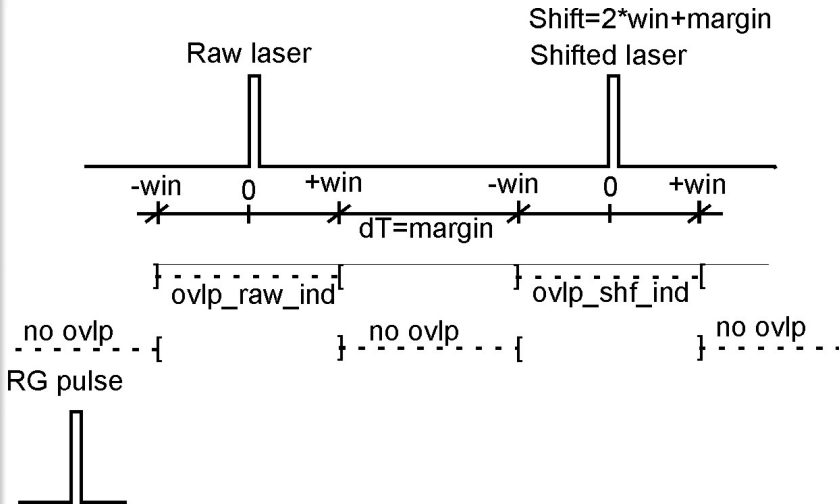
**Index Terms** — N/A

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### 1 INTRODUCTION

This is the design document for the new FPGA-based Satellite Laser Ranging system developed at the Finnish Geodetic Institute in Spring 2010. In its current version it offers 5ns timing resolution on the low-cost Cyclone II FPGA. A smaller project targetting the Altera MAX II development board of 100 FLUR is also board. For that a FIFO of 1024 points is used inside the board. Other functionality is controlling of the laser fire frequency, where the user might change on-the-fly the laser frequency. Also a calibration and CCD control is programmed, and fully automatic. One other application implemented in the board is Event timing with 5ns resolution. The start as well as stop events are timestamped and put into 1024 FIFOs in the board having integer and fractional part, so absolute reading is

# Note on OA



## OA verilog comments

```
// Description: Laser pwm and range gate pulses as input.
//
// Outputs a shifted laser pwm signal that
// attempts to avoid overlap of laser and range gate.
//
// Attempts to keep the rising(!) edges of the laser
// at a certain minimum distance away from range gate
// pulses. The window is symmetric, laser to RG
// and RG to laser edge time deltas are kept
// longer than the window time by adjusting the
// laser phase shift when it seems that laser/RG
// are too close.
//
// Adjustment method: overlap of direct Laser pwm and a
// fixed-delay ( $2 \cdot \text{window} + T$ ) Laser pwm versus Range gate
// is monitored. If direct pwm indicates overlap,
// we output the fixed-delay pwm. And vice versa.
```

## OA verilog comments

```
//  
// Does NOT act based on the _current_range gate  
// target. The time deltas are always taken from  
// the latest pulses already output.  
//  
// Note: the pulses are allowed to overlap in  
// time e.g. when pulse widths or duty cycle are long.  
// Only the rising edges are not allowed to be too close.  
//  
// output <= Raw_Laser when overlap_shifted_ind=='1' else  
//          Shifted_Laser when overlap_raw_ind=='1' else  
//          WhateverWasSelectedLastTime;  
//
```



And very important...

**IT IS FREE TO ANYONE INTERESTED!!**

**(GPL) licence; FPGA Verilog + Demo  
Code freely available to SLR  
community!**



That's all folks...

**THANK YOU**

**FOR YOUR ATTENTION**

**Questions?**



# Questions?

