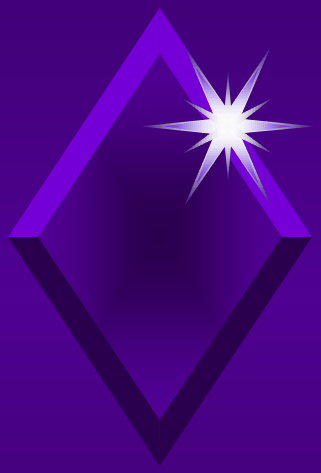
Improvements in the Automation of the Zimmerwald SLR Station



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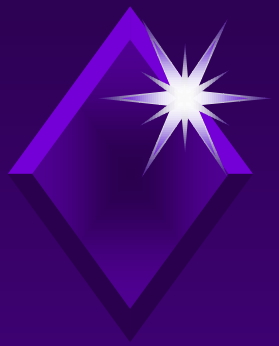

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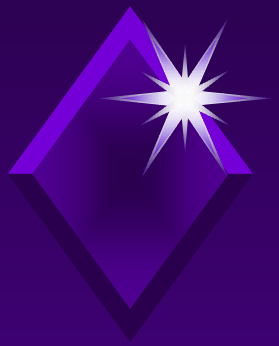


Introduction

- Remote control and/or automation mainly used in Zimmerwald for session extension
- Two sessions plus extensions cover 24 hours
- Paper discusses most topics addressed in the session announcement

Prediction Processing

- Predictions received by E-mail, extracted and processed automatically
  - Maintenance of satellite-dependent IRV files
  - Generation of pass lists
  - Computation of az/el/range files per pass
  - Replacement of IRVs by post-manoeuvre values at manoeuvre time, re-computation of pass lists and ephemeris files if necessary
  - Application of additional time bias corrections from time bias server at start of pass

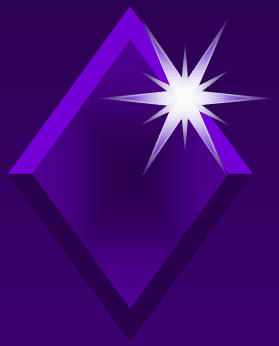
Sky Condition, Adverse Weather Detection

- Two external, roof-mounted color video cameras connected to web server
  - ➡ Remote inspection of weather conditions
- Color video camera on and b/w intensified camera in telescope connected to web server
  - ➡ Detailed weather condition in pointing direction
- Rain sensor
  - ➡ Rain warning, closes dome automatically
- No cloud detector!

Remote Visual Instrument Control (day)

Remote Visual Tracking Control (day)

Remote Visual Tracking Control (night)



Remote Control, User Interfaces

- VT-200 and X-11 graphics windows
  - On any remote system by Internet with VT terminal and X-11 emulation
  - Main interaction
  - Realtime system and tracking status display
  - Noise/return display
  - Sky plot of passes, sun and telescope positions
- Internet browser for camera image displays

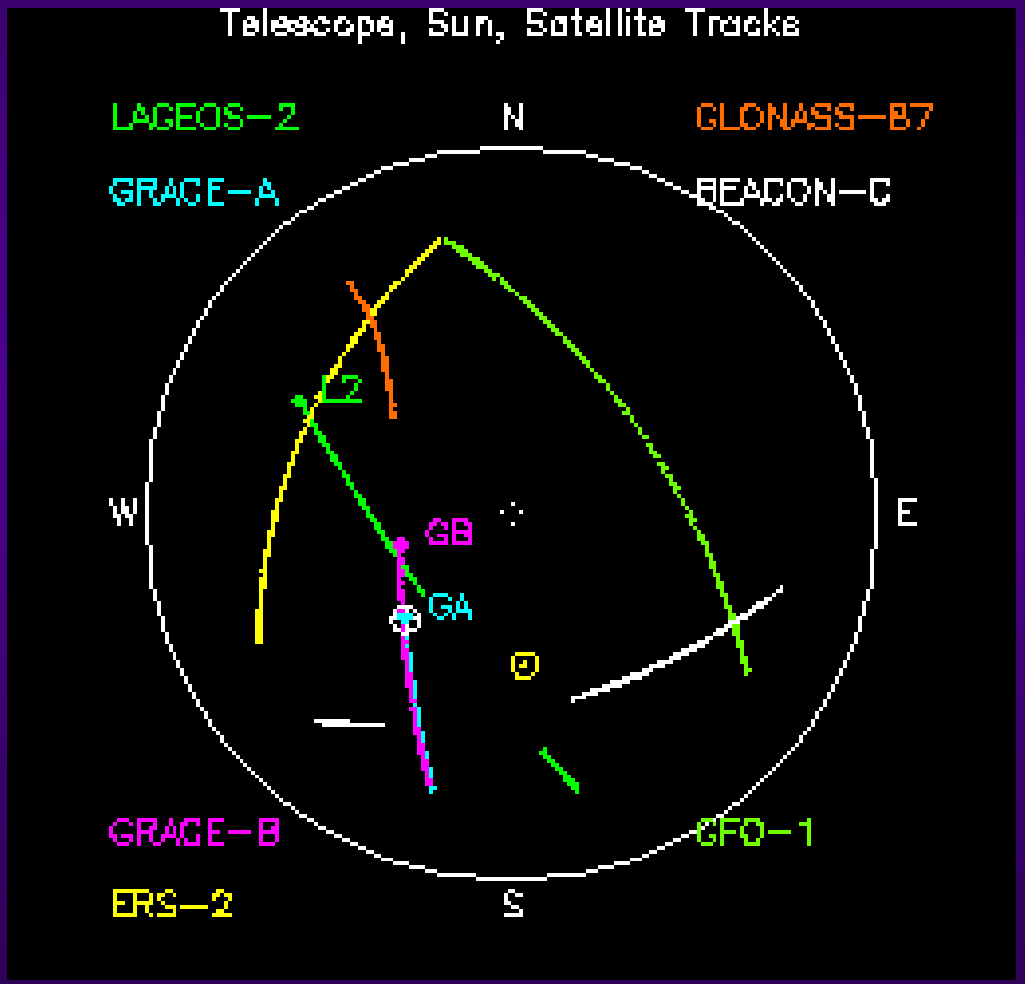
Realtime display of system parameters

```
+-------------------------------------------------------------------------+
|  Satellite   :  LAGEOS-2                          Visibility : SUN    43|
+-------------------------------------------------------------------------+
|  Initialize  :  Maximum   # of Shots :  40     Actual # of Shots :  36  |
|  OK             Necessary # of Hits  :   6     # of Init Cycles  :  12  |
|                                                                         |
|  Manual Corr.:  Step:  4" Up/Dn Lf/Rg:   0/  2 Total:   0/  2 E/A:  0/ -8  |
|  Search      :  Step:  4" Along/cross:   0/  0 Total:   0/  0          7 "  |
|                                                                         |
|  Obs.Interval:   0.1 s        ADC 1/2: 524   1 15.6 mJ  RT-Filter:     0 ns |
|      Window  :    40 ns       Rgtcorr:       0 ns       Previous :    44 ns |
|  Diverg/Blue :   300 1875    0Late by:  -0.004 s                        |
|                                                                         |
|  Calibration :  Each 70. obs  ADC 1/2: 728  42  0.2 mJ  Obs.Value:  53.97 ns |
|                                                                         |
|  Statistics  :  Calibr:  191 21%  Bad:  607  0% Ovfl:  3449  Hits:   1243 12%|
|                                                                         |
|  Auto: ON       Mode: M  Obs.: ON                ATC: OK   RNG     0100000000|
|                                                                    0111100001|
|  A 184.6987  E 31.3302  D 180      MAN CORR      13-AUG-02 16:10:19.8   6:41 |
+-------------------------+-------------------------+-------------------------+
|  DAY_TV            ON   |  TILT_ENA          ON   | DETECTORS          ON   |
|  ML_DRIVE    -5999 OK   |  ND_FILTER     143 OK   |                         |
+-------------------------+-------------------------+-------------------------+
```

EUROLAS Status Display

Graz	2002-08-13 14:17:32	Glonass87	LST	0	HON224	0.000
Potsdam	2002-08-13 14:18:01		OUT			
Zimmerwald	2002-08-13 14:18:48	Glonass87	CUR	0	COD791	0.000 (remote)
Wettzell	2002-08-13 14:18:41		OUT	(Tracking Idle)		
Grasse_slr	2002-08-13 14:06:10	Lageos2	LST	653	NER022	0.002
Herstmonceux	2002-08-13 14:18:26		OUT			
Ajaccio_ftlr	2002-08-13 13:59:00		OUT			

Sky Plot; Sun and Telescope Positions

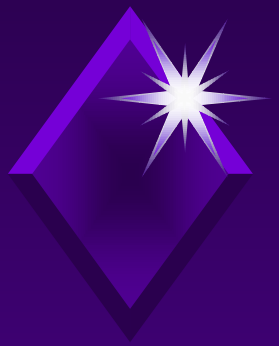


Automated Control

- Temporarily automated operation
  - Start in manual mode
  - Manual adjustment of system parameters
  - Switch to fully automated mode
  - Interaction still possible
- Fully automated operation

```
AUTO_SLR `power_up` `start` `stop` `oper_name`
AUTO_SLR    10:30    10:50   12:15   WG
```

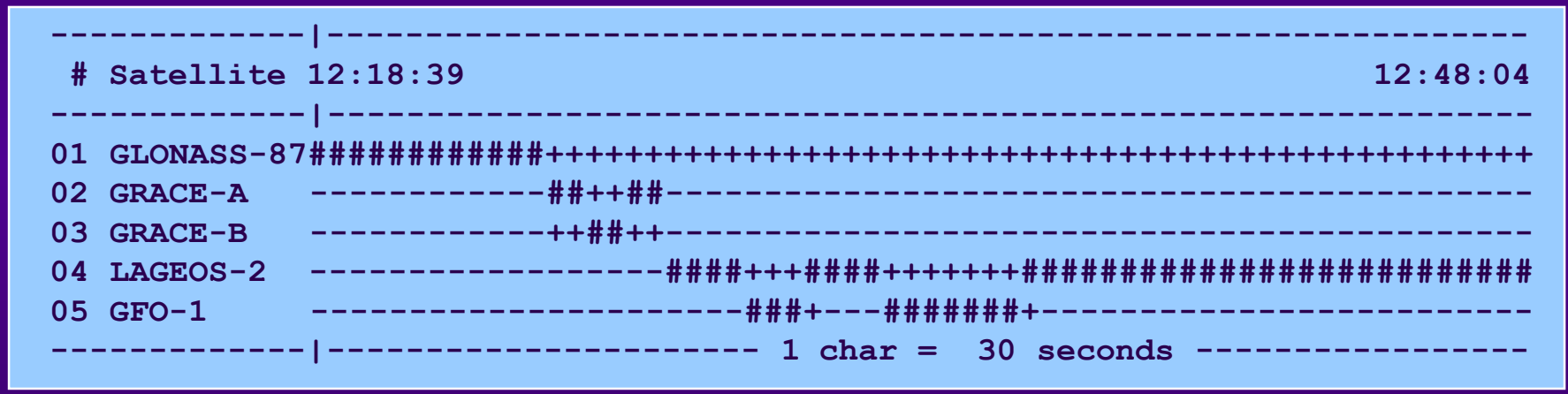
  - Uses pre-defined system parameters, automatically generated tracking scenario, etc



Automated Session Planning

- Check all possible or selected passes for sun interference, maximum elevation
- Split passes into parts of minimum length, distribute them according to priorities
- Propose tracking scenario to operator (manual mode) or directly use it (auto mode)
- Manual overwriting is easily possible

Automated Session Planning: Example



Realtime Noise Filtering and Tracking Improvement (1)

- Initialization Phase
  - Set relatively large range gate window depending on expected prediction accuracy and daylight
  - Compare all recent range residuals (50)
  - Compare all recent time biases (all range residuals are converted into along-track errors)
  - Search in a spiral around predicted position
  - Agreement between a minimum number of values (day: 6, night 4) ends initialization phase

    ⇨ **Current time bias**

Realtime Noise Filtering and Tracking Improvement (2)

- After initialization
  - Set range gate window to minimum (40 ns)
  - Improve predicted ranges with current time bias
  - Identify true returns from noise using improved prediction (threshold ~ 1 ns)
  - Adjust current time bias with confirmed range
  - Keep return rate below 30 percent (adjust transmitted energy)
  - Search around current position for stronger returns

Aircraft Detection

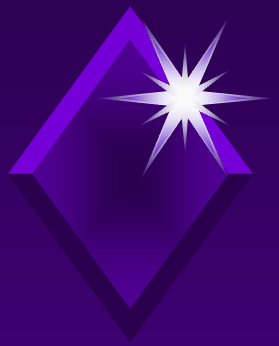
- Station computer
  - gets near-realtime positions of airplanes in an area around the stations from the Air Traffic Control
  - continually extrapolates positions to current time
  - compares positions with pointing direction of telescope
  - closes Laser shutter in case of conflicts
- Small radar
  - in parallel with telescope
  - detects small, low and near aircraft
  - closes Laser shutter in case of conflicts

Security and Safety Issues

- Sun protection
  - Station computer excludes portions of passes (25º)
  - Telescope PC avoids sun during positioning (20º)
  - Sun detector closes sun protection(< 20º)
- Rain detector
  - Closes open dome, stops tracking
- Laser hazard
  - Motion detector in dome interrupts laser firing
- General
  - Flash lamp in control room

Automated Data Postprocessing and Submission

- Currently done under operator control
  - Run programs for each selected pass to
    - apply averaged calibration constant
    - screen data (iteratively compute best-fitting orbit)
    - generate normal points
    - generate exchange format file
  - Daytime passes are inspected visually
  - System proposes passes to accept depending on post-fit RMS
  - No other interaction necessary



Experiences: Remote Control

- Nearly as successful as onsite observations
- Limitations
  - Some Laser adjustments can only be done on site
  - Some rare crashes need operator intervention (instrument run into limit switches)
  - Psychological element
- Used
  - in case of surprising weather changes
  - to bridge gaps between assigned sessions

Experiences: Automated Operation

- At night time very good performance
- During the day more difficult with weak returns (to keep instrument on track)
- Same limitations as with remote control
- Additionally:
  - Cloud coverage not known to the system
  - Tracking scenario not adjusted to actual conditions
  - Unpredicted weather changes
- Used to cover breaks (lunch, naps, …) and bridge gaps between sessions