TECHNISCHE UNIVERSITÄT WIEN

Satellite Scheduling with VieSched++

Helene Wolf

About me!

- master program at TU Wien
- started working in Oktober 2018
- 20 h/week
- VLBI group
- satellite scheduling – observing satellites with VLBI antennas
- implementing the satellite scheduling tool in VieSched++

Why observing satellites with VLBI antennas?

- scheduling observations to quasars is integral part of VLBI
- but also satellite scheduling is an important topic
- observations to satellites → enable interesting scientific applications
- new possibilities
  - improvement of geodetic products, in terms of ITRF
  - tracking satellite and space probes
  - provide geodetic space ties for connecting reference frames

So far, schedules generated using VieVS

- was upgraded with a satellite scheduling tool, written in Matlab (Andreas Hellerschmied)
- supports observations to quasars and satellites
- successful experiments were carried out

→ new scheduling software VieSched++ was developed (Matthias Schartner)

VieSched++

- new, modern software written in C++
- VieSched++ replaces scheduling module in VieVS

→ **open task:** implement satellite scheduling in VieSched++

Current status

VieSched++

import data:

- stations
- station parameters (horizon mask)
- session start time
- duration
- ….

Satellite Scheduling module

TLE data of satellite

↓

calculate satellite positions

↓

checking visibility for stations ⇄ C++ SGP4 Satellite Library

↓

looking angle of station (Az, El)

↓

create overlaps/scans

⇦

create schedule with pre-defined scans

Overlaps

```
start time: 2019-05-10 00:00:00  UTC
end time  : 2019-05-11 00:00:00  UTC
```

satellite	start	end	duration	stations
GSAT0221	02:58:44	03:52:52	00:54:08	Ny On
GSAT0221	03:52:52	03:56:16	00:03:24	Ny On Wn
GSAT0221	03:56:16	04:46:12	00:49:56	Ny On Wn Sa
GSAT0221	04:46:12	05:32:09	00:45:57	Ny On Sa
GSAT0221	05:32:09	06:19:31	00:47:22	Ny Sa
GSAT0221	13:54:22	14:11:02	00:16:40	Sa Wn
GSAT0221	14:11:02	15:00:54	00:49:52	Sa Wn On
GSAT0221	15:00:54	17:59:29	02:58:35	Sa Wn On Ny
GSAT0221	17:59:29	18:24:41	00:25:12	Sa Wn Ny
GSAT0221	18:24:41	21:07:41	02:43:00	Sa Wn Ny On
GSAT0221	21:07:41	21:35:24	00:27:43	Sa Wn On
GSAT0221	21:35:24	22:01:18	00:25:54	Wn On

Overlaps

```
start time: 2019-05-10 00:00:00  UTC
end time  : 2019-05-11 00:00:00  UTC
```

satellite	start	end	duration	stations
GSAT0221	02:58:44	03:52:52	00:54:08	Ny On
GSAT0221	03:52:52	03:56:16	00:03:24	Ny On Wn
GSAT0221	03:56:16	04:46:12	00:49:56	Ny On Wn Sa
GSAT0221	04:46:12	05:32:09	00:45:57	Ny On Sa
GSAT0221	05:32:09	06:19:31	00:47:22	Ny Sa
GSAT0221	13:54:22	14:11:02	00:16:40	Sa Wn
GSAT0221	14:11:02	15:00:54	00:49:52	Sa Wn On
GSAT0221	15:00:54	17:59:29	02:58:35	Sa Wn On Ny
GSAT0221	17:59:29	18:24:41	00:25:12	Sa Wn Ny
GSAT0221	18:24:41	21:07:41	02:43:00	Sa Wn Ny On
GSAT0221	21:07:41	21:35:24	00:27:43	Sa Wn On
GSAT0221	21:35:24	22:01:18	00:25:54	Wn On

Overlaps

start time: 2019-05-10 00:00:00 UTC
end time : 2019-05-11 00:00:00 UTC

satellite	start	end	duration	stations
GSAT0221	02:58:44	03:52:52	00:54:08	Ny On
GSAT0221	03:52:52	03:56:16	00:03:24	Ny On Wn
GSAT0221	03:56:16	04:46:12	00:49:56	Ny On Wn Sa
GSAT0221	04:46:12	05:32:09	00:45:57	Ny On Sa
GSAT0221	05:32:09	06:19:31	00:47:22	Ny Sa
GSAT0221	13:54:22	14:11:02	00:16:40	Sa Wn
GSAT0221	14:11:02	15:00:54	00:49:52	Sa Wn On

Station RAEGSMAR / Santa-Maria

13:54:22	Az: 189.39	El: 30.19	Rng: 25856.39	Dec: -22.24	LHA: 8.76
13:55:22	Az: 189.46	El: 30.59	Rng: 25823.06	Dec: -21.84	LHA: 8.77
13:56:22	Az: 189.53	El: 30.98	Rng: 25789.86	Dec: -21.44	LHA: 8.78
13:57:22	Az: 189.61	El: 31.37	Rng: 25756.79	Dec: -21.04	LHA: 8.78
13:58:22	Az: 189.68	El: 31.77	Rng: 25723.85	Dec: -20.64	LHA: 8.79
13:59:22	Az: 189.76	El: 32.16	Rng: 25691.05	Dec: -20.24	LHA: 8.80
14:00:22	Az: 189.84	El: 32.56	Rng: 25658.40	Dec: -19.84	LHA: 8.81
14:01:22	Az: 189.92	El: 32.95	Rng: 25625.88	Dec: -19.44	LHA: 8.82
14:02:22	Az: 190.00	El: 33.35	Rng: 25593.50	Dec: -19.04	LHA: 8.83
14:03:22	Az: 190.08	El: 33.75	Rng: 25561.28	Dec: -18.64	LHA: 8.84
14:04:22	Az: 190.17	El: 34.15	Rng: 25529.20	Dec: -18.23	LHA: 8.85
14:05:22	Az: 190.25	El: 34.54	Rng: 25497.27	Dec: -17.83	LHA: 8.86
14:06:22	Az: 190.34	El: 34.94	Rng: 25465.50	Dec: -17.42	LHA: 8.87
14:07:22	Az: 190.43	El: 35.34	Rng: 25433.88	Dec: -17.02	LHA: 8.88
14:08:22	Az: 190.52	El: 35.74	Rng: 25402.43	Dec: -16.61	LHA: 8.90
14:09:22	Az: 190.62	El: 36.14	Rng: 25371.13	Dec: -16.20	LHA: 8.91
14:10:22	Az: 190.71	El: 36.55	Rng: 25340.00	Dec: -15.79	LHA: 8.93
14:11:02	Az: 190.78	El: 36.82	Rng: 25319.21	Dec: -15.52	LHA: 8.94

Overlaps

start time: 2019-05-10 00:00:00 UTC
end time : 2019-05-11 00:00:00 UTC

satellite	start	end	duration	stations
GSAT0221	02:58:44	03:52:52	00:54:08	Ny On
GSAT0221	03:52:52	03:56:16	00:03:24	Ny On Wn
GSAT0221	03:56:16	04:46:12	00:49:56	Ny On Wn Sa
GSAT0221	04:46:12	05:32:09	00:45:57	Ny On Sa
GSAT0221	05:32:09	06:19:31	00:47:22	Ny Sa
GSAT0221	13:54:22	14:11:02	00:16:40	Sa Wn
GSAT0221	14:11:02			
GSAT0221	15:00:54			
GSAT0221	17:59:29			
GSAT0221	18:24:41			
GSAT0221	21:07:41			

Station WETTZ13N / Wettzell

13:54:22	Az: 226.80	El: 5.00	Rng: 28336.55	Dec: -22.34	LHA: 51.73
13:55:22	Az: 226.99	El: 5.31	Rng: 28302.88	Dec: -21.98	LHA: 51.73
13:56:22	Az: 227.17	El: 5.62	Rng: 28269.27	Dec: -21.61	LHA: 51.73
13:57:22	Az: 227.36	El: 5.93	Rng: 28235.71	Dec: -21.25	LHA: 51.73
13:58:22	Az: 227.55	El: 6.24	Rng: 28202.20	Dec: -20.89	LHA: 51.73
13:59:22	Az: 227.74	El: 6.55	Rng: 28168.75	Dec: -20.52	LHA: 51.73
14:00:22	Az: 227.93	El: 6.86	Rng: 28135.35	Dec: -20.16	LHA: 51.73
14:01:22	Az: 228.13	El: 7.18	Rng: 28102.02	Dec: -19.79	LHA: 51.74
14:02:22	Az: 228.32	El: 7.49	Rng: 28068.74	Dec: -19.42	LHA: 51.74
14:03:22	Az: 228.52	El: 7.80	Rng: 28035.52	Dec: -19.06	LHA: 51.74
14:04:22	Az: 228.71	El: 8.11	Rng: 28002.36	Dec: -18.69	LHA: 51.75
14:05:22	Az: 228.91	El: 8.42	Rng: 27969.26	Dec: -18.32	LHA: 51.76
14:06:22	Az: 229.11	El: 8.74	Rng: 27936.22	Dec: -17.95	LHA: 51.76
14:07:22	Az: 229.31	El: 9.05	Rng: 27903.25	Dec: -17.58	LHA: 51.77
14:08:22	Az: 229.51	El: 9.36	Rng: 27870.35	Dec: -17.21	LHA: 51.78
14:09:22	Az: 229.72	El: 9.67	Rng: 27837.51	Dec: -16.84	LHA: 51.79
14:10:22	Az: 229.92	El: 9.99	Rng: 27804.74	Dec: -16.47	LHA: 51.80
14:11:02	Az: 230.06	El: 10.19	Rng: 27782.81	Dec: -16.22	LHA: 51.80

Station RAEGSMAR / Santa-Maria

13:54:22	Az: 189.39	El: 30.19	Rng: 25		
13:55:22	Az: 189.46	El: 30.59	Rng: 25		
13:56:22	Az: 189.53	El: 30.98	Rng: 25		
13:57:22	Az: 189.61	El: 31.37	Rng: 25		
13:58:22	Az: 189.68	El: 31.77	Rng: 25		
13:59:22	Az: 189.76	El: 32.16	Rng: 25		
14:00:22	Az: 189.84	El: 32.56	Rng: 25		
14:01:22	Az: 189.92	El: 32.95	Rng: 25		
14:02:22	Az: 190.00	El: 33.35	Rng: 25		
14:03:22	Az: 190.08	El: 33.75	Rng: 25		
14:04:22	Az: 190.17	El: 34.15	Rng: 25		
14:05:22	Az: 190.25	El: 34.54	Rng: 25		
14:06:22	Az: 190.34	El: 34.94	Rng: 25		
14:07:22	Az: 190.43	El: 35.34	Rng: 25		
14:08:22	Az: 190.52	El: 35.74	Rng: 25		
14:09:22	Az: 190.62	El: 36.14	Rng: 25		
14:10:22	Az: 190.71	El: 36.55	Rng: 25		
14:11:02	Az: 190.78	El: 36.82	Rng: 25319.21	Dec: -15.52	LHA: 8.94

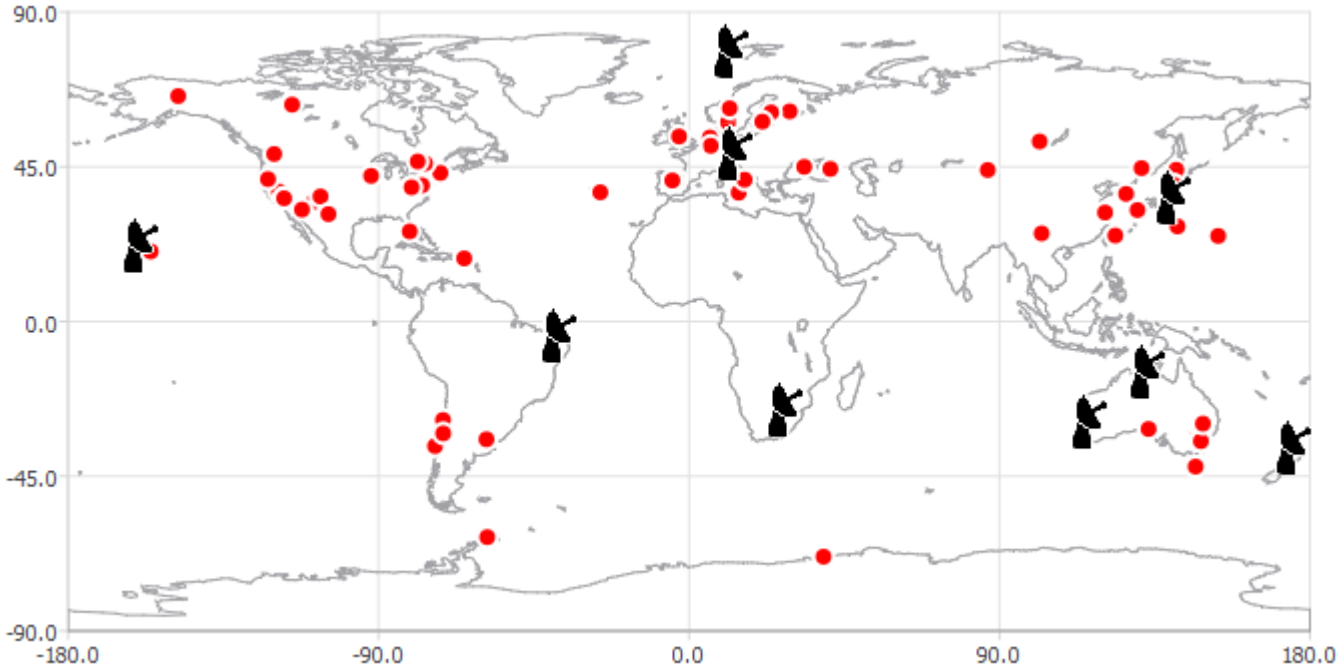
R4832 session

session start: 08.03.2018 18:30:00

session end : 09.03.2018 18:30:00

Network:

FORTLEZA	HART15M
KATH12M	KOKEE
WARK12M	WETTZ13N
YARRA12M	ISHIOKA
WETTZELL	NYALES20

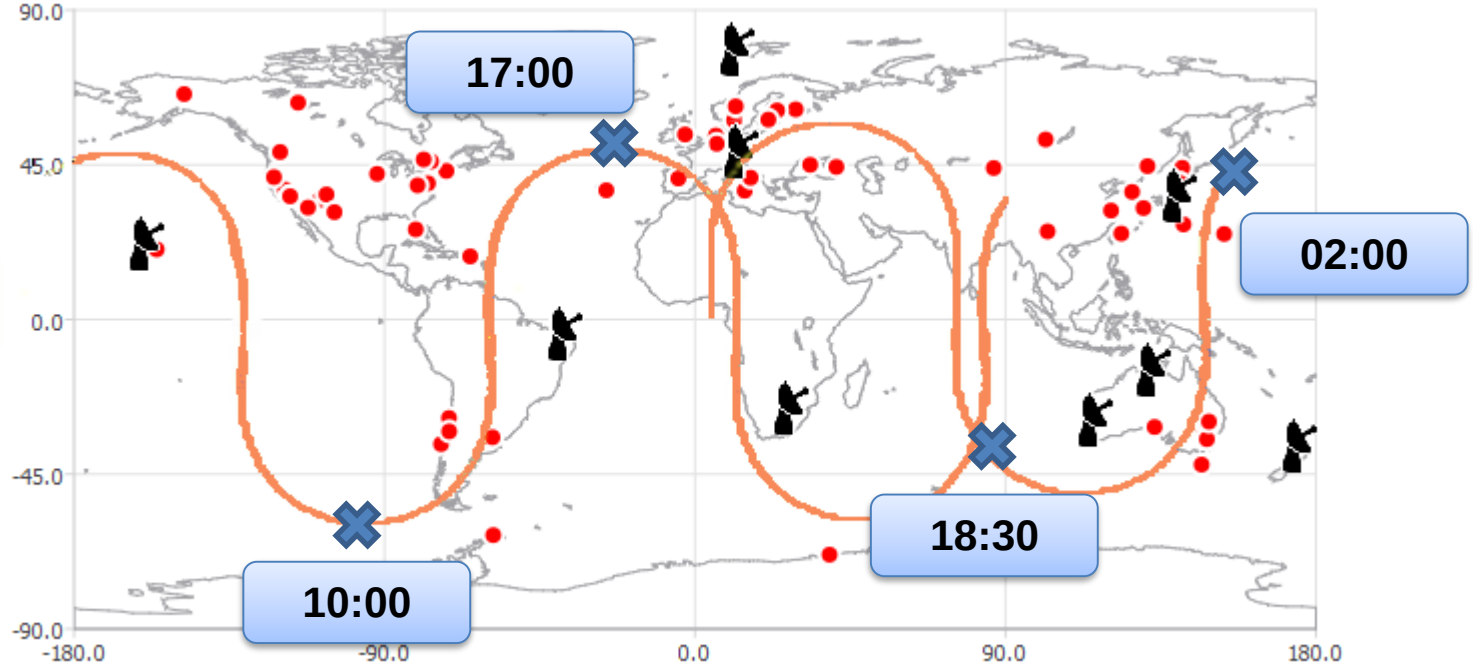


R4832 session

session start: 08.03.2018 18:30:00

session end : 09.03.2018 18:30:00

track of galileo satellite GSAT0218 (E31 - Plane A)



R4832 session – possible observations

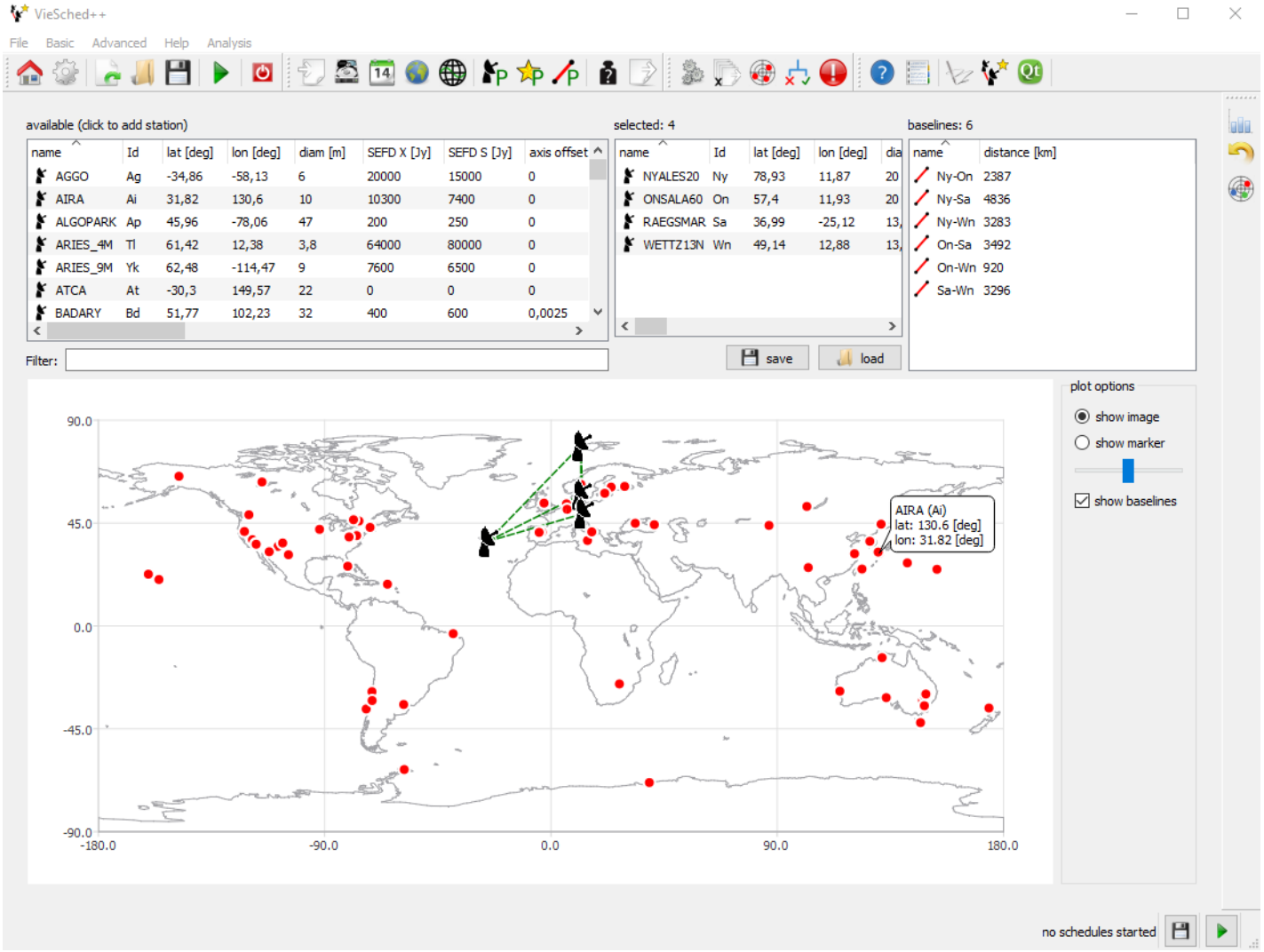
satellite	start	end	duration	stations
GSAT0218	18:30:00	19:43:13	01:13:13	Wz Ht Wn
GSAT0218	19:43:13	19:48:22	00:05:09	Wz Ht Wn Yg
GSAT0218	19:48:23	21:37:33	01:49:10	Ht Yg
GSAT0218	21:37:33	22:06:41	00:29:08	Ht Yg Ke
GSAT0218	22:06:41	00:25:14	02:18:32	Ht Yg Ke Ww
GSAT0218	00:25:14	00:29:36	00:04:21	Ht Yg Ke Ww Is
GSAT0218	00:29:36	01:50:54	01:21:18	Yg Ke Ww Is
GSAT0218	01:50:54	02:46:16	00:55:22	Yg Ke Is
GSAT0218	02:46:16	03:16:27	00:30:11	Yg Ke Is Ny
GSAT0218	03:16:27	03:55:28	00:39:00	Yg Ke Is Ny Wz Wn
GSAT0218	03:55:28	04:02:05	00:06:36	Yg Ke Is Ny Wz Wn Kk
GSAT0218	04:02:05	05:27:10	01:25:04	Ke Is Ny Wz Wn Kk
GSAT0218	05:27:10	05:52:21	00:25:10	Is Ny Wz Wn Kk
GSAT0218	05:52:21	06:31:04	00:38:43	Is Ny Kk
GSAT0218	06:31:04	07:19:55	00:48:50	Is Ny Kk Ke
GSAT0218	07:19:55	07:33:39	00:13:44	Is Ny Kk Ke Ww
GSAT0218	07:33:39	08:48:23	01:14:43	Is Kk Ke Ww
GSAT0218	08:48:23	10:01:49	01:13:26	Is Kk Ke Ww Yg
GSAT0218	10:01:49	11:31:25	01:29:35	Kk Ke Ww Yg
GSAT0218	11:31:25	12:08:55	00:37:29	Ke Ww Yg
GSAT0218	12:08:55	12:20:44	00:11:49	Ww Yg
GSAT0218	13:45:53	14:41:44	00:55:51	Ww Ft
GSAT0218	15:46:38	16:59:51	01:13:12	Ft Kk
GSAT0218	16:59:51	17:53:09	00:53:18	Ft Kk Ny
GSAT0218	17:53:09	18:30:00	00:36:50	Ft Kk Ny Wz Wn

R4832 session – possible observations

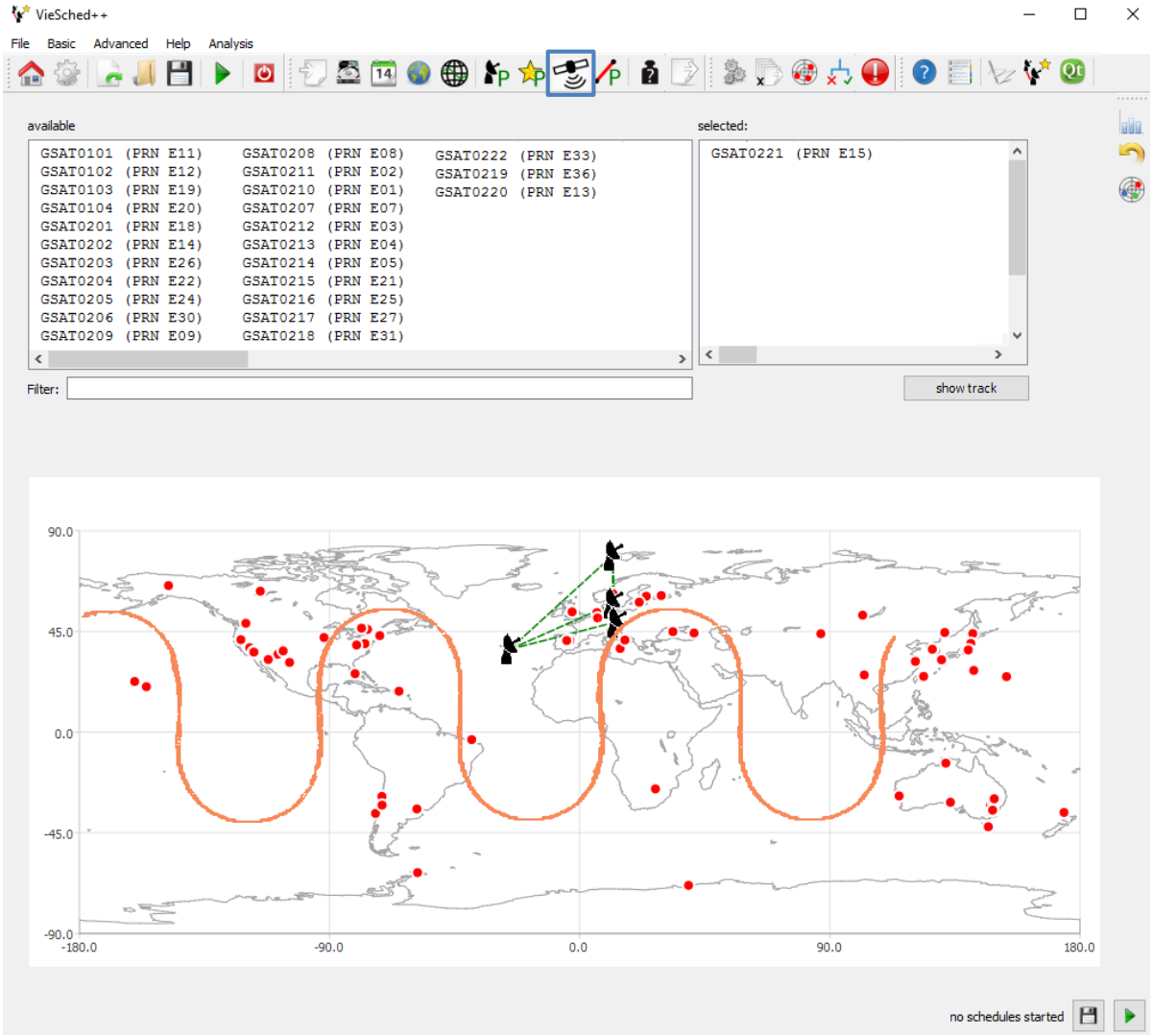
satellite	start	end	duration	stations
GSAT0218	18:30:00	19:43:13	01:13:13	Wz Ht Wn
GSAT0218	19:43:13	19:48:22	00:05:09	Wz Ht Wn Yg
GSAT0218	19:48:23	21:37:33	01:49:10	Ht Yg
GSAT0218	21:37:33	22:06:41	00:29:08	Ht Yg Ke
GSAT0218	22:06:41	00:25:14	02:18:32	Ht Yg Ke Ww
GSAT0218	00:25:14	00:29:36	00:04:21	Ht Yg Ke Ww Is
GSAT0218	00:29:36	01:50:54	01:21:18	Yg Ke Ww Is
GSAT0218	01:50:54	02:46:16	00:55:22	Yg Ke Is
GSAT0218	02:46:16	03:16:27	00:30:11	Yg Ke Is Ny
GSAT0218	03:16:27	03:55:28	00:39:00	Yg Ke Is Ny Wz Wn
GSAT0218	03:55:28	04:02:05	00:06:36	Yg Ke Is Ny Wz Wn Kk
GSAT0218	04:02:05	05:27:10	01:25:04	Ke Is Ny Wz Wn Kk
GSAT0218	05:27:10	05:52:21	00:25:10	Is Ny Wz Wn Kk
GSAT0218	05:52:21	06:31:04	00:38:43	Is Ny Kk
GSAT0218	06:31:04	07:19:55	00:48:50	Is Ny Kk Ke
GSAT0218	07:19:55	07:33:39	00:13:44	Is Ny Kk Ke Ww
GSAT0218	07:33:39	08:48:23	01:14:43	Is Kk Ke Ww
GSAT0218	08:48:23	10:01:49	01:13:26	Is Kk Ke Ww Yg
GSAT0218	10:01:49	11:31:25	01:29:35	Kk Ke Ww Yg
GSAT0218	11:31:25	12:08:55	00:37:29	Ke Ww Yg
GSAT0218	12:08:55	12:20:44	00:11:49	Ww Yg
GSAT0218	13:45:53	14:41:44	00:55:51	Ww Ft
GSAT0218	15:46:38	16:59:51	01:13:12	Ft Kk
GSAT0218	16:59:51	17:53:09	00:53:18	Ft Kk Ny
GSAT0218	17:53:09	18:30:00	00:36:50	Ft Kk Ny Wz Wn

min. 2 stations	89,6 %
min. 3 stations	72,2 %
min. 4 stations	52,3 %
min. 5 stations	19,7 %
min. 6 stations	8,6 %
min. 7 stations	0,5 %

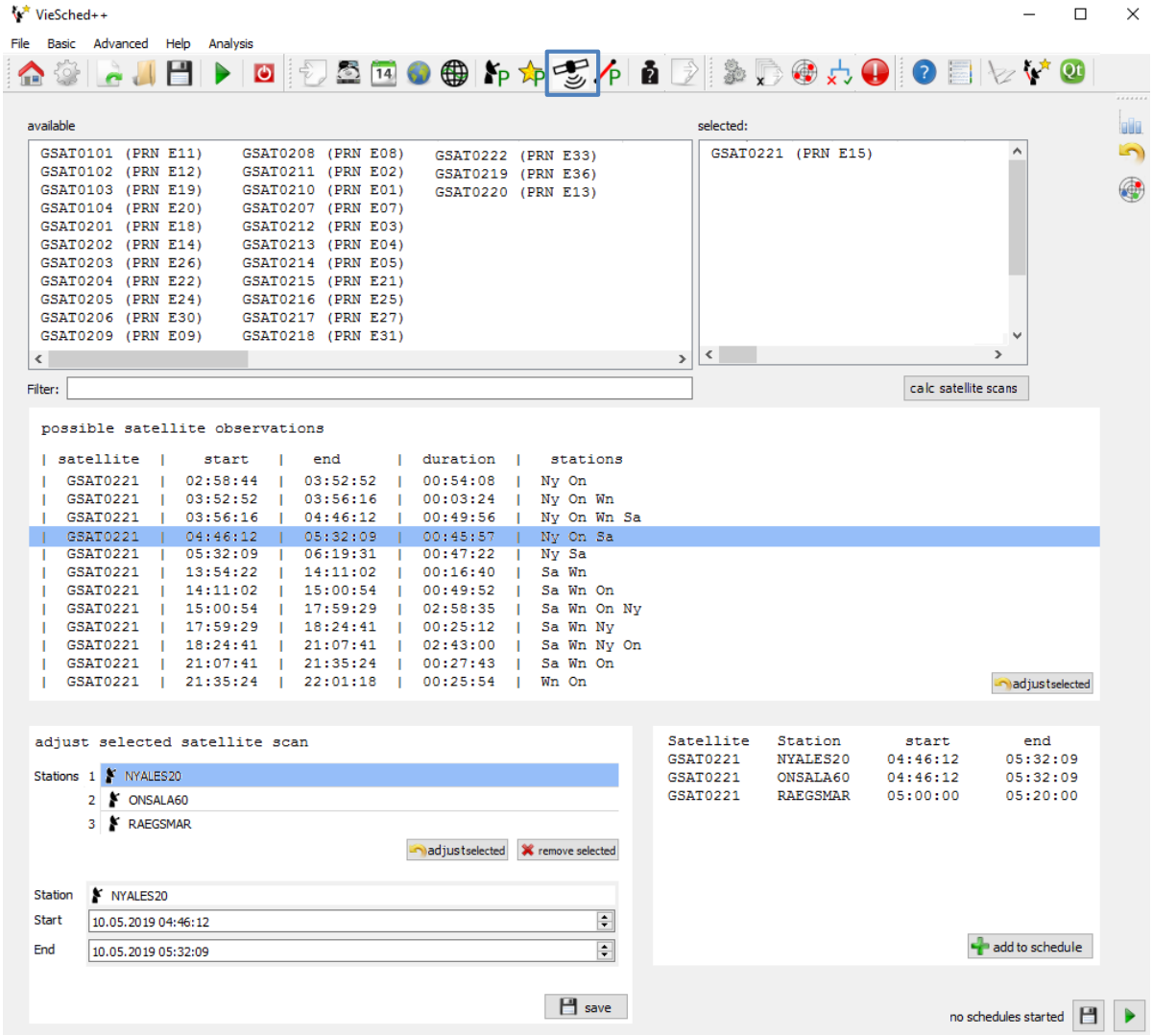
GUI - VieSched++



Outlook - GUI


VieSched++
File
Basic
Advanced
Help
Analysis
available
GSAT0101 (PRN E11)
GSAT0102 (PRN E12)
GSAT0103 (PRN E19)
GSAT0104 (PRN E20)
GSAT0201 (PRN E18)
GSAT0202 (PRN E14)
GSAT0203 (PRN E26)
GSAT0204 (PRN E22)
GSAT0205 (PRN E24)
GSAT0206 (PRN E30)
GSAT0209 (PRN E09)
GSAT0208 (PRN E08)
GSAT0211 (PRN E02)
GSAT0210 (PRN E01)
GSAT0207 (PRN E07)
GSAT0212 (PRN E03)
GSAT0213 (PRN E04)
GSAT0214 (PRN E05)
GSAT0215 (PRN E21)
GSAT0216 (PRN E25)
GSAT0217 (PRN E27)
GSAT0218 (PRN E31)
GSAT0222 (PRN E33)
GSAT0219 (PRN E36)
GSAT0220 (PRN E13)
selected:
GSAT0221 (PRN E15)
Filter:
show track
90.0
45.0
0.0
-45.0
-90.0
-180.0
-90.0
0.0
90.0
180.0
no schedules started

Outlook - GUI


VieSched++
File Basic Advanced Help Analysis
available
GSAT0101 (PRN E11) GSAT0208 (PRN E08) GSAT0222 (PRN E33)
GSAT0102 (PRN E12) GSAT0211 (PRN E02) GSAT0219 (PRN E36)
GSAT0103 (PRN E19) GSAT0210 (PRN E01) GSAT0220 (PRN E13)
GSAT0104 (PRN E20) GSAT0207 (PRN E07)
GSAT0201 (PRN E18) GSAT0212 (PRN E03)
GSAT0202 (PRN E14) GSAT0213 (PRN E04)
GSAT0203 (PRN E26) GSAT0214 (PRN E05)
GSAT0204 (PRN E22) GSAT0215 (PRN E21)
GSAT0205 (PRN E24) GSAT0216 (PRN E25)
GSAT0206 (PRN E30) GSAT0217 (PRN E27)
GSAT0209 (PRN E09) GSAT0218 (PRN E31)
selected:
GSAT0221 (PRN E15)
Filter:
calc satellite scans
possible satellite observations
| satellite | start | end | duration | stations
| GSAT0221 | 02:58:44 | 03:52:52 | 00:54:08 | Ny On
| GSAT0221 | 03:52:52 | 03:56:16 | 00:03:24 | Ny On Wn
| GSAT0221 | 03:56:16 | 04:46:12 | 00:49:56 | Ny On Wn Sa
| GSAT0221 | 04:46:12 | 05:32:09 | 00:45:57 | Ny On Sa
| GSAT0221 | 05:32:09 | 06:19:31 | 00:47:22 | Ny Sa
| GSAT0221 | 13:54:22 | 14:11:02 | 00:16:40 | Sa Wn
| GSAT0221 | 14:11:02 | 15:00:54 | 00:49:52 | Sa Wn On
| GSAT0221 | 15:00:54 | 17:59:29 | 02:58:35 | Sa Wn On Ny
| GSAT0221 | 17:59:29 | 18:24:41 | 00:25:12 | Sa Wn Ny
| GSAT0221 | 18:24:41 | 21:07:41 | 02:43:00 | Sa Wn Ny On
| GSAT0221 | 21:07:41 | 21:35:24 | 00:27:43 | Sa Wn On
| GSAT0221 | 21:35:24 | 22:01:18 | 00:25:54 | Wn On
adjust selected
adjust selected satellite scan
Stations 1 NYALES20
2 ONSALA60
3 RAEGSMAR
adjust selected
remove selected
Station NYALES20
Start 10.05.2019 04:46:12
End 10.05.2019 05:32:09
save
Satellite Station start end
GSAT0221 NYALES20 04:46:12 05:32:09
GSAT0221 ONSALA60 04:46:12 05:32:09
GSAT0221 RAEGSMAR 05:00:00 05:20:00
add to schedule
no schedules started

Outlook – next steps

- combination of my part and the software VieSched++
- semi-automatic mode
  - user manually select satellite scans → added as fixed scans to the schedule
  - schedule is filled with observations to quasars around satellite scans automatically

- Graphical User Interface

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Satellite Scheduling with VieSched++

Helene Wolf