# GSA

# GMES Station Analysis Tool

# Software User Manual

**8th May 2017**

**Ref. TTS-GSA-TN-0101 Iss.2.0**



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# 1. Introduction

The GSA, or **GMES Station Analysis Tool**, allows simulation and analysis of GMES payload station scenarios.

The GSA was initially developed to support Copernicus satellites, but has been engineered to support any mission.

The GSA provides advanced modeling of satellites orbit, sensors, on board recorders, downlink scenarios, ground station acquisition timelines, and multiple areas of interest. It supports also ground segment processors, algorithms, dissemination links and user access points with the goal of determining end-to-end delivery timelines.

The GSA simulates the planning of satellites, ground stations and their attached ground segment to implement the user requests expressed in terms of areas of interest and frequency and modality of acquisitions. The GSA models as well many mission constraints to comply with duty cycle, transition times, optimization rules, and many more.

The GSA is built as a plug-in module on top of the SaVoir application.

- SaVoir provides a well proven infrastructure in terms of Graphical User Interface, visualization capabilities, file input / output, configuration editing, etc.
- The GSA plugin provides for specific modeling of Copernicus satellites, on-board recorder and downlink planning, and additional visualization functions.

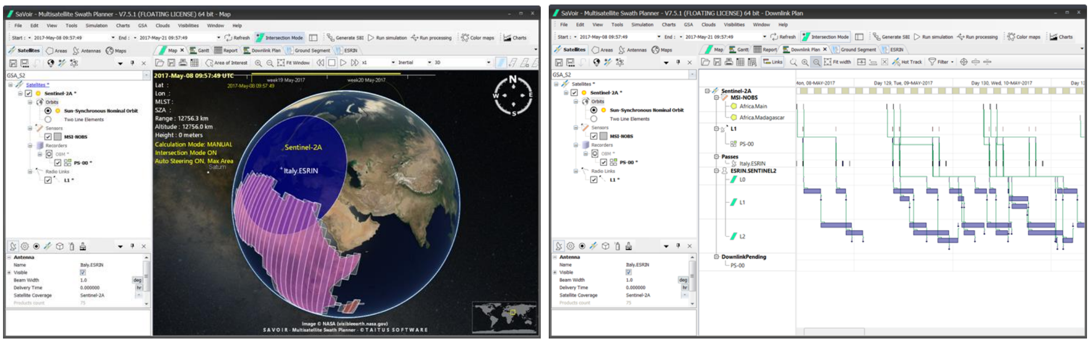

**Figure 1. SaVoir With GSA**

## 1.1 Document History

| Issue | Date | Comments |
|---|---|---|
| 2.0 | 8/5/17 | New issue with additions of Ground Segment planning |
| 1.0 | 14/4/13 | First Issue |

## 1.2 Acronyms

ANX Ascending Node Crossing
AOI Area of Interest
AOS Acquisition of Signal



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| | |
|---|---|
| DNX | Descending Node Crossing |
| DRS | Data Relay Satellite |
| EDRS | European Data Relay Satellite System |
| FIFO | First In First Out |
| FOS | Flight Operations Segment |
| FOV | Field of View |
| GMES | Global Monitoring of the Environment and Security |
| GSA | GMES Station Analysis tool |
| GUI | Graphical User Interface |
| LOS | Loss of Signal |
| MLST | Mean Local Solar Time at Ascending Node Crossing |
| NRT | Near Real Time |
| OBM | On Board Memory |
| OSAT | On Site acceptance testing |
| OSV | Orbit State Vector |
| OZA | Observation Zenith Angle |
| RF | Radio Frequency |
| ROEF | Reference Orbit Event File |
| SAR | Synthetic Aperture Radar |
| SBI | Simulation Baseline Input |
| SDP4 | Simplified General Perturbations model 4, for Deep Space (orbit period > 225 minutes) |
| SGP4 | Simplified General Perturbations, model 4 |
| SSO | Sun Synchronous Orbit |
| SxP4 | SGP4 / SDP4 algorithm |
| TLE | Two Line Elements |

# 2. Installation

## *2.1 Prior to installation*

GSA is a Plugin module to the SaVoir application. Make sure SaVoir is installed in your machine prior to installing GSA.

Any SaVoir licensed version (Stand – Alone or Floating) will operate with SaVoir.

The GSA plugin has a version number (latest 7.5.0) which has to match the version number of SaVoir indicating that they both have been compiled together and are consistent as regards the use of common libraries and data structures.

If the version numbers are not compatible GSA will refuse to load, so make sure you install the GSA plugin with the same version as SaVoir.



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## 2.2 Installing

Installing GSA requires simply executing the GSA installation setup.exe and following the installation wizard.

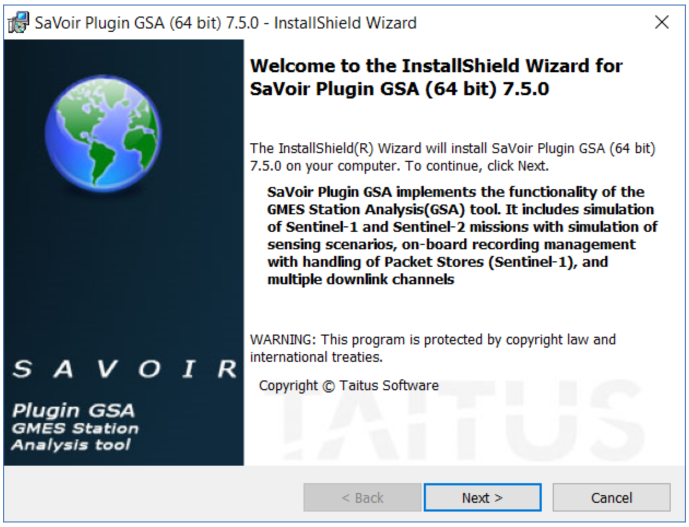


**Figure 2. Installer Wizard**

## 2.3 Verify GSA is installed

At the end of GSA installation, follow these steps:

Open SaVoir.

Verify the Top Menu includes a GSA menu header, and the tool bar includes the GSA toolbar, with "Generate SBI" and "Run Simulation" buttons.

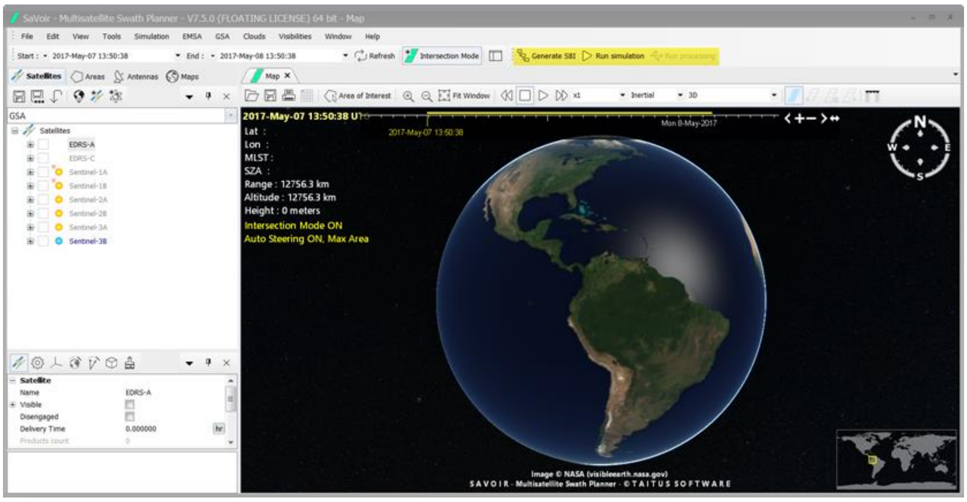

**Figure 3. GSA Opening Screen**

Open Edit / Properties / Plugins / Loaded, and verify that the GSA plugin is loaded and installed (checked).



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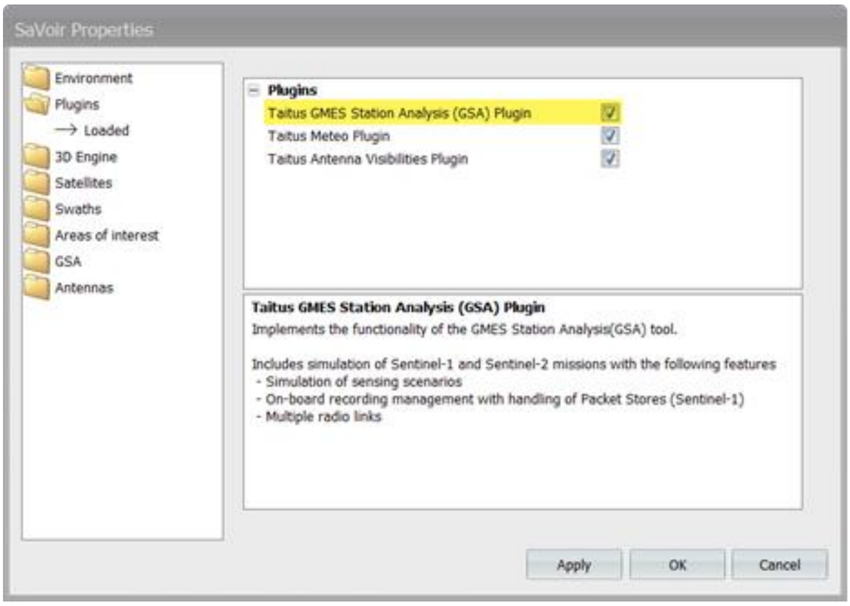


**Figure 4. Plugins Properties page**

Verify that the GSA Satellites, Regions and Antennas default configuration files have been installed in the factory cnf folder:

| | Folder | File |
|---|---|---|
| 32-bit | C:\Program Files(x86)\Taitus Software\SaVoir\cnf\satellites | _GSA.xml |
| | C:\Program Files(x86)\Taitus Software\SaVoir\cnf\antennas | _GSA_GroundSegment.xml |
| | C:\Program Files(x86)\Taitus Software\SaVoir\cnf\regions | _GSA_S1_Regions.xml |
| 64-bit | C:\Program Files\Taitus Software\SaVoir\cnf\satellites | _GSA.xml |
| | C:\Program Files\Taitus Software\SaVoir\cnf\antennas | _GSA_GroundSegment.xml |
| | C:\Program Files\Taitus Software\SaVoir\cnf\regions | _GSA_S1_Regions.xml |



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# 3. Quick start

This chapter provides a quick walk-through of GSA by defining a simple simulation scenario and running it to obtain results. It will illustrate the typical steps required to obtain results in GSA.

## *3.1 Simple satellite acquisition, downlink and processing*

As a quick start we will show a simple scenario of one satellite (Sentinel-2A), one sensor (MSI-NOBS), one area of interest (Africa), one Ground Station (Italy.ESRIN) and one processing chain and repository, as shown in Figure 8.

### 3.1.1 Layout preparation

Open SaVoir and select a simple Sentinel 2 simulation scenario as follows:

- Open the dropdown box on top of the Satellites scenario. Scroll down to select "Browse…" and select the sample scenario file GSA_S2.xml.

| | Folder | File |
|---|---|---|
| 32-bit | C:\Program Files(x86)\Taitus Software\SaVoir\samples\gsa\sentinel2_ESRIN | GSA_S2.xml |
| 64-bit | C:\Program Files\Taitus Software\SaVoir\samples\gsa\sentinel2_ESRIN | GSA_S2.xml |

- On the Areas pane select **Continents**
- Open the dropdown box on top of the Antennas scenario. Scroll down to select "Browse…" and select the sample scenario file GSA_ESRIN.xml.

| | Folder | File |
|---|---|---|
| 32-bit | C:\Program Files(x86)\Taitus Software\SaVoir\samples\gsa\sentinel2_ESRIN | GSA_ESRIN.xml |
| 64-bit | C:\Program Files\Taitus Software\SaVoir\samples\gsa\sentinel2_ESRIN | GSA_ESRIN.xml |

- Set Manual Intersection Mode.

  This is advisable to avoid automatic triggering of intersection calculation when activating regions or sensors. In Manual Intersection Mode intersection calculation will be triggered only when explicitly pressing the Refresh or the Generate SBI buttons. To set Manual Intersection Mode go to **Edit / Properties / Swaths / Intersections / Calculation = Manual**. Notice that the Label "Calculation Mode: MANUAL" will appear on the top left corner of the Map View.

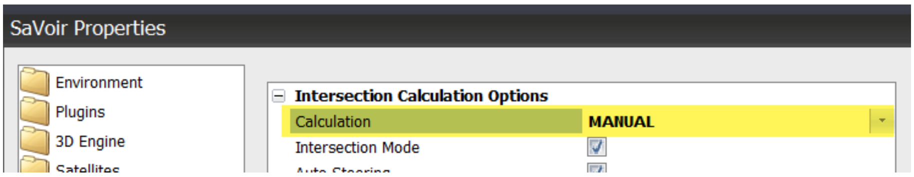


**Figure 5. Setting Manual Intersection Mode**

- Make sure **Intersection Mode** is enabled on the main toolbar.



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### 3.1.2 Define the simulation scenario

- Set the simulation time. From the application toolbar select 14 days.

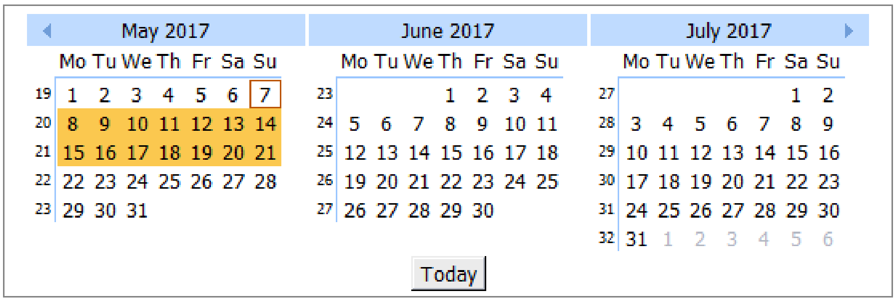


**Figure 6. SaVoir Time selection interactive calendar**

- On the Satellite Scenario panel select a satellite sensor configuration. Select **MSI-NOBS** on **Sentinel-2A**.
- On the Areas pane select **Africa.** If not available in the Continents scenario, press "Revert" to revert to the factory scenario.
- On the Antennas pane select **Italy.ESRIN**.

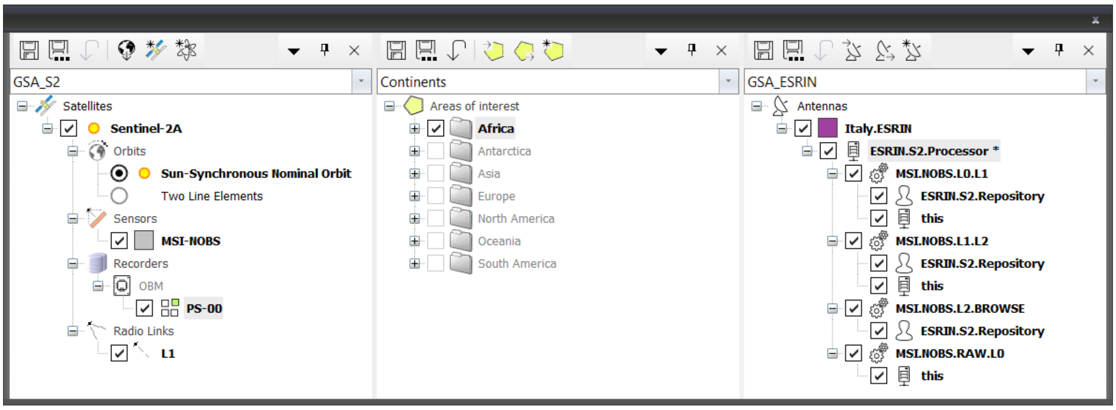


**Figure 7. GSA Scenario panes**

### 3.1.3 Check out the Ground Segment configuration

The Ground Segment is defined in the antennas file GSA_ESRIN.xml, containing an antenna at ESRIN feeding a Processing computer with algorithms for generation of Level-0, 1, 2 and Browse products to be stored in a User Access Point collocated at ESRIN.

You may obtain a global ground segment diagram in menu "GSA / Ground Segment Diagram"



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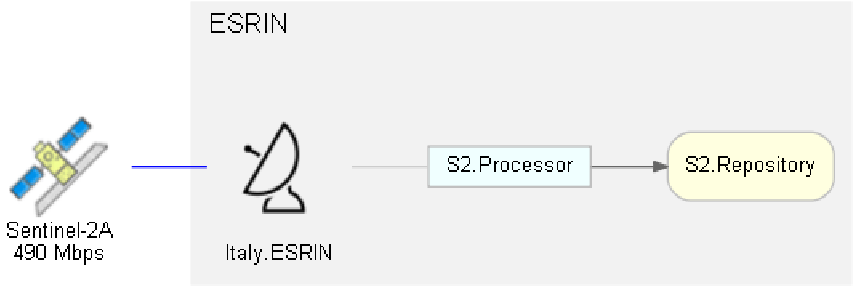


**Figure 8. Ground Segment Diagram**

A more detailed "center" diagram can be obtained by right-click on the Italy.ESRIN antenna and selecting "Center diagram" which shows a more detailed breakdown of the processing and dissemination workflow.



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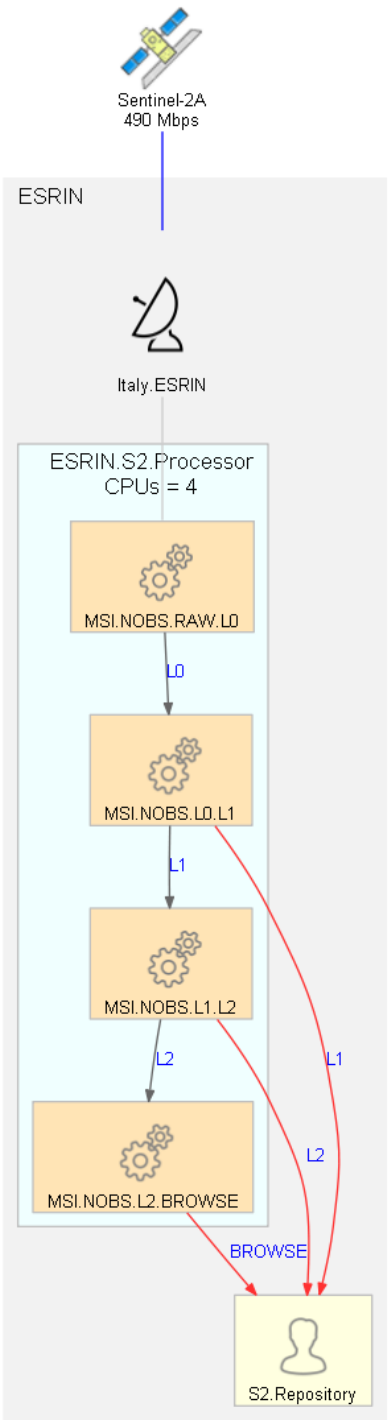


**Figure 9. Center Diagram**

This configuration shows that data from Sentinel-2 is downlinked to ESRIN station, and then processed in the 4-CPU Esrin Sentinel-2 processor, through 4 sequential algorithms: from raw to L0, then to level 1, level 2 and browse. The outputs of L1, L2 and browse are sent to the ESRIN Sentinel 2 repository.



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### 3.1.4 Generate the SBI

The SBI (Simulation Baseline Input) is a basic acquisition and downlink opportunity plan that provides the input elements to the simulator in terms of:

- Candidate timeline of swath acquisitions compatible with instrument and AOI constraints.
- Candidate timeline of downlink opportunities over compatible ground stations (antennas).

To generate the SBI just press the SBI button on the GSA toolbar or, on the GSA menu, select "**Generate SBI**".

Verify that a timeline of 14 days is generated by inspecting the Gantt view.

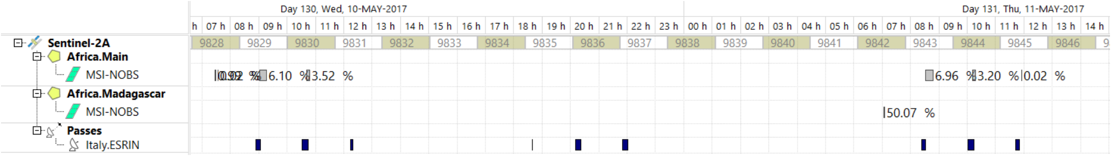


**Figure 10. SBI Gantt display**

### 3.1.5 Running a simulation

Click on the "**Run Simulation**" button on the application toolbar to launch the simulation of on-board recording and downlink based on the generated SBI.

Wait few minutes to obtain a timeline of storage and downlink plan for the defined SBI.

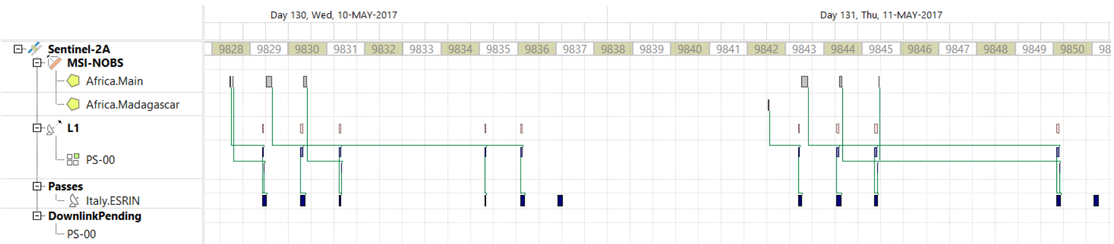


**Figure 11. Downlink Plan display**

### 3.1.6 Run processing simulation

Click on the "**Run Processing**" button on the application toolbar to launch the simulation of Ground Segment processing based on the downlinked data.

A timeline of processing and dissemination will be shown on the downlink plan window.



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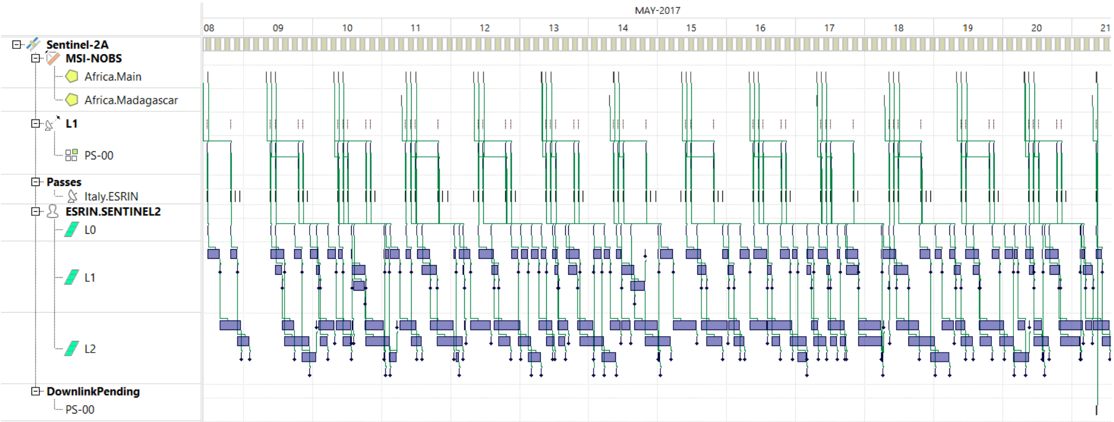

**Figure 12. Downlink Plan with Ground Segment processing and dissemination**

Right click on any downlink task (e.g. a L2 task) and select "View tree" to focus on the processing timeline of a given acquisition. This will show the simulated timeline from sensing to downlink, processing, dissemination and reception at user access points, also called repositories.

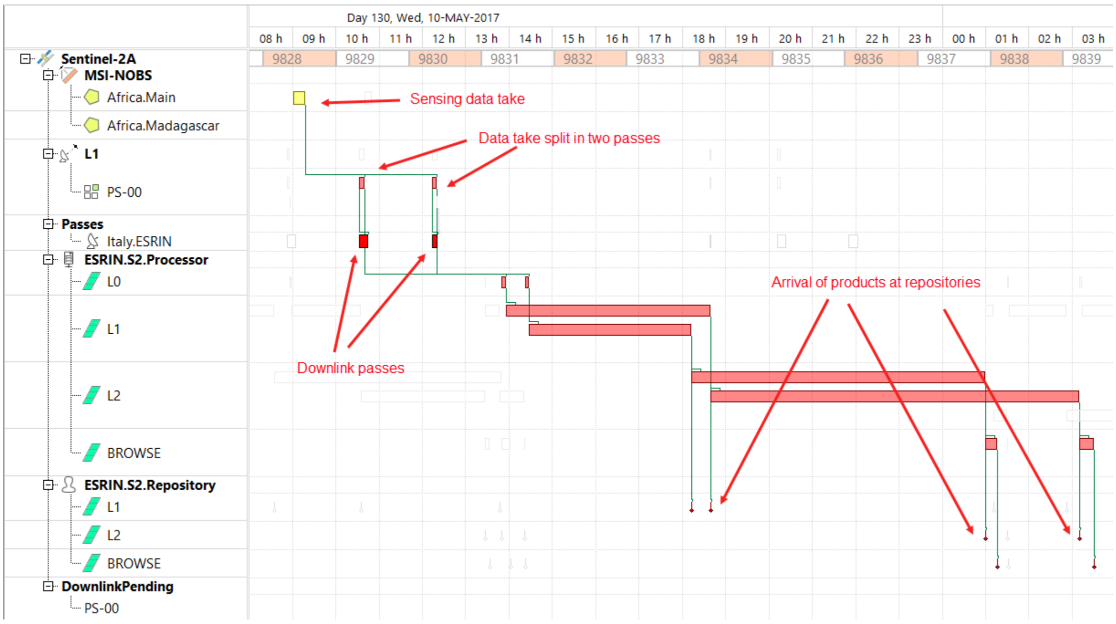


**Figure 13. Breakdown of production timeline**

### 3.1.7 Check simulation output and reports

The GSA will produce the following

- Downlink plan, with or without processing, as seen in Figure 11. Figure 13.
- On board memory size profiles for all packets stores and per-packet store, as shown in Figure 14. Figure 15. (trigger with menu GSA / On-board memory size and GSA / On-board data take count)
- Count of data takes profiles, as shown in Figure 14. Figure 15. (trigger with menu GSA / On-board data take count)



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- End-to-end sensing delivery times, as shown in Figure 16. (trigger with menu GSA / End to end)
- Packet Store allocation tables (in text form and in Excel), as shown in Figure 17. (trigger with menu GSA / Packet store / Data Allocation)
- Sensing and downlink statistics, as shown in Figure 19. (trigger with menu GSA / Statistics / Sensing and downlink).
- Processing statistics, as shown in Figure 20. (trigger with menu GSA / Statistics / Processing
- All outputs can be generated via the GSA top menu after any simulation run.

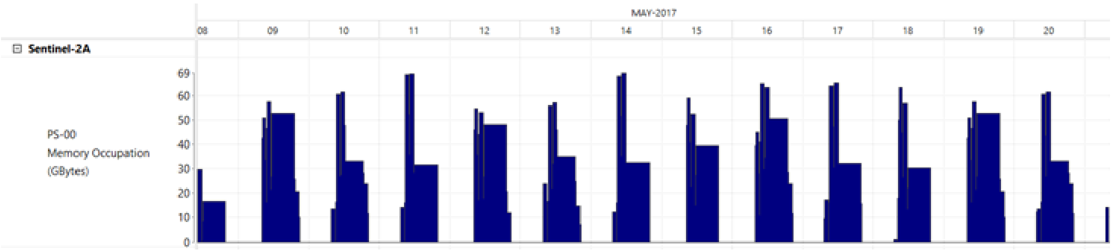


**Figure 14. Memory occupation profiles**

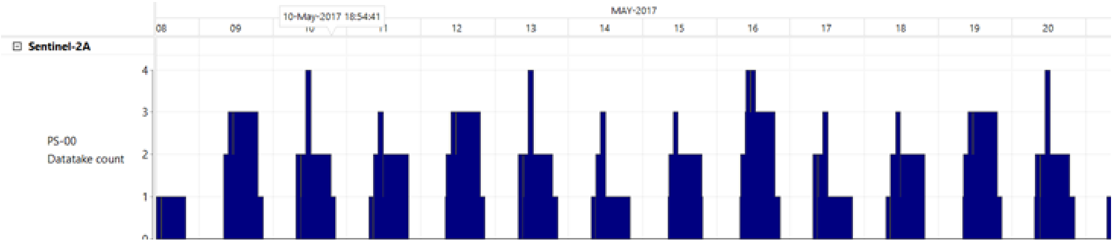


**Figure 15. Data Take Count profiles**

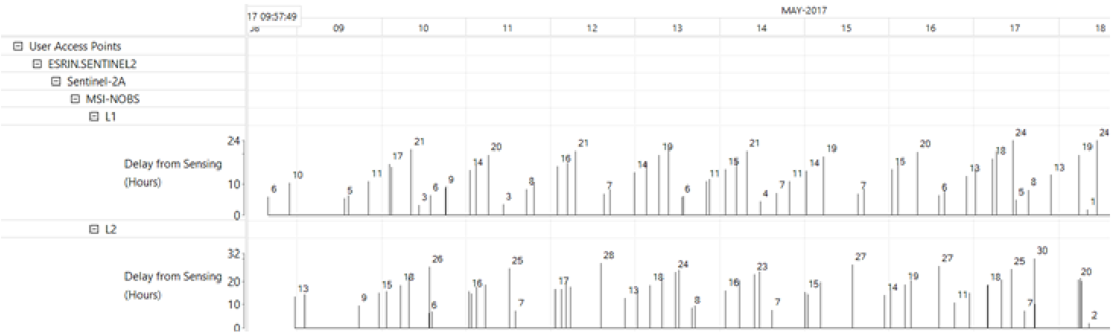


**Figure 16. End-to-end, “sensing-to-delivery” latency times**



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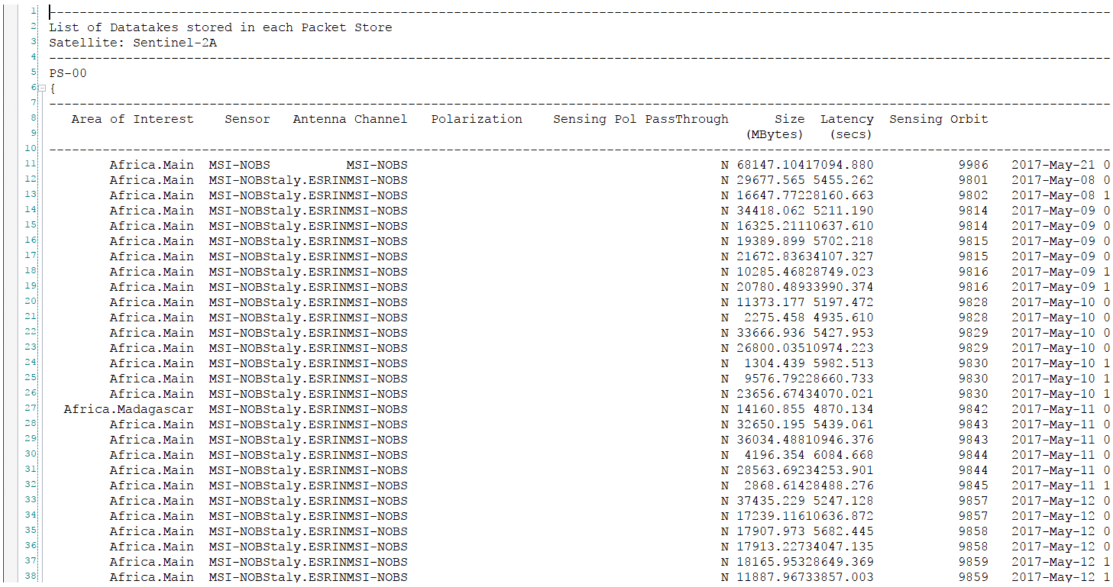
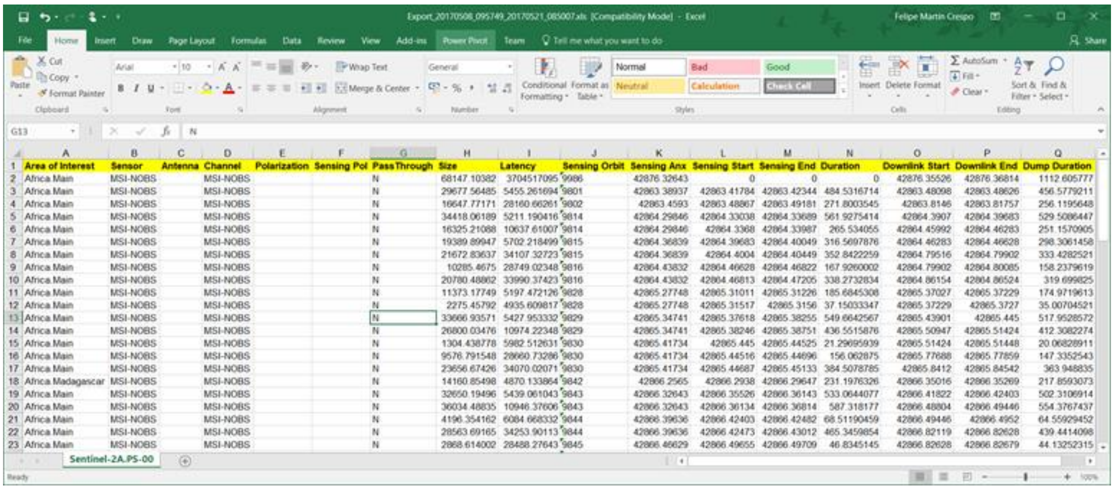


```
----------------------------------------------------------------------------------------------------------------------------------------------------------
List of Datatakes stored in each Packet Store
Satellite: Sentinel-2A
----------------------------------------------------------------------------------------------------------------------------------------------------------
PS-00
{
----------------------------------------------------------------------------------------------------------------------------------------------------------
   Area of Interest    Sensor   Antenna Channel   Polarization    Sensing Pol PassThrough      Size  Latency  Sensing Orbit
                                                                                          (MBytes)    (secs)
----------------------------------------------------------------------------------------------------------------------------------------------------------
        Africa.Main  MSI-NOBS          MSI-NOBS                                          N 68147.10417094.880          9986   2017-May-21 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 29677.565 5455.262          9801   2017-May-08 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 16647.77228160.663          9802   2017-May-08 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 34418.062 5211.190          9814   2017-May-09 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 16325.21110637.610          9814   2017-May-09 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 19389.899 5702.218          9815   2017-May-09 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 21672.83634107.327          9815   2017-May-09 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 10285.46828749.023          9816   2017-May-09 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 20780.48933990.374          9816   2017-May-09 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 11373.177 5197.472          9828   2017-May-10 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N  2275.458 4935.610          9828   2017-May-10 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 33666.936 5427.953          9829   2017-May-10 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 26800.03510974.223          9829   2017-May-10 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N  1304.439 5982.513          9830   2017-May-10 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N  9576.79228660.733          9830   2017-May-10 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 23656.67434070.021          9830   2017-May-10 1
  Africa.Madagascar  MSI-NOBStaly.ESRINMSI-NOBS                                          N 14160.855 4870.134          9842   2017-May-11 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 32650.195 5439.061          9843   2017-May-11 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 36034.48810946.376          9843   2017-May-11 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N  4196.354 6084.668          9844   2017-May-11 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 28563.69234253.901          9844   2017-May-11 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N  2868.61428488.276          9845   2017-May-11 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 37435.229 5247.128          9857   2017-May-12 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 17239.11610636.872          9857   2017-May-12 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 17907.973 5682.445          9858   2017-May-12 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 17913.22734047.135          9858   2017-May-12 0
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 18165.95328649.369          9859   2017-May-12 1
        Africa.Main  MSI-NOBStaly.ESRINMSI-NOBS                                          N 11887.96733857.003          9859   2017-May-12 1
```

**Figure 17. Packet Store / Data Take allocation (text)**



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | Area of Interest | Sensor | Antenna | Channel | Polarization | Sensing Pol | PassThrough | Size |
| 2 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 68147.10382 |
| 3 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 29677.56485 |
| 4 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 16647.77171 |
| 5 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 34418.06189 |
| 6 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 16325.21088 |
| 7 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 19389.89947 |
| 8 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 21672.83637 |
| 9 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 10285.4675 |
| 10 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 20780.48862 |
| 11 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 11373.17749 |
| 12 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 2275.45792 |
| 13 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 33666.93571 |
| 14 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 26800.03476 |
| 15 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 1304.438778 |
| 16 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 9576.791548 |
| 17 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 23656.67426 |
| 18 | Africa.Madagascar | MSI-NOBS | | MSI-NOBS | | | N | 14160.85498 |
| 19 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 32650.19496 |
| 20 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 36034.48835 |
| 21 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 4196.354162 |
| 22 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 28563.69165 |
| 23 | Africa.Main | MSI-NOBS | | MSI-NOBS | | | N | 2868.614002 |

| | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Latency | Sensing Orbit | Sensing Anx | Sensing Start | Sensing End | Duration | Downlink Start | Downlink End | Dump Duration |
| 2 | 3704517095 | 9986 | 42876.32643 | 0 | 0 | 0 | 42876.35526 | 42876.36814 | 1112.605777 |
| 3 | 5455.261694 | 9801 | 42863.38937 | 42863.41784 | 42863.42344 | 484.5316714 | 42863.48098 | 42863.48626 | 456.5779211 |
| 4 | 28160.66261 | 9802 | 42863.4593 | 42863.48867 | 42863.49181 | 271.8003545 | 42863.8146 | 42863.81757 | 256.1195648 |
| 5 | 5211.190416 | 9814 | 42864.29846 | 42864.33038 | 42864.33689 | 561.9275414 | 42864.3907 | 42864.39683 | 529.5086447 |
| 6 | 10637.61007 | 9814 | 42864.29846 | 42864.3368 | 42864.33987 | 265.534055 | 42864.45992 | 42864.46283 | 251.1570905 |
| 7 | 5702.218499 | 9815 | 42864.36839 | 42864.39683 | 42864.40049 | 316.5697876 | 42864.46283 | 42864.46628 | 298.3061458 |
| 8 | 34107.32723 | 9815 | 42864.36839 | 42864.4004 | 42864.40449 | 352.8422259 | 42864.79516 | 42864.79902 | 333.4282521 |
| 9 | 28749.02348 | 9816 | 42864.43832 | 42864.46628 | 42864.46822 | 167.9260002 | 42864.79902 | 42864.80085 | 158.2379619 |
| 10 | 33990.37423 | 9816 | 42864.43832 | 42864.46813 | 42864.47205 | 338.2732834 | 42864.86154 | 42864.86524 | 319.699825 |
| 11 | 5197.472126 | 9828 | 42865.27748 | 42865.31011 | 42865.31226 | 185.6845308 | 42865.37027 | 42865.37229 | 174.9719613 |
| 12 | 4935.609817 | 9828 | 42865.27748 | 42865.31517 | 42865.3156 | 37.15033347 | 42865.37229 | 42865.3727 | 35.00704521 |
| 13 | 5427.953332 | 9829 | 42865.34741 | 42865.37618 | 42865.38255 | 549.6642567 | 42865.43901 | 42865.445 | 517.9528572 |
| 14 | 10974.22348 | 9829 | 42865.34741 | 42865.38246 | 42865.38751 | 436.5515876 | 42865.50947 | 42865.51424 | 412.3082274 |
| 15 | 5982.512631 | 9830 | 42865.41734 | 42865.445 | 42865.44525 | 21.29695939 | 42865.51424 | 42865.51448 | 20.06828911 |
| 16 | 28660.73286 | 9830 | 42865.41734 | 42865.44516 | 42865.44696 | 156.062875 | 42865.77688 | 42865.77859 | 147.3352543 |
| 17 | 34070.02071 | 9830 | 42865.41734 | 42865.44687 | 42865.45133 | 384.5078785 | 42865.8412 | 42865.84542 | 363.948835 |
| 18 | 4870.133864 | 9842 | 42866.2565 | 42866.2938 | 42866.29647 | 231.1976326 | 42866.35016 | 42866.35269 | 217.8593073 |
| 19 | 5439.061043 | 9843 | 42866.32643 | 42866.35526 | 42866.36143 | 533.0644077 | 42866.41822 | 42866.42403 | 502.3106914 |
| 20 | 10946.37606 | 9843 | 42866.32643 | 42866.36134 | 42866.36814 | 587.318177 | 42866.48804 | 42866.49446 | 554.3767437 |
| 21 | 6084.668332 | 9844 | 42866.39636 | 42866.42403 | 42866.42482 | 68.51190459 | 42866.49446 | 42866.4952 | 64.55929452 |
| 22 | 34253.90113 | 9844 | 42866.39636 | 42866.42473 | 42866.43012 | 465.3459854 | 42866.82119 | 42866.82628 | 439.4414098 |
| 23 | 28488.27643 | 9845 | 42866.46629 | 42866.49655 | 42866.49709 | 46.8345145 | 42866.82628 | 42866.82679 | 44.13252315 |



**Figure 18. Packet Store / Data Take allocation (Excel)**



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```
----------------------------------------------------------------------------------------------------------------
GSA simulation statistics
Execution date:2017-May-08 12:54:31.000ZL
Simulation period: 2017-May-08 09:57:49.000Z to 2017-May-21 08:50:07.486Z
----------------------------------------------------------------------------------------------------------------
Satellite: Sentinel-2A
{
----------------------------------------------------------------------------------------------------------------
          Data takes        Single       %         Double       %          TOTAL        %          units
{
----------------------------------------------------------------------------------------------------------------
                 All           121                      0                     121
                Lost             0     0.0              0                       0     0.0
              Stored           121   100.0              0                     121   100.0
       Full downlink            46    38.0              0                      46    38.0
    Partial downlink             0     0.0              0                       0     0.0
         No downlink            75    62.0              0                      75    62.0
      Split downlink            28    23.1              0                      28    23.1

                 All         60832                      0                   60832              seconds
                Lost             0     0.0              0                       0     0.0      seconds
              Stored         60832   100.0              0                   60832   100.0      seconds
       Full downlink         24722    40.6              0                   24722    40.6      seconds
    Partial downlink             0     0.0              0                       0     0.0      seconds
         No downlink         36110    59.4              0                   36110    59.4      seconds
      Split downlink         20345    33.4              0                   20345    33.4      seconds

                 All      1514.234                  0.000                1514.234               GBytes
                Lost         0.000     0.0          0.000                   0.000     0.0       GBytes
              Stored      1514.234   100.0          0.000                1514.234   100.0       GBytes
       Full downlink      1514.234   100.0          0.000                1514.234   100.0       GBytes
    Partial downlink         0.000     0.0          0.000                   0.000     0.0       GBytes
         No downlink         0.000     0.0          0.000                   0.000     0.0       GBytes
      Split downlink      1246.142    82.3          0.000                1246.142    82.3       GBytes

}
----------------------------------------------------------------------------------------------------------------
      Downlink Usage    Period        Passes    Visibility     L1 Unused           L2 Unused
```

**Figure 19. Overall GSA Statistics**

```
--------------------------------------------
Report on Data Reception delays at User Access Points

--------------------------------------------
ESRIN.SENTINEL2
End to End Report
--------------------------------------------
           Overall Report
     Number of Products: 156
                                      Min         Avg         Max
  Delay from sensing (hours)        1.490      15.328      32.353
     Delay from dump (hours)        0.142      11.084      22.853
Persistence on-board (hours)        1.336       4.244       9.565


             Satellite : Sentinel-2A
                Sensor : MSI-NOBS
          Product Type : L1
     Number of Products: 78
                                      Min         Avg         Max
  Delay from sensing (hours)        1.490      12.915      24.232
     Delay from dump (hours)        0.142       8.672      17.753
Persistence on-board (hours)        1.336       4.244       9.565


             Satellite : Sentinel-2A
                Sensor : MSI-NOBS
          Product Type : L2
     Number of Products: 78
                                      Min         Avg         Max
  Delay from sensing (hours)        1.734      17.741      32.353
     Delay from dump (hours)        0.386      13.497      22.853
Persistence on-board (hours)        1.336       4.244       9.565
```

**Figure 20. Processing statistics**

## 3.2 Complex satellite acquisition, downlink and processing

Here we will exercise a more complex scenario with two satellites (Sentinel-1 and Sentinel-2) and a complex ground segment made of 5 ground stations.

### 3.2.1 Layout preparation

Open SaVoir and select a multi satellite sample scenario as follows:

Open the dropdown box on top of the Satellites scenario. Scroll down to select "Browse…" and select the sample scenario file GSA_Satellites_multi.xml.



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| | Folder | File |
|---|---|---|
| 32-bit | C:\Program Files(x86)\Taitus Software\SaVoir\samples\gsa\multisatellite | GSA_Satellites_multi.xml |
| 64-bit | C:\Program Files\Taitus Software\SaVoir\samples\gsa\multisatellite | GSA_Satellites_multi.xml |

- On the Areas pane select **Continents**
- Open the dropdown box on top of the Antennas scenario. Scroll down to select "Browse…" and select the sample scenario file GSA_Antennas_multi.xml.

| | Folder | File |
|---|---|---|
| 32-bit | C:\Program Files(x86)\Taitus Software\SaVoir\samples\gsa\multisatellite | GSA_Antennas_multi.xml |
| 64-bit | C:\Program Files\Taitus Software\SaVoir\samples\gsa\multisatellite | GSA_Antennas_multi.xml |

- Set Intersection Mode and Manual Intersection Mode.

### 3.2.2 Define the simulation scenario

- Set the simulation time. From the application toolbar select 48 hours period.

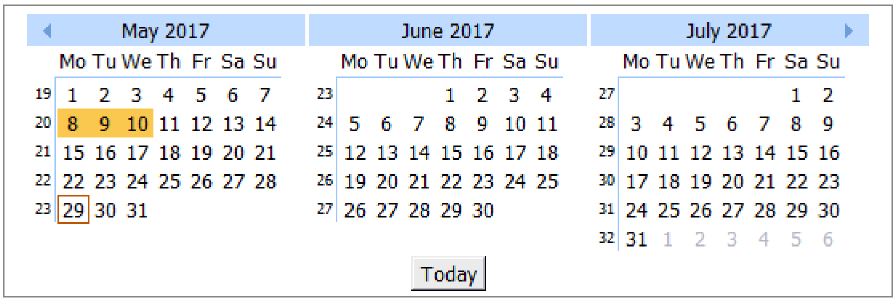


**Figure 21. SaVoir Time selection interactive calendar**

- On the Satellite Scenario panel select a satellite sensor configuration. Select **MSI-NOBS** on **Sentinel-2A, and CSAR/IWS on Sentinel-1A**.
- On the Areas pane select **Africa.** If not available in the Continents scenario, press "Revert" to revert to the factory scenario.
- On the Antennas pane select them all.



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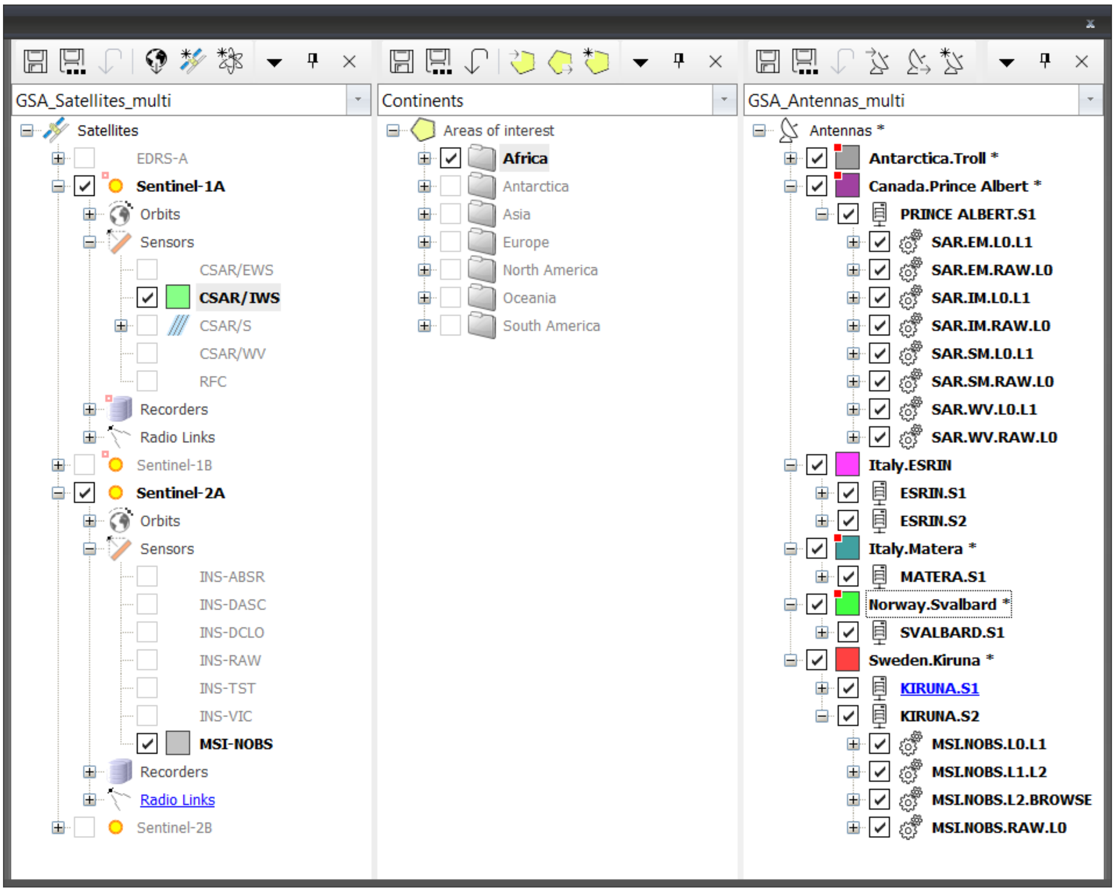


**Figure 22. GSA Scenario panes**

### 3.2.3 Check out the Ground Segment configuration

You may obtain a global ground segment diagram in menu “GSA / Ground Segment Diagram”



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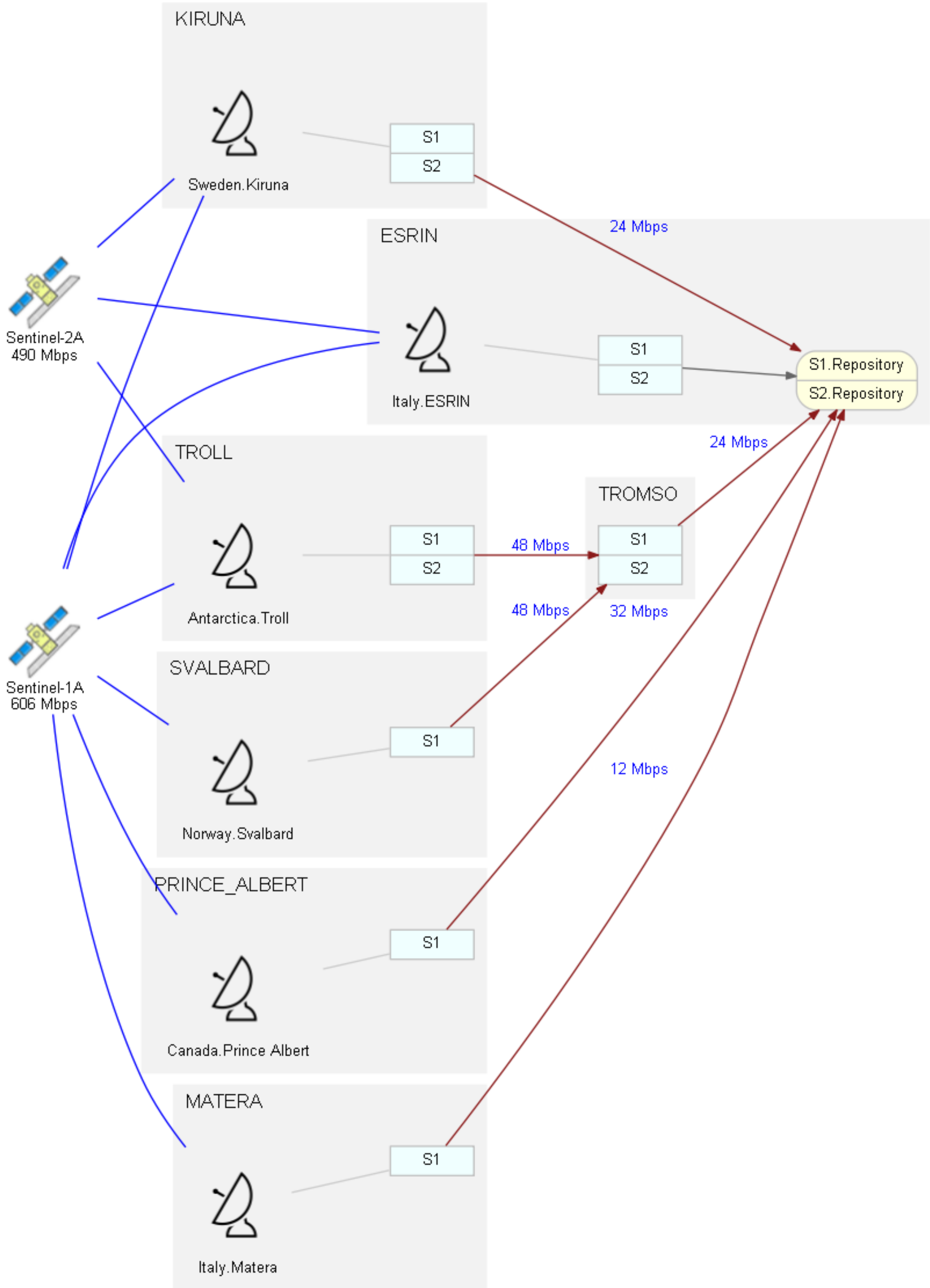


**Figure 23. Ground Segment Diagram**



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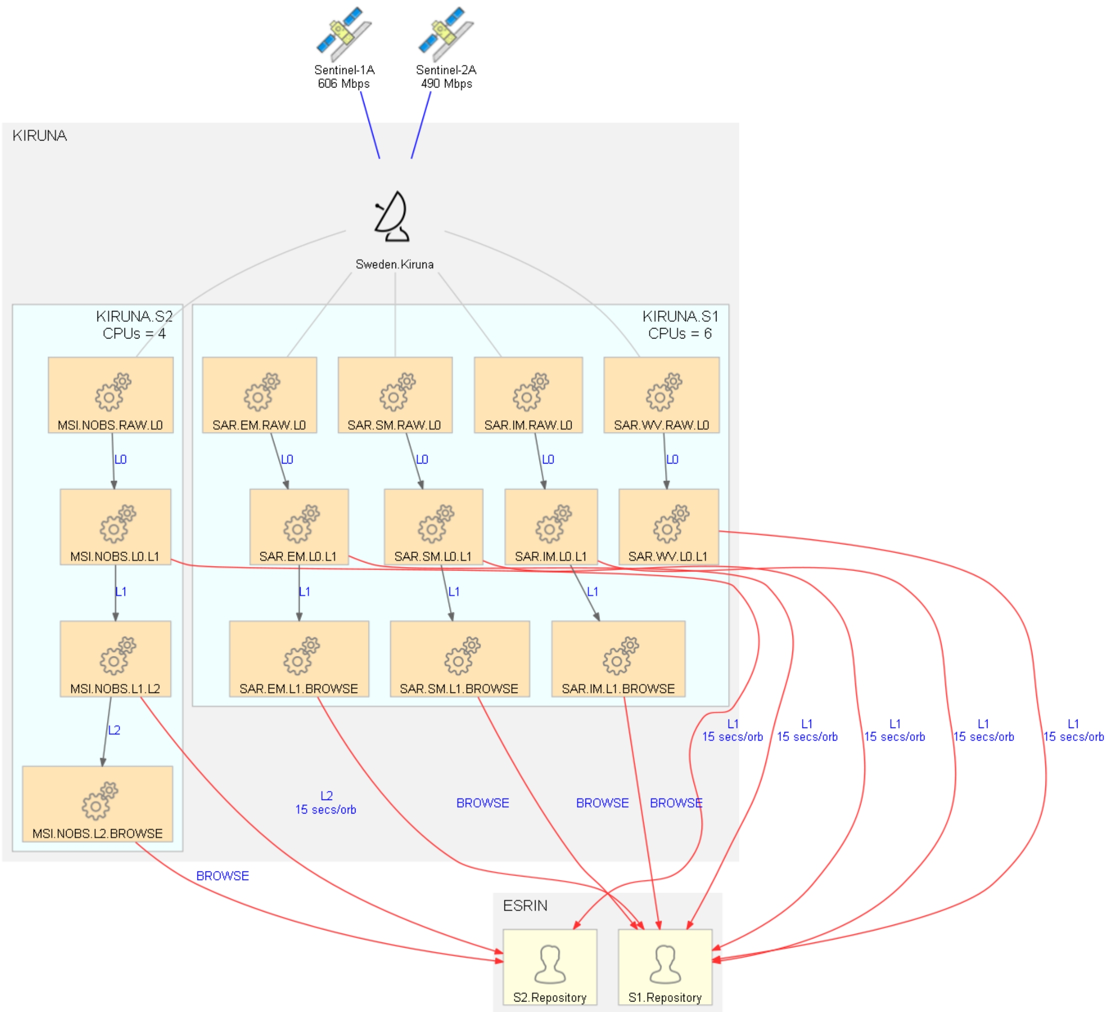


**Figure 24. Center diagram (Kiruna)**

### 3.2.4 Running a simulation

Run a simulation of sensing, downlink and processing to obtain the downlink plan and the associated end-to-end data



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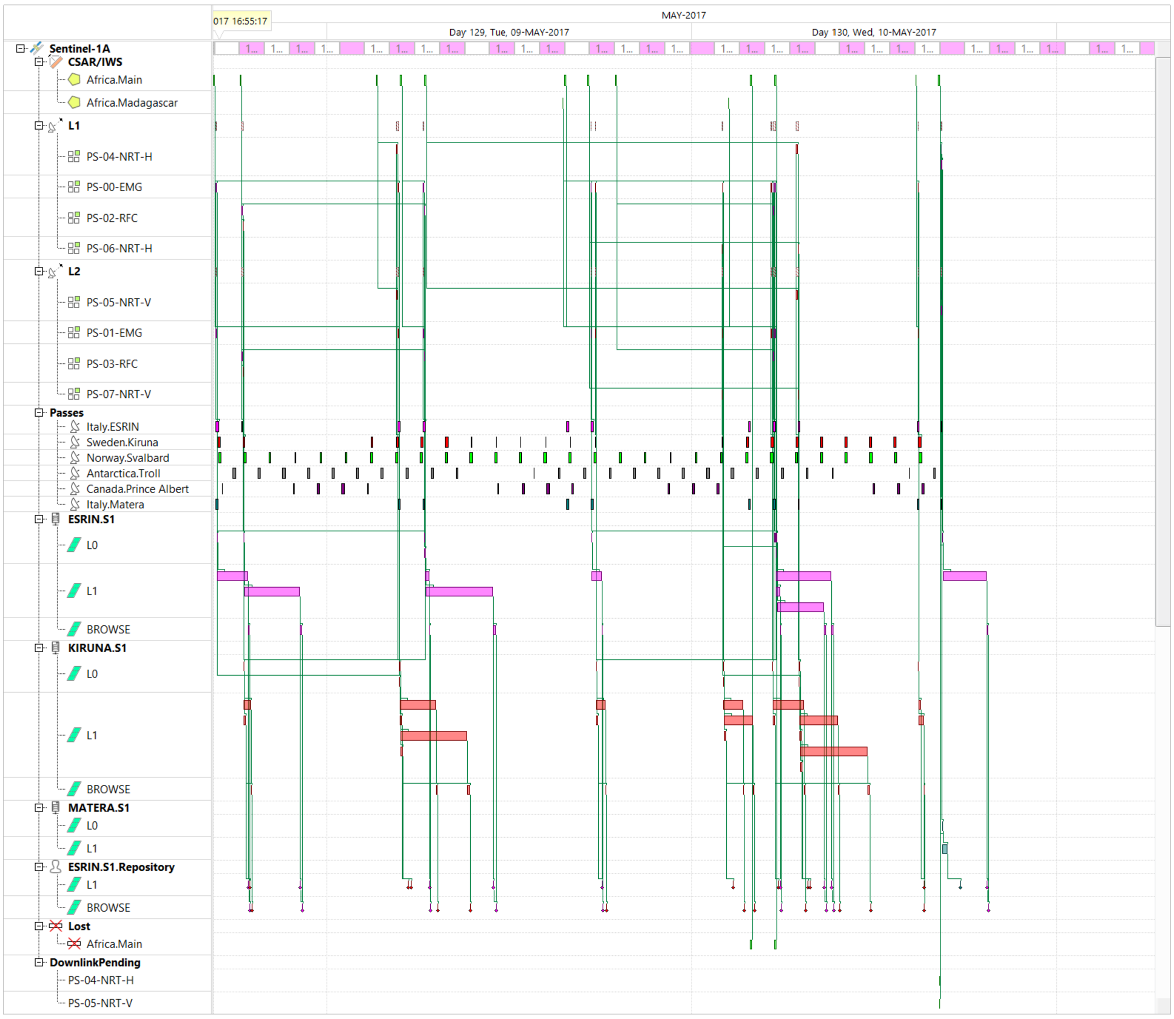


**Figure 25. Downlink and processing**

## 3.3 Handling Data Relay Satellites

SaVoir and GSA plugin support DRS links. We will demonstrate this with a simple scenario when Sentinel-1 is supported by EDRS-A satellite. We will downlink over ESRIN in DRS mode and over Kiruna in X-Band.

### 3.3.1 Load sample scenario

Open the GSA_Satellites_DRS.xml and GSA_Antennas_DRS.xml scenarios in folder

| | Folder | File |
|---|---|---|
| 32-bit | C:\Program Files (x86)\Taitus Software\SaVoir\samples\gsa\drs | GSA_Satellites_DRS.xml<br>GSA_Antennas_DRS.xml |
| 64-bit | C:\Program Files\Taitus Software\SaVoir\samples\gsa\drs | |

Select the Continents AOI scenario, and select Africa.



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We will convert Italy.ESRIN ground station to a DRS ground station:

1. Right click on the Italy.ESRIN antenna and open the Antenna wizard.
2. Skip the wizard pages until reaching the DRS page, and configure a DRS link with EDRS-A

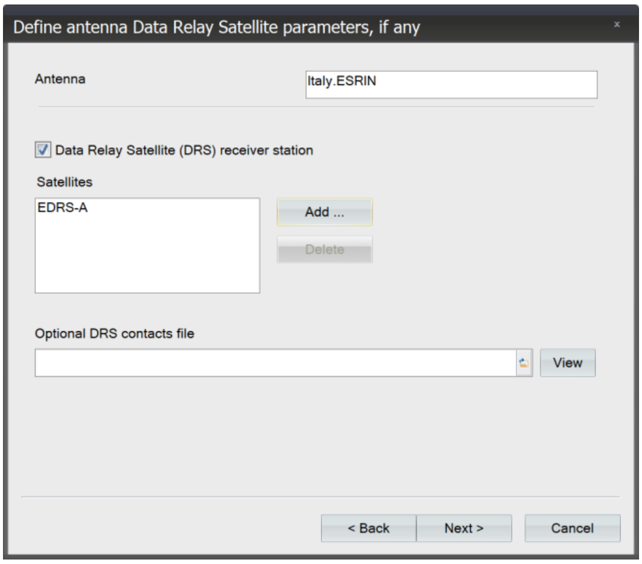
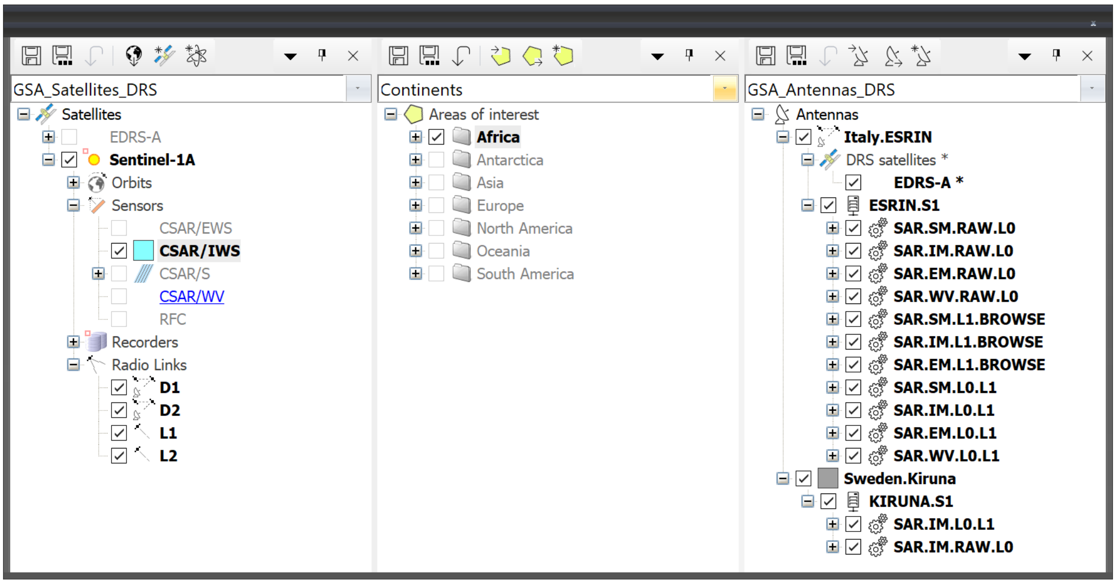



**Figure 26. Antenna DRS wizard page**

3. Close the wizard and check that Italy.ESRIN is now configured as a DRS station




**4. Sample DRS scenario**



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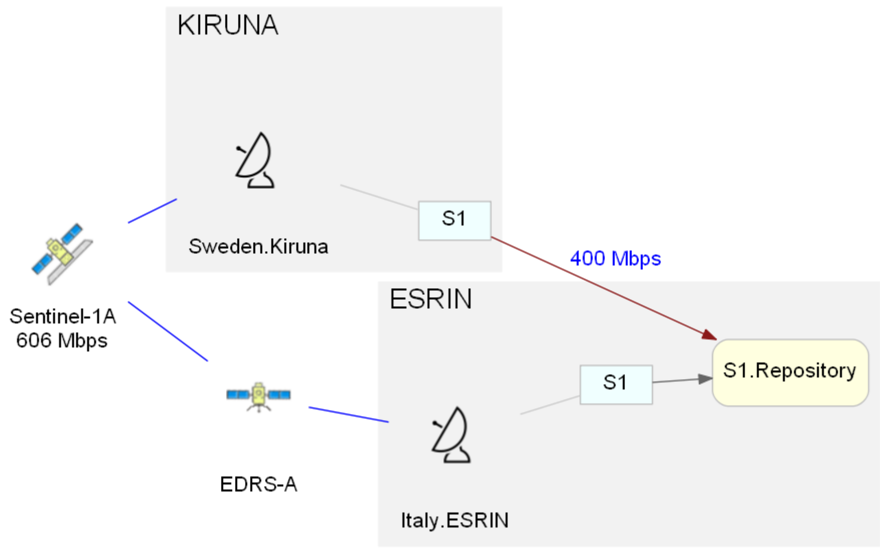


**5. Sample DRS Ground segment**

Run a simulation to verify that the ground segment is now operated with a DRS satellite over ESRIN.

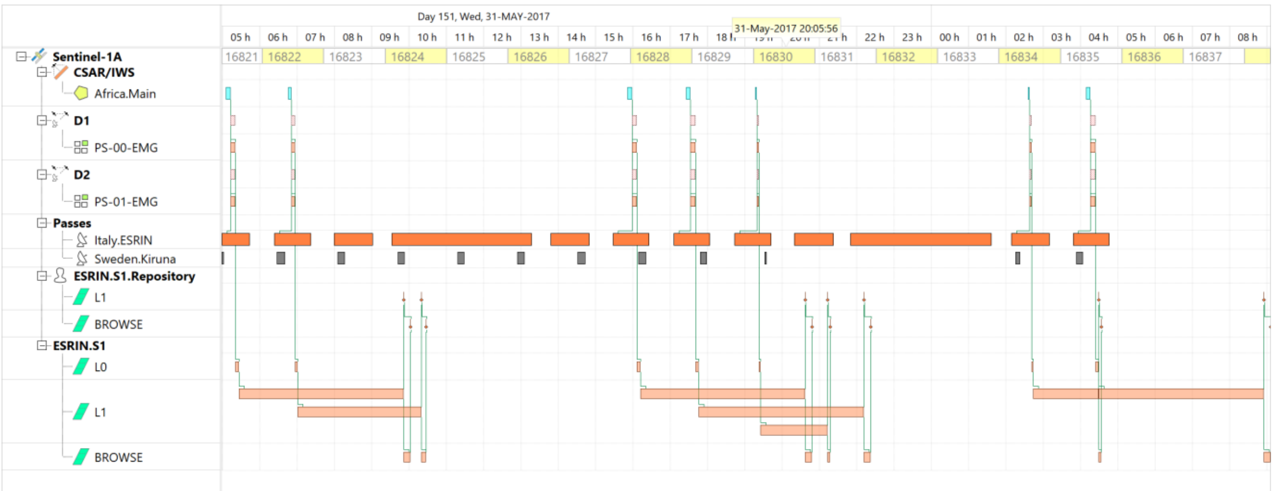


**Figure 27. Downlink and processing simulation with DRS**



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# 4. GSA Fundamentals

SaVoir domain is mostly the modeling of satellite orbits, sensor geometries and constraints, areas of interest and acquisition plans. SaVoir is also capable of calculating satellite to antenna visibility contacts.

In short, we could say that SaVoir domain is the "**Sensing domain**", including a capability to calculate potential latency times between sensing and downlink.

The GSA extends the SaVoir domain to "**On-Board Storage domain**" and "**Downlink domain**".

- **On board storage** is covered by modeling the on-board recorder operation including Packet Stores implementing different recording policies according to input sensor, polarization, timeliness, and antenna and region constraints.
- **Downlink** is covered by modeling the recorder dump policies during downlink opportunities, including priority downlink, pass-through modes, downlink to Local and Core ground stations, management of the RF downlink channels, and implementing numerous configurable constraints conditioning the downlink planning.

The simulation input is always as follows:

- A time window (absolute dates and times)
- One or several satellites, with selected sensors, packet stores and downlink channels
- One or several Areas of Interest
- One or several Downlink Stations (Antennas).

SaVoir will calculate the SBI (Simulation Baseline Input) by determining the potential swath acquisitions and the downlink opportunities.

GSA will perform the simulation proper, by providing a plan of On-Board data recording, including Pass-Through downlink, and organization of on-board data storage according to Packet Stores and their constraints, and providing a downlink plan to ground stations (antennas). In doing so it will need to simulate the running Packet Store which will alternatively do storage and dump operations, while keeping control that the storage capacity limits are kept under defined limits.

## 4.1 Time window

The time window is typically defined in the toolbar drop-down combo boxes, by click and drag on the provided calendars.

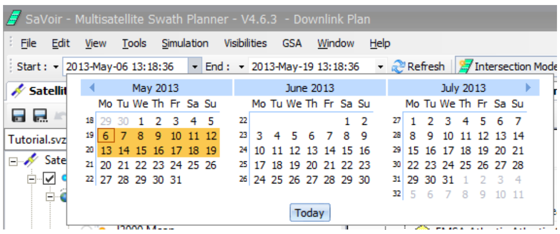


**Figure 28. Time selection calendar**



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It is also possible to define time, to seconds accuracy, by editing the time tag on the Start or End time combo box edit window.

As a result of the time window selection, the map time bar will be updated. The Map time bar allows navigating in time by click and drag, and mouse-wheel zoom to fix accurate map visualization events.


**Figure 29. Map Time Bar**

In addition, SaVoir offers the possibility to make advanced time window setting via Edit / Time / Advanced ... menu (also accessible from the dropdown menu on the main tool bar, below the Start and End buttons). This will open the time definition dialog which, among other functions, permits adjusting the time window according to orbit and cycle (for SSO orbits) boundaries.

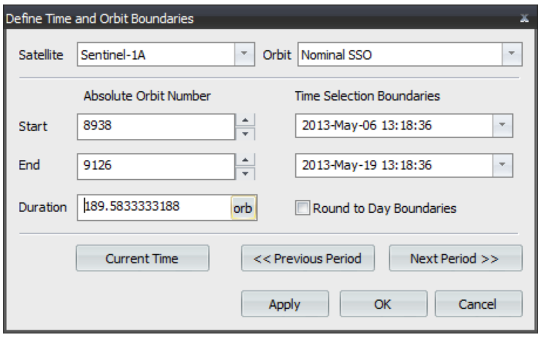


**Figure 30. Advanced time selection**

## 4.2 Scenario Panes

The GUI provides several scenario panes defining the GSA configuration. There are 3 scenario panes (Satellites, Areas of Interest and Antennas) and one Maps pane.

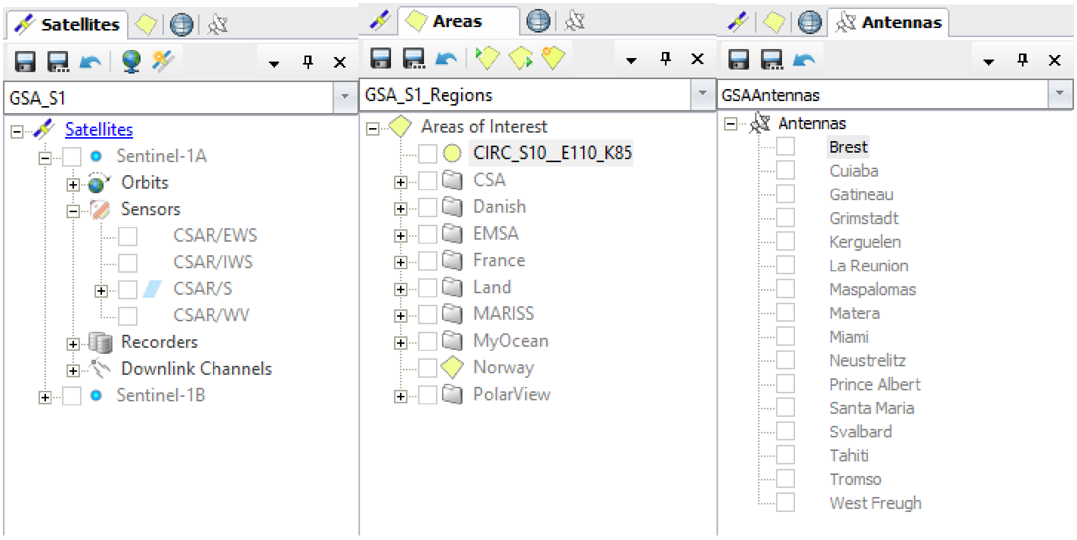




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**Figure 31. Satellites, Areas of Interest and Antennas panes**

You may change scenarios by selecting them from the dropdown box on top of the scenario tree.

Scenarios are defined in XML files. GSA is preconfigured with a several different scenarios. It includes configurations ffor Sentinel-1 and Sentinel-2.

Defining scenarios is complex because it ussually involves many elements, each one with many parameters. You may create new scenarios by editing existing XML files or adding and modifying single objects (Satellite, Sensor, etc) via the GSA GUI or via the available Wizards (see menu Edit / Wizards / ..)

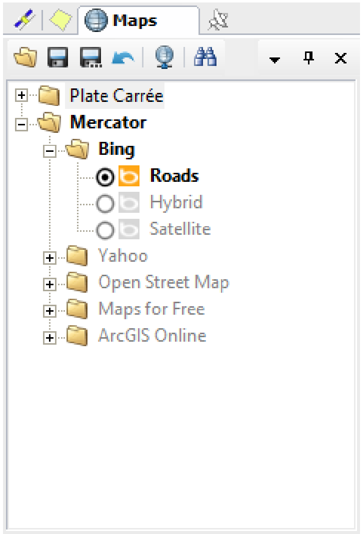


**Figure 32. Maps pane**

The Maps pane allows changing the background maps the Earth 3D rendering. There are over 200 different maps to choose from.

## 4.3 Satellites

SaVoir allows defining any collection of satellites as part of the simulation.

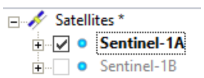


**Figure 33. Satellites tree**

Only satellites ticked as “visible”, i.e. selected, will participate in the simulation.

“Visible” means both that the satellite is engaged in simulation and visible on the map (including orbit trace, 3D model, actual position, etc).

A satellite may contain any number of orbits, sensors, recorders and downlink channels.



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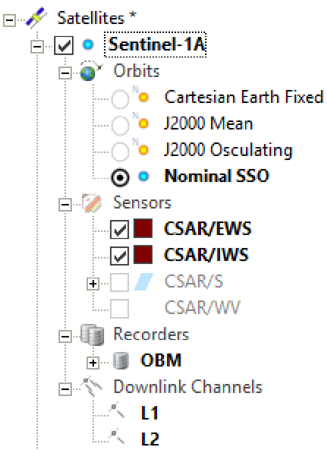


**Figure 34. Typical GSA satellite scenario**

### 4.3.1 Orbits

A satellite requires that an orbit is defined, providing the means to calculate its position at any point in time.

In practice, a satellite is configured with a collection of orbits, as in the case of Figure 34. , where four orbits are defined. Despite this multiplicity of orbits, only the selected orbit is active for the purpose of simulation. Having several orbits is convenient just for quick switching between different orbital hypotheses.

An orbit is defined typically by an orbit state vector (OSV), defined either with Keplerian or Cartesian elements, or with Two Line Elements as well. It is also possible to define orbits based on Reference Orbit Event File.

The satellite scenario tree represents the orbits with an icon indicating the orbit type. For a complete definition of the meaning of these icons, please refer the following link:

http://help.taitus.it/SaVoir/ReleaseNotes/Content/Release%20Notes/Historical/4.4.6/OrbitIcons/OrbitIcons.htm

GSA comes with predefined OSVs for all satellites.

It is also possible to modify the orbit parameters and to create new orbits with the satellite wizard.

To inspect each orbit definition parameters, obtain a dump of the orbits XML Content (right-click menu / XML Content), or read the orbit parameters in the properties pane, or run the Satellite wizard.

It is possible also to define an "orbit modifier" to simulate hypothetical orbit keeping maneuvers for maintaining the Sun Synchronous repeat cycle.

### 4.3.2 Sensors

Sensors represent the actual instruments embarked on the satellite. The sensor model is a two-tier model, with each sensor having a collection of possible Sensor Modes. This model is sufficient for most cases, like one-mode instruments (e.g. Landsat ETM+) or one-mode steerable instruments (e.g. SPOT-5 HRG)

Sentinel-1 CSAR instruments maybe would be better modeled with a three-tier system (Sensor / Sensor Modes / Beams), but for the purpose of GSA we maintain the two-tier



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system with the different CSAR modes acting as separate instruments (CSAR/EM, CSAR/IM, CSAR/S, CSAR/WV). This approach is well handled in SaVoir / GSA, and any situation of cross-incompatibility (e.g. CSAR/EM and CSAR/IM cannot operate simultaneously) is handled via the Exclusive Grouping constraints.

SaVoir supports many sensor types, including push-broom, steerable, conical, polygonal, leap-frog, spotlight, stereo, etc.

For the purpose of GSA (Sentinel-1 and Sentinel-2 missions) we are mostly interested in push broom Fixed (one-mode) and Steerable Enumerative sensors (multi-mode with a limited number of predefined possible beams)

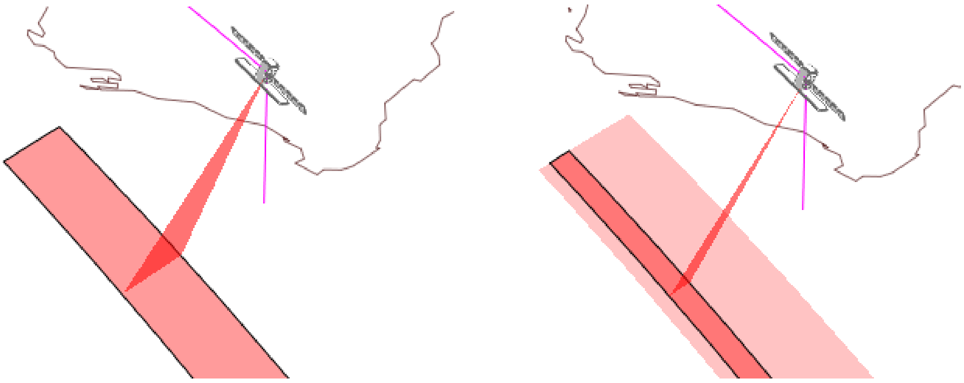

**Figure 35. Push broom Fixed and Steerable modes**

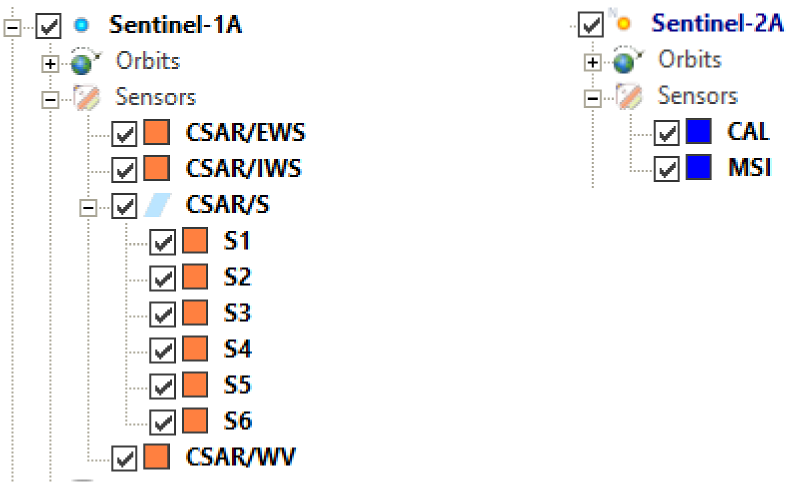


**Figure 36. Sentinel-1 and Sentinel-2 sensors**

Each Sensor Mode is characterized by its look geometry or Field of View (FOV), basically the look-angles shaping the final footprint on ground.

The FOV defines two guide points **Left** and **Right** with their pointing geometry definitions. Guide points will be used to build the swath scan lines as the sensor look pattern on the earth surface at a given moment of time.

Each guide point is defined by three geometrical parameters: **Aperture**, **Azimuth** and **Altitude**.



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The most important parameter is the **Aperture**, which is interpreted according to the FOV mode. There are three FOV modes possible:

- **STANDOFF**: In STANDOFF mode the Aperture value represents the on-ground distance between sub satellite point and sensor observation hit-point. The distance is in kilometers, measured as a great-arc on earth's surface. The distance is measured to the right of the satellite trajectory. Looking at left you will need negative values. In STANDOFF mode we can only define perfect across-track sensors. The Azimuth value is disregarded.
- **VIEW_ANGLE**: The Aperture represents the look angle of the sensor with respect to NADIR, measured from the Satellite barycenter. Angles to the left of satellite trajectory should be negative. Angle unit: degrees. The sign convention can be changed by setting the Azimuth to 180 degrees, see below.
- **INCIDENCE_ANGLE**: The Aperture represents the incidence angle at the sensor observation hit-point, measured as angle between the local normal and the line between satellite and observation hit-point. Angle unit: degrees. Right looking satellites (with respect to the forward satellite direction on the earth surface) present positive incidence angle, while left looking satellites the incidence angle sign will be negative.

The **Azimuth** value represents the bearing of the sensor look direction. A perfect across-track right-looking sensor should have Azimuth = 0. Looking front = 90. Left = 180, Back = 270. You may define any Azimuth value. For GSA all Azimuth values are always = 0.

The **Altitude** is always zero for observation hit-point at sea level. Not used in GSA.

### 4.3.2.1 Editing Sensor parameters

Sensor configuration is complex and includes many parameters having to do with sensor geometry, sensor constraints and priorities, bit rates, spatial resolution, framing definition, render styles, etc. These parameters can be consulted and edited through the properties panes at the bottom of the Scenario Pane

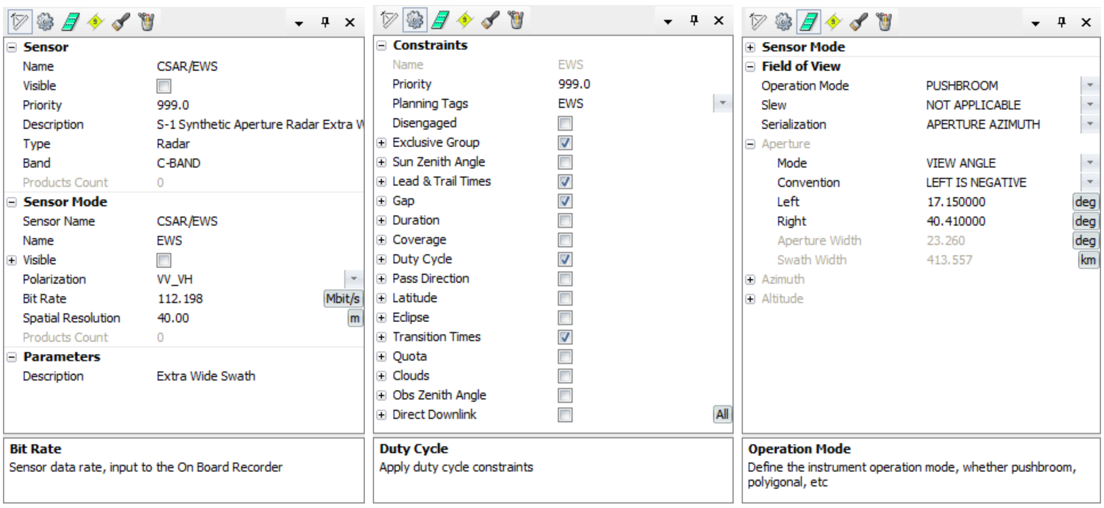


**Figure 37. Sensor property panes**



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#### 4.3.2.2 Sensor Constraints

The constraints panel allows configuring many sensor constraints to support complex planning modelling. Constraints are handled in the Constraints pane.

Constraints define operational rules (e.g. max duration of a swath) and they are handled as independent items that can be active or not. Constraints are also applied to Areas of Interest, to Antennas, to Downlink Channels and to Packet Stores. They are further explained in a separate chapter4.6 .

### 4.3.3 Recorders

Each satellite has a collection of recorders. In the current implementation of GSA, only the first recorder of the collection is used for simulation. The recorder is called OBM, as On-Board Memory.

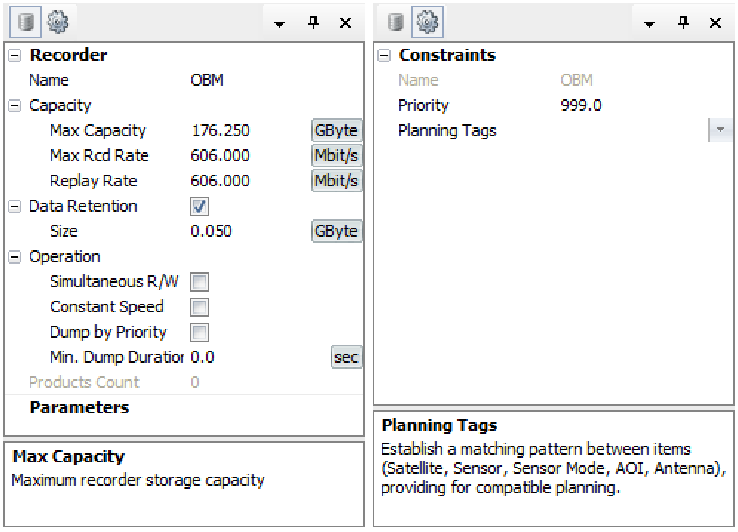


**Figure 38. Recorder Configuration**

The recorder configuration has the following parameters:

- **Max Capacity**: The maximum allowed capacity of the Recorder (GBytes). If during operation the maximum size is reached, the Recorder will not allow storing additional data.
- **Max Recording Rate**: the maximum bit rate at recorder input (Mbit / sec)
- **Replay Rate**: Nominal output rate of the recorder (Mbit / sec)
- **Data Retention**: If enabled, the recorder will retain a tail portion of a dump to allow save product stitching from different dumps.
- **Data Retention Size**: Define the Data Retention size (Mbytes), globally for all packet stores of this recorder.
- **Simultaneous R/W**: Enable or disable the capability to ingest and output data simultaneously.
- **Constant Speed**: Specifies that recording will take place at constant speed, marked by the Max Rcd Rate. <u>This property is disregarded in GSA, as the input rate is fixed by the instrument data rates</u>.



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- **Dump by Priority**: Specifies that the recorder will dump higher priority data takes first. Otherwise dump will operate in first-in-first-out mode. This property is disregarded in GSA, as the dump priority is governed by the Packet Stores timeliness and priorities.
- **Minimum Dump Duration**: Specifies the minimum allowed duration of the dump window. This property is ignored by GSA, as the dump duration constraints are defined in the Downlink Channels constraints.

### 4.3.4 Packet Stores

The OBM is composed of a collection of partitions or Packet Stores. In Sentinel-1 there are over 50 different Packet Stores. In Sentinel-2 only one Packet Store has been configured.

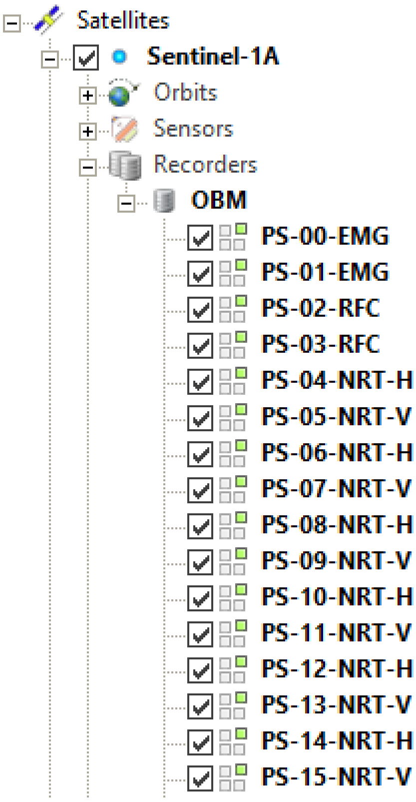


**Figure 39. Sentinel-1 packet stores**

Packet Stores have been named with the following naming convention (Sentinel-1)

PS-<number>-<Timeliness>-<Sensor>-<Polarization>

The default Sentinel-1 configuration contains packets with names PS-00-EMG (Emergency), PS-02-RFC (RF Characterization), PS-04-NRT-H (Near Real Time Horizontal), PS-20-WVM (Wave Mode), PS-21-STD-H (Standard Horizontal), PS-37-PTH-IWS-H (Pass Through IWS Horizontal), PS-48-HKTM (House Keeping Telemetry), PS-49-GPS (Packet Store with GPS data). These names are just for descriptive purpose. The naming convention is arbitrary and has no applicability in the simulation algorithm.



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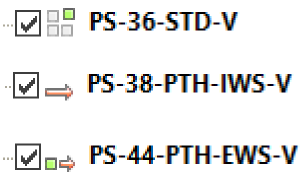
Packet Stores are associated with icons to provide a clearer indication of their role. Three icons are used:




Standard Packet Store. Timeliness Standard or NRT

Passthrough Packet Store

Passthrough Packet Store with Data Retain

**Figure 40. Packet Store Icons**

### 4.3.5 Packet Store Configuration

Each Packet Store configuration is accessible for consultation and editing in the properties pane. The configuration includes general parameters and constraints.

**General Parameters**:

- **Name**: Unique name of the Packet Store
- **Visible**: if unchecked the Packet Store will not participate in the simulation.
- **Max Capacity**: The maximum allowed capacity of the Packet Store (GBytes). If during operation the maximum size is reached, the Packet Store will not allow storing additional data.
- **Simultaneous R/W**: Enable or disable the capability to ingest and output data simultaneously.

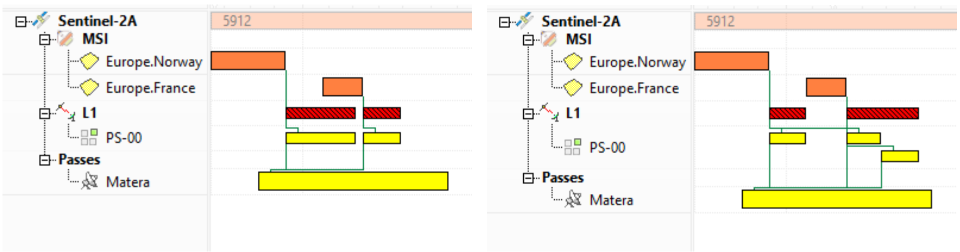



**Figure 41. Simultaneous R/W, = true (left), and = false (right)**

- **Timeliness**: Timeliness defines a priority class for storage. This Packet Store will ingest data only of the defined Timeliness. There are three Timeliness values defined
    - **Pass Through**: will dump data in real time to the downlink station without increasing Packet Store storage (Data Retain = false) or increasing it (Data Retain = true). Remaining data will be downlinked in deferred mode
    - **NRT**: will dump data in deferred mode or, if possible and not conflicting with other Pass-Through operations, also in real time.
    - **Standard**: will dump data in deferred mode to downlink stations.
- **Polarization**: Polarization associated to this Packet Store, indicating that this Packet Store will ingest data of only the defined polarization. Values: H or V
- **Data Retain**: Defines that this Packet Store will apply Data Retention when downlinking in Pass Through, indicating that the data will be kept on the Packet Store



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after downlink over a Local Station and downlinked again to a Core Station in deferred mode later on.

- **Sensors**: Defines a subset (comma separated) of sensors associated to this Packet Store, indicating that this Packet Store will ingest data of only the defined sensors. Set to "all" if all sensors are allowed to be stored in this Packet Store.
- **Regions**: Defines a subset (comma separated) of AOIs associated to this Packet Store, indicating that this Packet Store will ingest data of only the AOIs. Set to "all" if all AOIs are allowed to be stored in this Packet Store.

**Constraints**:

- **Priority**: Unique priority of this Packet Store. Lower numbers are higher priority. When two Packet Stores are valid candidates to perform an operation, the Packet Store with higher priority will be chosen.
- **Planning Tags**: See description of planning tags in 4.7
- **Direct Downlink**: subset of Local Ground Stations to which data in this Packet Store will be downlinked. See more information in section 4.6.15

**Restrictions:**

- It allows to disable operation with certain sensors and / or antennas, effectively restricting the Packet Store to work on data from the selected sensors and downlinked only to the selected antennas.

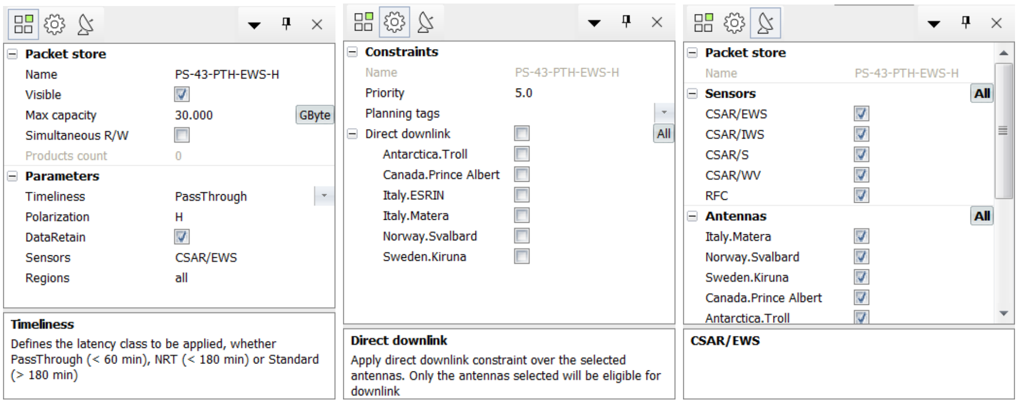


**Figure 42. Packet Store configuration**

## 4.3.6 Downlink Channels

Downlink channels represent the RF equipment and antenna to downlink data to Earth. They are positioned at the output of the recorder. Each satellite can be modeled with several downlink channels. The GSA default configuration foresees two downlink channels for Sentinel-1 and one for Sentinel-2.



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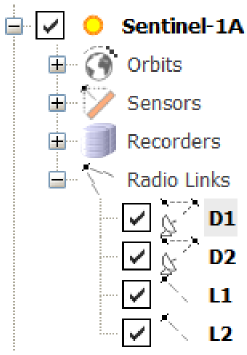


**Figure 43. GSA Downlink Channels**

### 4.3.7 Downlink Channel Configuration

Each downlink channel configuration has general parameters, constraints and associated antennas:

**General Parameters**:

- **Downlink Rate**: Bit rate of the downlink channel (Mbit / sec).
- **Link Type**: whether Direct Link or via Data Relay Satellite

**Constraints**

- **Priority**: Unique priority of this Downlink Channel. Lower numbers are higher priority. When two Downlink Channels are valid candidates to perform an operation, the Downlink Channel with higher priority will be chosen.
- **Planning Tags**: See description of planning tags in 4.7.
- **Gap:** It controls minimum and maximum gaps. It is used typically to keep the Link active between activations to reduce the number of transmitter RF on / off switching. See more information in 4.6.5
- **Duration**: Limit the duration of RF activations. See more information in 4.6.6
- **Quota**: Provides rules to control the usage of the RF link by establishing quotas according to several criteria. See more information in 4.6.7

**Restrictions:**

- It allows defining a subset of antennas that can operate with the Downlink Channels

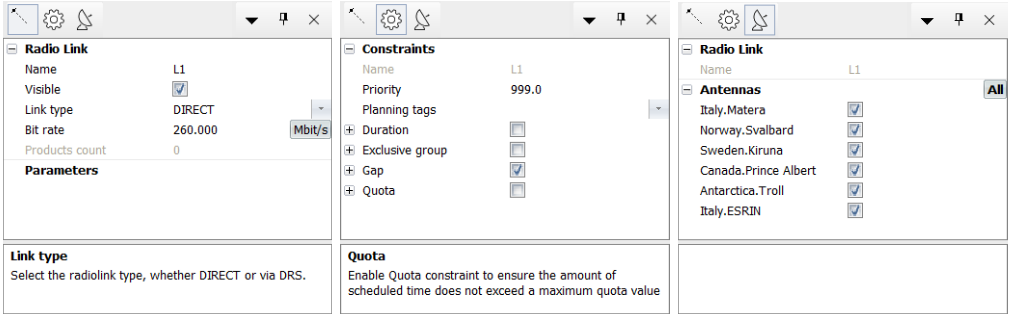


**Figure 44. Downlink Channel configuration**



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## 4.4 Areas of Interest

SaVoir allows defining any collection of AOIs as part of the simulation.

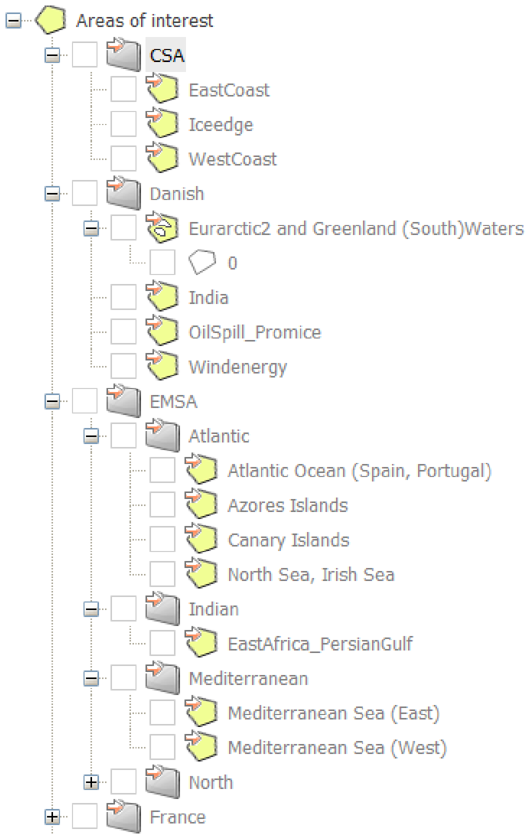


**Figure 45. Areas of Interest tree**

Only AOIs ticked as "visible", i.e. selected, will participate in the simulation.

"Visible" means both that the AOI is visible on the map. If, in addition, the AOI is "engaged" then it will participate in simulation and intersection calculation

### 4.4.1 Area of Interest Configuration

Each AOI configuration has general parameters, constraints and associated satellites.

**General Parameters**

- **Timeliness:** Timeliness defines a priority class for AOI. Swaths acquired over this AOI will be assigned the AOI Timeliness, which will then be used to store the swath in a compatible Packet Store according to its Timeliness. There are three Timeliness values defined
  - Pass Through
  - NRT
  - Standard



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- **Group:** Description string not used by the GSA algorithms. It is added to the AOI to easily represent the AOI in the AOI table (Edit / Tables / Areas of Interest) and allow hierarchical classification.
- **Data Retain:** Flag (true / false) defining that Data Retention should be applied on swaths acquired over this AOI. When the swath is downlinked over a Local Station it should also be downlinked later on over a Core station. This flag will also condition in what Packet Store storing the swath
- **Latency:** Latency class, indicating the required maximum delay between sensing and data delivery. This parameter is used only for descriptive purpose to allow evaluation of GSA output results. The parameter is ignored for GSA storage and downlink algorithm.

**Constraints**

- Same as for Sensors, it is possible to define several planning constraints for each AOI. More information is available in 4.6.
- The Optimization constraint is of particular interest, as it allows to define coverage plans over the AOI with minimum number of acquisitions.

**Constraints**

- It allows defining a subset of satellites that may operate with the AOI, and antennas suitable for downlink. If a satellite is ticked out from the list, GSA will not generate planning events for the satellite over the AOI. Same for the antennas.

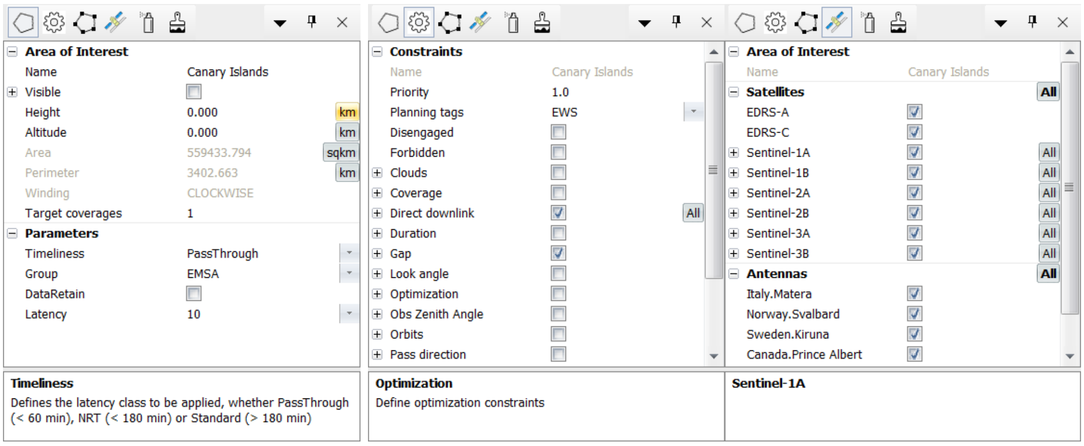


**Figure 46. AOI Configuration**

## 4.4.2 Area of Interest Types

AOIs can be of several types, including polygons, rectangles, etc. The deifferat AOI types are shown in Figure 47.



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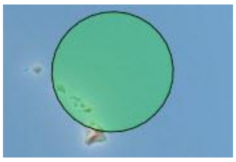
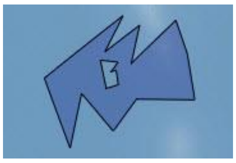
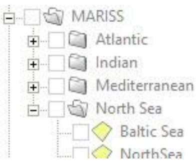
| AOI Type | |
|---|---|
| **Polygon**<br>Polygon region with arbitrary shape ("self-folding" artifacts are forbidden) |  |
| **Circle**<br>Circle Region, defined , by a center and a radius |  |
| **Rectangle**<br>Rectangle Region defined by two geographical coordinates |  |
| **Polyline**<br>Polyline region made of an arbitrary list of points |  |
| **Point**<br>Point Regions defined by single geographical coordinate |  |
| **Multipart**<br>Multipart collection of separated regions, treated as a single entity |  |
| **Hole**<br>Circle Region, defined , by a centre and a radius |  |
| **Folder**<br>Recursive folder containing other regions |  |

**Figure 47. AOI Types**



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## 4.5 Antennas

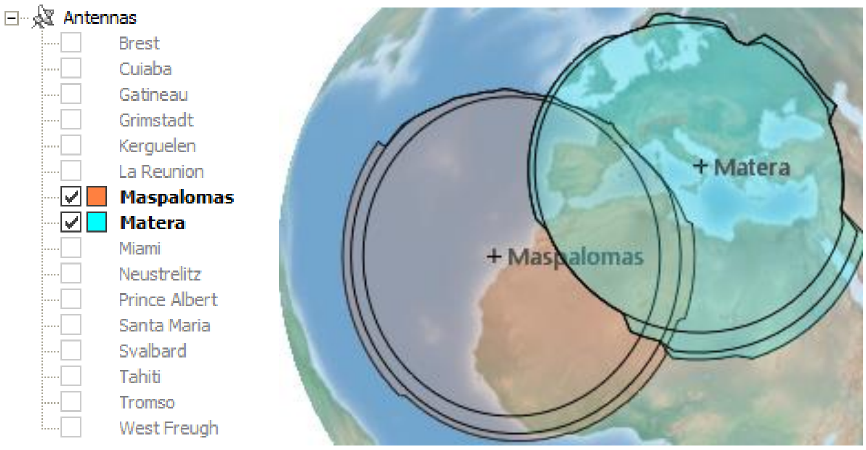


**Figure 48. Antennas tree**

It is possible to define any collection of Antennas (Ground Stations) in GSA. They are listed as a tree of Antenna objects in the Antennas Pane.

Antennas are defined by their geographical location (latitude, longitude, height), by an optional horizon mask (list of Az / El minimum values), planning constraints and associated satellites.

Each antenna is represented on the map by a cross at its geographical position, together with a text caption, and with an optional coverage profile indicating the visibility zone for that antenna when the satellite (sub satellite nadir) enters the coverage area. By default SaVoir draws three circles, at 0, 2 and 5 degrees elevation. It is possible to configure these minimum elevations in Edit / Properties …/ Antennas / Properties

**General Parameters**

- **Beam Width:** Antenna beam width in degrees. The GSA will use the beam width for detecting interference situations of two or more satellites on the same antenna. Interference calculation is triggered in the Visibilities / Interference Analysis menu.
- **Satellite Coverage:** It defines one satellite for drawing the coverage profile. During simulation the coverage will be calculated per-satellite, disregarding this parameter.
- **Downlink Channels:** list of satellite downlink channels associated with this antenna. It is expressed as a comma separated list. If the satellite has channels with ids L1 and L2, this parameter should contain the string "L1, L2". If the string is "L2", then only data downlink from channel L2 is allowed on this antenna.

**Constraints**

- Same as for Sensors, it is possible to define several planning constraints for each antenna, affecting the scheduling of satellite to antenna contacts.. More information is available in 4.6.

**Horizon Profile**

- Circular horizon around the antenna defining obstacles (building, mountains) that prevent satellite contact below a certain elevation. It is defined as a list of Azimuth /

Elevation values. The Horizon Profile is optional, and will be used in calculating satellite contacts if available.

**Associated Satellites**

- It allows defining a subset of satellites that may operate with the antenna. If a satellite is ticked out from the list, GSA will not generate visibility contacts over the antenna.

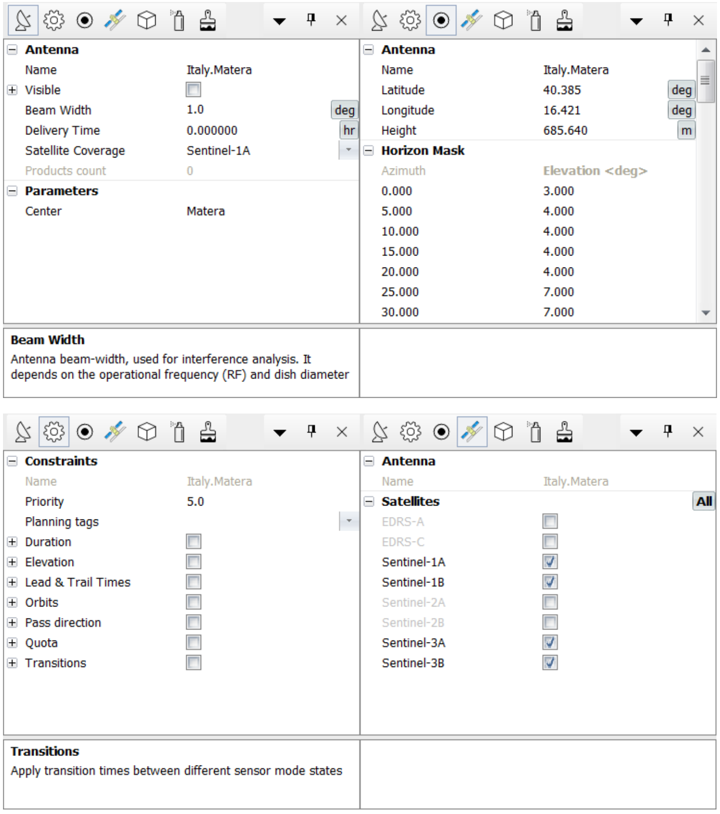


**Figure 49. Antenna Configuration**



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## 4.6 Constraints

Constraints are managed through ad-hoc constraint entities, configured independently. Each Constraint may be Active or not, and has configurable parameters.

Constraints can be applied to Sensors, Areas of Interest, Antennas, Packet Stores and Downlink Channels.

| Constraint | Sensors | Antennas | Areas of Interest | Packet Stores | Downlink Channels |
|---|---|---|---|---|---|
| Albedo | x | | | | |
| Clouds | x | | x | | |
| Coverage | x | | x | | |
| Custom mask | x | | | | |
| Direct Downlink | x | | x | x | |
| Duration | x | x | x | | x |
| Duty Cycle | x | | | | |
| Eclipse | x | | | | |
| Elevation | | x | | | |
| Exclusive Group | x | | | | x |
| Gap | x | | x | | x |
| Land | x | | | | |
| Latitude | x | | | | |
| Lead & Trail Times | x | x | | | |
| Look angle | x | | x | | |
| Obs Zenith Angle | x | | x | | |
| Optimization | | | x | | |
| Orbits | x | x | x | | |
| Pass Direction | x | x | x | | |
| Polarizations | | | x | | |
| Quota | x | x | x | | x |
| Resolution | x | | x | | |
| Sun glint | x | | x | | |
| Sun Zenith Angle | x | | x | | |
| Transition Times | x | x | | | |



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**Figure 50. Applicability of constraints to different GSA elements**



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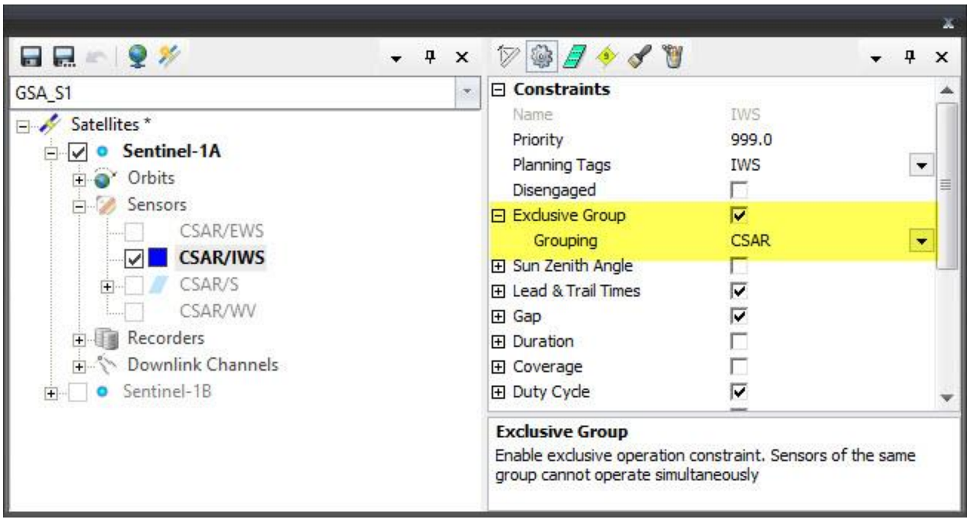
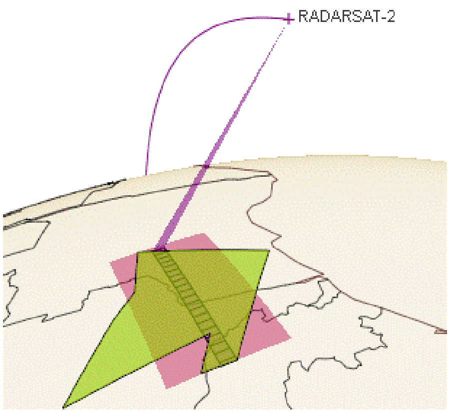
### 4.6.1 Exclusive Grouping




Sometimes sensor modes cannot operate simultaneously. For example Radarsat-2 SAR instrument provides 12 different modes which cannot operate simultaneously. In SaVoir they are configured as separate sensors. To ensure exclusive operation they are configured with an Exclusive Group Flag, consisting of a simple text string. Sensors having the same Grouping flag cannot operate simultaneously. When scheduling acquisitions over an Area of Interest only one sensor will be selected. Selection is done according to Sensor priority. Sensors with highest priority (lowest number) will be scheduled first.

For example if you have selected RADARSAT-2-Fine (priority 3) and RADARSAT-2-Multi-Look Fine (priority 6) and both are configured with the SAR Exclusive Group flag, SaVoir will select RADARSAT-2-Fine acquisitions because of highest priority.



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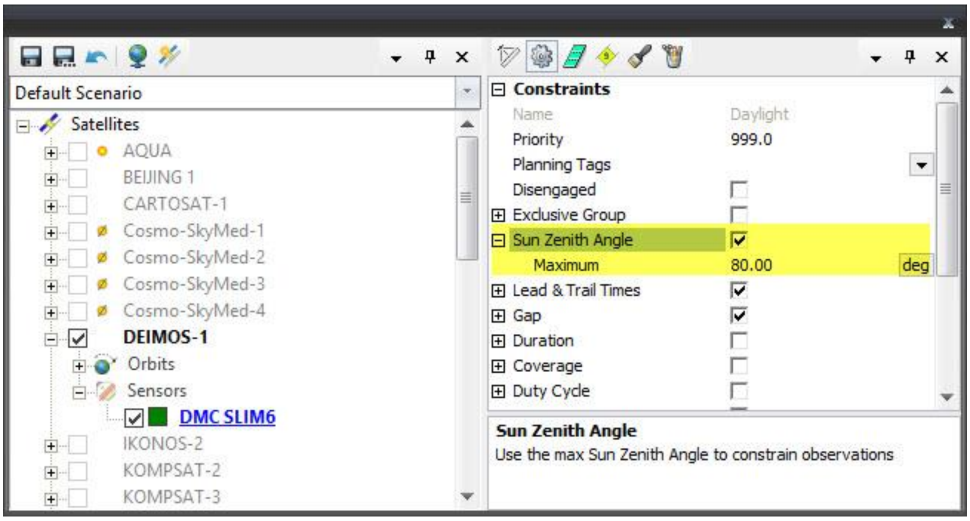
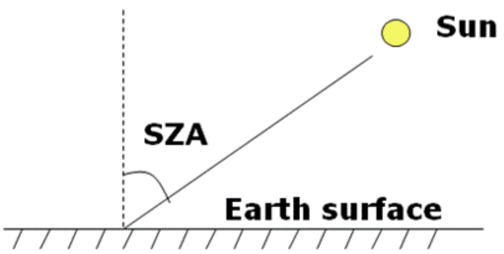
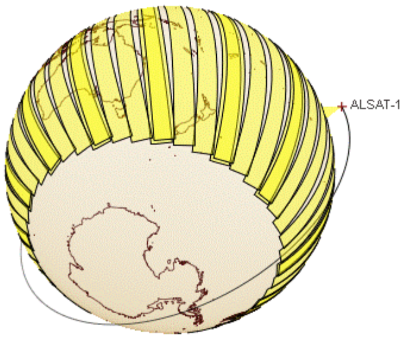
### 4.6.2 Sun Zenith Angle




When the Sun Zenith Angle (SZA) constraint is active the sensor will not be operated when the SZA is above the maximum value defined. The SZA is measured at the satellite NADIR on the Earth Surface.



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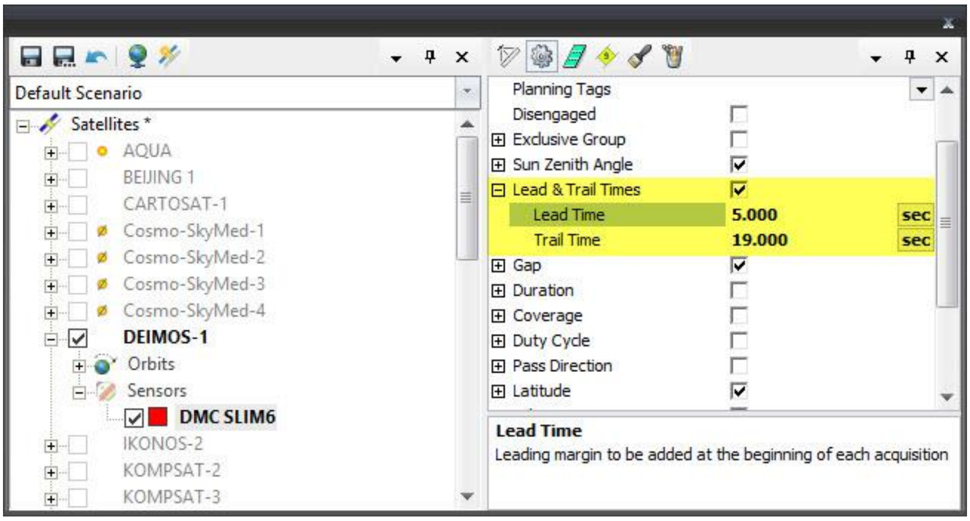
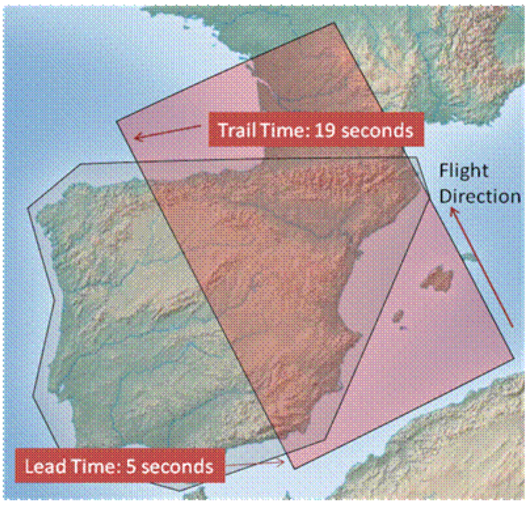
### 4.6.3 Lead and Trail Times




When the Lead & Trail Times constraint is active all acquisitions will be padded with additional time guards as defined in the Lead and Trail time parameters. The time guards will be calculated adding to the minimum swath duration required.

If the sensor is defined with Framing and "Keep Frame Boundaries" is ON, the Frames will be rounded ensure complete frames with the likely result that the Lead & Trail Times are increased additionally.



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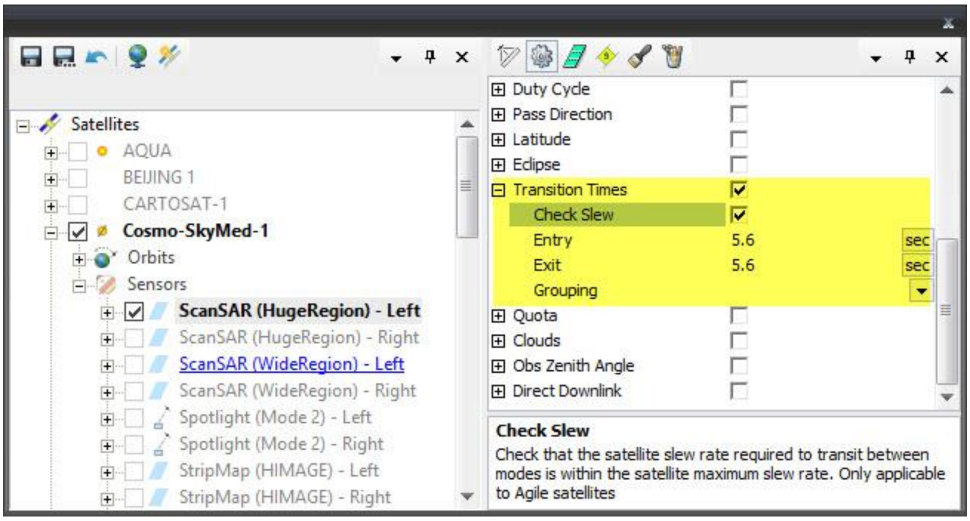
### 4.6.4 Transition Times




Transition Times are applied to Sensor Modes, and represent time gaps that must be respected between mode activations.

- Check Slew: for agile sensors and for sensors capable of right / left slewing (e.g. Cosmo Skymed) it checks that the transition times are compatible with a slew operation compatible with the maximum slew rate allowed for the satellite.
  - If the satellite is Agile (see Satellite properties) mode activations require satellite slewing from one mode to another. The slewing requires a time lag which is dependent on the slew angle and the maximum slew rate. The lower priority swath (or the later swath in case of equal priorities) will be clipped to ensure that the maximum slew rate is respected.
  - If the satellites perform left / right slewing (e.g. Cosmo Skymed) the slewing time lag will be calculated for the angle distance between left and right slewing. Note that for this feature to work you need to link Left and Right modes with the same non-empty Grouping tag.
- The Entry Transition Time represents a time gap before Sensor Mode switch ON.
- The Exit Transition Time is the time gap after Sensor Mode Switch OFF.
- The Grouping is a text string that identifies a transition times group within the same satellite. Sensors of the same group will apply transition time constraints in a combined way

If two swaths of the same sensor are too close together, breaching transition times, one swath will be trimmed following a priority criteria. In the case of same priorities then the earlier swath will be scheduled, and the later trimmed.

E.g. when planning MODE1 and MODE2 in sequence the minimum time gap equals MODE1.Exit + MODE2.Entry.



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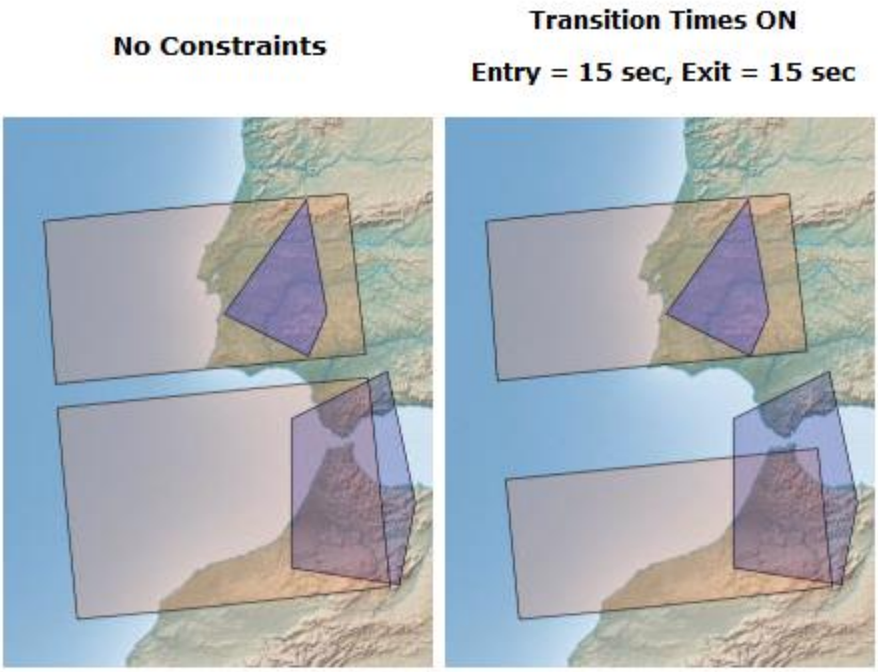




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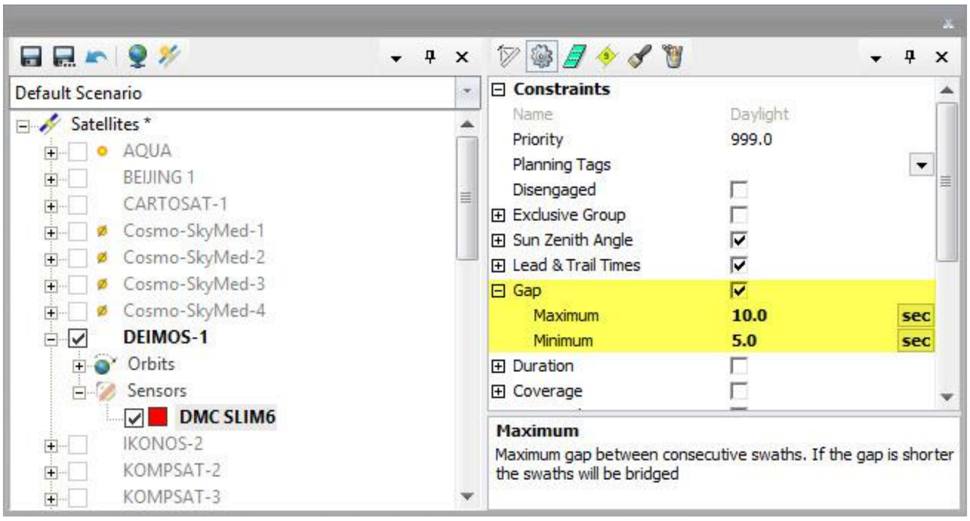
### 4.6.5 Gap




- **Maximum**: If the gap between consecutive swaths is shorter than the Maximum gap the swaths will be bridged in a single swath.
- **Minimum**: If the gap between acquisitions is shorter than the Minimum gap the exceeding swaths will be removed. This allows implementing analysis scenarios like e.g. "take one acquisition per week"

**No Constraint** | **Constraint ON, with Maximum Gap = 90 sec**



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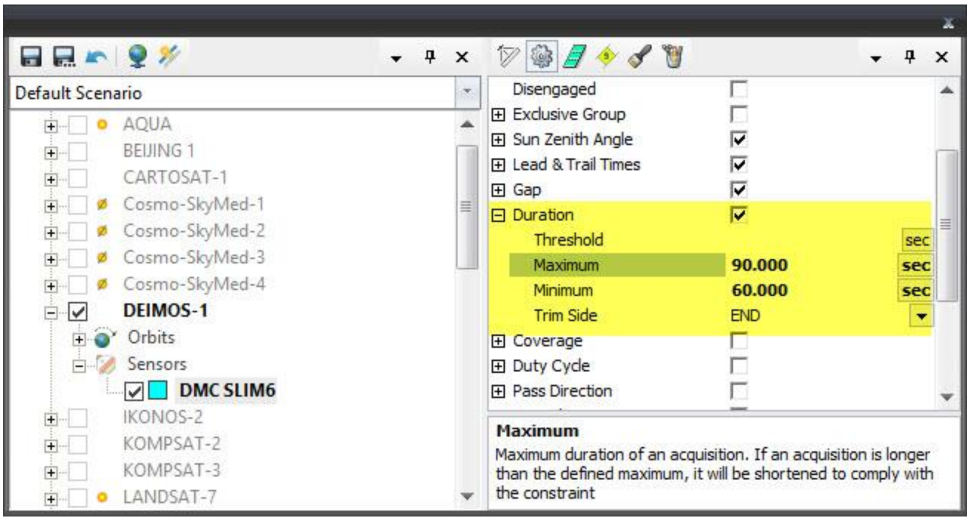
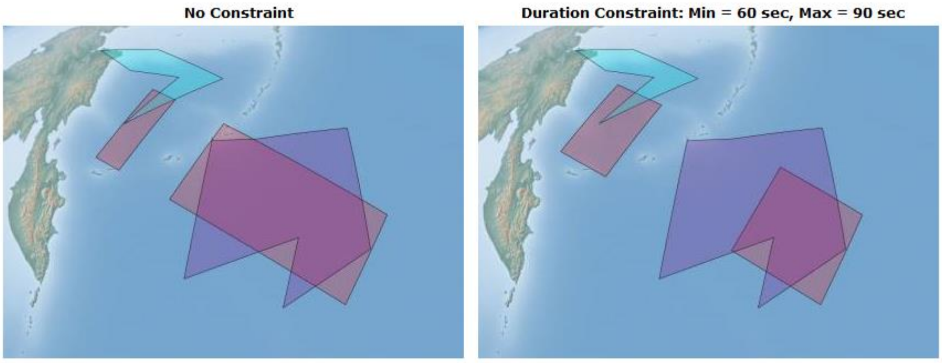
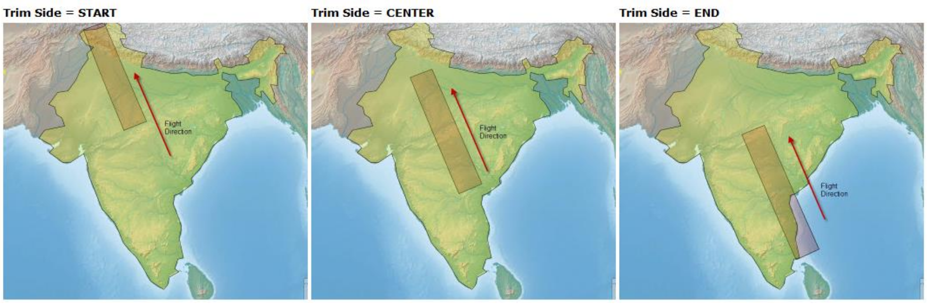
### 4.6.6 Duration




Define threshold, minimum and maximum duration constraints for each swath.

- **Threshold**: If an acquisition is shorter than the defined threshold, it will be cancelled
- **Maximum**: If an acquisition is longer than the defined maximum, it will be shortened to comply with the constraint.
- **Minimum**: If an acquisition is shorter, then it will be extended to comply with the constraint
- **Trim Side**: Defines the side for applying the constraint, whether end of swath, start of swath or center (both sides).



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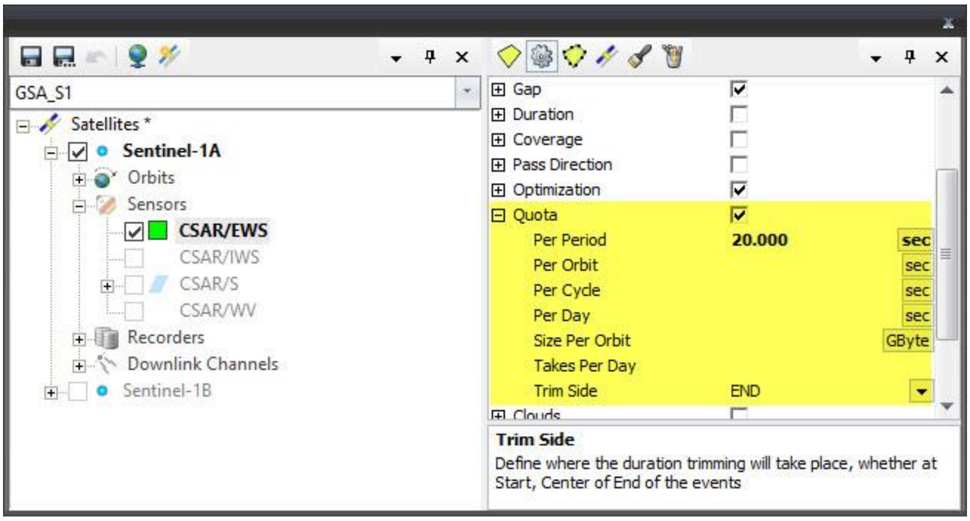
### 4.6.7 Quota




Define a maximum quota of data to be acquired in the selected period. The following options are available:

- Quota for simulation period (SaVoir time bar and time combos)
- Quota per Orbit for the applicable satellite
- Quota per Cycle for the applicable satellite, provided it is configured as Sun Synchronous orbit
- Quota per Day
- Quota in Size of data acquired per orbit
- Maximum Number of data takes per day

In addition it is possible to define a Grouping constraint. The Grouping is an Optional Text string that identifies a quota group within the same satellite. Sensors of the same group will share the quota resource in a combined way.

It is also possible to define the Trim Side, i.e. the side for applying the constraint, whether end of swath, start of swath or center (both sides).

If, for example, the analysis period is one day and the Maximum quota is 20 minutes, then the cumulative sensing time should be below that limit within one day. All other suitable data will be discarded.



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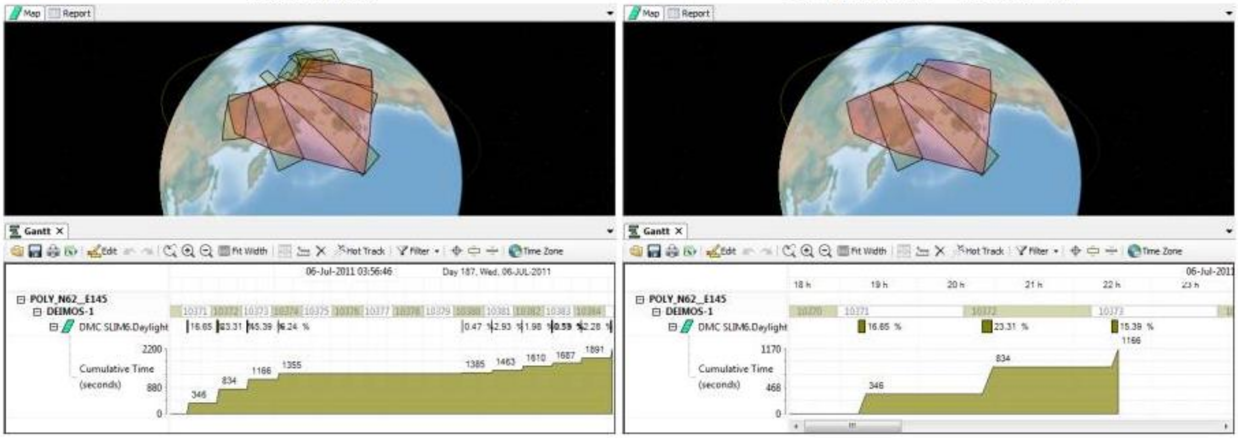
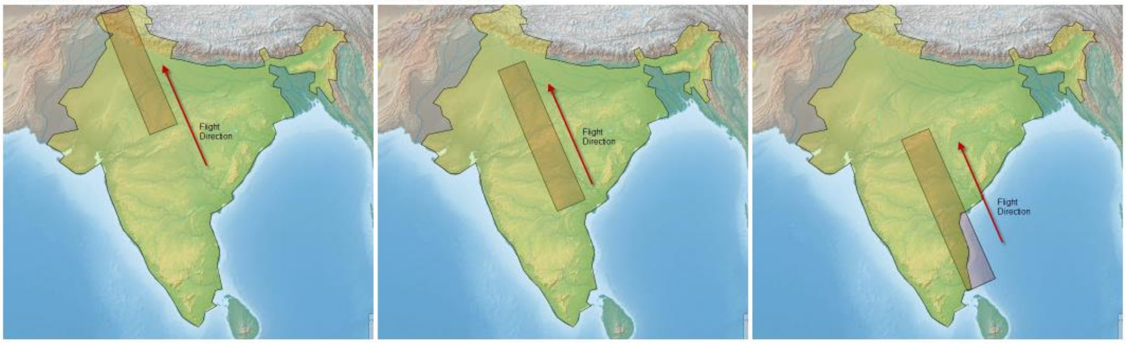
**Without Quota** **With Quota, Max = 20 min / day**




**Trim Side = START** **Trim Side = CENTER** **Trim Side = END**



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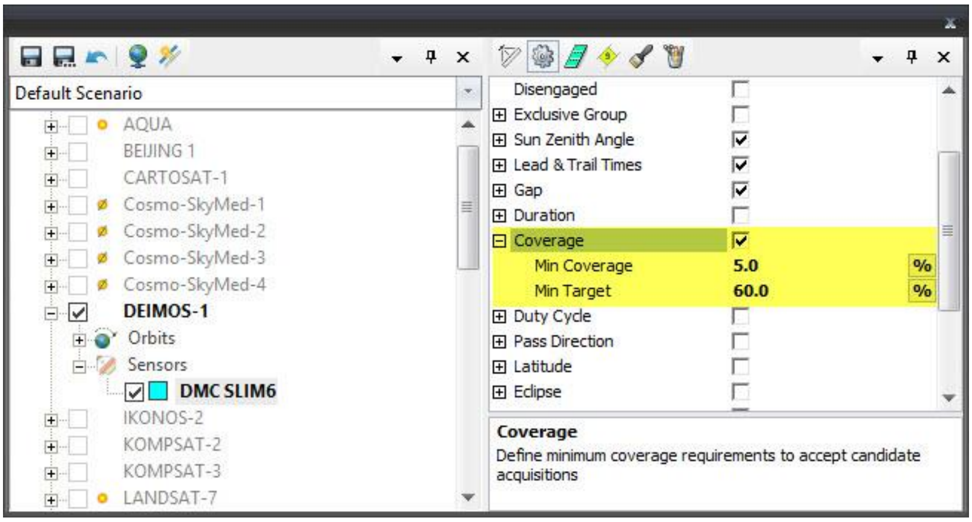
### 4.6.8 Coverage



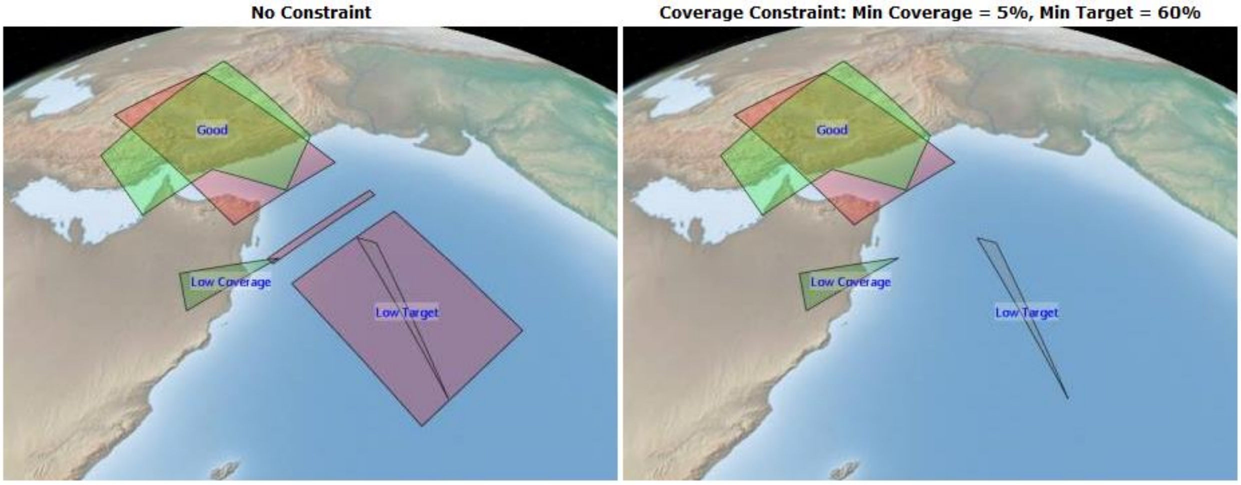

Define minimum Area Coverage requirements for scheduled acquisitions:

- **Min Coverage**: Minimum ratio between **AOI** portion covered and Total **AOI** area.
- **Min Target**: Minimum ratio between Swath portion which is of value and Total Swath area.

If the swath does not comply with any of the requirements it will be discarded.

| Region | Duration (sec) | AreaCovered% | TargetInImage% |
|---|---|---|---|
| Satellite: DEIMOS-1 | | | |
| Good | 192.057 | 68.43 | 75.44 |
| Low Coverage | 5.718 | 0.91 | 1.61 |
| Low Target | 117.768 | 100.00 | 5.54 |

No Constraint　　Coverage Constraint: Min Coverage = 5%, Min Target = 60%



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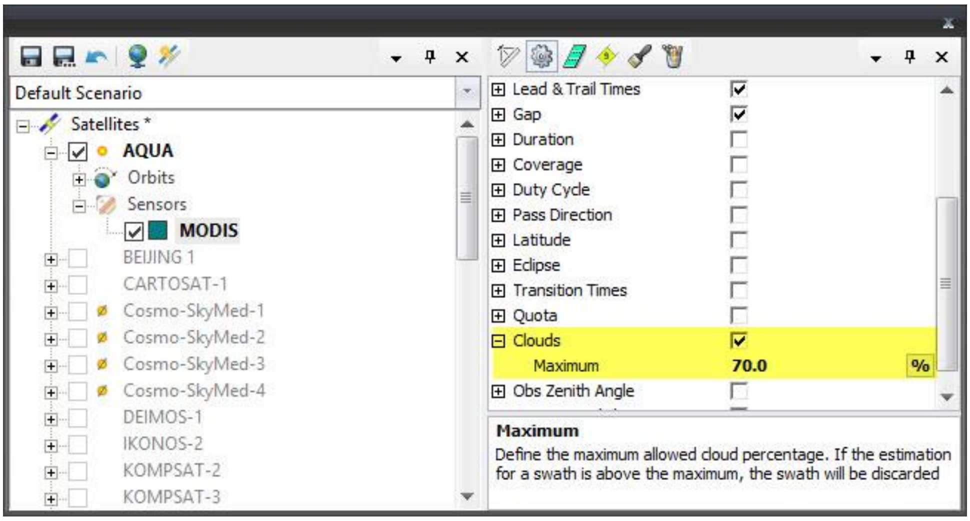
### 4.6.9 Clouds

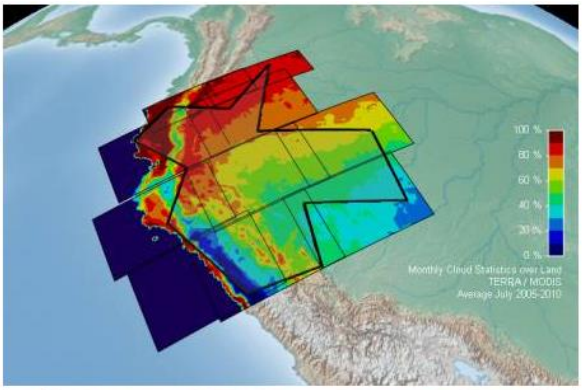



Define maximum Cloud Cover Probability. If the Cloud Cover average probability for a given swath is above the Max Clouds limit the swath will be discarded. Cloud Probabilities are obtained from 1-degree grid (360 x 180) monthly Cloud Statistical maps distributed with SaVoir. The Statistics were obtained from TERRA / MODIS average Cloud fraction maps between 2005 and 2012. Each swath is qualified with a Cloud Average % value, calculated at center of the swath-AOI intersection section.

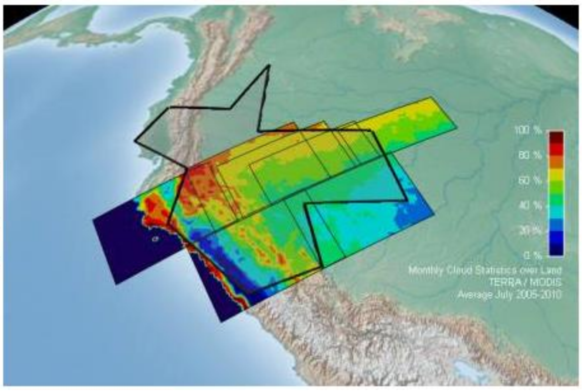
Optimized acquisition plan with duration

Min = 30 sec,

Max = 60sec



Same as before, discarding swaths with > 70% cloud average probability





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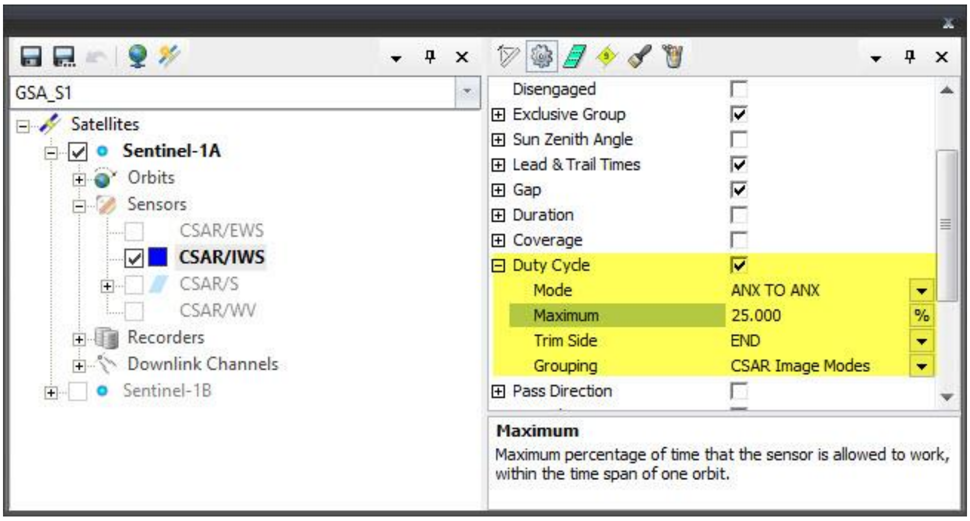
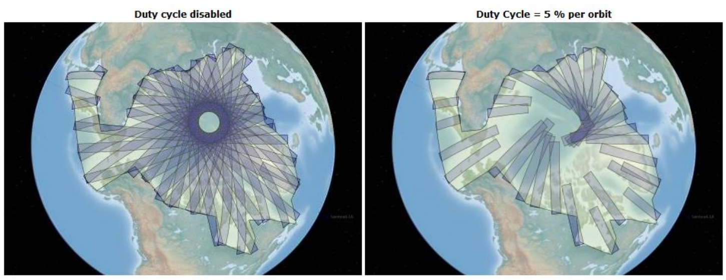
### 4.6.10 Duty Cycle

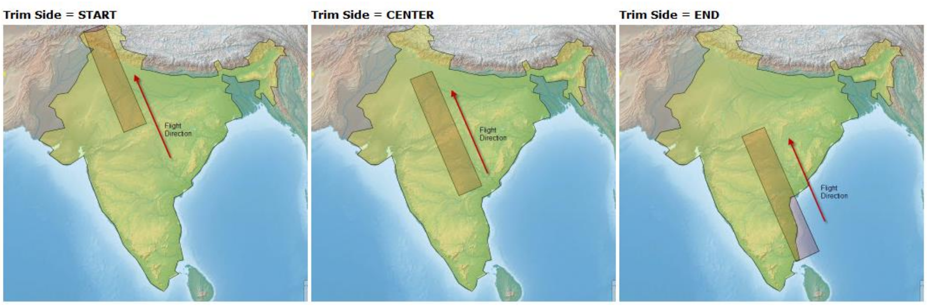



Define orbit-based Duty cycle constraints for a given Sensor Mode. Swaths will be cut to ensure the Duty cycle constraint is not breached.

The following can be configured:

- **Mode**: Select how to calculate the Duty Cycle, whether **Anx** to **Anx**, **Dnx** to **Dnx**, or Sliding Window.
- **Value**: Maximum percentage of time that the sensor is allowed to work within one orbit span.
- **Grouping**: Optional Text string that identifies a duty cycle group within the same satellite. Sensors of the same group will share the duty cycle resource in a combined way.
- **Trim Side**: Defines the side for applying the constraint, whether end of swath, start of swath or center (both sides).



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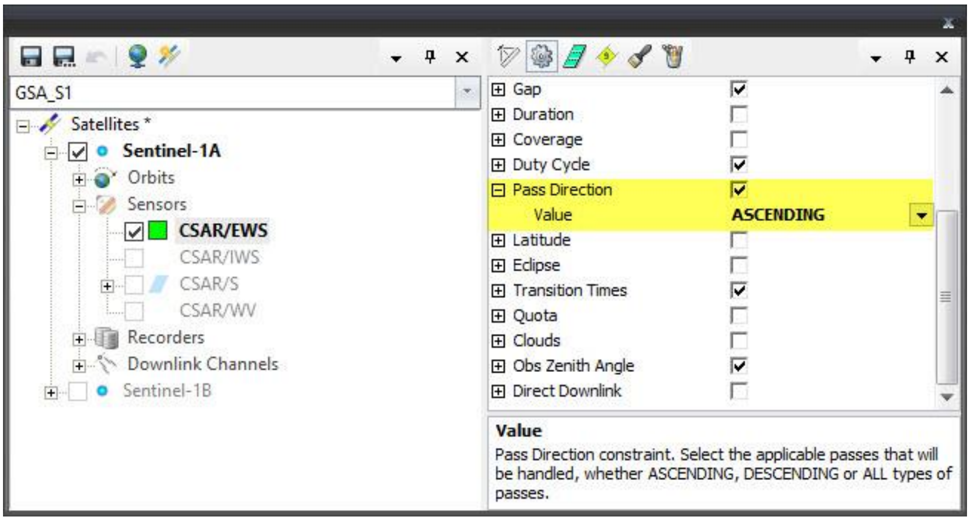
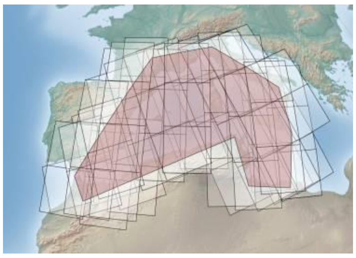
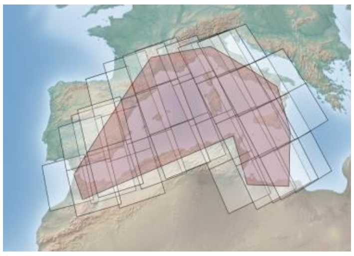
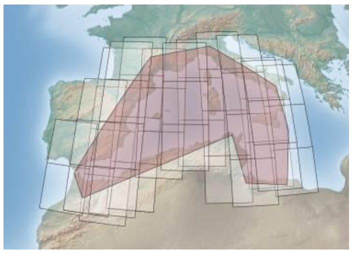
### 4.6.11 Pass Direction




Define the pass direction (ALL, ASCENDING, DESCENDING) to be used for swath scheduling.

| ALL | ASCENDING | DESCENDING |
|---|---|---|
|  |  |  |



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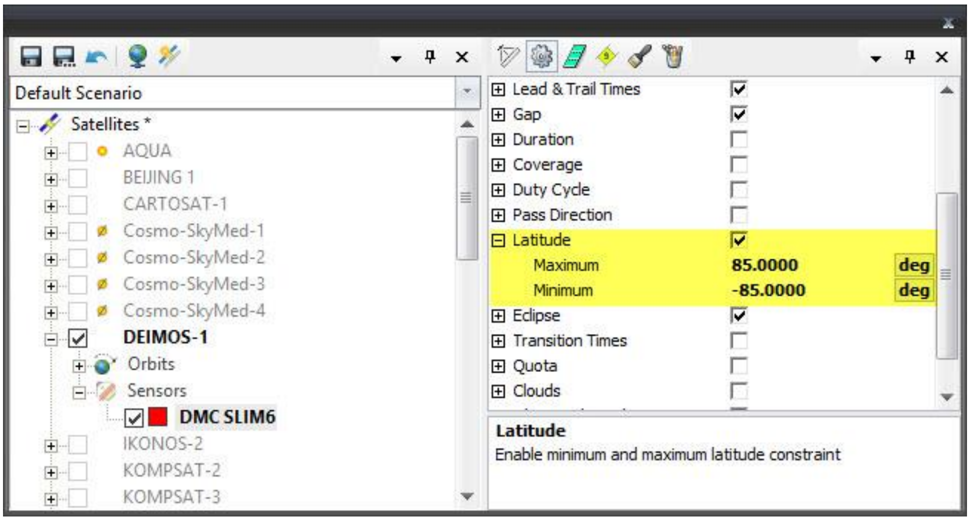
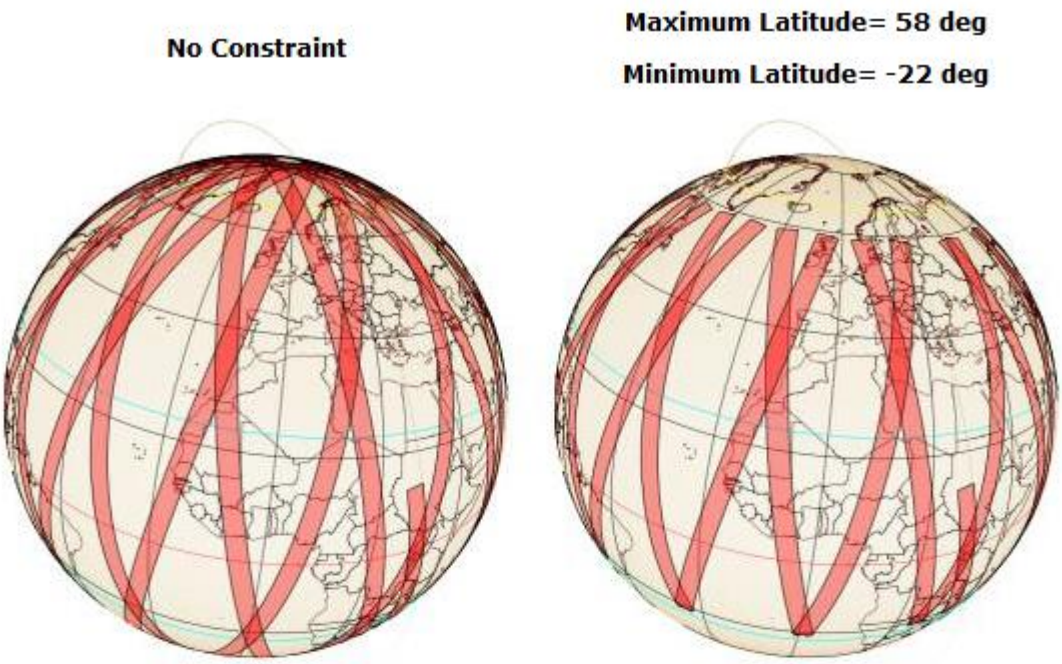
### 4.6.12 Latitude




Define minimum and maximum latitude limits. Swaths will be cut to ensure that the swath latitude remains within limits.



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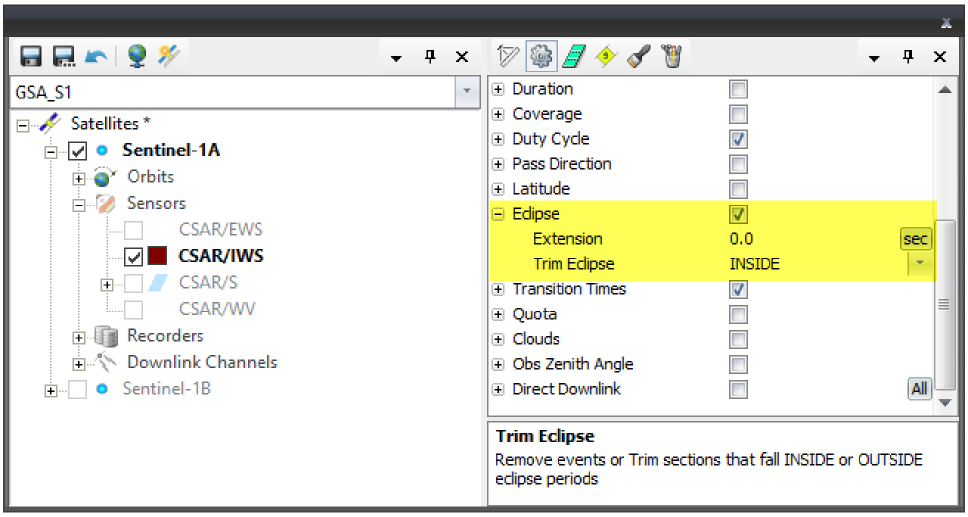
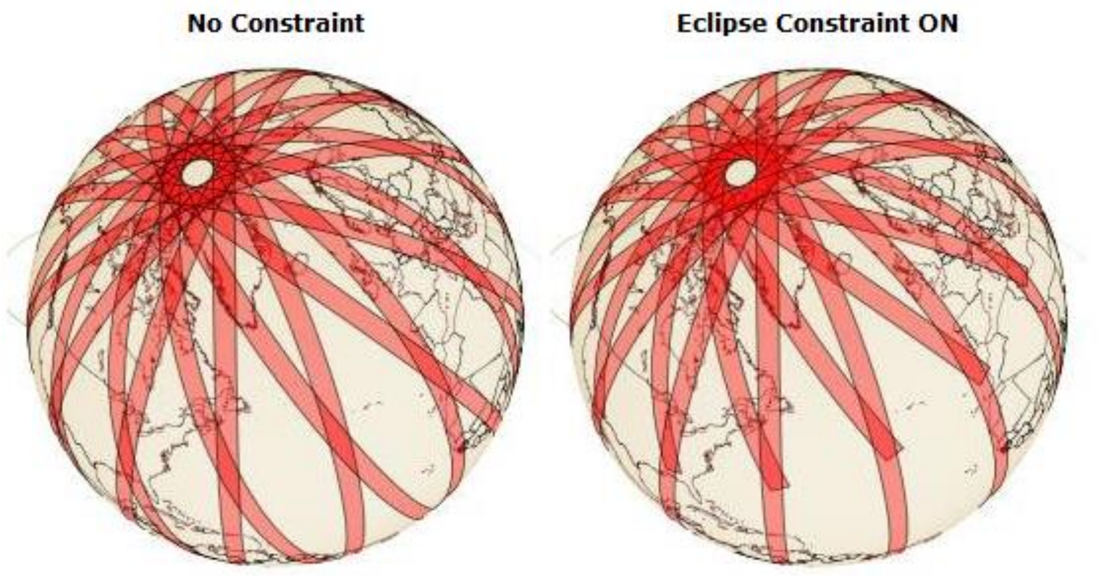
### 4.6.13 Eclipse




When enabled the Eclipse constraint will ensure that no sensing operation is performed when the satellite is in Eclipse. This occurs when the line of sight between satellite and the Sun is obstacled by the Earth.

It is possible to provide a margin to the Eclipse boundaries to advance or delay the effective start and stop of the Eclipse period, i.e. the constrain is applied in the time window [tEnterEclipse - tMargin, tExitEclipse + Margin]. The Margin can be positive or negative. The constraint is activated at sensor level in the properties grid and via the Sensor Wizard



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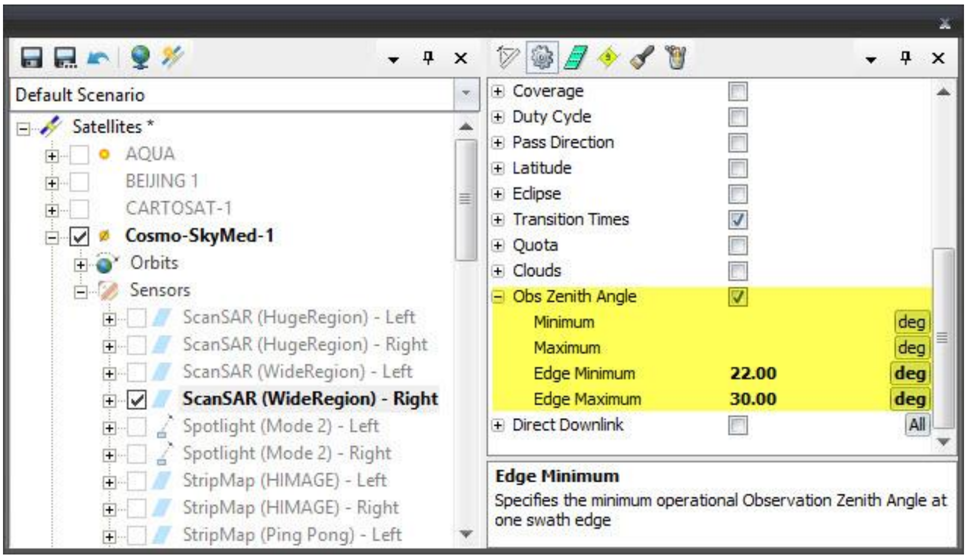
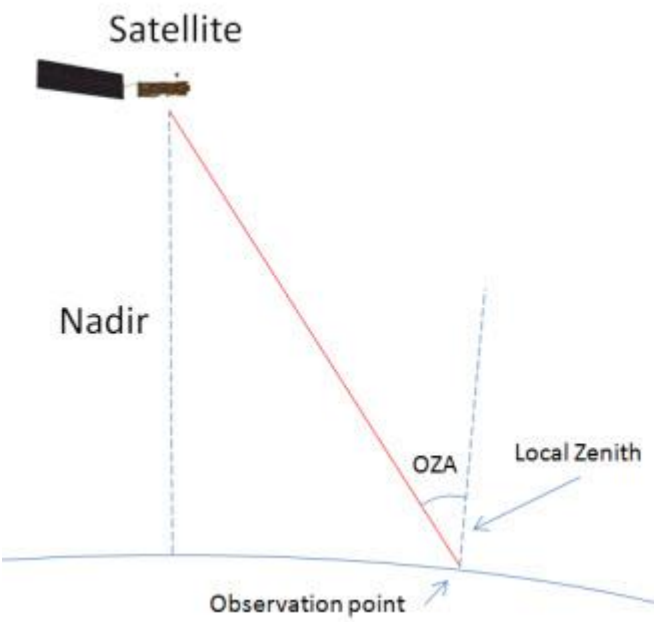
### 4.6.14 Observation Zenith Angle




The Observation Zenith Angle (OZA), also called Incidence Angle, is the angle between the satellite vector and the local zenith measured at the observation point.




When the OZA constraint is active any swath with OZA outside of the defined minimum and maximum values will be discarded.

You can also configure limits for the OZA at the swath edges via the Edge Minimum and Edge Maximum. This is useful to constrain the auto-steering mode to select a reduced set of candidate beams fulfilling the constraint, and discard the others.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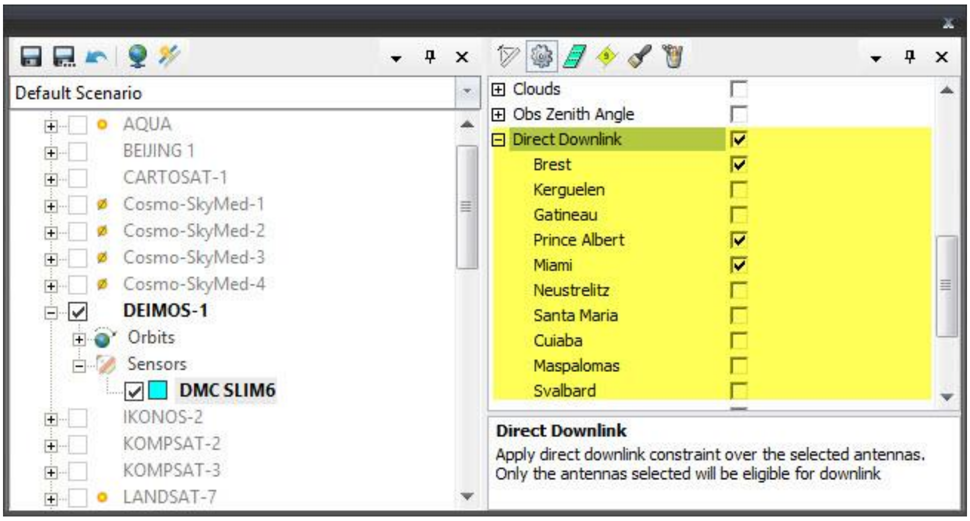
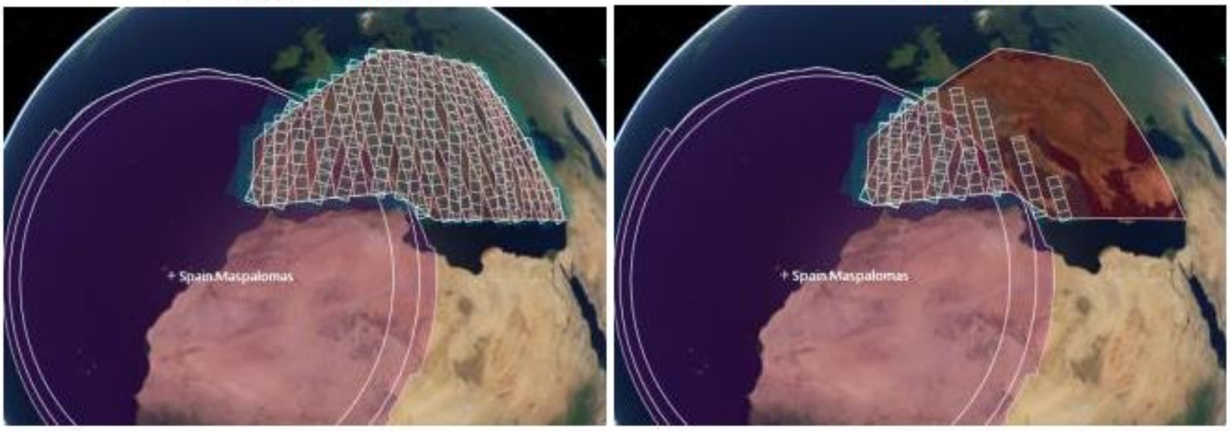
### 4.6.15 Direct Downlink




Direct Downlink constraint will trim all swaths generated with this sensors to be compatible with direct downlink on the selected antennas. In other words, the sensing start and stop times will be selected so that they fall within antenna visibility.

**Direct Downlink OFF** **Direct Downlink ON**



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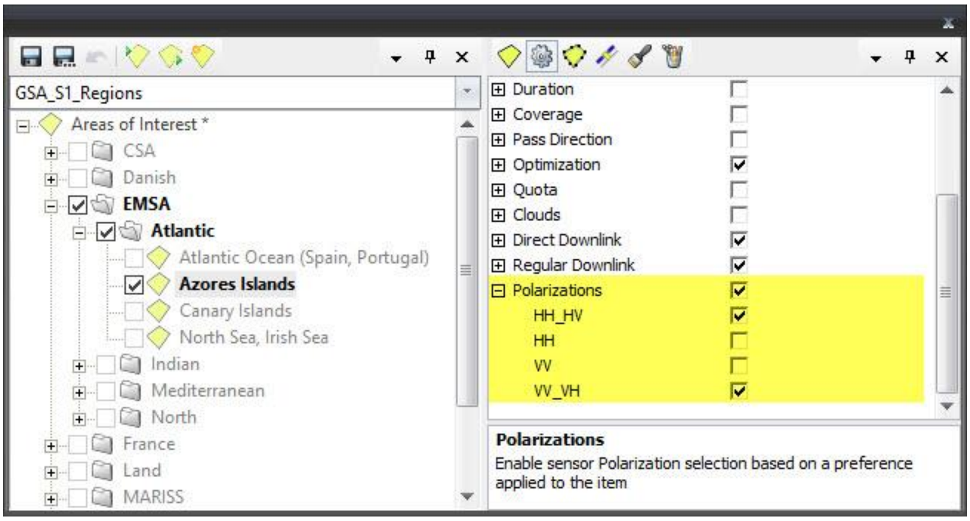
### 4.6.16 Polarizations




"Polarization" is a parameter usually associated with SAR sensors. The different combinations of Horizontal and Vertical polarizations that can be used during radar pulse transmission and reception allow for different imaging options.

The bottom line is that each polarization combination will have an impact in the sensor bit rate, typically ranging from nominal bit rate when in SINGLE polarization and double bit rate when in DOUBLE polarization.

SaVoir can evaluate the byte size of each acquisition by knowing the start and stop times and the polarization-dependent sensor bit rate.

By default all sensors are configured with a single bit rate parameter, but it is possible to define optional polarizations and bit rates for each sensor.

The Polarizations constraint allows configuring an AOI to choose a given polarization for its resulting acquisitions.



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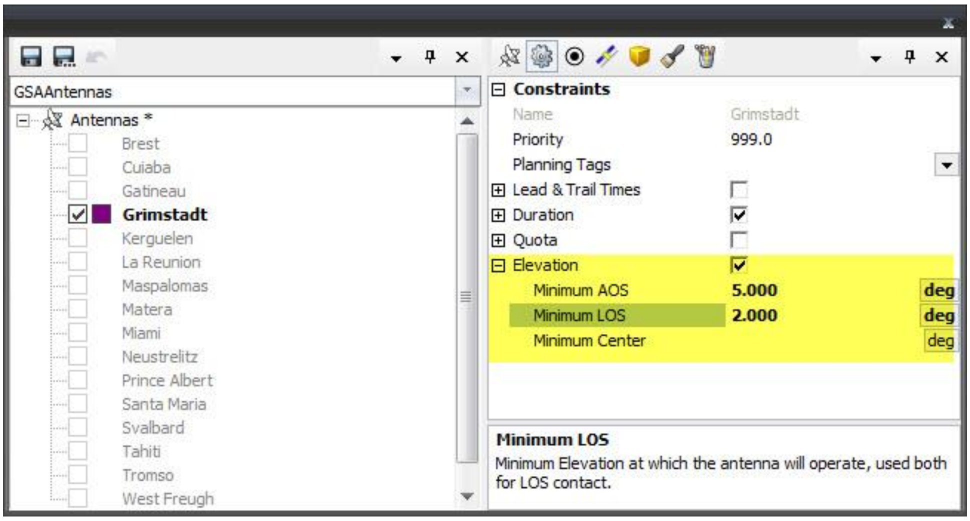
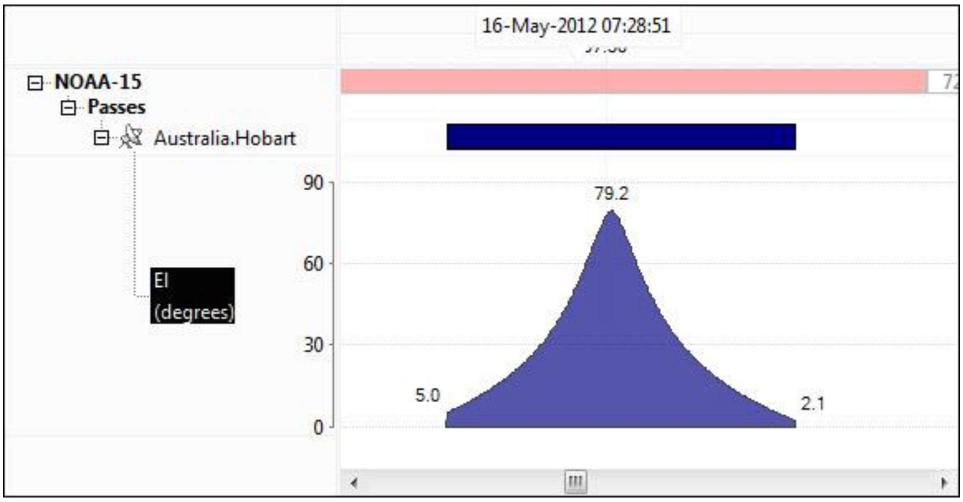
### 4.6.17 Elevation




The Elevation Constraint allows to define minimum elevation angles for a given antenna for the purpose of pass scheduling

- **Minimum AOS**: Minimum elevation at which AOS will be done. A pass will not start below this elevation.
- **Minimum LOS**: Minimum elevation at LOS. A pass will not finish below this elevation
- **Minimum Center**: Minimum elevation at the center of the pass. If the elevation at pass center is below this value the pass will not be scheduled.



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## 4.7 Planning Tags

Sometimes it is desired to assign Satellites or Sensors to Areas of Interest for intersection calculation.

For example the Sentinel-1 CSAR/EW (Extra Wide Swath) is planned to operate over ICE preferably, while CSAR/WV (Wave Mode) should operate only over SEA. It should be desired to "tag" an AOI as "ICE" or "SEA" and make SaVoir identify this circumstance so that CSAR/EW or CSAR/WV are not planned out of ICE or SEA.

The Planning Tags feature establishes a valid matching between Satellites, Sensors, Sensor Modes and AOIs.

Planning Tags are comma separated text strings (tags). They can be edited in the constraints grid.

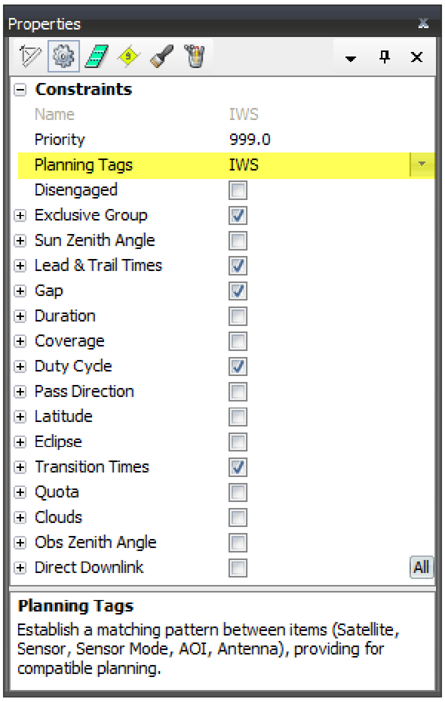


**Figure 51. Planning Tags**

For example, we may define the following Planning Tags:


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| | Id | Planning Tags |
|---|---|---|
| Sensor | CSAR / EM | "ICE, SNOW, GLACIER" |
| | CSAR / WV | "SEA" |
| | CSAR / IM | "" |
| | CSAR/S | "LAND, ICE" |
| AOI | Mediterranean | "SEA" |
| | Spain | "LAND" |
| | Artic | "ICE" |
| | Alaska | "LAND, SNOW" |
| | India | "" |

These Planning Tags definitions lead to the following matching table (a cross means "matching = yes")

| | Mediterranean | Spain | Artic | Alaska | India |
|---|---|---|---|---|---|
| CSAR / EM | | | x | x | x |
| CSAR / WV | x | | | | x |
| CSAR / IM | x | x | x | x | x |
| CSAR/S | | x | x | x | x |

Planning Tags matching is a prerequisite for planning. When an item has its Planning Tags empty (default state) it will always provide valid matching. The following SaVoir items are provided with Planning Tags:

- Constellation
- Satellite
- Sensor
- Sensor Mode
- Area of Interest
- Antenna

Planning Tags are also used for planning visibility timelines between Antennas and Satellites or Constellations, and between Satellites.



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# 5. Simulation Baseline Input

The Simulation Baseline Input (SBI) is the input to the simulation. The SBI is generated via menu GSA / Generate SBI or via the GSA Toolbar Generate SBI.

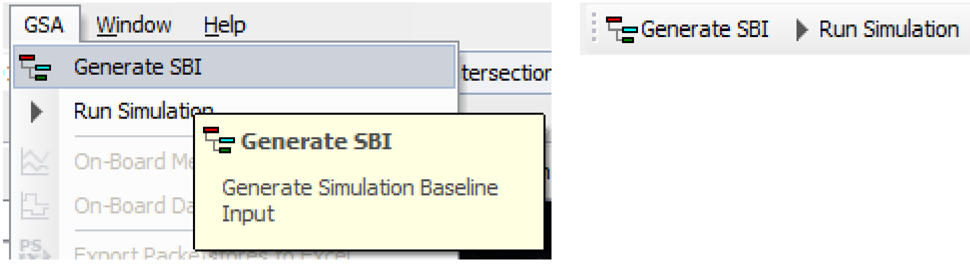


**Figure 52. Generate SBI**

When activated GSA will launch two actions in sequence:

- Calculate intersections (sensing plan)
- Calculate conflict-free visibility contacts (contacts plan)

In fact, pressing Generate SBI is equivalent to this sequence

- Refresh
- Visibilities / Antenna to Satellite Conflict – free

## *5.1 Sensing Plan*

"Refresh" will generate a sensing plan taking into account the defined time window, selected satellites and sensors, steering modes, optimization modes, areas of interest and other constraints. This is a core SaVoir operation, without any intervention of the GSA plugin.

It will be applied only to the selected items in the satellites, areas and antennas scenarios. You need to have **Intersection Mode ON** for a sensing plan to be generated.

The sensing plan will be shown on the Map, with swath footprints, on the Gantt view and the report view.

In order to generate the Sensing Plan SaVoir will also take into account those situations where Direct Downlink is required. Therefore it needs to have access to the Antennas scenarios and calculate visibility timelines compatible with the downlink requirements. This is done automatically by SaVoir, and requires that the suitable antennas are selected (visible).

Note that the Sensing plan will account for all defined Sensor and AOI constraints. It will also be conditioned by the Planning Tag rules, as defined in 4.7.

### 5.1.1 Polarization selection

Each sensor XML configuration has an optional section of <Polarizations> (see Figure 53. ). When present it defines

- the polarizations types allowed (e.g. HH_HV, HH, etc)
- for each one, whether it is SINGLE or DOUBLE polarization
- for each one the nominal instrument output bit rate



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- the preferred (Active) polarization, when no other requirements apply.

This configuration can be edited in the Sensor Properties pane (see Figure 54. )


```
- <Polarizations>
    <ActivePolarization>VV_VH</ActivePolarization>
  - <Polarization id="HH_HV">
      <Mode>DOUBLE</Mode>
      <Value>HH_HV</Value>
      <BitRate units="Mbps">112.198</BitRate>
    </Polarization>
  - <Polarization id="HH">
      <Mode>SINGLE</Mode>
      <Value>HH</Value>
      <BitRate units="Mbps">56.099</BitRate>
    </Polarization>
  - <Polarization id="VV">
      <Mode>SINGLE</Mode>
      <Value>VV</Value>
      <BitRate units="Mbps">56.099</BitRate>
    </Polarization>
  - <Polarization id="VV_VH">
      <Mode>DOUBLE</Mode>
      <Value>VV_VH</Value>
      <BitRate units="Mbps">112.198</BitRate>
    </Polarization>
  </Polarizations>
```


Areas of Interest maybe configured with a Polarization Constrain, indicating the required instrument polarization for covering the Area (see Figure 54. ).

When generating the SBI, the GSA will assign Polarization values to each swath, according to the following rules:

- If the sensor does not have any Polarization configuration, the swath will not have any Polarization value.
- If the sensor has a Polarization configuration, the swath will be configured with the active Polarization. The instrument bit rate will be the one defined for the Active Polarization.
- If the swath covers an Area of Interest with a defined Polarization constraint, the polarization will be the one defined for the Area of Interest, only if the Sensor has the same polarization available. Otherwise the sensor will not be scheduled over the Area of Interest.

**Figure 53. Sensor Polarization configuration**



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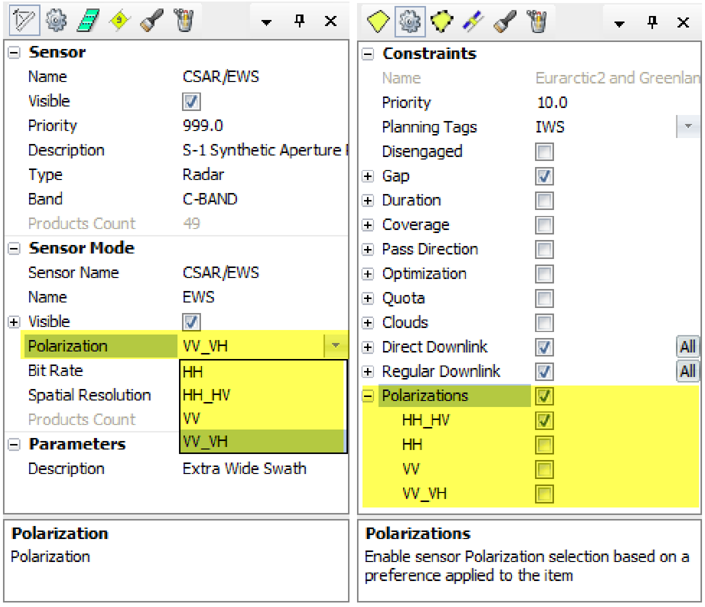

**Figure 54. Sensor and Region Polarization constraints**

## 5.2 Contacts Plan

The contacts plan is the **timeline of Satellite to Antenna visibilities**, calculated in the simulation window, and taking into account satellite orbits, horizon profiles (if defined), satellite-antenna associations, and minimum elevation constraints at AOS and LOS.

The contact plan is generated without conflicts. A conflict is when an antenna is in visibility of two or more satellites simultaneously. In this case SaVoir will clip the visibility timelines such that an antenna is assigned only to one satellite at any given time. The clipping is done automatically in SaVoir respecting the satellite priorities (to assign priorities, see the Properties pane / Constraints).

Antenna reconfiguration times are respected when managing switching between different satellites via the antenna Transition Times constraint, which, if active, will clip passes in order to respect a minimum time gap between consecutive passes on the same antenna.

Note that the Contacts plan will account for all defined Satellite and Antenna constraints. It will also be conditioned by the Planning Tag rules, as defined in 4.7.

The contacts plan is represented on the Gantt and on the Report Views, simultaneously with the sensing plan.

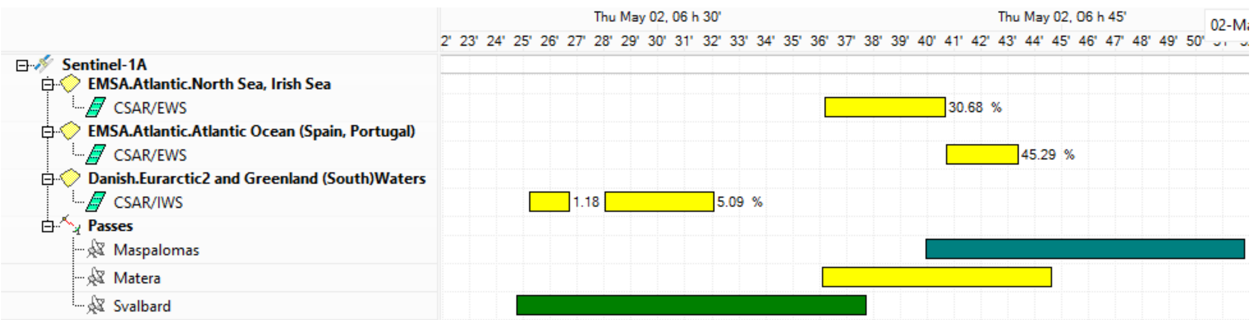



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**Figure 55. SBI Gantt View**



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# 6. Run Simulation

Running a simulation requires as a prerequisite that an SBI has been generated.

The simulation is triggered via the GSA / Run Simulation menu or via the GSA toolbar / Run Simulation.

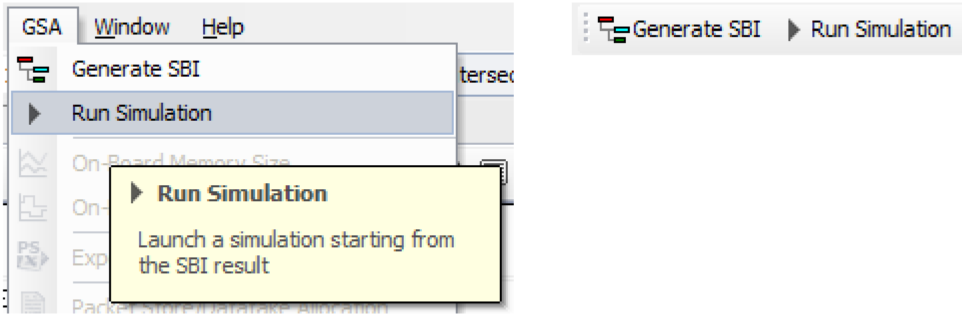


**Figure 56. Run Simulation menu**

The simulation will generate:

- Recording plan
- Downlink plan

Generating the recording plan has to be done simultaneously with generating the downlink plan because on-board storage has to account for the available storage space, which is dynamically increased and decreased by frequent storage and downlink operations. Therefore the logic followed in GSA is as follows:

1. For each satellite, collect all applicable satellite swaths and satellite passes over ground stations.
2. Order swaths and passes by time, older ones first.
3. For each pass,
   a. **Load applicable swaths on board**. Applicable swaths are those swaths that can be downlinked on that pass. Of course this implies swaths that occur before or during the pass, and are compatible with the pass constraints (antenna, downlink channel, etc).
   b. **Downlink data on the pass**, from pass-through data takes and / or from stored data takes.
4. Continue to step 3 until all passes have been processed.
5. Do final antenna assignments of passes according to antenna priority.

Therefore the mechanism is an alternation between storage and downlink with the granularity of one pass until all passes are completed at the end of the simulation window.

The last step is required to guarantee that dumps are assigned to antennas according to antenna priority. Without the last step the assignment would be commanded by pure start-time sequence of passes, see 6.4.



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## 6.1 Travelling tasks

The mechanism is also called "travelling tasks":

- Each single Sensing Data Take is represented as a Swath, contained in GanttX "**Task**".
- Each Task performs its data flow through On-Board Recorder, Packet Store, Downlink Channel up to the Ground Station element. In this **Travel** each Task records times of different events and other useful information (e.g. data sizes).
- At the end of the **Travel** the Reporting Manager will be able to process all results and display the required reports, by simple inspection of the Tasks data.

A "**Task**", in GanttX terminology, is a single time event with characterized by:

- Unique Id (string)
- Start Time
- Stop Time

Optionally, a Task may also include:

- Link to a Parent Task, or a set of Parent Tasks
- Parameters collection

The Parameters collection allows adding any number of useful information that can be used for the purpose of GSA reporting post-processing, for example:

- Sensing Start / Stop times.
- Recorder Dump Start / Stop times.
- Time of Arrival to Antenna.
- Data Size (GByte).
- Satellite – Sensor – Sensor Mode.
- Ground Station of downlink.

The Task is the most basic GanttX object and includes with it functions of visualization, contextual styling (colors, dimming, highlighting, etc) and XML serialization functions (Load / Save to file).

A Task is also handled by SatX and can be visualized in the form of Swaths or orbit tracks on the world map.

A Task contents can easily be inspected in SaVoir by clicking on the task or swath body and selecting "Details", a multi-tab pane will show the task parameters.



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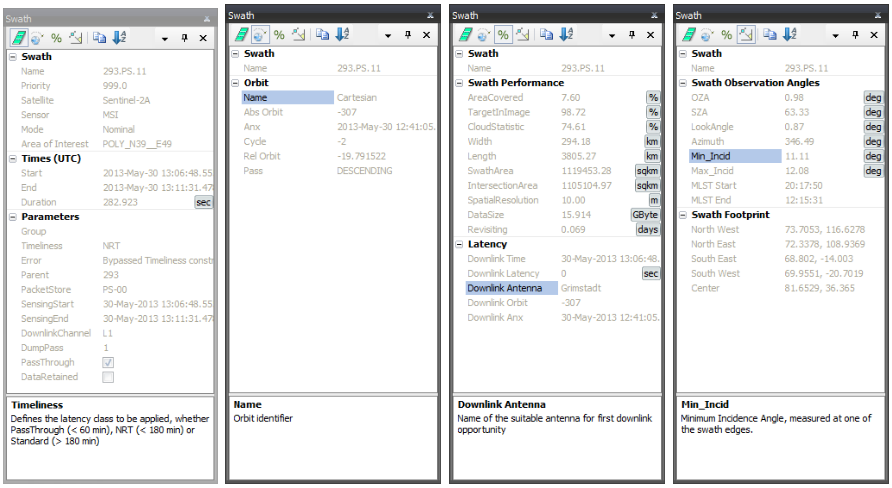


**Figure 57. Task Contents**

## 6.2 Recording Plan

The recording plan is the timeline of acquisition events stored on-board the Satellite recorder, distributed on the different Packet Stores.

The recording plan has to account for all recording constraints, including

- Sensor data rates,
- Sensor polarization configurations
- Recorder bit rate
- Recorder capacity
- Packet stores maximum capacities
- Packet Store Timeliness
- Packet store constraints
- others

At every new pass SaVoir will try to load swaths on board. It will try to load first those **deferred**, then those with **pass-through** (direct downlink to ground station). The deferred swaths were taken before AOS, in the period between passes, and therefore occur before the pass-through passes which have to occur during the pass.

The first step in assigning a swath to a Packet Store is identifying the sensor polarization:

- For single polarization the swath will go to one Packet Store only.
- For double polarization the swath will be split in two parts, the H and the V, and will be stored in two different Packet Stores, each associated with the same polarization, H or V.



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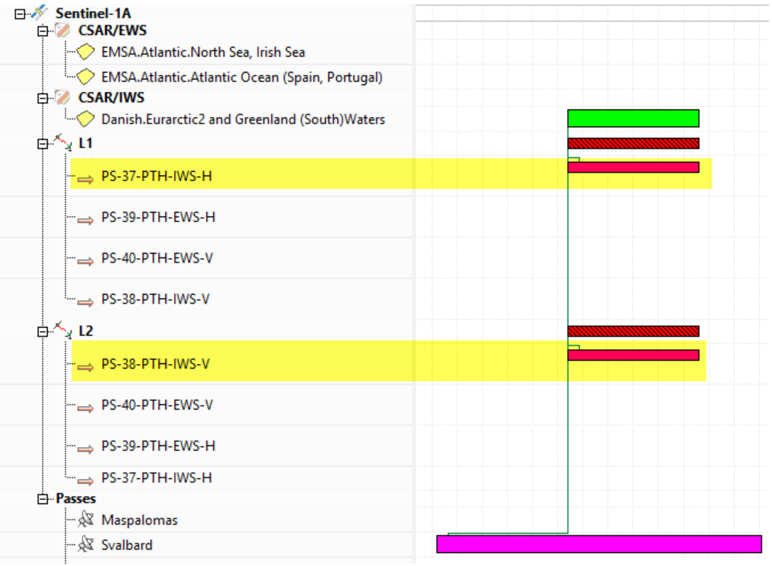


**Figure 58. Swath split in H and V polarizations over separate PS and Links**

## 6.2.1 Compatible Packet Stores

A subset of "Compatible" Packet Stores will be identified by checking several criteria:

- The Packet Store must be selected in the Satellite tree (visible)
- Pass-through swaths must go to Pass-through Packet Stores only
    - Data Retain swaths (as defined in the AOI) must go to Data Retain Packet Stores.
    - Direct Downlink constraint on the Packet store must be compatible with the swath downlink antenna constraints, as defined in the AOI Direct Downlink constraint.
- Timeliness of Packet Store must be compatible with the Timeliness of the swath, as defined in the AOI Timeliness.
- If defined, the Sensors and Regions subsets defined in the Packet Store must be compatible with the swath, for example if the swath is an "IWS" swath and the Packet Store Sensors parameter is "EWS, WVM", then the swath is not compatible.
- The polarization constraints, if defined, must be compatible with the swath polarization.

It could happen that a compatible Packet Store is not found. Depending on the state of the "Timeliness promotion" flag (see Edit / Properties / GSA) GSA may try to look for a possible packet store as follows:

- **Timeliness promotion = false**: If a compatible Packet Store is not found, the swath will not be stored on board and will not be downlinked. It will appear on the Simulation Timeline as "Lost" swath, and will be accounted in the final statistics as lost data.



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**Figure 59. Lost Swath**

- **Timeliness promotion = true**: If a compatible Packet Store is not found, a new search will for a compatible Packet Store will be done, this time without checking Timeliness requirements. This could lead to a Pass-Through Packet Store ingesting data with lower Timeliness requirements.

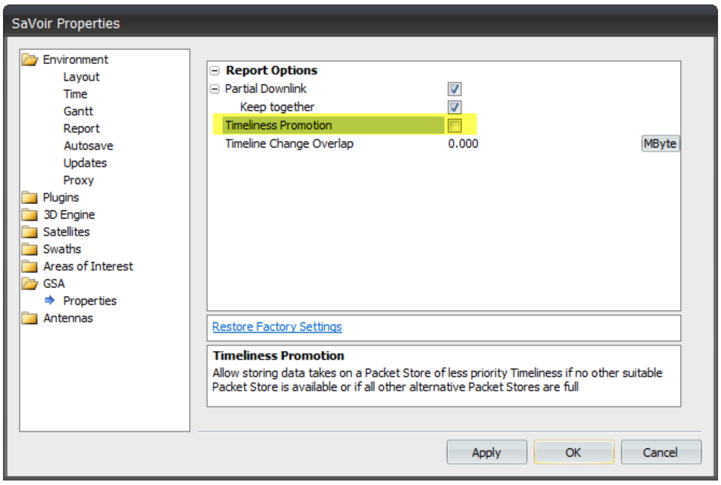


**Figure 60. Timeliness Promotion**

### 6.2.2 Best Packet Store

Once a subset of compatible Packet Stores has been identified, GSA will select the "best" of them for storing the incoming swath.

GSA will detect the "next in ring" Packet Store, i.e. look in the compatible subset the Packet Store that was used last, and the "next in ring" is the next in the number sequence. This ensures a fair distribution of load between Packet Stores.

- In case of **Pass-Through swath**, the "best" Packet Store is simply the "next in ring" among Pass-through packet stores.
- In case of **Standard or NRT swath**, the best Packet store is selected as follows,
  - Verify there is enough recording capacity left in the On-Board Recorder.
  - Select the "next in ring" Packet Store that has sufficient storage capacity left to load the incoming swath.

Once a "best" Packet Store is found the swath will be stored there, and the current capacity indexes (full Recorder and Packet Store) will be updated.

It could happen that no "best" Packet Store is found due to lack of memory. In this case the swath will be lost; it will appear as "Lost" in the simulation timeline and will account for the final statistics as lost data.



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For double polarization swaths, two “best” Packet Stores must be found. If only one is found (e.g. H and not V), the swath will also be “Lost”.

### 6.2.3 Storage

The Packet Store is treated as a FIFO queue. When retrieving data for downlink, older data will be taken first.

## *6.3 Downlink Plan*

Downlink planning is performed on a per-pass basis. All passes are time-ordered and processed in sequence. It is assumed that pass-clipping (remove antenna conflicts) has been performed when generating the SBI.

Initially GSA will create the Downlink Slots collection, to keep track of the available time windows for downlink.

To define the downlink sequence over an Antenna on a given pass the following steps will be followed:

- Obtain a subset of suitable Packet Stores candidates for downlink
- Order the Packet Stores
- Perform downlink sequentially for the selected Packet Stores

### 6.3.1 Downlink Slots

From the available passes for a satellite, GSA will create a collection of “downlink slots” at the beginning of simulation. A downlink slot contains

- a reference to a **Downlink Channel** (L1 and L2 for Sentinel-1), and
- a set of **Time Windows** suitable for downlink.

Each pass will generate as many slots as downlink channels. For Sentinel-1 two slots per pass will be created, L1 and L2.

Initially the slot will contain one time window identical to the pass time span. As the simulation proceeds each slot will be fragmented in smaller time windows by subtracting the periods of downlink, therefore ensuring that each downlink channel is following a strict sequential booking sequence.

### 6.3.2 Regular Downlink and Direct Downlink

GSA models two types of antennas:

- Regular Downlink Antennas: synonym of Core Stations. They receive deferred and real time downlink.
- Direct Downlink Antennas: synonym of Local Stations. They receive real time downlink only.

Packet Stores and AOIs have optional constraints requiring specific subset of antennas to be used as Core or Local stations. The Downlink planning algorithm will make use of these constraints to define suitable Packet Stores for Downlink.



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### 6.3.3 Suitable Packet Stores for downlink

The suitable packet stores for downlink are selected as follows:

- The Packet Store must be selected on the Satellite tree (visible)
- The Packet Store must be non-empty, with data ready for download.
- The first data take in the Packet Store queue (FIFO queue, i.e. oldest data) is analysed.
- If the data take is Pass-Through
    - If the Packet Store is Valid for Direct Downlink, then is suitable
    - If the Packet Store is Valid for Regular Downlink and is a "Data Retain" Packet Store, then is suitable.
- If the data take is not Pass-Through (NRT or Standard)
    - If the Packet Store is Valid for Regular Downlink, then is suitable.

A Packet Store is valid for Direct or Regular Downlink if there is a compatibility between the Packet Store Downlink Constraints (Regular or Direct) and the data take Downlink Constraints, as defined by the AOI constraints and / or the Sensor Constraints.

### 6.3.4 Ordering Packet Stores

When selecting the Packet Store for downlink GSA will do it by ordering the suitable Packet Stores according to two criteria:

- Priority
- Timeliness

Higher priority Packet Stores will be processed first. Those of equal priority will be ordered by Timeliness: Pass-Through first, then NRT, then Standard.

### 6.3.5 Downlinking a Packet Store

Downlink of a Packet Store over an Antenna is done as follows:

- Select suitable Downlink Slots for downlink. A slot is not suitable if its Downlink Channel is not compatible with the Antenna (see Downlink Channels parameter on the Antenna, chapter 4.5.)
- Packet Store downlink will be done in FIFO mode by downlinking older data first until the slots capacity have been consumed. For each data take:
    - If the Data Take is Pass-Through or NRT an attempt will be done to downlink in real time
    - If the Data Take is Standard, the downlink will be done in deferred mode.
- Attempt to downlink in deferred mode all Pass-Through events that could not be downlinked in real time because the channel was blocked.



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### 6.3.6 Real Time downlink

Here we explain the steps for downlinking a data take in real time, i.e. simultaneous with data sensing. It is assumed that a best Packet Store and a Data Take have been identified over the given Pass.

- Find the best slot for downlink.
  - Make sure Downlink Channel **threshold** duration constraints are fulfilled, by trimming the Downlink Slots according to the Duration constraints defined in each Downlink Channel (see 4.3.7)
  - Analyse only Downlink Slots that overlap the Data Take (Pass-Through requires this)
  - Trim the candidate slot to avoid simultaneous downlink on two channels.
  - Apply Downlink Channels constraints to clip the slot according to **maximum duration and quota**.
  - Select the slot with duration closest to the Data Take duration with as little spill over as possible.
- Dump on the Data Take to the selected slot.
  - Apply the "Partial Downlink" flag (see Edit / Properties / GSA) to control whether downlink should permit downlinking a data take in separate chunks or downlinking in a single chunk the complete data take.
  - Recalculate the remaining Downlink Slot space.
  - Qualify the Downlink Task with information of downlink Start / Stop, data size (Mbytes),
  - Recalculate the remaining part of the Data Take in the Packet Store which could not be downlinked yet (if Partial Downlink). Add Overlap Retain margins if needed (see Recorder parameters Data Retention in 4.3.3)

### 6.3.7 Deferred Downlink

Here we explain the steps for downlinking a data take in deferred mode, i.e. after data sensing from data takes stored on-board. It is assumed that a best Packet Store and a Data Take have been identified over the given Pass.

- Find the best slot for downlink.
  - Make sure Downlink Channel **threshold** duration constraints are fulfilled, by trimming the Downlink Slots according to the Duration constraints defined in each Downlink Channel (see 4.3.7)
  - Trim the slot to avoid Simultaneous Read and Write operation on the Packet Store, in case Simultaneous R/W is forbidden.
  - Trim the candidate slot to avoid simultaneous downlink on two channels.
  - Apply Downlink Channels constraints to clip the slot according to **maximum duration and quota**.
  - Select the slot with duration closest to the Data Take dump duration (accounting for data size and downlink data rate) with as little spill over as possible.



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- Dump on the Data Take to the selected slot.
    - Apply the "Partial Downlink" flag (see Edit / Properties / GSA) to control whether downlink should permit downlinking a data take in separate chunks or downlinking in a single chunk the complete data take.
    - Recalculate the remaining Downlink Slot space.
    - Qualify the Downlink Task with information of downlink Start / Stop, data size (Mbytes),
    - Calculate Latency Times, i.e. times between sensing and downlink.
    - Recalculate the remaining part of the Data Take in the Packet Store which could not be downlinked yet (if Partial Downlink). Add Overlap Retain margins if needed (see Recorder parameters Data Retention in 4.3.3)

If the data take cannot be downlinked, it will appear in the Gantt View as "Downlink Pending" and accounted in the final statistics.

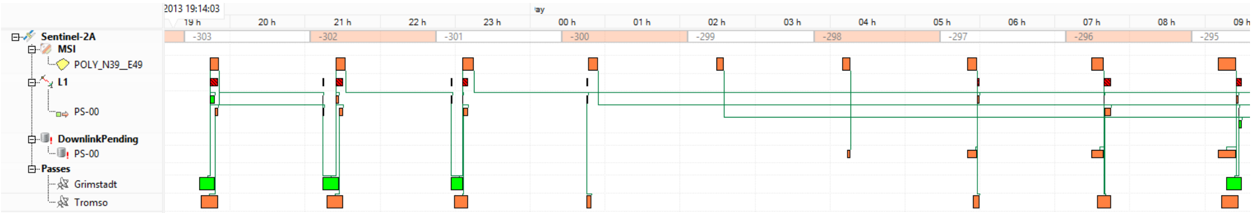

**Figure 61. Downlink Pending due to lack of downlink passes**

## 6.4 *Final antenna assignment*

The assignment of a dump to an antenna is done following the above mentioned constrains and associations. The algorithm that assigns packet stores and downlink slots follows a per-pass method, with earlier passes treated first. In the case of two overlapping passes (same satellite visible simultaneously by two antennas) the algorithm will deal first with the pass having earliest start time. As a consequence pass priorities are not handled, i.e. if the earliest pass has lower priority, it will still be treated first.

Therefore we need a "final antenna assignment" step that reassigns downlink dumps to antennas according to priorities. This is done automatically by GSA at the end of the Recording-Downlink sequence, as shown the example below.

In this example there are two overlapping passes of Sentinel-2A over Tromso and Grimstadt. Tromso pass starts first, so downlink starts as soon as possible over Tromso in Pass-through mode. We show cases:

Case 1 (Figure 62. ): Tromso has priority (19) over Grimstadt (20). Therefore the full dump is assigned to Tromso, including a final deferred dump to downlink data stored on PS-00 before starting the Tromso pass.

Case 2 (Figure 63. ): Grimstadt has priority (20) over Tromso (999). The dump starts in Pass-Through over Tromso, but as soon the Grimstadt visibility is available the dump is assigned to Grimstadt. The final deferred dump is also assigned to Grimstadt.



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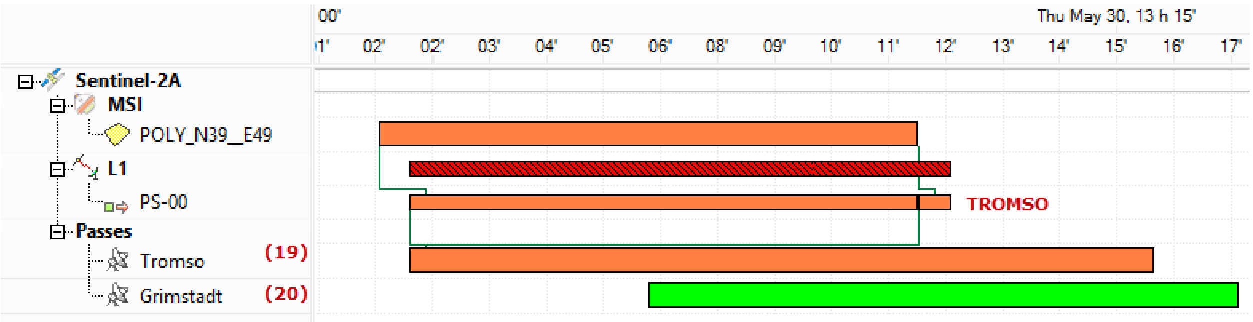


**Figure 62. Tromso has priority**

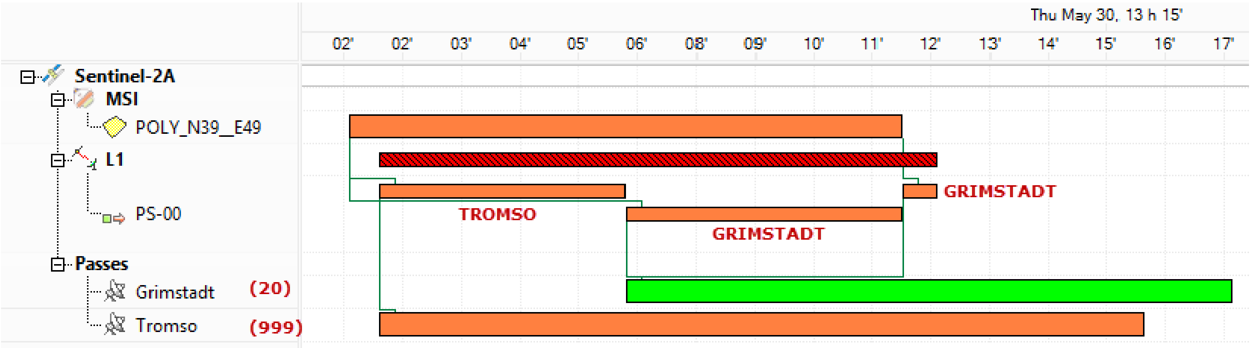


**Figure 63. Grimstadt has priority**

# 7. Collecting Results

At the end of simulation the "travelling tasks" have finished their trip through the sensors, recorders, packet stores, downlink channels and antennas. GSA will collect these tasks in their final locations according to their fate during simulation:

- Original sensing data takes (swaths)
- Dumps to Antennas
- Antenna passes

All tasks have associated parameters registering their different operations during sensing, recording and downlink. These parameters permit to build the Downlink Plan view (see Figure 11. ) with a hierarchical timeline representation (Gantt) of the sequences in a cascading representation.

## *7.1 Parent – Child relations*

Relations between a swath a dump and an antenna pass are implemented through parameters in the Dump task:

- Swath to Dump: parameter "Parent"
- Dump to Antenna pass: parameter "Downlink Antenna"

By parsing these parameters GSA will build the links between tasks which allow displaying tree relationships on the Gantt display.



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# 8. Visualizing results

GSA uses the visualization infrastructure of SaVoir too visualize the SBI. This includes basically three views: the Map, the Gantt and the Report View. At the of SBI generation the three views will be loaded automatically with the SBI results:

# 9. GSA Configuration files

GSA uses the same configuration files of SaVoir. These are:

1. Satellite scenario files
2. Antenna scenario files
3. Areas scenario files

They are XML files containing a hierarchical serialization of GSA objects, including satellites, sensors, orbits, etc.

GSA is delivered with default configurations in the following files and locations.

| File | Location | Comments |
|---|---|---|
| _GSA_S1.xml | C:\Program Files (x86)\Taitus Software\SaVoir\cnf\satellites | Sentinel-1A and 1B, with nominal orbits, sensors (EWS, IWS, S and WV), on board recorder with 50 Packet Stores, 2 Downlink Channels |
| _GSA_S2.xml | C:\Program Files (x86)\Taitus Software\SaVoir\cnf\satellites | Sentinel-2A and 2B, with nominal orbits, sensors (CAL and MSI), on board recorder with 1 Packet Store, 1 Downlink Channels |
| _GSA_S1_Regions.xml | C:\Program Files (x86)\Taitus Software\SaVoir\cnf\regions | Over 100 preconfigured regions with different polarization and scheduling constraints |
| _GSA_S2_Regions.xml | C:\Program Files (x86)\Taitus Software\SaVoir\cnf\regions | Over 100 preconfigured regions with different polarization and scheduling constraints |
| _GSAAntennas.xml | C:\Program Files (x86)\Taitus Software\SaVoir\cnf\antennas | 16 antennas in different real world locations (Svalbard, Tromso, Matera, etc) |

The Files can be loaded by drag & drop on SaVoir, by drop-down selection on the scenario pane or by simple File / Open menu.

The files will be copied in the working directory when called. GSA will use the copied files during GSA operation. The working directory is located typically in

- "C:\Users\<<user>>\Documents\SaVoir\satellites\..."
- "C:\Users\<<user>>\Documents\SaVoir\regions\..."
- "C:\Users\<<user>>\Documents\SaVoir\antennas\..."

The copied files maybe modified, extended or reduced by the user during GSA operation. They can be edited by the user without any constraint. The user may also operate different scenario files for GSA simulations.



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The user may return to the default configuration by pressing the Revert button on the scenario pane.



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