GAMMA SOFTWARE VALIDATION REPORT:
ENVISAT ASAR DATA PROCESSING

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GAMMA REMOTE SENSING

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1 Introduction

In the frame of the adaptations of GAMMA software to ENVISAT ASAR parts of the geocoding procedures were adapted to optimally support **geocoding** of ENVISAT ASAR data. To test if these adaptations are functional and to validate the quality achieved some tests were conducted which are reported in this document. Furthermore, adaptations to support the **radiometric calibration** of ASAR data products were conducted.

Some of these tests were conducted using ASAR data which are made available by ESA (for online distribution see http://envisat.esa.int and http://earth.esa.int). ESA is acknowledged for providing these data.

In the following the main adaptations are shortly explained and then the tests which were conducted are presented.

A first version of this document was written in Nov. 2002. A major update concerning the radiometric calibration was made in January 2003.

2 ASAR adaptations in GAMMA Software (as per Jan. 2003)

So far, no adaptations in the MSP for ASAR stripmap processing were included in the official software version. Raw data have become available to us and an upgrade of the MSP for ASAR stripmap processing is expected for the near future.

Main adaptations in the ISP and DIFF&GEO are required for the following reasons:

- Specific ASAR data format (image data and meta data are provided in a single file using a mixed ASCII and binary format)
- There are many different ASAR modes including also low and medium resolution modes and the alternative polarization mode where two images (at different polarizations) are provided in the data file.

- For ground-range images polynomials are provided to calculate the corresponding slant ranges
- Slightly different concept used for radiometric calibration (as compared to ERS)

2.1 ISP: par_ASAR

To support the new input data format a program par_ASAR was written to read the ASAR data file provided by ESA, extract the image and meta data required, and write it out in the standard format used by the GAMMA software. par_ASAR automatically determines the ASAR mode and generates accordingly format specifications and file names for the output image data and parameter files. In addition, the entire unchanged header section of the input data is copied to a separate header file for possible later reference.

In order to include important geometric information, a few parameters were added to the SLC parameter file. These are:

- Slant range from ground range polynomials for start, center, and end of image (0.0 values for images in slant range geometry or non-ASAR ground-range images)
- Azimuth line time (time per azimuth line in seconds)
- Image geometry (GROUND_RANGE or SLANT_RANGE)
- Image format (FLOAT, SHORT, SCOMPLEX, FCOMPLEX)

As an additional feature par_ASAR permits to transcribe the input data to GAMMA format and to apply in the same step the radiometric calibration. This was included to avoid to write out the uncalibrated PRI image (which is an amplitude product in short integer format as compared to intensities in float format as used for all other backscatter image products in the GAMMA software).

ASAR can be operated in many different modes. In order to facilitate the use of ASAR data par_ASAR automatically determines the image mode of the provided data. According to the mode, the names for the output SLC parameter and image files are defined.

The program supports the following modes:

- ASAR images mode (IMS, IMP, IMM, IM)
- ASAR alernating polarization mode (APS, APP, APM, AP)
- ASAR wide swath mode (WSM, WS)
- ASAR global monitoring mode (GM1,GM)

This includes the following data types:

- SLC (IMS, APS) (slant range geometry, scomplex)
- PRI (IMP, IMM, APP, APM, WSM, GM1) (ground range geometry, short)
- PRI (IM, AP, WS, GM) (ground range geometry, uchar)

The ASAR modes supported by par_ASAR and the related naming conventions are indicated in the Table 1. For details on the products, names and formats see: http://envisat.esa.int/pub/ESA_DOC/ENVISAT/ASAR/asarProductHandbook.pdf.zip.

ASAR swath and polarization are documented in the sensor element of the SLC parameter file. Resulting ASAR sensor types looks like ASAR_IS3_VV (image mode 3, VV polarization) or ASAR_WS_VV (wide swath VV-polarization).

ASAR mode	SLC_par	image	type	format	geometry
IMS	*.VV.SLC.par	*.VV.SLC	SLC	SCOMPLEX	SLANT_RANGE
IMP	*.VV.PRI.par	*.VV.PRI	PRI	SHORT	GROUND_RANGE
IMM	*.VV.PRI.par	*.VV.PRI	PRI	SHORT	GROUND_RANGE
IM	*.VV.PRI.par	*.VV.PRI	PRI	UBYTE	GROUND_RANGE
APS	*.VV.SLC.par *.HH.SLC.par	*.VV.SLC *.HH.SLC	SLC	SCOMPLEX	SLANT_RANGE
APP	*.VV.PRI.par *.HH.PRI.par	*.VV.PRI *.HH.PRI	PRI	SHORT	GROUND_RANGE
APM	*.VV.PRI.par *.HH.PRI.par	*.VV.PRI *.HH.PRI	PRI	SHORT	GROUND_RANGE
AP	*.VV.PRI.par *.HH.PRI.par	*.VV.PRI *.HH.PRI	PRI	UBYTE	GROUND_RANGE
WSM	*.VV.PRI.par	*.VV.PRI	PRI	SHORT	GROUND_RANGE
WS	*.VV.PRI.par	*.VV.PRI	PRI	UBYTE	GROUND_RANGE
GM1	*.VV.PRI.par	*.VV.PRI	PRI	SHORT	GROUND_RANGE
GM	*.VV.PRI.par	*.VV.PRI	PRI	UBYTE	GROUND_RANGE

Table 1: ASAR modes supported by par_ASAR and the related naming conventions.

2.2 ISP: ASAR_XCA

ASAR sensor information as antenna diagrams (for all modes), reference look angles for the antenna diagrams, and calibration scaling factors (for each mode and data product) are provided in the so called ASAR external calibration file which is available as a separate ASAR product with a name like ASA_XCA_… . This product can be ordered from ESA. It may get updated from time to time.

The information provided in the ASAR external calibration file is used by GAMMA software for radiometric calibration of SLC and PRI type products as well as in the SAR processing. The new ISP program ASAR_XCA permits to display the calibration data contained in the ASAR external calibration file and to convert the antenna diagrams to the standard format required in GAMMA software.

Concerning the antenna diagrams please notice that the values provided by ESA are two-way gains expressed in linear scale (0.5 meaning half the value in the center) while the format used by GAMMA software is one-way gain and is expressed in dB (-3.0 dB corresponding to 0.5 in linear scale).

According to information provided by the ESA Helpdesk the most recent versions of the required auxiliary files are available for download from the following web site:
http://envisat.esa.int/services/auxiliary_data/asar/
They are also directly reachable from the User Services/ Software Tools section on the Envisat Web site (http://envisat.esa.int).

2.3 ISP: SR_to_GRD and GRD_to_SR

The programs to convert between ground-range and slant range geometry were adapted to take into account the slant-range from ground range polynomials provided for ASAR ground-range images. For transformations without such polynomial the method used already in the past which is based on a local spherical earth model is used.

2.4 ISP: radcal_PRI, radcal_SLC, radcal_MLI

The programs for radiometric calibraton of ground-range and slant range data were slightly adapted to support the calibration scheme of ASAR. The ASAR calibration schemes are defined in the ASAR user handbook.

For PRI data the procedure is more or less the same as for ERS data. The same program, radcal_PRI, is used. For all ASAR modes 90 deg. (instead of 23. deg.) is used as reference incidence angle for the ground-area projection correction. The reference incidence angle needs to be indicated on the command line of radcal_PRI. Calibration scale factors also need to be indicated on the command line. Calibration scale factors (per mode and data product, and possibly updated over time) can be found in the ASAR external calibration data. ASAR_XCA supports the access to this information for GAMMA software users. The calibration scale factors for Jan 2003 are listed in the Table 2.

For SLC data and multi-look intensity images generated from SLC data the procedure is also more or less the same as for ERS data. The same programs radcal_SLC and radcal_MLI are used. For all ASAR modes 90 deg. (instead of 23. deg.) is used as reference incidence angle for the ground-area projection correction. This is accounted for automatically by the calibration programs when identifying ASAR as the sensor (as indicated in the SLC/MLI parameter file). Calibration scale factors also need to be indicated on the command line. For the range spreading loss correction a r^3 dependence is used (as for ERS) except for alternating polarization mode data where a r^4 dependence is used. This needs to be specified on the command line. For the range spreading correction, a constant slant range reference of 800 km is used for all ASAR swaths. For MLI data generated by multi-looking an ESA processed SLC the calibration factor as indicated for the SLC product needs to be used. Calibration scale factors (per mode and data product, and possibly updated over time) can be found in the ASAR external calibration data. ASAR_XCA supports the access to this information for GAMMA software users. The calibration scale factors for Jan 2003 are listed in Table 2, the reference elevation angles in Table 3.

Mode	IS1	IS2	IS3	IS4	IS5	IS6	IS7
IMS_HH	46.040	46.040	46.040	46.040	46.040	46.040	46.040
IMS_VV	46.040	46.040	46.040	46.040	46.040	46.040	46.040
IMP_HH	55.030	55.030	55.030	55.030	55.030	55.030	55.030
IMP_VV	55.030	55.030	55.030	55.030	55.030	55.030	55.030
IMG_HH	55.030	55.030	55.030	55.030	55.030	55.030	55.030
IMG_VV	55.030	55.030	55.030	55.030	55.030	55.030	55.030
IMM_HH	67.490	67.490	67.490	67.490	67.490	67.490	67.490
IMM_VV	67.490	67.490	67.490	67.490	67.490	67.490	67.490
APS_HH	0.000	43.430	45.150	43.460	48.460	44.790	50.410
APS_VV	0.000	43.430	45.150	43.460	48.460	44.790	50.410
APS_HV	0.000	43.430	45.150	43.460	48.460	44.790	50.410
APS_VH	0.000	43.430	45.150	43.460	48.460	44.790	50.410
APP_HH	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APP_VV	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APP_HV	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APP_VH	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APG_HH	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APG_VV	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APG_HV	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APG_VH	57.150	57.350	57.280	56.850	64.040	60.190	65.520
APM_HH	69.570	69.770	69.700	69.270	72.920	69.070	74.400
APM_VV	69.570	69.770	69.700	69.270	72.920	69.070	74.400
APM_HV	69.570	69.770	69.700	69.270	72.920	69.070	74.400
APM_VH	69.570	69.770	69.700	69.270	72.920	69.070	74.400
WV_HH	0.000	47.380	0.000	0.000	0.000	0.000	0.000
WV_VV	0.000	47.380	0.000	0.000	0.000	0.000	0.000
WS_HH	68.880						
WS_VV	68.880						
GM_HH	0.000						
GM_VV	0.000						

Table 2: ASAR Calibration factors in dB (status Jan. 2003 from ASAR_XCA: external calibration scaling factors, 0.000 means not provided).

Mode	IS1	IS2	IS3	IS4	IS5	IS6	IS7	SS1
all	16.628	20.138	25.243	29.533	32.818	35.633	38.058	19.163

Table 3: ASAR_XCA: reference elevation angles (in deg., status jan. 2003).

Regarding the required auxiliary files, the most recent versions are available for download from the following web site: http://envisat.esa.int/services/auxiliary_data/asar/

2.5 DIFF&GEO: gc_map_grd, and gec_map_grd

The geocoding programs for ground-range images were adapted to take into account the slant-range from ground range polynomials provided for ASAR ground-range images. For transformations without such polynomial the method used already in the past which is based on a local spherical earth model is used.

3 Geocoding verification for ENVISAT ASAR

3.1 Introduction

Validation of the ENVISAT ASAR geocoding was conducted for the ENVISAT ASAR sample products made available by ESA after the calibration review of 9 September 2002. Sample products are available for the Image Mode over The Netherlands, the Alternating Polarization mode over Germany, and the Wide Swath Mode over Spain. A topographic map was available to us for geocoding accuracy assessment only for the Dutch test site. The ENVISAT ASAR sample products do not include state vectors of precision orbits, high geocoding errors are therefore expected. The purpose of this analysis is therefore mainly to verify that geocoding of ENVISAT ASAR images with the GAMMA software is operational and conforming to the standard achieved in numerous cases with ERS and JERS SAR data. The analysis does not include any consideration on the radiometric calibration of ASAR data.

3.2 Wide Swath Mode over Spain

The sample product in Wide Swath Mode over Spain (ASA_WSM_1P) is in VV polarization and PRI (ground-range) format. Geocoding to the UTM projection, zone 31, Datum WGS 1984, with a posting of 100 m was tested with use of the GTOPO30 DEM (pixel spacing of about 1 km) and on the ellipsoid. In both cases only the upper part of the image could be geocoded because the state vectors distributed with the image only covered half of the scene.

Both ellipsoid and terrain corrected geocoding of the ENVISAT ASAR data in Wide Swath Mode run operationally. As an example, the whole area geocoded with use of the DEM is shown in Figure 1. The difference between the two geocoded products is on the order of several pixels, including not only topographic dependent structures but also a translation in range and azimuth. This reflects the offsets found between the real SAR image and the one simulated from the DEM, which were around -6 pixels in range and 1 pixel in azimuth at image center. The standard deviation for range and azimuth fits was 4.4 and 0.4 pixels, respectively (corresponding to 300 m in ground-range and 30 m in azimuth). The reason for this large offset is related to the precision of the state vectors distributed with the image. This example shows the importance of the refinement step in the geocoding procedure. In Figures 2, 3 and 4 the shaded relief of the GTOPO30 DEM, the terrain corrected geocoded product, and the ellipsoid geocoded product are compared for a small area of the ENVISAT ASAR scene.

3.3 Image Mode over The Netherlands

Sample products in Image Mode over The Netherlands were considered in SLC (slant-range, ASA_IMS_1P) and PRI (ground-range, ASA_IMP_1P) format for VV polarization and IS3. As a first test, the SLC image was multi-looked and transformed to the same ground-range geometry as the PRI. A comparison of the two images shows an almost perfect correspondence between the two products with range and azimuth offsets of less than $1/20^{th}$ of pixel in average.

Geocoding to the UTM projection, zone 31, Datum WGS 1984, with a posting of 25 m was then tested for both the multi-looked image in slant-range geometry derived from the SLC and the PRI in ground-range geometry. In both cases, ellipsoid geocoding was successfully accomplished. The results of the two geocoding procedures are almost identical (range and azimuth offsets of less than $1/20^{th}$ of pixel in average). An extract of the results is shown in Figure 5. The validation of the geocoded ENVISAT ASAR intensity image was performed for eleven ground-control points extracted from a topographic map. We found range and azimuth offsets of 8.0 and -1.0 pixels (-200 and -25 m), respectively, and standard deviations for range and azimuth of 0.6 and 0.4 pixels (15 and 10 m), respectively.

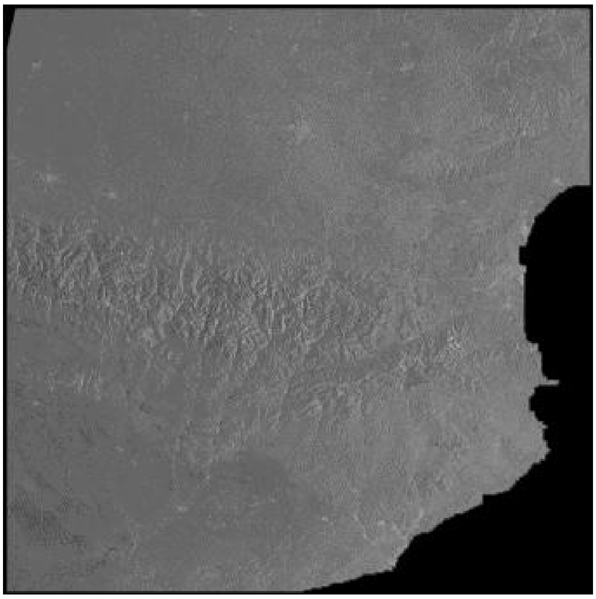


Figure 1. Terrain corrected geocoded ENVISAT ASAR WSM backscattering image over part of Spain.

Figure 2. Extract of the GTOPO30 DEM for part of Spain resampled to 100 m pixel spacing.

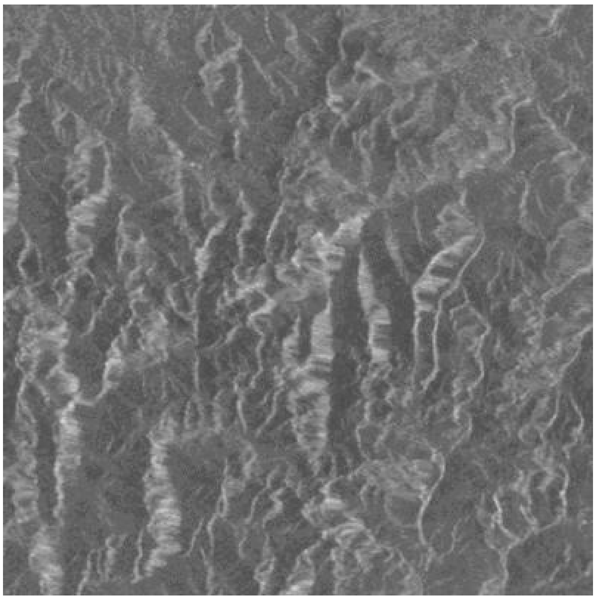


Figure 3. Extract of the terrain corrected geocoded ENVISAT ASAR WSM backscattering image over part of Spain.

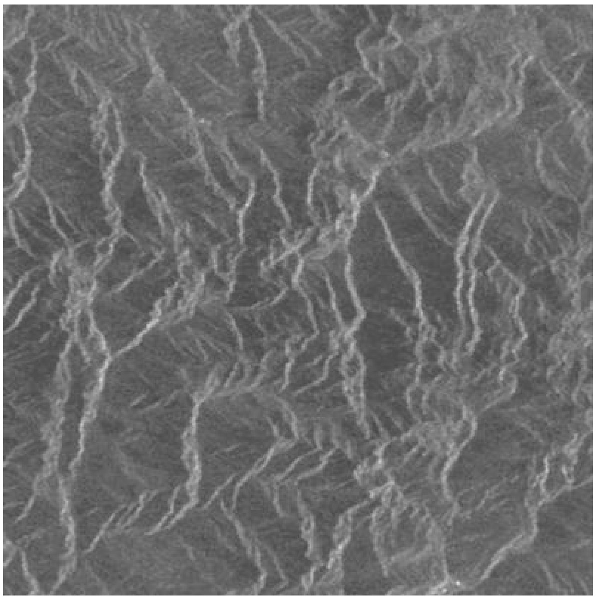
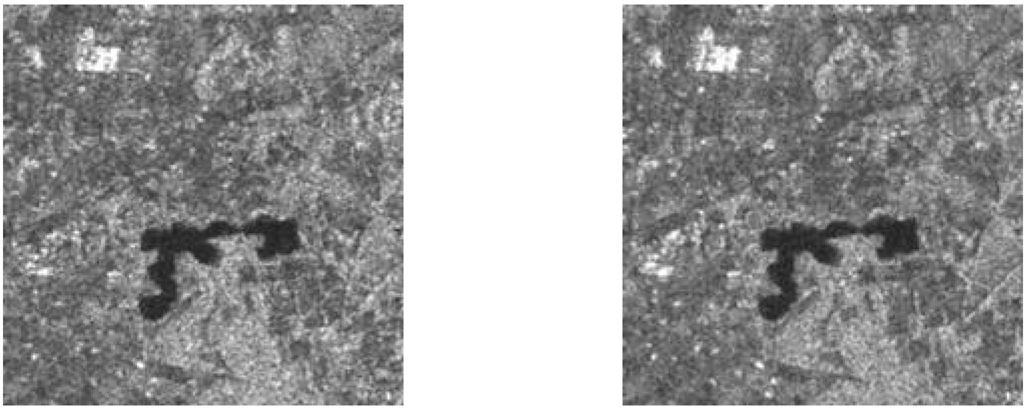


Figure 4. Extract of the ellipsoid geocoded ENVISAT ASAR WSM backscattering image over part of Spain.

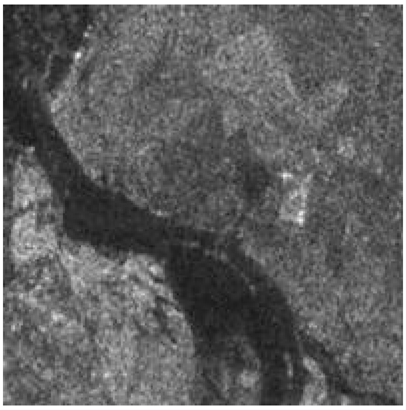


ASA_IMS_1P ASA_IMP_1P

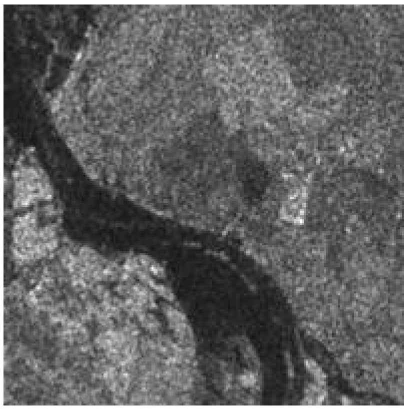
Figure 5. Extracts of ellipsoid geocoded ENVISAT ASAR sample products in Image Mode over The Netherlands derived from different products.

3.4 Alternating Polarization Mode over Germany

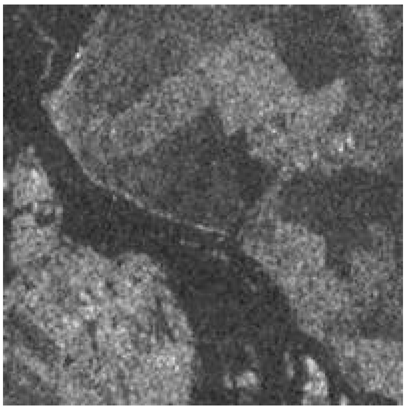
Sample products in Alternating Polarization Mode over Germany were considered in SLC (slant-range, ASA_APS_1P) and PRI (ground-range, ASA_APP_1P) format for HH and HV polarization. Similar tests as those previously described for the Image Mode over The Netherlands were made and similar results were obtained. The correspondence between the multi-looked image in ground-range geometry derived from the SLC and the PRI in ground-range geometry was nearly perfect. Geocoding to the UTM projection, zone 33, Datum WGS 1984, with a posting of 25 m was tested for both the multi-looked image in slant-range geometry derived from the SLC and the PRI in ground-range geometry. In both cases, ellipsoid geocoding was successfully accomplished. The results for the co- and cross-polarization channels are compared in Figure 6. As for the sample products in Image Mode over The Netherlands, the results of the two geocoding procedures are nearly identical.



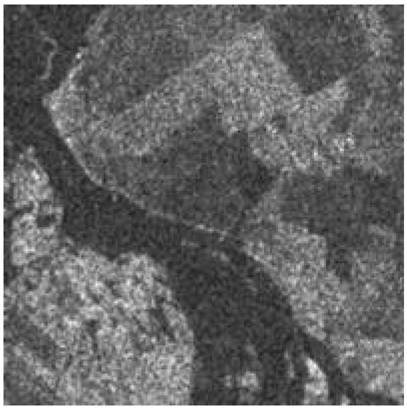
ASA_APS_1P_HH



ASA_APP_1P_HH



ASA_APS_1P_HV



ASA_APP_1P_HV

Figure 6. Extracts of ellipsoid geocoded ENVISAT ASAR sample products in Alternating Polarization Mode over Germany derived from different products.

4 Conclusions

Validation of the ENVISAT ASAR geocoding was conducted for the ENVISAT ASAR sample products made available by ESA after the calibration review of 9 September 2002. Sample products were available for the Image Mode over The Netherlands, the Alternating Polarization mode over Germany, and the Wide Swath Mode over Spain. A topographic map was available to us for geocoding accuracy assessment only for the Dutch test site. Our analysis showed that geocoding of ENVISAT ASAR images with the GAMMA software is operational and conforming to the standard achieved in numerous cases with ERS and JERS SAR data. The analysis also demonstrated the importance of the refinement step in the geocoding procedure of SAR images.

5 Useful related internet sites

For latest version of ENVISAT ASAR Documentation:
http://envisat.esa.int (see in particular under the sections "Product Handbook - ASAR" and "Library")

ENVISAT sample products:
http://envisat.esa.int/services/sample_products/

Auxillary files such as ASAR_XCA (most recent version):
http://envisat.esa.int/services/auxiliary_data/asar/