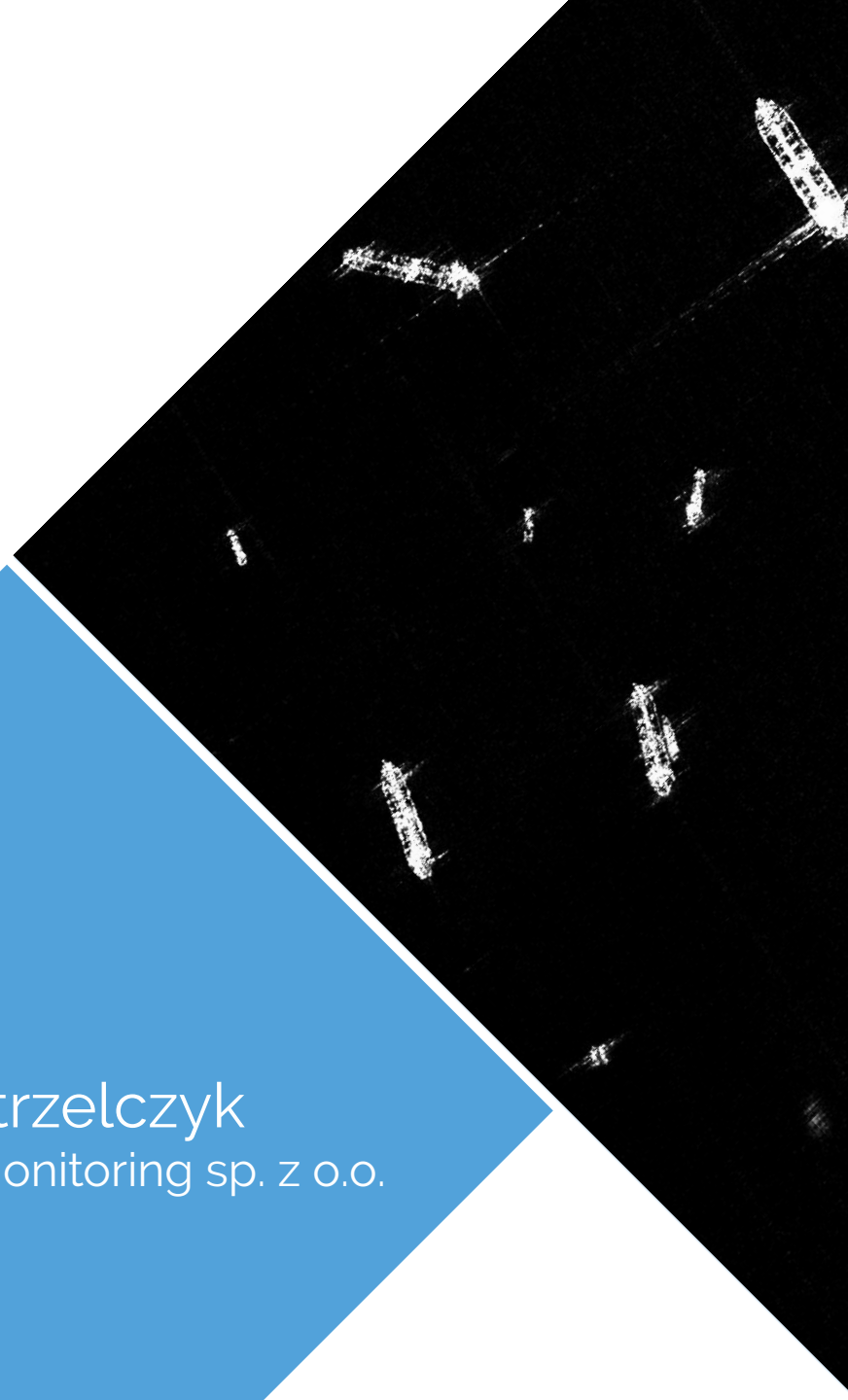


A faint, light blue illustration of a satellite with a large parabolic dish antenna and a smaller circular component, orbiting a small sphere representing Earth. The satellite is positioned diagonally across the upper left portion of the slide.

satrec

AN INNOVATIVE SOFTWARE FOR
IDENTIFICATION OF OBJECTS ON
SATELLITE **SAR** IMAGES

Jacek Strzelczyk
SATIM Satellite Monitoring sp. z o.o.





PROJECT TITLE:

„DEVELOPMENT OF AN INNOVATIVE SOFTWARE CALLED **SATREC FOR IDENTIFICATION OF OBJECTS ON SATELLITE **SAR** IMAGERY BY MODELING AND RECOGNITION OF RADAR SIGNATURES”**

DURATION:

1.08.2017 - 31.07.2019

CONTRACTOR:

SATIM SATELLITE MONITORING

ESA PROGRAMME:

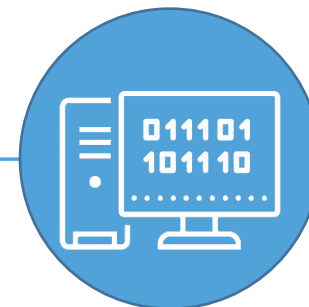
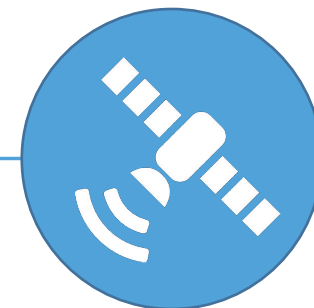
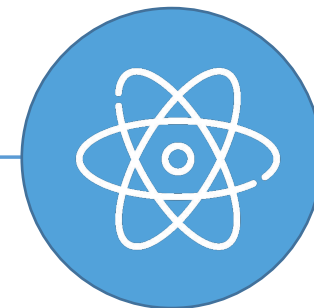
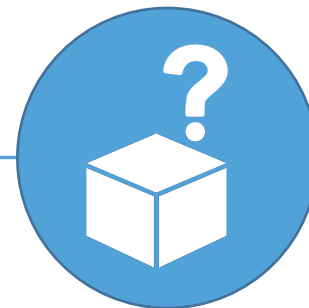
POLISH INDUSTRY INCENTIVE SCHEME

ESA TECH OFFICER:

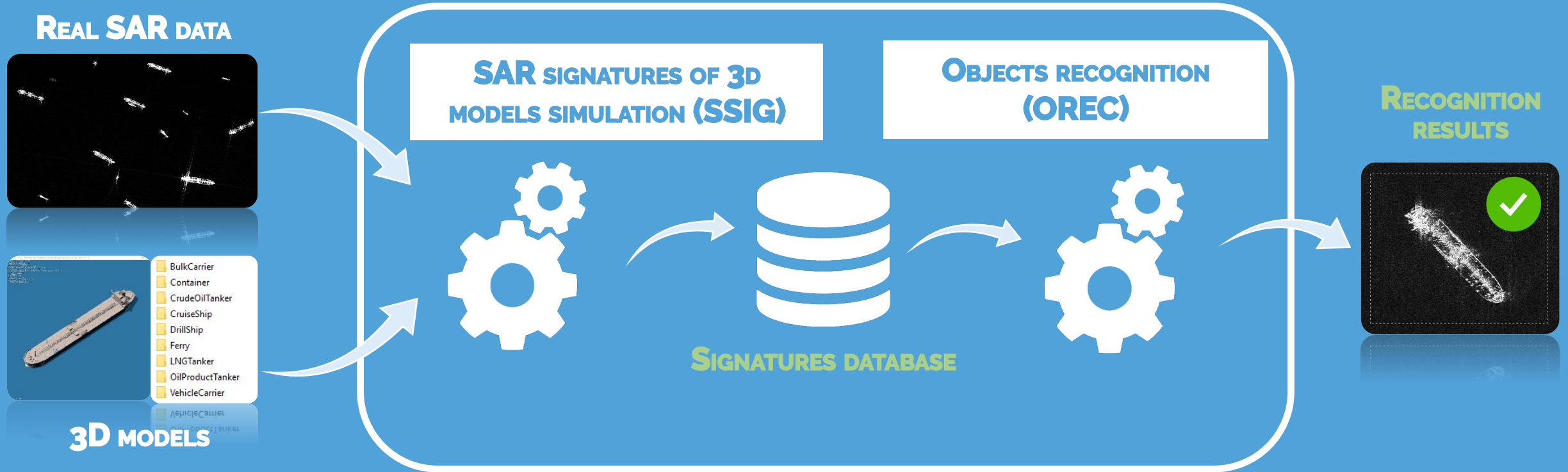
NICOLAS FLOURY



INNOVATIVE SOFTWARE
FOR
IDENTIFICATION OF OBJECTS
ON
SATELLITE SAR IMAGERY
BY
MODELING OF RADAR SIGNATURES

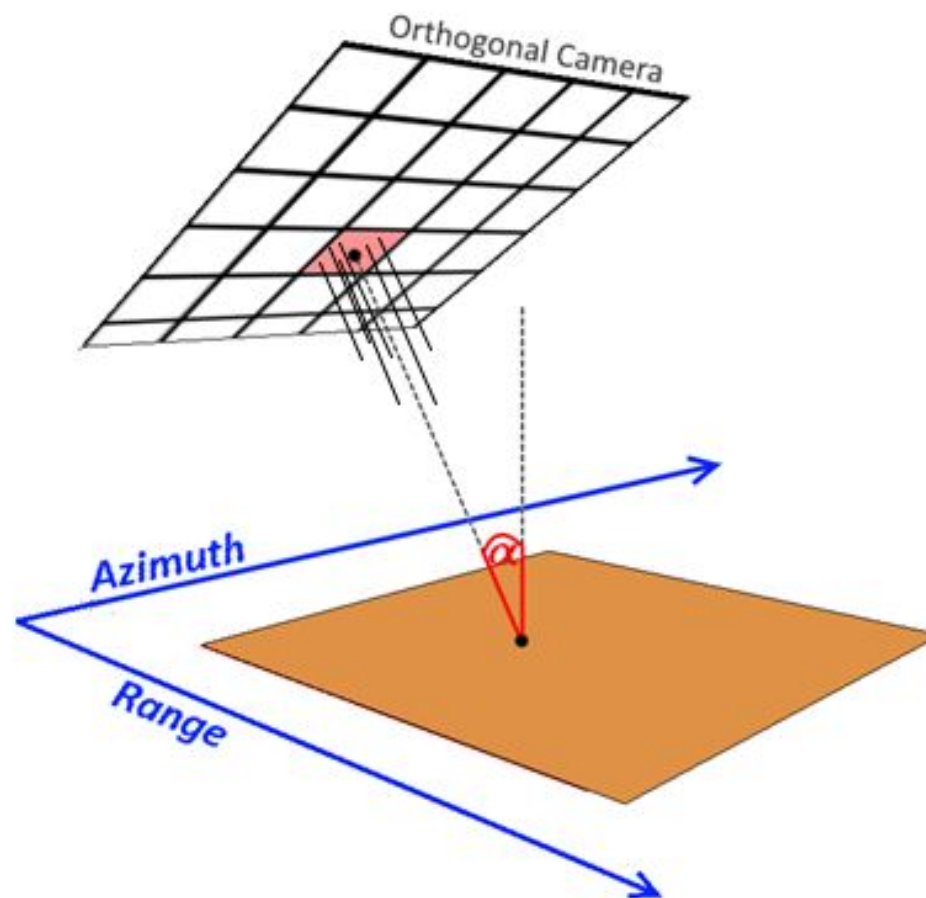


SATREC SOFTWARE



satrec

IN SATREC SOFTWARE RAY-TRACING METHOD IS USED TO SIMULATE RADAR SIGNATURES OF 3D OBJECTS



SSIG – FEATURES



**POSSIBILITY TO LOAD ANY 3D MODEL (.OBJ
FORMAT)**



**POSSIBILITY TO SIMULATE SIGNATURES FROM ANY
SAR IMAGE**



SIGNATURE GENERATION IN REAL TIME



SIGNATURES STORED IN THE DATABASE



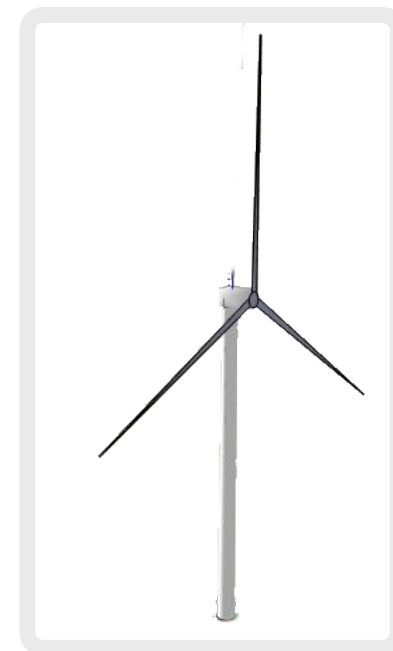
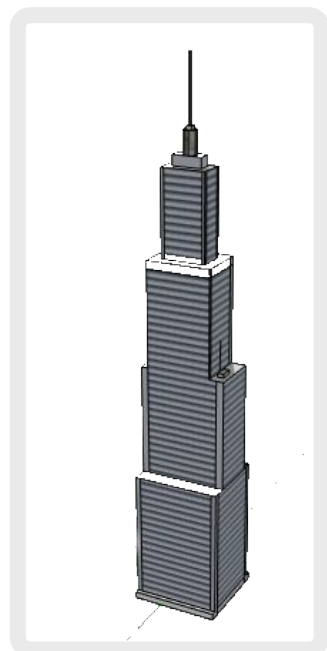
**PARAMETERS CORRESPONDING TO THE REAL SAR
SYSTEM**



USER FRIENDLY



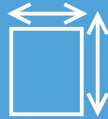
IN SATREC IT IS POSSIBLE TO MODEL THE **SAR** SIGNATURE FOR EVERY **3D** OBJECT
(SUCH AS SHIPS, GROUND VEHICLES, BUILDINGS, ETC.)



SSIG – MODELING PARAMETERS



GEOMETRICAL CORRECTNESS



PIXEL SPACING



SPATIAL RESOLUTION



INCIDENCE ANGLE



IMPULSE RESPONSE FUNCTION



OBJECT ROTATIONS



WATER CLUTTER



SSIG – MODELING PARAMETERS



POLARIMETRIC INFORMATION



PHYSICAL PARAMETERS OF MATERIALS

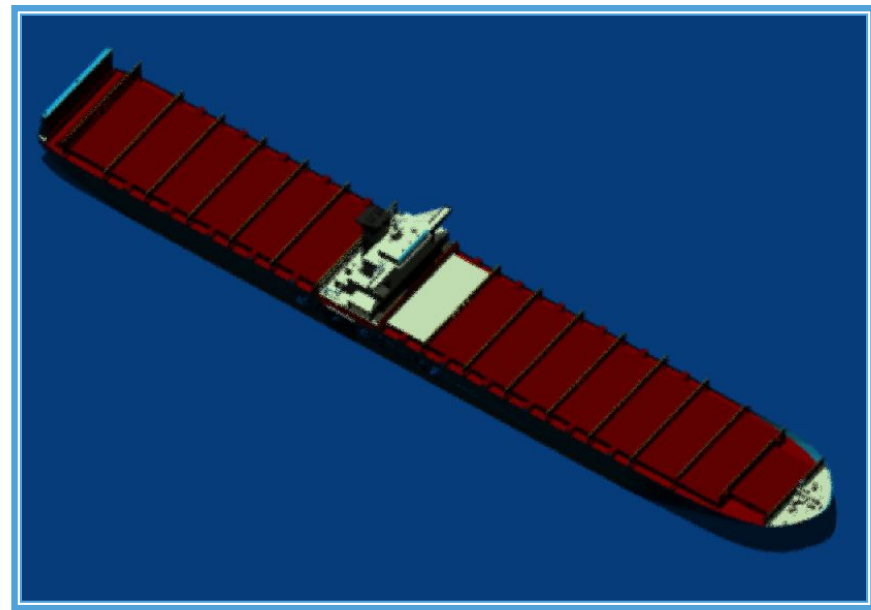


RADIOMETRIC CORRECTNESS

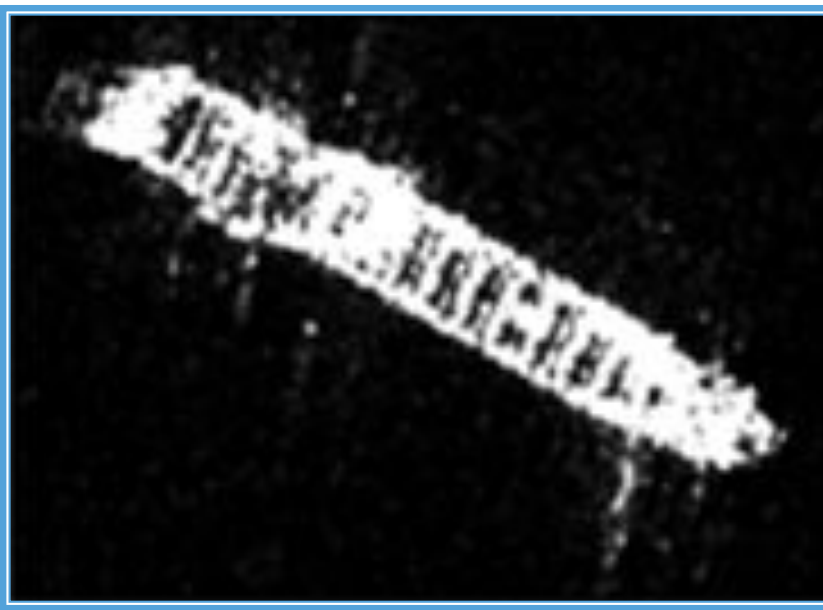


GEOMETRICAL CORRECTNESS

IN **SATREC** SOFTWARE THE GEOMETRICAL CORRECTNESS OF **SAR** SIGNATURE SIMULATION IS OF FIRST IMPORTANCE. THE GENERATED SIGNATURES ARE VERY WELL GEOMETRICALLY MATCHED TO THE REAL SIGNATURES IN THE **SAR** IMAGE.



3D MODEL OF A SHIP



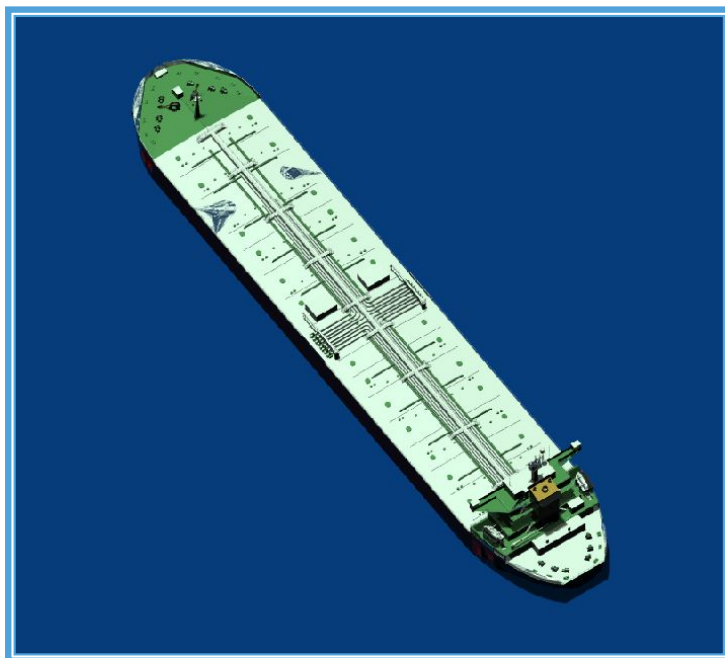
REAL **SAR** SIGNATURE



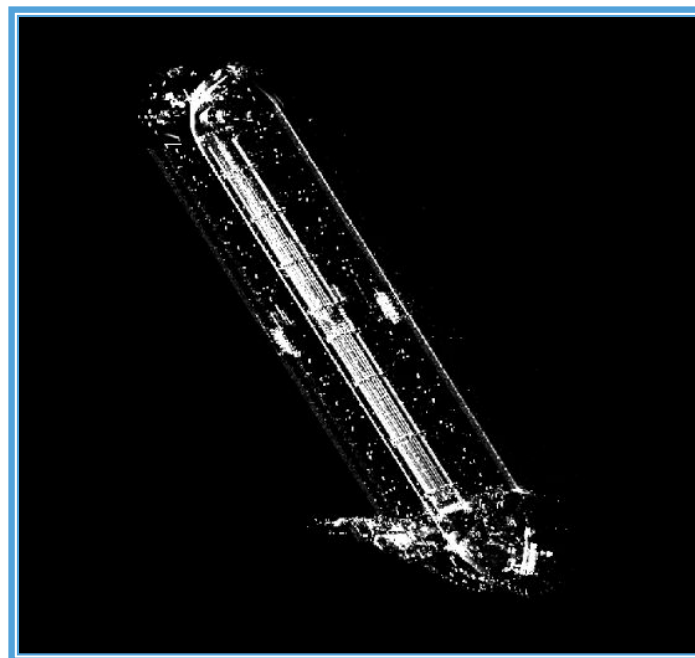
SIMULATED SIGNATURE

PIXEL SPACING IN AZIMUTH AND RANGE

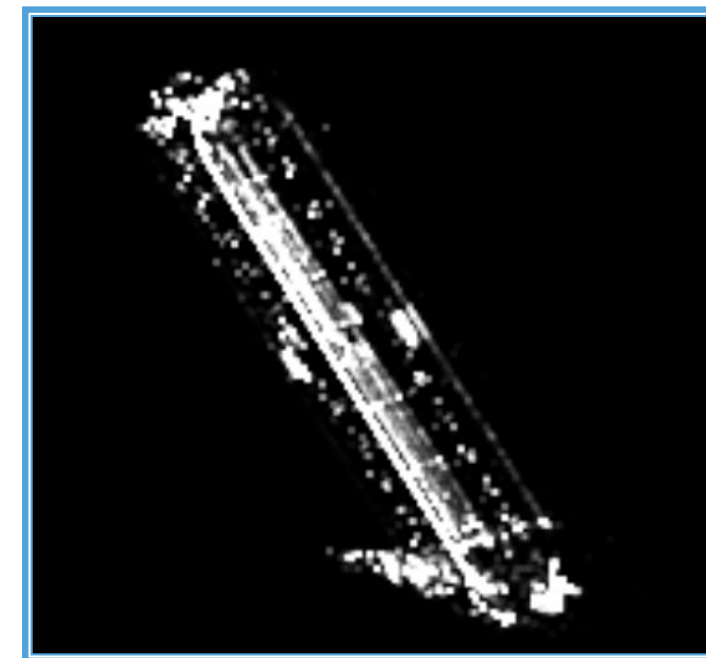
THE USER CAN DEFINE THE DISTANCE (PIXEL SPACING) BETWEEN ADJACENT PIXELS IN AZIMUTH AND RANGE DIRECTIONS. SMALLER VALUES OF PIXEL SPACING MEANS THAT THE GENERATED SIGNATURES WILL BE MORE DETAILED. SATREC WILL AUTOMATICALLY ADJUST THE PIXEL SPACING OF THE SIGNATURES TO THE LOADED REAL SAR IMAGE.



3D MODEL OF A SHIP



**SIMULATED SIGNATURE: PIXEL
SPACING 0,2M X 0,4M**



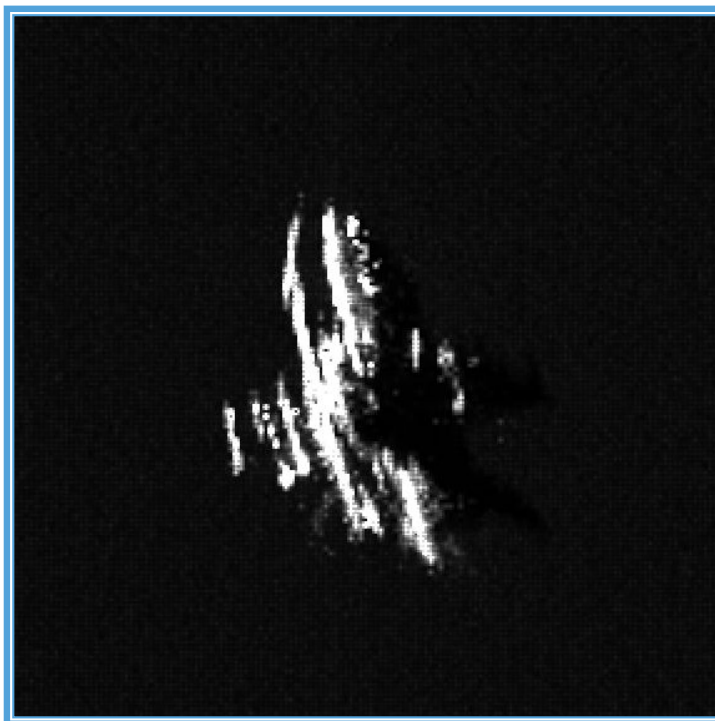
**SIMULATED SIGNATURE: PIXEL
SPACING 1M X 2M**

INCIDENCE ANGLE

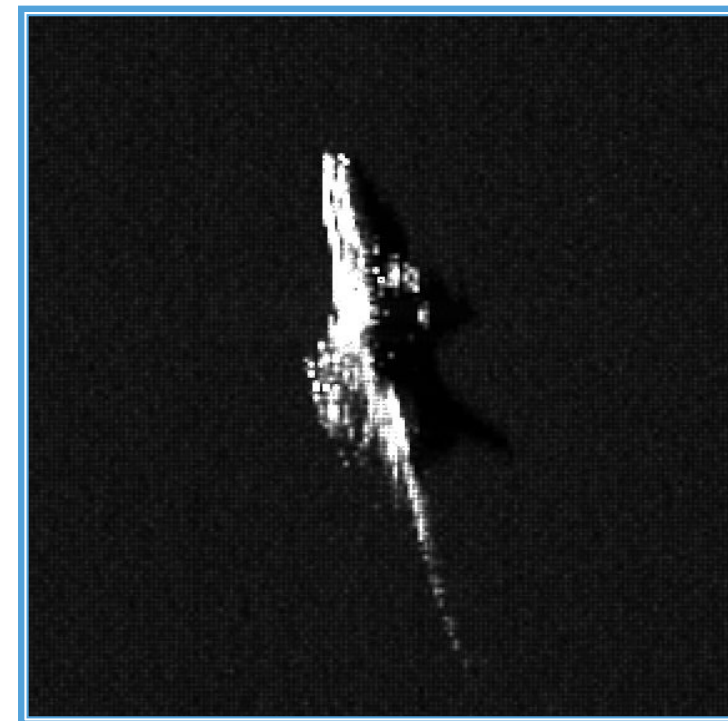
THE INCIDENCE ANGLE IS THE ANGLE DEFINED BY THE INCIDENT RADAR BEAM AND THE VERTICAL (NORMAL) TO THE INTERCEPTING SURFACE. IN GENERAL, REFLECTIVITY FROM DISTRIBUTED SCATTERERS DECREASES WITH INCREASING INCIDENCE ANGLE. THE SIGNATURE CHANGES WITH INCIDENCE ANGLE CHANGE.



3D MODEL: F-16



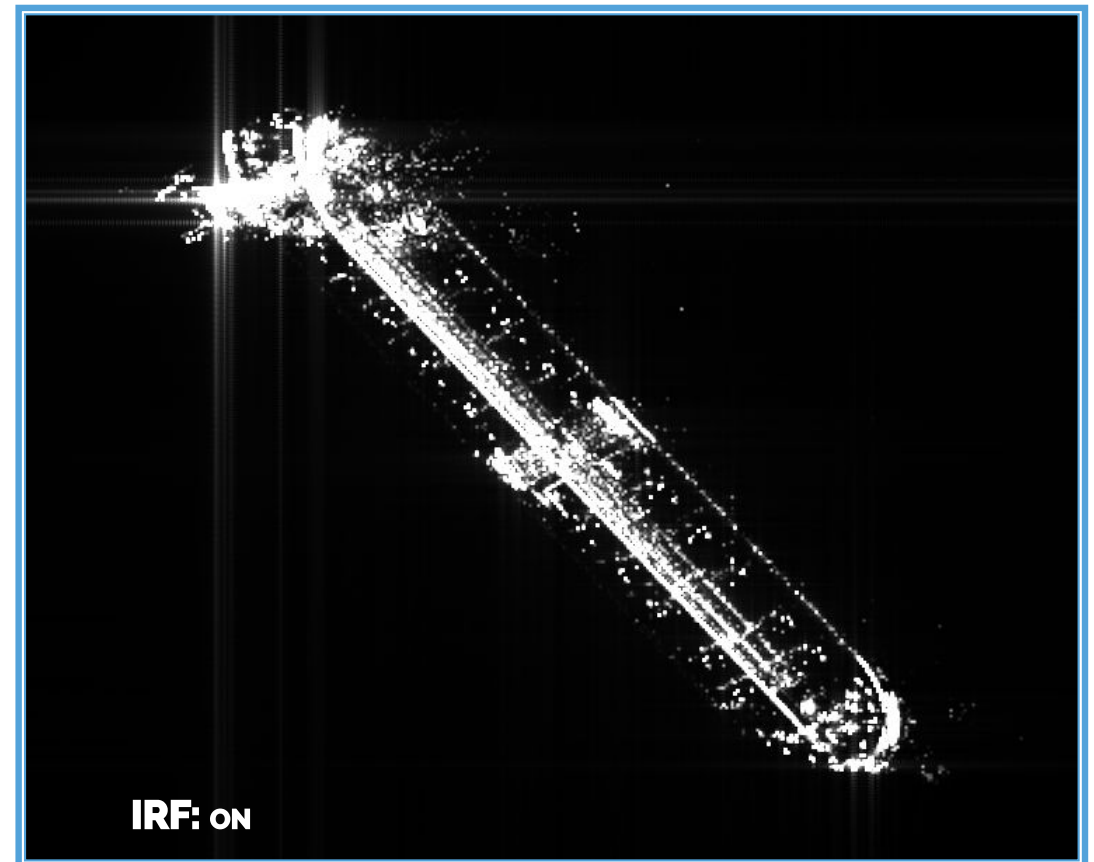
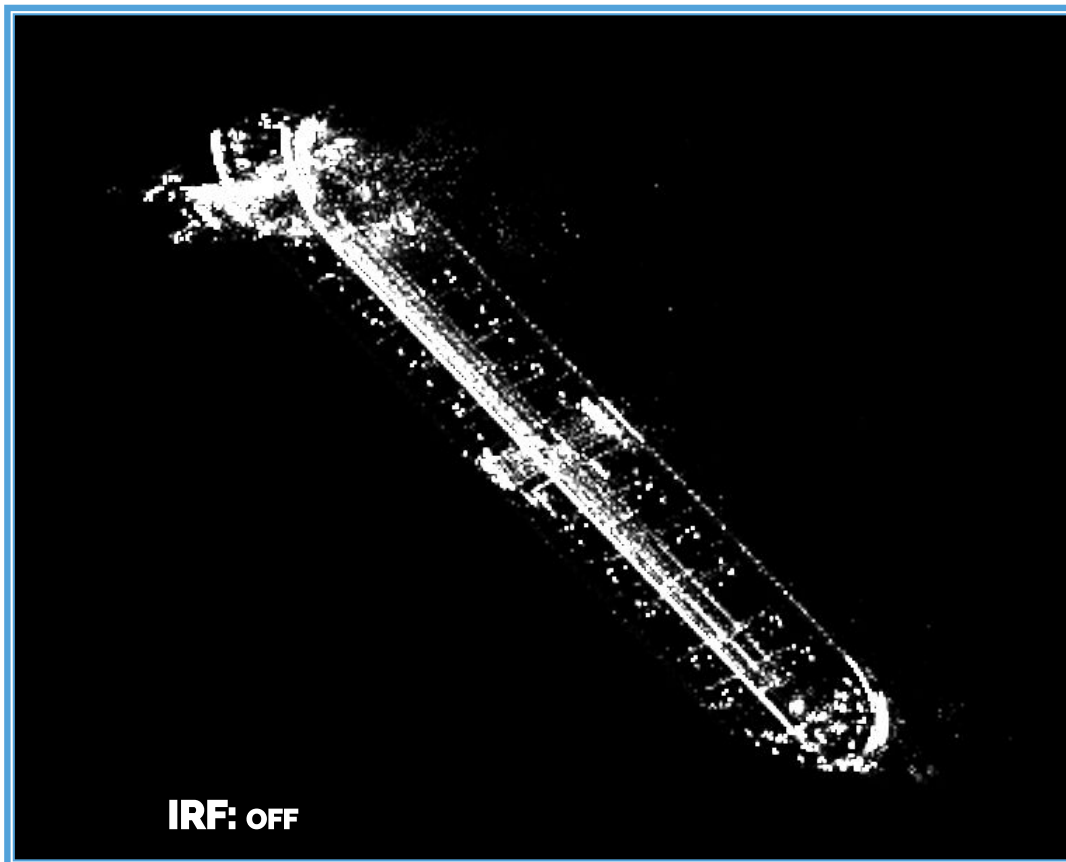
**SIMULATED SIGNATURE:
INCIDENCE ANGLE: 45°**



**SIMULATED SIGNATURE:
INCIDENCE ANGLE: 60°**

IMPULSE RESPONSE FUNCTION (IRF)

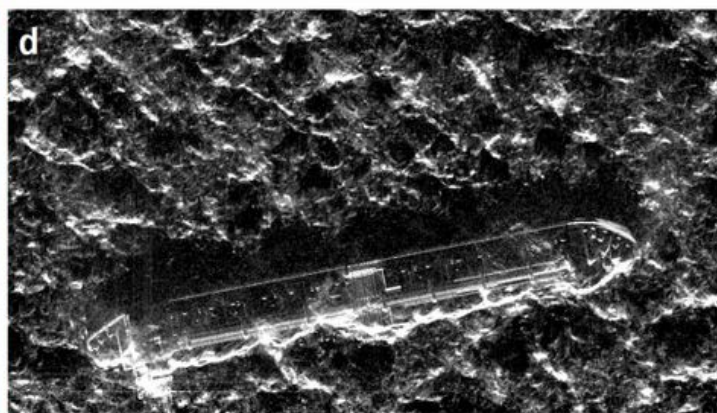
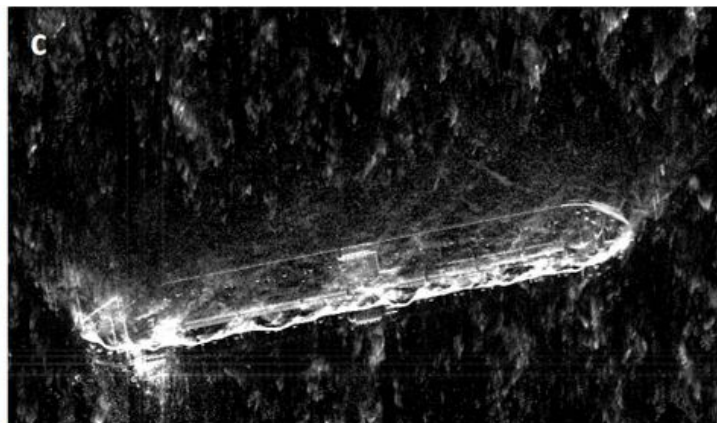
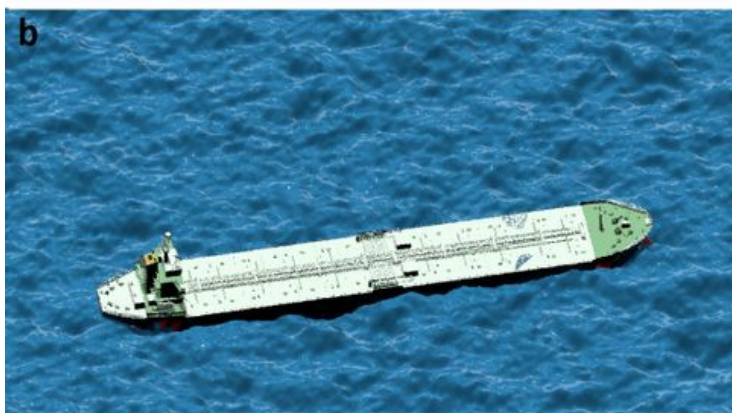
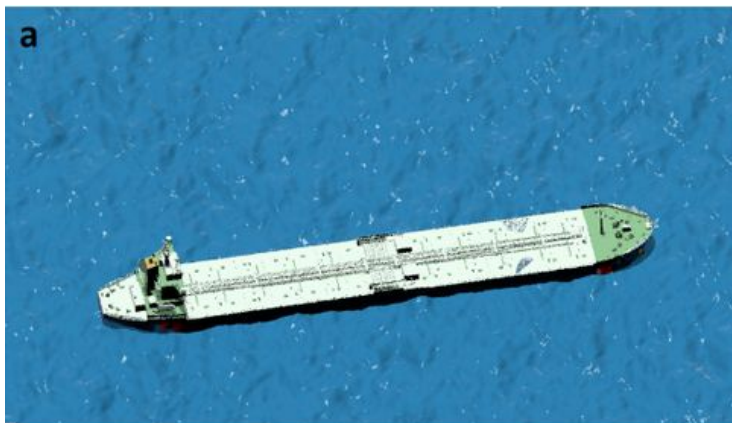
THE CHARACTERISTIC TWO-DIMENSIONAL BRIGHTNESS PATTERN OCCURRED ON **SAR** IMAGES CONSISTING OF A SINGLE POINT-LIKE SCATTER.



WATER CLUTTER

IT IS POSSIBLE TO ADJUST SPEED AND DIRECTION OF WIND FOR SEA SURFACE MODELING.

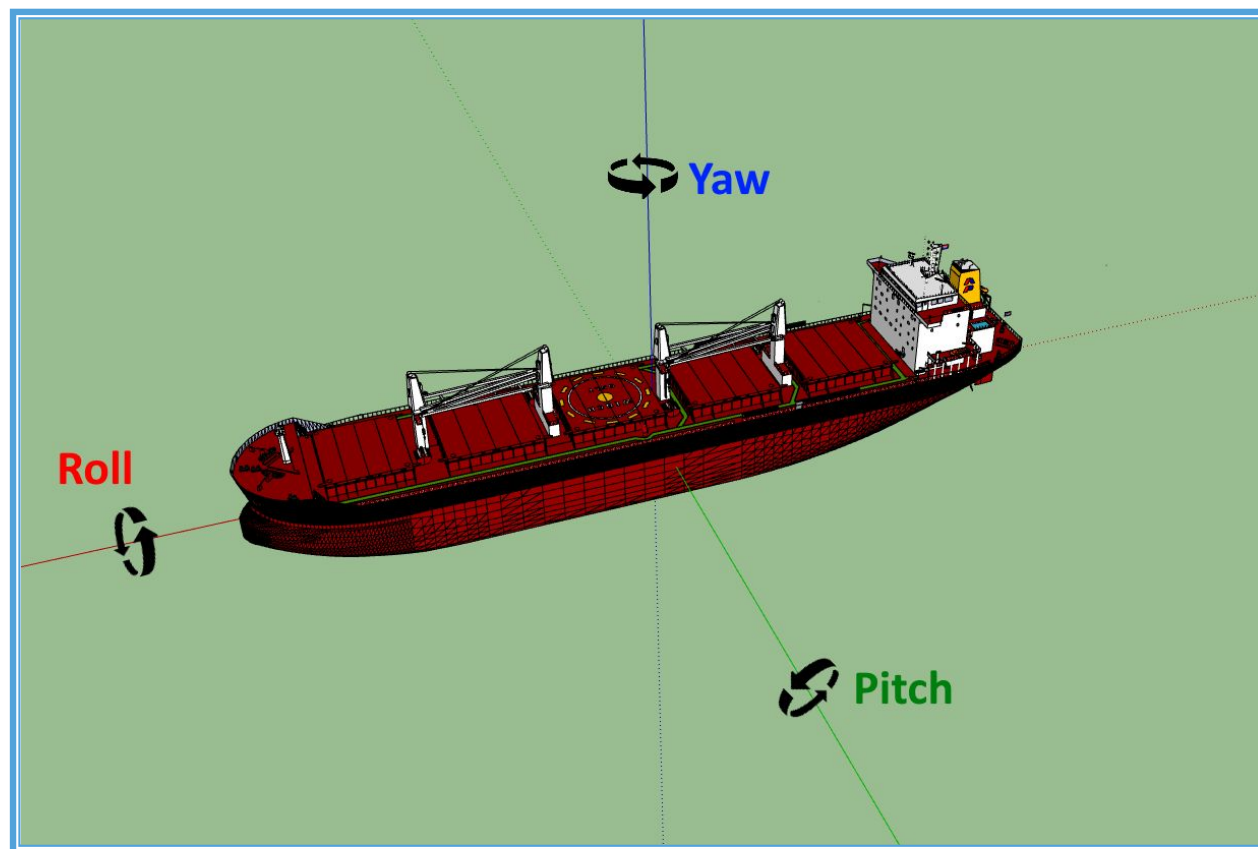
OPTICAL IMAGES OF SHIPS
AND SEA SURFACE



RADAR SIGNATURES
GENERATED IN SATREC

OBJECT ROTATIONS

IN THE **SATREC** SOFTWARE USER CAN ROTATE THE MODELS IN 3 PLANES IN REAL TIME (YAW, ROLL, PITCH). IT IS ALSO POSSIBLE TO INCREASE AND DECREASE THE SUBMERGENCE OF SHIPS.



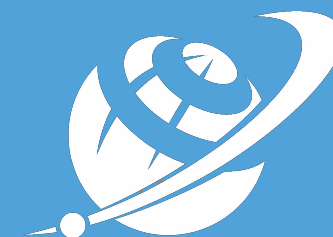
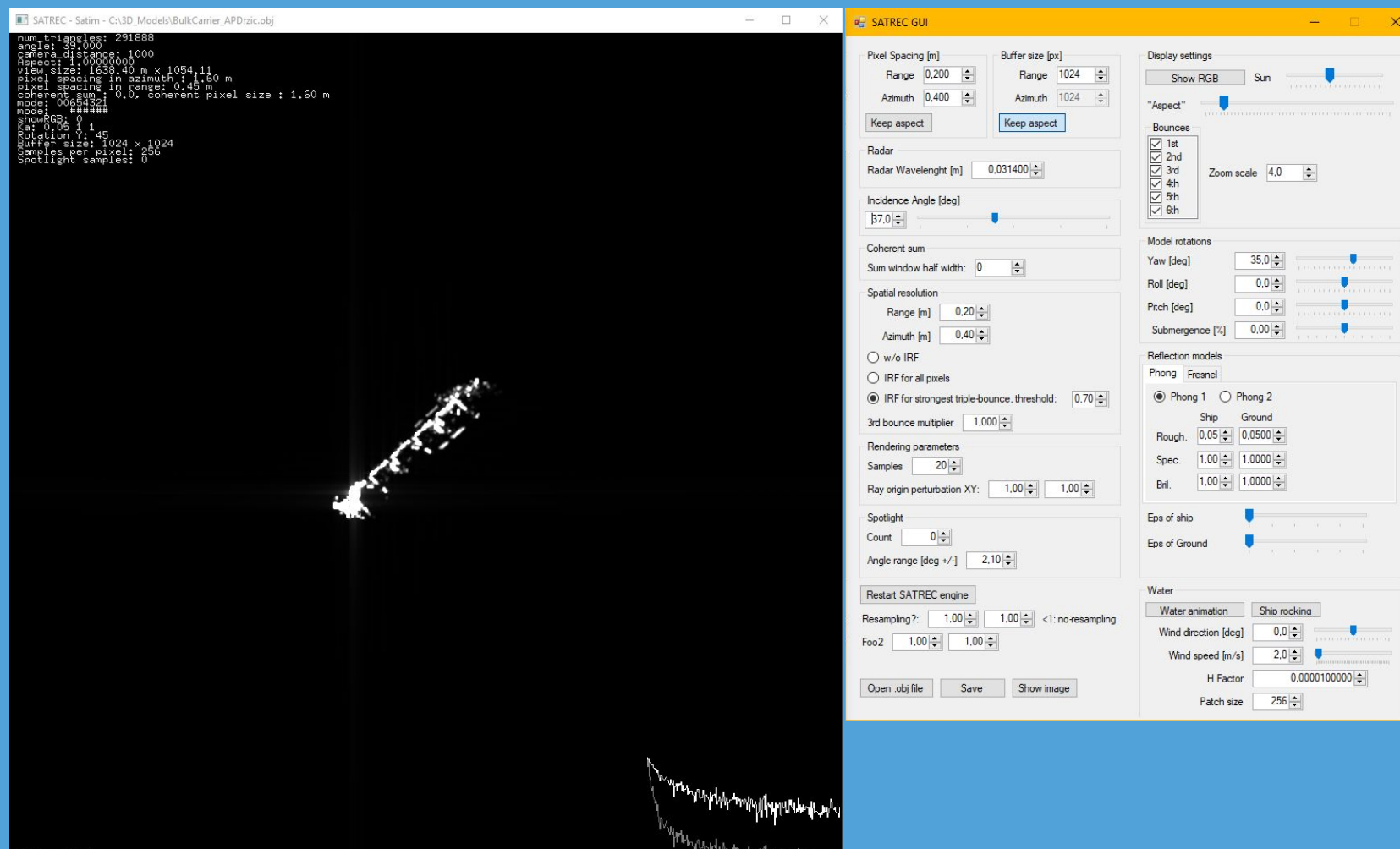
SSIG – USER EXPERIENCE

USER IS ABLE TO SWITCH BETWEEN RGB VIEW AND SAR SIGNATURE VIEW



SSIG – USER EXPERIENCE

2. SET SIMULATION PARAMETERS (OR USE DEFAULT)



SSIG – USER EXPERIENCE

SIGNATURE DATABASE

The interface is titled "Signature Browser" and is divided into several sections:

- Existing Settings:** A table with columns: ID, Angle [deg.], Pixel Spacing X [m], Pixel Spacing Y [m], Resolution X [m], Resolution Y [m], Method, and Samples. The table contains three rows, with the third row (ID 2) selected.
- SIGNATURES DATASETS*:** A large empty grey area.
- Objects 3D:** A list of objects including BulkCarrier_PanamaxLeda_Ocranes, BulkCarrier_PearlK, Container_BalticMeridian_loaded, Container_BSCAngelo_loaded, Container_MaerskSigneta_unloaded, Container_MaerskTripleE_loaded, and Container_Stefany_unloaded.
- SIGNATURE PREVIEW*:** A window showing a 2D signature of a ship's hull.
- OBJECT ROTATIONS:** A slider control for rotating the object, currently set to 342 deg.
- 3D MODEL PREVIEW:** A window showing a 3D model of a ship.

At the bottom, a note states: "Double click on object's name to load it into 3D Preview window".

**OBJECTS IN SELECTED
SIGNATURES SET**

3D MODEL PREVIEW

- * SIGNATURE DATASET CONSIST OF SIGNATURES SIMULATED WITH SPECIFIED MODELING PARAMETERS
- * A SINGLE SIGNATURE TAKES ONLY 12MB OF DISK SPACE



SSIG – USER EXPERIENCE

IT IS ALSO POSSIBLE TO PERFORM SIMULATION IN BATCH MODE

```
C:\bin\RenderingEngine.exe
Init OCEAN
calculateOCEAN
size: 1566726
ocean done!
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R0_0.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R5_1.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R10_2.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R15_3.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R20_4.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R25_5.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R30_6.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R35_7.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R40_8.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R45_9.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R50_10.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R55_11.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R60_12.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R65_13.bin'
```



```
C:\bin\RenderingEngine.exe
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R220_44.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R225_45.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R230_46.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R235_47.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R240_48.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R245_49.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R250_50.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R255_51.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R260_52.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R265_53.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R270_54.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R275_55.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R280_56.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R285_57.bin'
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Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R305_61.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R310_62.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R315_63.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R320_64.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R325_65.bin'
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Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R335_67.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R340_68.bin'
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Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R355_71.bin'
Saving current frame to 'C:\BulkCarrier/BulkCarrier_BlueStar.obj_R0_72.bin'
```



PROCESSING TIME

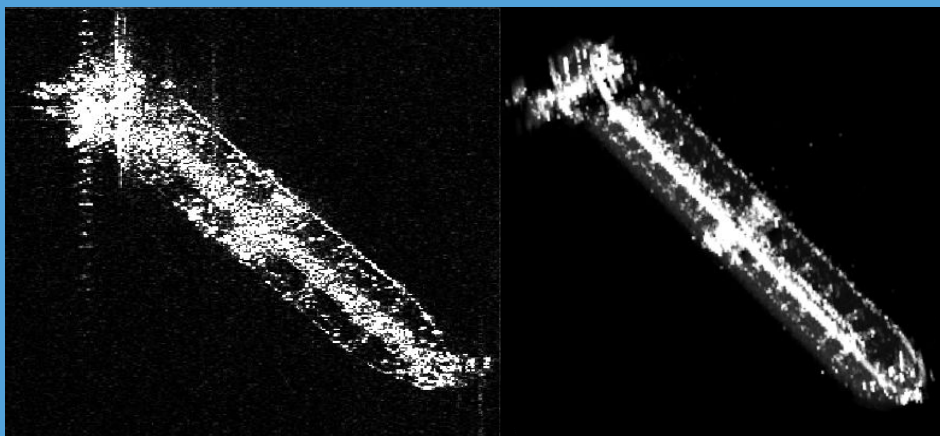


- GENERATION OF A SINGLE SIGNATURE TAKES LESS THAN **1 SEC**
- SIGNATURES GENERATION OF ONE **3D** OBJECT WITH **5** DEGREES ROTATION STEP TAKES ABOUT **10 SEC**
- THE TIME OF GENERATING THE SIGNATURES DEPENDS ON PARAMETERS SUCH AS: BUFFER SIZE, NUMBER OF SAMPLES, PIXEL SPACING...

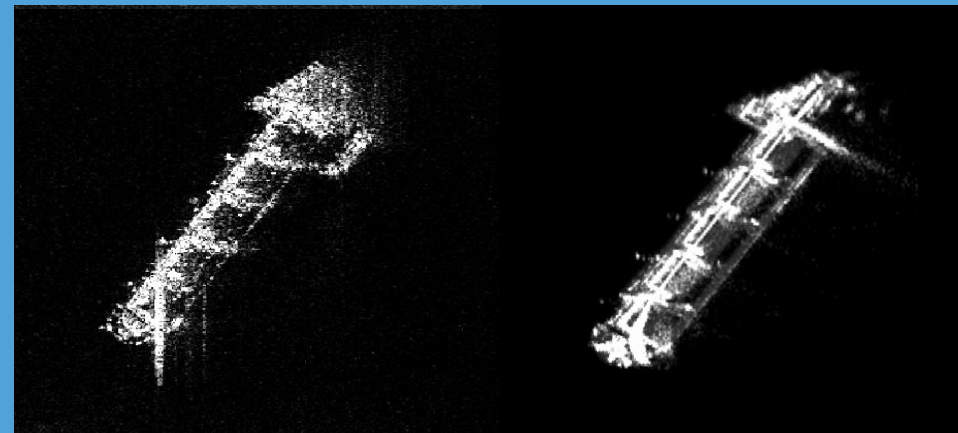


SSIG – PERFORMANCE

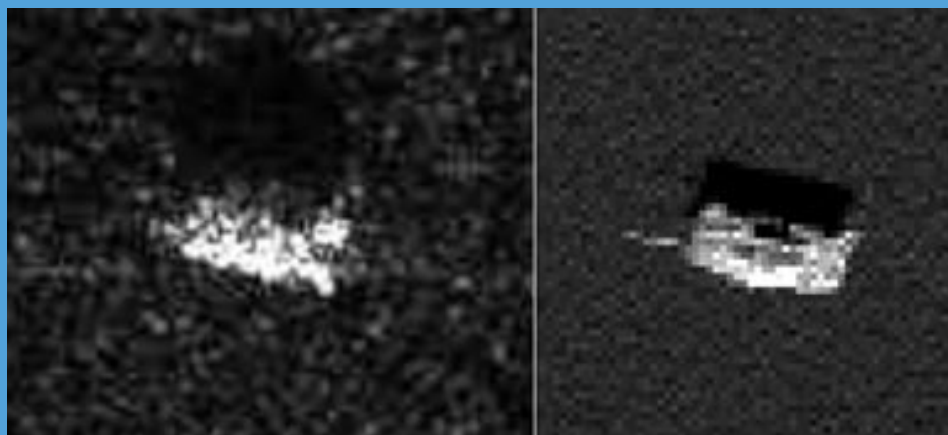
EXAMPLES OF SIGNATURES GENERATED IN SSIG



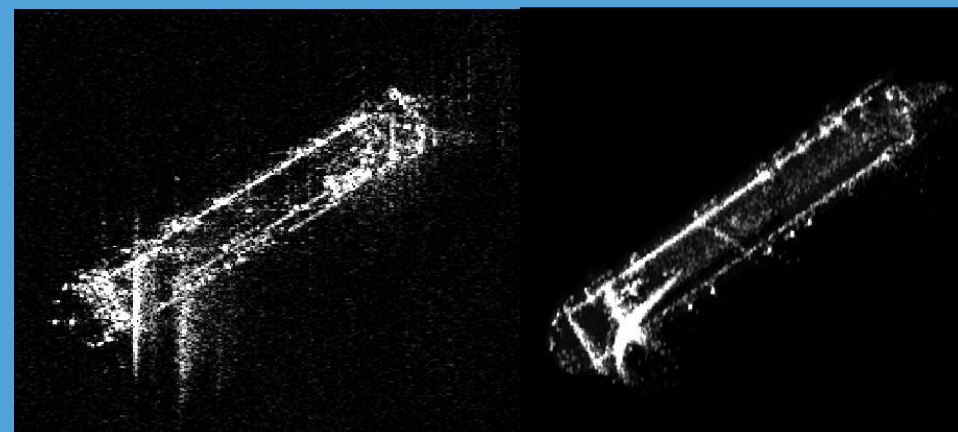
CRUDE OIL TANKER (LEFT: TERRASAR-X IMAGE, RIGHT: SIMULATED SIGNATURE) - 0,4M X 0,8M PIXEL SPACING



BULK CARRIER (LEFT: TERRASAR-X IMAGE, RIGHT: SIMULATED SIGNATURE) - 0,4M X 0,8M PIXEL SPACING



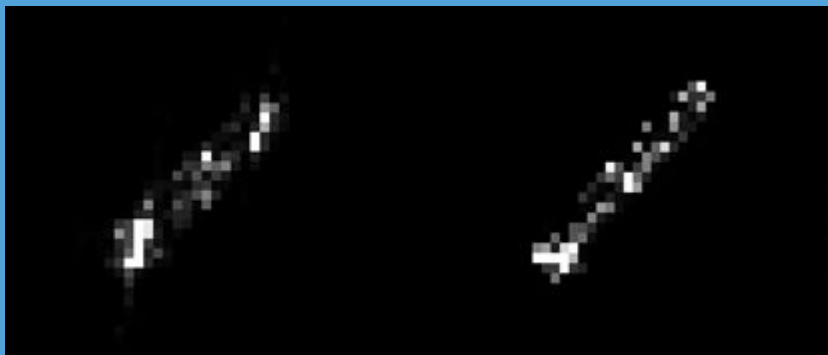
TANK T-62 (LEFT: AIRBORNE SAR IMAGE, RIGHT: SIMULATED SIGNATURE)



VEHICLE CARRIER (LEFT: TERRASAR-X IMAGE, RIGHT: SIMULATED SIGNATURE) - 0,4M X 0,8M PIXEL SPACING

SSIG – PERFORMANCE

EXAMPLES OF SIGNATURES GENERATED IN SSIG



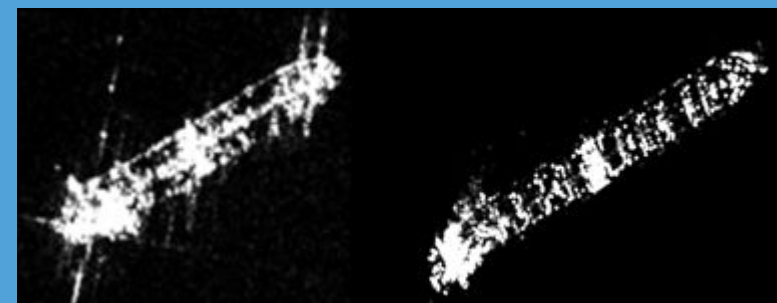
CRUDE OIL TANKER (LEFT: SENTINEL-1 IMAGE, RIGHT: SIMULATED SIGNATURE)



BULK CARRIER (LEFT: SENTINEL-1 IMAGE, RIGHT: SIMULATED SIGNATURE)



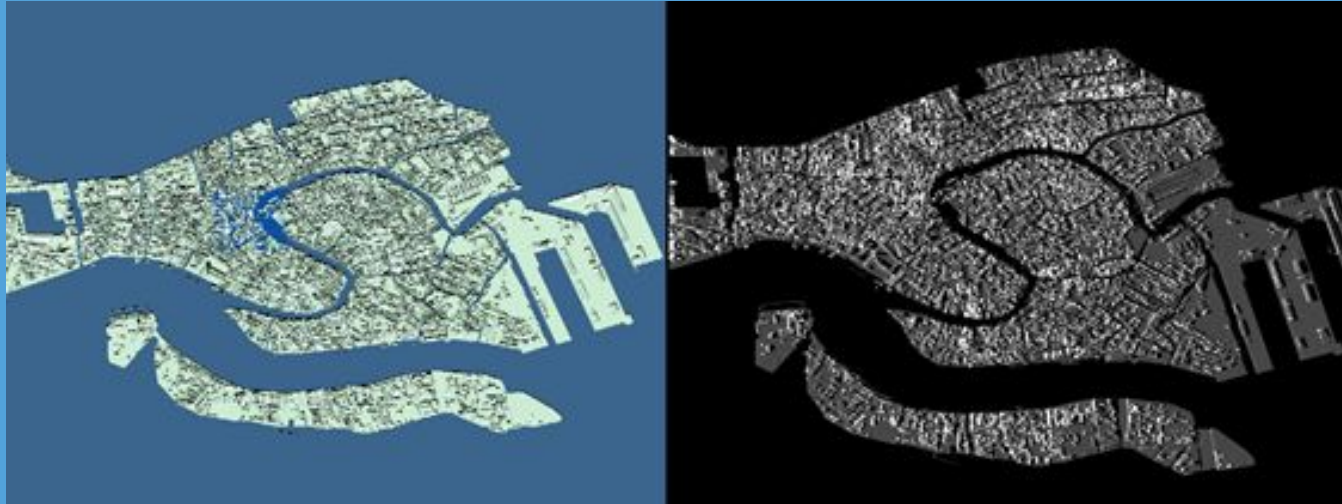
CONTAINER SHIP (LEFT: TERRASAR-X IMAGE, RIGHT: SIMULATED SIGNATURE) - 0,9M X 1,8M PIXEL SPACING



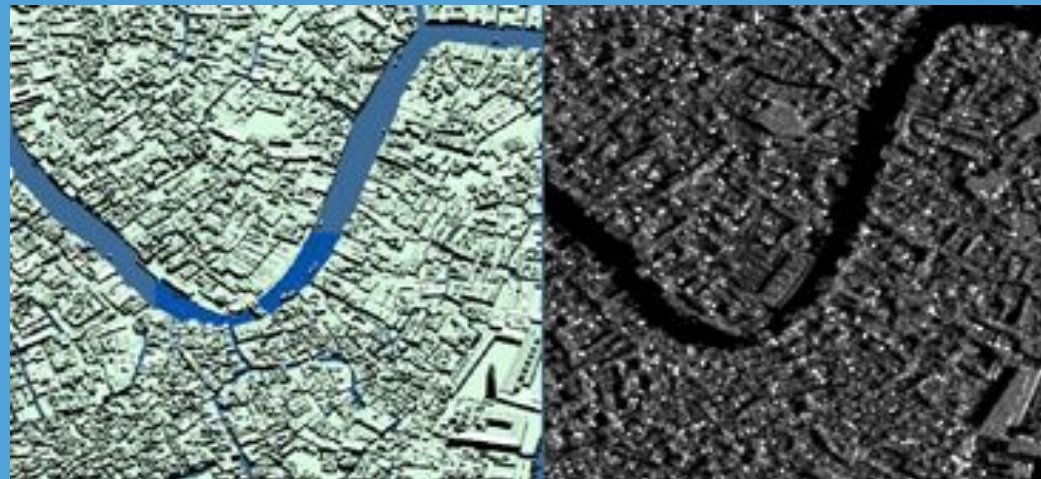
CRUDE OIL TANKER (LEFT: TERRASAR-X IMAGE, RIGHT: SIMULATED SIGNATURE) - 0,9M X 1,8M PIXEL SPACING

SSIG – PERFORMANCE

EXAMPLES OF SIGNATURES GENERATED IN SSIG



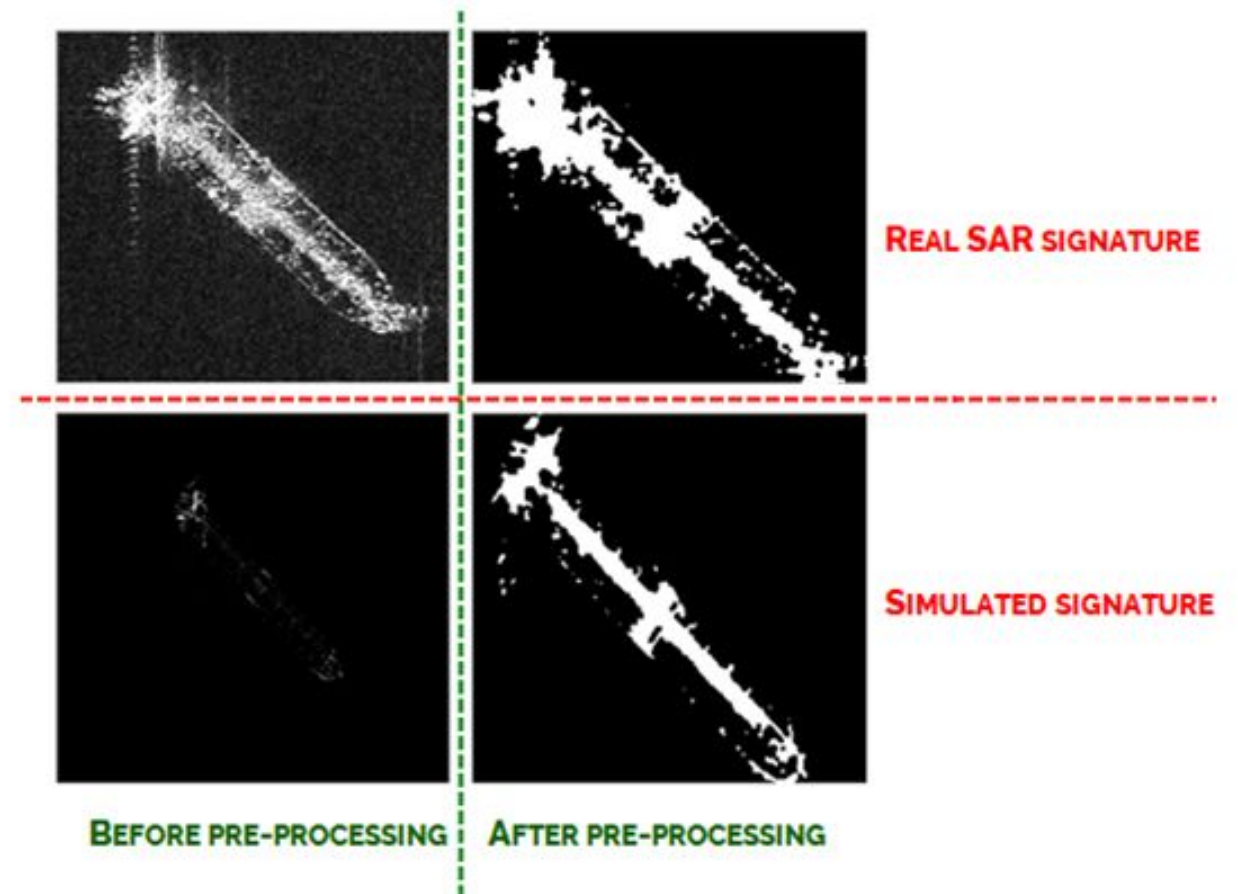
LEFT: **3D** OBJECT, RIGHT: SIMULATED SIGNATURE. **PIXEL SPACING: 2M X 4M; NUMBER OF SAMPLES: 50; INCIDENCE ANGLE: 40 DEG.**



PIXEL SPACING: 1.5M X 3M; NUMBER OF SAMPLES: 2; INCIDENCE ANGLE 40 DEG.

OBJECT RECOGNITION BASED ON TEMPLATE MATCHING

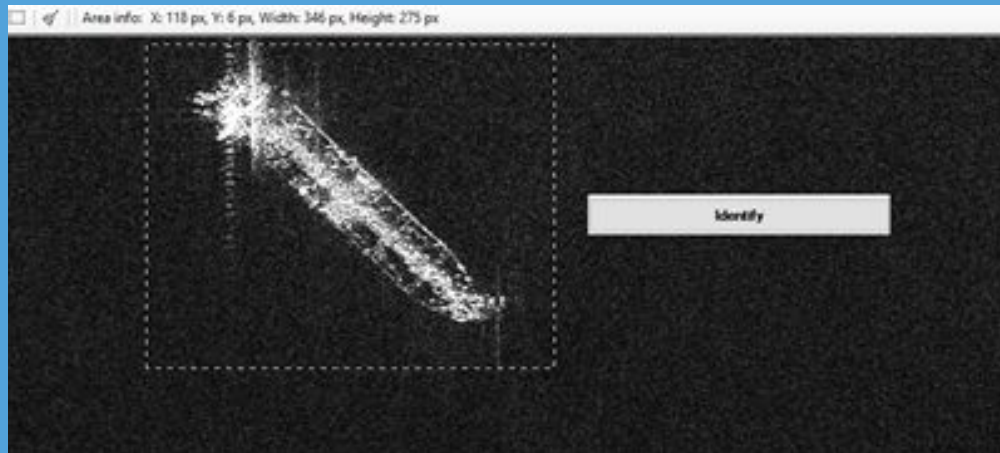
THE METHODS WORK IN SUCH A WAY THAT THE SIMILARITY OF THE OBJECT ON THE SIMULATED SIGNATURE TO THE OBJECT IN THE REAL SAR IMAGE IS EXAMINED. THESE SIMULATED AND REAL SIGNATURES ARE SET IN SUCH A WAY THAT THE CENTER OF GRAVITY OF THE OBJECT IN THESE TWO SIGNATURES OVERLAP. THEN THE SIMILARITY OF THESE SIGNATURES IS ANALYZED



OPERATIONAL MODES

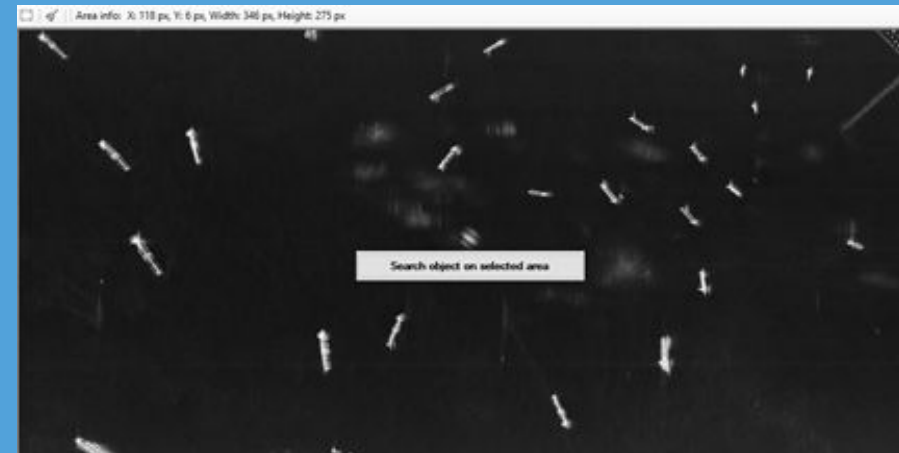
SEARCH BY **SAR** QUERY

SEARCH FOR SIMULATED **SAR** SIGNATURE MOST SIMILAR TO A GIVEN PATTERN IN THE FORM OF A FRAGMENT OF THE **SAR** IMAGE



SEARCH OBJECT BY **SIGN** QUERY

SEARCH FOR OBJECTS IN REAL **SAR** IMAGE MOST SIMILAR TO THE GIVEN SIMULATED **SAR** SIGNATURE FROM THE DATABASE OF SIMULATED **SAR** SIGNATURES



SATREC ACCURACY

SAR IMAGES USED IN ACCURACY TESTS

IMAGE 1

TDX1_SAR_SSC_ST_S_SRA_20160509T225410_20160509T225411

MISSION: TSX

ACQUISITION DATE: 09 MAY 2016

INCIDENCE ANGLE: 34,5 DEG

POLARIZATION: HH

RANGE SPACING: 0.455 M

AZIMUTH SPACING: 0.168 M

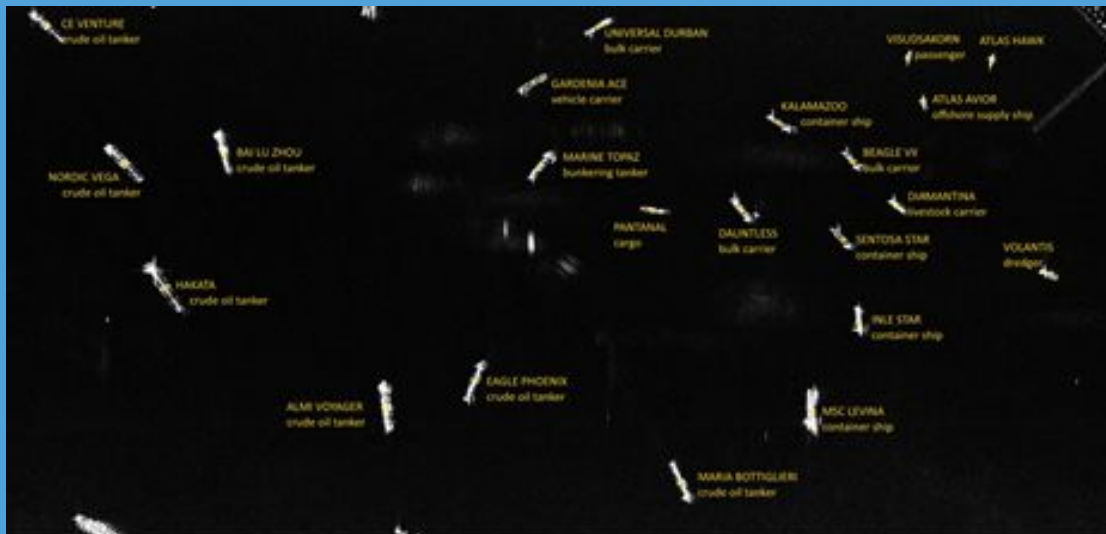


IMAGE 2

TDX1_SAR_SSC_HS_D_SRA_20110806T225349_20110806T225350

MISSION: TSX

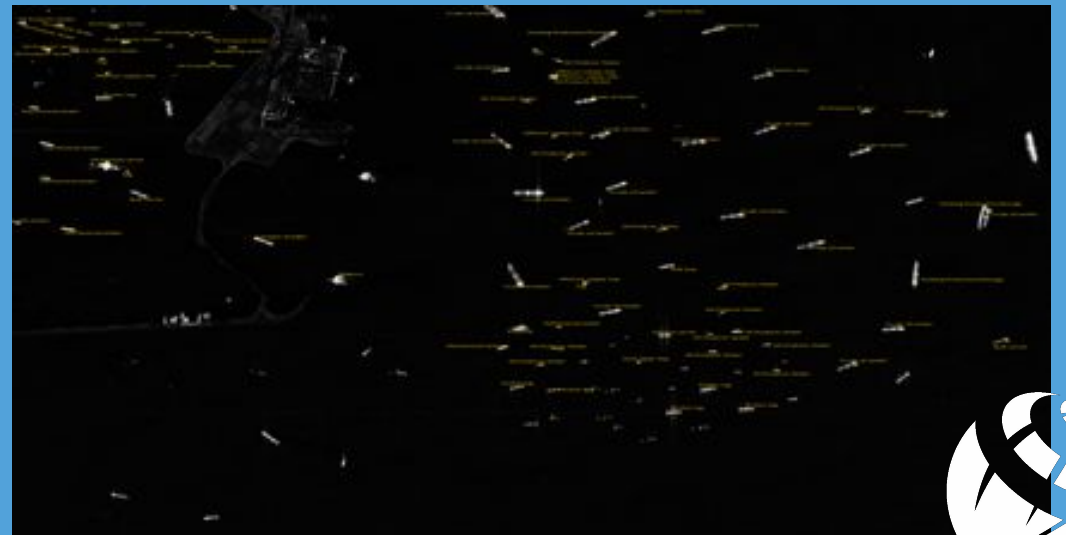
ACQUISITION DATE: 06 AUGUST 2011

INCIDENCE ANGLE: 37 DEG

POLARIZATION: HH, VV

RANGE SPACING: 0.9 M

AZIMUTH SPACING: 1,82 M



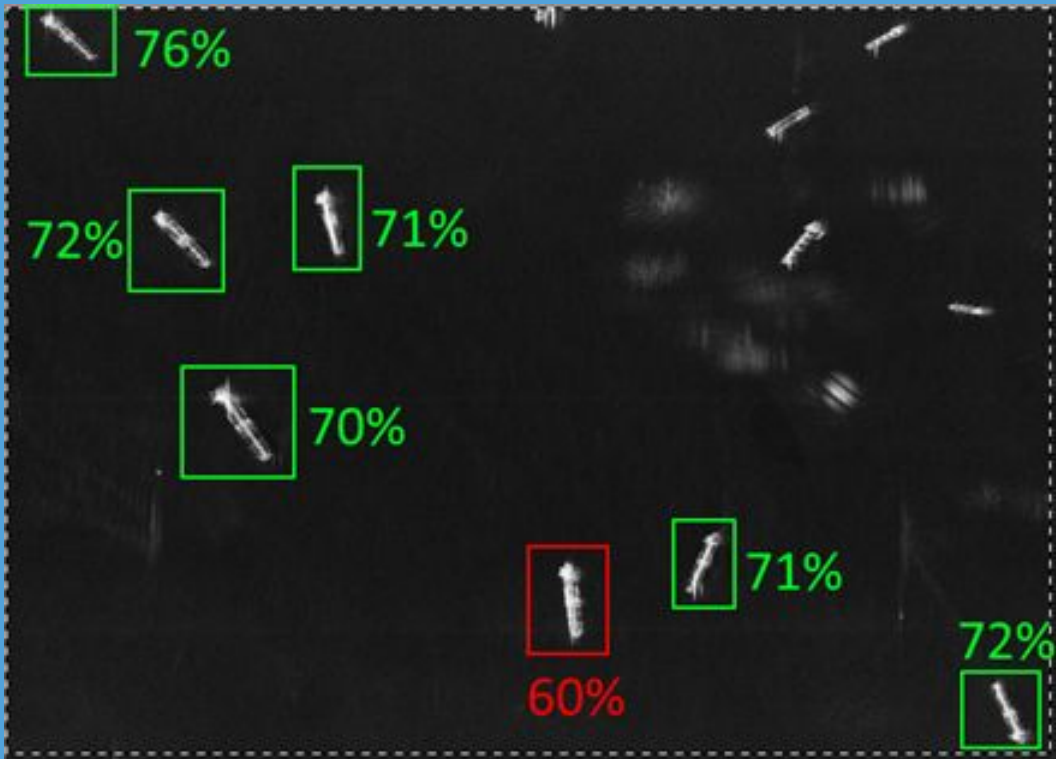
ACCURACY - IDENTIFY OBJECT

**30 VESSELS CAPTURED IN TSX IMAGES (15 ON THE IMAGE 1, 15 ON THE IMAGE 2)
HAVE BEEN SUBJECTED TO THE IDENTIFICATION PROCESS.**

	Correct identification	Wrong identification	Accuracy
Image 1 (0.45m x 0.83m)	13	2	87%
Image 2 (0.9m x 1.8m)	9	6	60%
Total	22	8	73%



ACCURACY - SEARCH OBJECT



SEARCH OBJECT OREC FUNCTIONALITY WAS TESTED USING HIGH RESOLUTION TERRASAR-X IMAGE – IMAGE1. THE AIM WAS TO FIND ALL SHIPS OF CRUDE OIL TANKER TYPE. A FRAGMENT OF THE IMAGE WAS SEARCHED WHERE THE MOST VESSELS OF THE SAME TYPE WERE PRESENT.

FOR 7 CRUDE OIL TANKERS PRESENT IN THE IMAGE, 6 WERE CORRECTLY RECOGNIZED (SIMILARITY > 70%). ONLY ONE SHIP WAS NOT CORRECTLY RECOGNIZED – SIMILARITY 60%. THE REASON FOR THIS WAS SHIPS ORIENTATION (ALMOST PERPENDICULAR TO THE RANGE DIRECTION) THAT CAUSES THE SIGNIFICANT DISTORTIONS OF SIGNATURE. THERE WERE NO FALSE ALARMS IN THIS AREA. HENCE IT CAN BE CONCLUDED THAT FOR CRUDE OIL TANKERS “SEARCH OBJECT” ACCURACY IS ABOVE 80%.





THANK YOU!

SATIM Monitoring Satelitarny sp. z o.o.
Urzędnicza 36/1
30-048 Kraków