Centre for Instrumentation

BAE SYSTEMS

# CEOI 5th and 6th Open Calls Final Review

# Level 1 On-Board Processing for Squinted SAR

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All the space you need

ASTRIUM
AN EADS COMPANY

# Project Introduction (1 of 2)

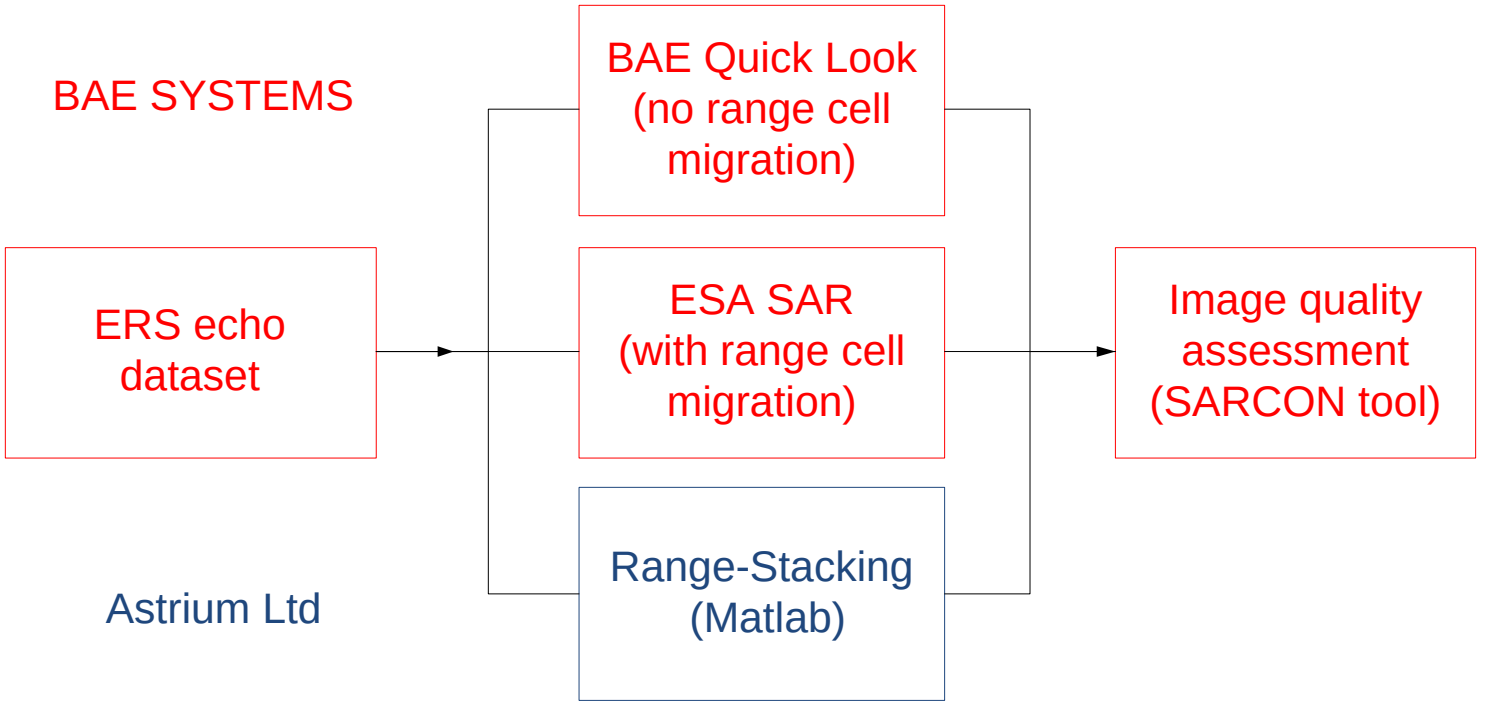
- In conventional spaceborne SAR, Level 1 products are generated in ground segment:
  - Detected SAR images (intensity)
  - Complex images preserving phase for interferometric products
- Interest in generating SAR Level 1 products on board the spacecraft
- Rationale
  - Real-time dissemination of imagery direct to users
    - met-ocean products for ship navigation, offshore engineering (including gas & oil platforms) and weather forecasting
    - sea-ice products for navigation
    - humanitarian aid and disaster monitoring (earthquakes, floods, forest fires, oil spills)
  - Data compression (mass memory, TM bandwidth constraints)
    - *Wavemill* oceanographic SAR (squinted system)
    - planetary missions

⇨ Develop SAR Level 1 algorithm in form suitable for flight processor

# Project Introduction (2 of 2)

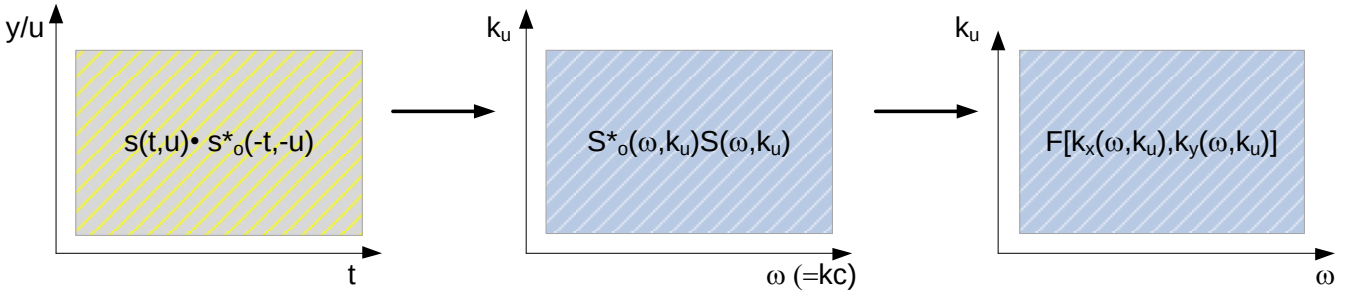
- Astrium Ltd
  - Techniques and technologies for on-board processing
  - Acquired in telecoms applications, applied to SAR Level 1 processing
  - CEOI 5th call activity: MATLAB algorithm
    - Stephen Brown, Kehinde Latunde-Dada, Alex Wishart
- BAE SYSTEMS ATC
  - SAR Level 1 image processing and commercial applications
  - CEOI 5th call activity: echo dataset preparation and image quality analysis
    - Steven Blythe, Trevor Macklin, Peter Meadows
- Team worked together on CEOI 4th Call study on SAR Level 1 OBP
  - Focus on range, azimuth compression in range-Doppler algorithm
- 5th Call Study extends this work to general case, which includes squint

# Technical Report (1 of 5)



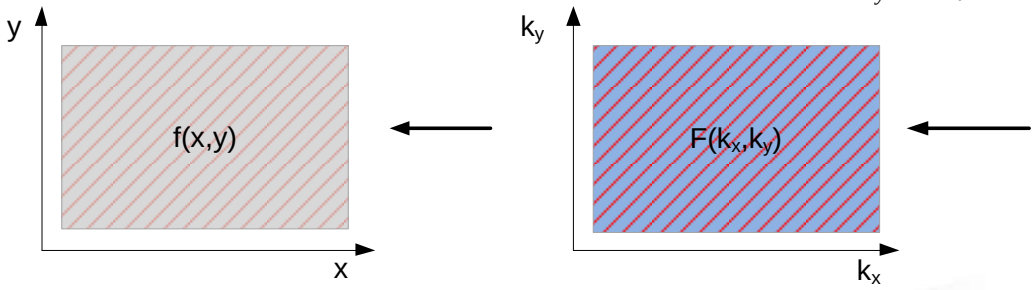
# Technical Report (2 of 5)

signal space




$$k_x(\omega,k_u)=\sqrt{4k^2-k_u^2}$$
$$k_y(\omega,k_u)=k_u$$

image space



# Technical Report (3 of 5)

- Image results for ERS-2 Greenland scene (acquired 21st March 2011)
  - Measure azimuth offset: difference between azimuth positions of distinctive features at near range (left) and far range (right).
  - Astrium-processed image at 4x coarser spatial resolution (range) – positions of features agree with ESA-processed image.
  - BAE-processed quick-look image omits the correction for range cell migration: some features appear displaced relative to the other two images.
  - ESA-processed image includes range cell migration.

Astrium Image

BAE quick-look Image

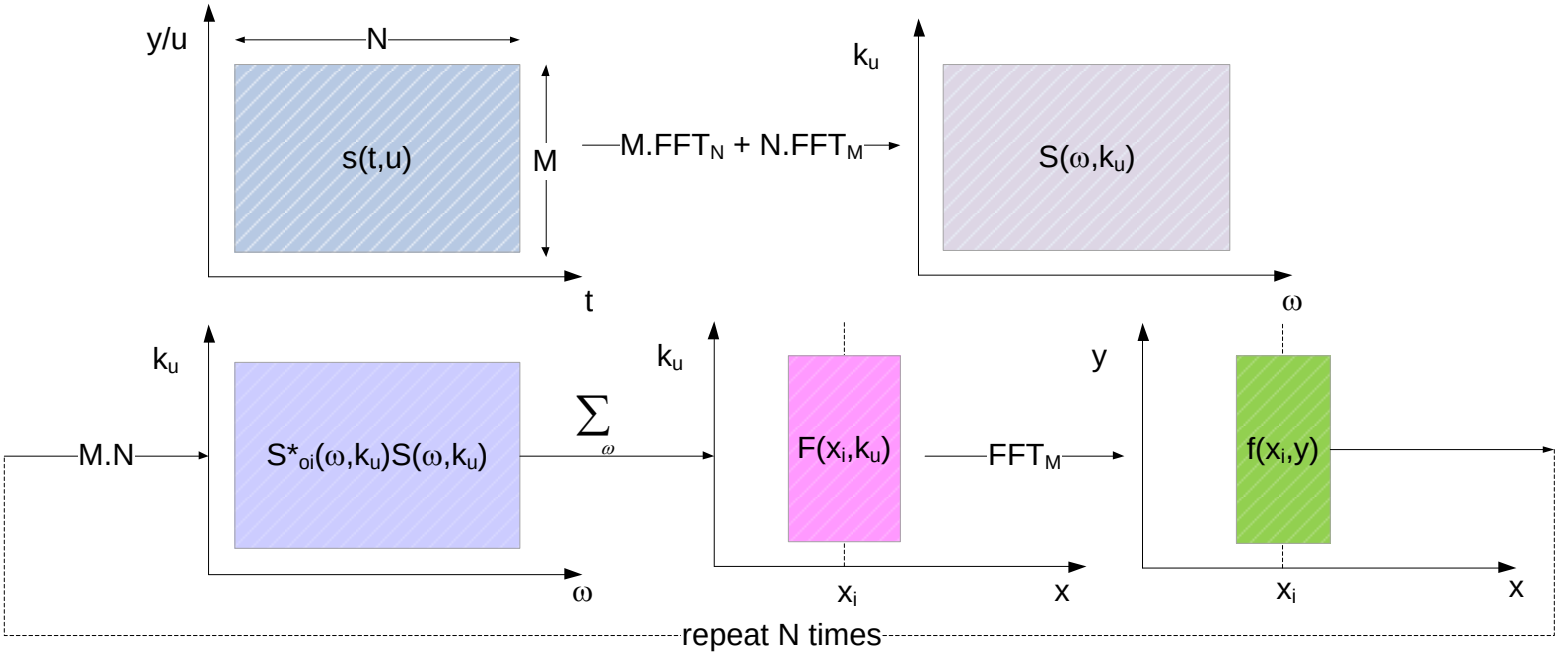
ESA Image

# Technical Report (4 of 5)

- Measured azimuth offsets between features at near and far range show that range cell migration has been successfully applied to the Astrium-processed image.
  - Results confirmed on 3 ERS-2 SAR images, including one case where there is 1° squint
  - Summary of measured azimuth offsets (two pairs of features are measured on each scene):

| Image | Notes | Astrium | ESA | BAE |
|---|---|---|---|---|
| Greenland<br>21 Mar 2011 | Astrium at<br>4x resolution. | 3000 m<br>2050 m | 3410 m<br>2200 m | 5010 m<br>3810 m |
| Flevoland<br>13 Dec 1995 | Astrium at full<br>resolution. | 333 m<br>554 m | 324 m<br>550 m | 279 m<br>418 m |
| Flevoland<br>18 Apr 2001 | 1° squint.<br>Astrium at<br>4 x resolution. | 2890 m<br>3340 m | 2640 m<br>3160 m | 1090 m<br>1760 m |

# Technical Report (5 of 5)




$$\frac{M.N[2\log_2 M + \log_2 N + N]}{M.PRI} \approx PRF.N^2$$

- PRF = 2000 Hz, N = 2000 pixels ⇒ multiplications/sec ~ $8.10^9$
- Virtex 5 FPGA multiplications/sec ~ $5.10^{10}$
- ASIC (180 nm) 0.1 nJ/multiplication ⇒$10^{10}$ multiplications/sec ~ 1 Watt

# Achievements and Positioning (1 of 1)

- Insight into ‘wavefront reconstruction’ approach to SAR imaging
  - Places ‘conventional’ algorithms in context
- Developed methodology for systematic performance analysis
  - Initially applied for modest squint
  - Further work would include IR characterisation, greater degree of squint
- First assessment of on-board processing hardware resources
- Strengthened Astrium Ltd/BAE SYSTEMS teaming
  - Complementary expertise, enhances UK capability
- Presentations
  - NCEO CEOI Conference, Nottingham, September 2012
  - CEOI Knowledge Exchange Event, London, January 2013

# Roadmap (1 of 1)