GLOBAL SPACE PARTNERSHIP

C-SIGMA

Collaboration in Space for

*For International Stewardship of the Maritime Environment and its Resources
*For Maritime Safety
*For Security

Global Maritime Awareness

Photo Courtesy of MDA

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C-SIGMA

# Providing Environmental Monitoring*
# Increasing Security*
# Enabling Safety Efforts*
# Guarding Natural Resources*
  - Fish
  - Energy
  - Mineral

*Maritime & Otherwise
C-SIGMA

# Not a Program
# Not a Canned Solution
# Not Even a Proposal
# Governance is NOT Discussed
# Is an Technology Examination
# Is an Awareness Effort

A Call to Action!
C-SIGMA

LiMES

- Special Thanks to:
  - CSTARS – University of Miami
  - MacDonald Detweiler & Associates (MDA)
  - Johns Hopkins University/Applied Physics Lab (JHU/APL)
  - Ball Aerospace
  - DLR
C-SIGMA Concept

USE TODAY'S COMMERCIAL SATELLITE TECHNOLOGY

- Inexpensive
- Readily available
- Worldwide coverage
- Wide choice of sensors

AUTOMATE ALL PROCESSING

- Get results fast
- Keep it simple and easy to use
- Minimize manpower and user intervention
C-SIGMA Concept (continued)

Be able to monitor large Ocean Areas
* Wide Area Persistent Surveillance

Able to re-survey area quickly
Accurately detect Vessels of interest
* Minimize false hits
* Increased Probability of Detection

LiMES
Global Maritime Awareness

Collaboration is THE Silver Bullet
Combined MSSIS & S-AIS* 

*From One Small, Cheap Satellite
Important Factors re Maritime Awareness from Space

- Integrated into Existing Surveillance Efforts
- Data Latency Drives Relevance of data & Provides cross-cueing opportunities

- Applications:
  - Detection: Wide Area Surveillance requires reliable detection
    - Largest Possible Swath & Shortest Revisit Time
  - Classification: AIS & Other Self Reporting Systems (or lack thereof)
  - Identification: High Resolution EO/IR
Data Latency

- Drives Tactical Relevance of Data
- Drives Cross Cueing Opportunities
4 Types of Satellites (at a minimum)

- Synthetic Aperture Radar (SAR)
- EO/IR Imaging
- AIS Collectors
- Transponders

Each makes **UNIQUE** contributions
Space-Based SAR Provides Global Access

- All-Weather, Day-Night, Dynamically-Tasked, Tactical-Resolution SAR
  - Optimized for large area collections
  - Cues higher-resolution systems - Tipping & Cueing
- Repeat Orbit
  - Nominal 24 Hour Repeat
  - Optimal CCD over wide area
  - Maritime Domain Awareness
  - Non-SAR Mode for Vessel Detection
  - SAR mode for wake detection
- Simultaneous SAR Imaging & Tagging
- TPED using existing ISR Infrastructure
  - Theater tasking/downlink
  - Automated CCD Processing

Analysis of Change Indicates Potential Activities of Interest
Cosmos Sky Med

Technology
- Constellation of four X-band SAR imaging satellites with multi-polarization

The So What
- Resolutions from sub-meter in spotlight mode through several tens of meters
- Rapid revisit, improved persistence, 24-hr, global coverage
- The only commercial imagery satellite constellation with this capability
- Dual-use system for defense and civil applications
### SARS launched in Last Year

<table>
<thead>
<tr>
<th></th>
<th><strong>RADARSAT II</strong></th>
<th><strong>TerraSAR-X</strong></th>
<th><strong>Cosmo-SkyMed</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>MDA - Canada</td>
<td>EADS Astrium GmbH/DLR – Germany</td>
<td>Telespazio - Italy</td>
</tr>
<tr>
<td><strong>Commercial Imagery Provider</strong></td>
<td>MDA - Canada</td>
<td>infoterra - Germany</td>
<td>eGeos - Italy</td>
</tr>
<tr>
<td><strong>Band &amp; Polarity</strong></td>
<td>C-band multi-polarimetric</td>
<td>X-band multi-polarimetric</td>
<td>X-band multi-polarimetric</td>
</tr>
<tr>
<td><strong>Orbit / Repeat / Revisit</strong></td>
<td>Sun-Synchronous Polar / 24 days / Hours north of 48 latitude</td>
<td>Sun-Synchronous / 11 days / 2.5 days</td>
<td>Sun-Synchronous / 6 hours / Less than 12 hours</td>
</tr>
<tr>
<td><strong>Satellites in Constellation</strong></td>
<td>One operational with a Tandem planned</td>
<td>One operational, undergoing acceptance testing with a TanDEM-X planned</td>
<td>Four with two operational, one awaiting launch (23-24 Oct 08), one in build</td>
</tr>
<tr>
<td><strong>Modes &amp; Resolution in Meters</strong></td>
<td>Ultra-Fine – 3 meters Fine – 8 meters ScanSAR – 50 meters + 7 add’l beam modes</td>
<td>Spotlight – 1 meter Strip Map – 3 meters Scan SAR – 18 meters</td>
<td>Spotlight – sub-meter HIMAGE – 3 meters WideRegion - tens of</td>
</tr>
<tr>
<td><strong>NIIRS (Estimated)</strong></td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td><strong>Projected Life</strong></td>
<td>7 years</td>
<td>5 years</td>
<td>5 years</td>
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</tbody>
</table>
Why SAR?

World-wide Cloud Cover Prevalence (8 year mean average)

Cloud Amount (%)
SARSAT CONOPS

--SARSAT systematically images areas of interest

- Ground System receives, processes and detects targets in real time, uplinking probable target coordinates back to RADARSAT-2.

- RADARSAT-2 places a 10m resolution beam on probable targets to capture an image of the target.

- Ground System creates a 10m image chip and derived Target Detection Report.

Courtesy MDA
Cosmo-SkyMed 1,

StripMap-HI imaging mode; 5 m resol.
13 Nov 2007 16:13 UTC,
Descending orbit, Left looking
2-D AESA Offers Agile Collection Capability

- No need to slew vehicle
- No missed collect if on wrong side of vehicle track
- Greatly increases area coverage rates

Nadir Facing 2-D Electronically Steered Phased Array Offers Agile Collection with Tasking on Either Side of Vehicle Track

Courtesy Ball Aerospace
BASIC SARSAR Modes with Resolution

- **Spotlight**: res. $<< 1$ m, identification of tanks possible (T72, Leo, ...)
- **Strip Map**: res. $1.0$ m, recognition of airplanes (Transport, Fighter, ...)
- **ScanSAR**: res. $3.0$ m, detection of infrastructure (roads)
- **ScanSAR**: res. $16.0$ m, detection of coarse land cover features

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**Identification** | **Recognition** | **Detection**
L-Band SARSat

Wake and Ship Detection

Courtesy of Ball Aerospace
L-Band SAR CONOPS

- Circular orbit 518 km altitude
- 70 Degree Inclination (Family of orbits possible)

- LEO Orbit Tuned for CCD Exact Repeat of Target Viewing Geometries Within 1 Day
- Surveil all ocean areas twice a day, detecting all vessels above 25m.

Courtesy Ball Aerospace
IMAGING OPPORTUNITIES PER PASS

Start Collection

End Collection

24 hours @ 60 km/hr (~30kts)
36 hours @ 60 km/hr (~30kts)

11 minute duration, 1.2 rpm
455 x 455 x 48 deg, 8 day repeat

Courtesy JHU/APL
ACCESES PER DAY, SPINNER ARRAY

Up to 14-30 “hits” per day on Atlantic and Pacific CONUS approach routes

Graphic shows one day of an eight-day repeat orbit

Courtesy JHU/APL
L-Band SAR Daily Collection

Courtesy Ball Aerospace
Frequency & FoPen
(Also applies to Wake Detection)
Optical Systems

High Res Optical Satellites:

- EROS-A1, EROS-B, OrbView, QuickBird, WorldView, IKONOS, Spot Image, GEOEYE

- Suitable for Ship Classification
  - Coverage from 8KM to 16.5KM
  - Resolutions from .5 to 1.80m (Panchromatic)
- Agile satellites with up to 12 hour to revisit times
- Some include direct tasking to support Tactical Surveillance applications
This 1-meter resolution image was collected November 20, 2008 by the IKONOS satellite. The image shows the SIRIUS Star, the Saudi-owned crude oil carrier Hijacked by Somali pirates, anchored approximately 5 miles off the Somali coast.

(IKONOS is 10 years old....)
Freighter off-loading at Casablanca, Morocco

½ meter resolution photo of Collected on October 25, 2008 by GEOEYE
GEOEYE’s First Pictures
Data Latency:
Ground Systems can provide imagery in minutes

- Data downlink: real-time
- Processing: immediately after downlink
- Images can be processed in priority order
- Pipelined product generation + image processing
- First Images can be delivered minutes after the target was acquired

- Currently, a commercial buy has latency of 4 - 48 hours
3rd Part of the C-SIGMA Equation

AIS

CRUCIAL NEW COMPONENT

LETS YOU KNOW WHO THE **GOOD** GUYS ARE
Over 25,000 Unique Vessels Tracked Daily
AIS Detections
from a Single Pass
Full OrbComm AIS Satellite Coverage
Comparison of Shore-Based Vs. Satellite Based AIS Receivers

Shore-Based MSSIS Data

SpaceQuest AIS Data

AIS Messages collected during one 24-hour period.
4th Part of the C-SIGMA Equation

Transponder Systems

- IMARSAT
- ORBCOM
- Iridium
- Global Star
- Etc.

Often overlooked, not very sexy?
The Real Maritime IFF System?
AKA

Self Reporting Systems

• Tracking, (fishers +), trucks, status change,
• Formatted Message
• Can be programmed to report
  – On a time schedule (every hour, every 30 minutes, etc.)
  – By geographic limit (cross a boundary)
  – Upon event (door open, temperature out of limits, etc.)
  – Combination of rules (e.g. LRIT)
  – Upon demand from shore
Dynamic Data Analysis

- **Goal:** Detect suspicious ship behavior from position tracking data

- **Approach:** Define a set of discrete zones and predict the ship movements in the grid

- **Challenges:**
  - prediction precision
  - lack of positive examples
  - ship traffic variability
  - privacy vs. security tradeoff

- **Scenarios:**
  - vendor data distribution
  - regional data distribution
Cross Cueing provides Tactical Surveillance

- Items of interest from one sensor can be assigned high priority for collection by other sensors,
- Both space based and tactical, e.g.

You CANNOT do it ALL from SPACE
Routine Event
C-SIGMA Event Timeline

A. Commercial Satellites equipped with AIS receivers (S-AIS) continuously Detects all AIS emitters in area of interest.

B. Several Commercial Comm Satellites collect all ship positions reported via LRIT, VMS and private systems.
C-SIGMA Event Timeline

1. Radar Satellite images area of interest on routine pass.

2. Central processing facility correlates contacts detected via RadarSat to S-AIS, VMS and LRIT data. Detects three vessels of interest &

3. Alerts appropriate ground stations to task HR imaging satellite(s) to image the areas where the three vessels of interest can next be accessed, based on Traffic Patterns
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<tr>
<td><strong>C-SIGMA Event Timeline</strong></td>
<td><strong>Routine Event</strong></td>
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<tr>
<td>4.</td>
<td>All three resulting images are studied for items of interest, anomalous activity.</td>
<td>One unit is deemed suspicious.</td>
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<td>5.</td>
<td>MPA is dispatched for a closer look, and Cutter is diverted to intercept, if needed.</td>
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<tr>
<td>6.</td>
<td>MPA detects possible illegal activity and maintains track until...</td>
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<tr>
<td>7.</td>
<td>Cutter arrives on scene and boards</td>
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Cross Cueing Timeline

RADARSAT collects with Scan SAR
East Coast Satellite Ground System (ECSGS) Detects unk Target with no AIS.
TRINITY determines EROS-1A could image Target at 1023
MOSIC tasks ECSGS to image target
AUROA launched to intercept Target at 1200
Image command uplinked to EROS-1A
EROS-1A images Target
ECSGS sends message with coordinates, heading and 1.0m resolution image to MOSIC
MOSIC IDs ship and informs AUROA crew. Based on ID as friend crew cancels reaction and resumes normal patrol.
Proposed Network of Ground Stations

San Diego? Ensenada? San Felipe?

Puerto Rico? Isla Margarita?

Cape Verde Islands

Galapagos? Chiclayo?

Nigeria? Sao Tome?

Three more in Hawaii, Midway and Alaska
All of the foregoing begs the question: “HOW?”

Initial Steps:
1. Set up International committee?

Immediate Next Steps
C-SIGMA  Exploratory Workshop

Purpose

• Achieve consensus:
  – With international and inter-agency partners
  – Need to build an unclassified system using available space based (+ Terrestrial) systems
  – To establish a mechanism for Global Maritime Awareness (GMA)

• Identify:
  – Basic System Components
  – Next Steps to Implement GMA.
Bottomline

There is no Silver Bullet

BUT

SPACE could be HUGE!

COLLABORATION is the Key
C-SIGMA, just a concept

- “PPD-4, National Space Policy, June 28, 2010, emphasizes U.S. leadership in space and directs international collaboration on mutually beneficial space activities for the purpose of broadening and extending the benefits of space. To implement the President’s direction the U.S. will begin the development of an open source system, utilizing government and commercial capabilities, to enhance global maritime domain awareness.”
QUESTIONS ?