Radar Open System Architecture
For Lincoln Space Surveillance Activities

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Definitions

- Open Systems (U.S. Department of Defense/Software Engineering Institute) [1]
  
  “An open system is a collection of interacting software, hardware and human components, designed to satisfy stated needs, with the interface specification of its components fully defined, available to the public, maintained according to group consensus in which the implementation of components are conformant to the specification.”

- Commercial Off The Shelf (COTS) (summary from Federal Acquisition Regulations) [2]
  
  - Customarily used for nongovernmental purpose
  - Has been sold, leased or licensed to the general public
  - Exists a priori (in a catalogue or price list)²
Outline

• Objectives & motivation
• Radar Open System Architecture (ROSA)
• ROSA implemented
• Space surveillance challenges and benefits
• Summary
Lincoln Space Surveillance Complex
Westford, Massachusetts

Millstone
- High sensitivity
- Radar Cross Section (RCS) vs Time
- Small object search

Haystack
- Very high sensitivity
- Range-Doppler imaging

HAX
- High-resolution imaging

<table>
<thead>
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<th></th>
<th>Millstone</th>
<th>Haystack</th>
<th>HAX</th>
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<tbody>
<tr>
<td>Beamwidth (deg)</td>
<td>0.44</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Frequency</td>
<td>1295 MHz</td>
<td>10 GHz</td>
<td>16.7 GHz</td>
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</tbody>
</table>
Kwajalein Missile Range

- **ALTAIR** [7]
  - High sensitivity
  - Radar Cross Section (RCS) vs Time
  - Primary space tracking radar
- **TRADEX** [8]
  - Alternative space tracking radar
- **ALCOR, MMW** [6]
  - Range-Doppler imaging

ALTAIR
  - VHF, 158 MHz / UHF, 422 MHz

TRADEX
  - L-band, 1320 MHz
  - S-band, 2950 MHz

MMW
  - Ka-band, 35 GHz
  - W-band, 95 GHz

ALCOR
  - C-band, 5664 MHz


5-S.E. Andrews 4/20/10

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Objectives & Motivation

• Establish an open systems approach as the foundation for radar systems development in order to:
  – lower development time
  – Improve life-cycle costs
  – Increase systems performance

• Improve:
  – Portability
  – Interoperability
  – Compatibility
  – Reusability
  – Maintainability
  – Affordability - improve acquisition model
  – Scalability- quick insertion of new technology

• Develop plug-and-play radar components
  – Share components between DOD programs
  – Migrate to commercial world

Outline

• Objectives & motivation
• Radar Open System Architecture (ROSA)
  – Radar Architectures Old & New
  – Benefits
  – Example
• ROSA implemented
• Space surveillance challenges and benefits
• Summary
Radar Architectures Old & New

• Traditional Radar Systems Model
  – Master computer and centralized hardware
  – Custom development, proprietary HW & SW

• Open Systems Architecture
  – Radar functionally decomposed into building block components
  – Industry standard COTS hardware and interfaces
  – Components available for technology transfer

**ROSA** Generic Subsystem Example

- **COTS/Open Systems hardware core:**
  - VME/VXI, PCI and other IEEE standard technology
  - Standard networks and interfaces
- **Additional VME boards added to provide subsystem functions**
- **POSIX-compliant operating system (POSIX, NFS, ANSI C)**
- **Built in diagnostics provided by CPU**
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Kwajalein Radar Modernization

- 80% Reduction in custom hardware
  > 85 % COTS
  Seven custom boards for all Radars
  70% reduction in number of racks
- Automated and remote operations/diagnostics
- Dramatic improvement in flexibility

New common radar system

- Common radar software for all radars
  - 70% reduction in lines of code
  - 85% reduction in languages/OS/Platforms
- Extensive capability
  - >150 waveforms supported
  - 16 Channel coherent integration and detection
  - Multi-Target-Tracking (64 targets)
  - Bayesian Classifier (WB features)
  - Automated script-driven operations
  - Space surveillance functions
  - Common data recording format (> 80 Mbytes/sec)
  - Full PRI rate digital simulation
    - 64 targets and simulated targets over live data
Radar Open Systems Architecture - *ROSA*

**Benefits**

- Reduced development time and operations and maintenance cost
- Decomposition provides efficient use of engineering resources
  - Allows many small development teams (distributed locations)
  - Concurrent integration, test and evaluation
- Components easily added, shared and modified
  - Migration to new technology can be done at the unit level
- New developments can begin with working components
  - Better acquisition model, reduced non-recovered engineering costs
- Subsystems encapsulate specific radar function
  - Underlying hardware and software is hidden
- Communication is key to architecture
  - Subsystem components completely define their functionality and interfaces to the outside world

![Diagram of Radar Open Systems Architecture](image)

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ROSAS Development Significant to Space Surveillance

- Debris Mode
  - Stare at Fixed Azimuth and Elevations and detect and record debris objects as they go through beam

- Trajectory Scans ($\alpha/\beta$ Scan) & (Progressive $\alpha/\beta$ Scan)
  - Scans along satellite trajectory in time and orthogonal by beam width

- Satellite Tracking Displays
  - Simplified Displays for Satellite Tracking

- Selective Radar Channel Recording
  - Ability to record selective Radar Channel data (PP; PP/OP or all four channels)

- Deep Space Tracking (MHR SATCIT)
  - Integrate SATCIT on MHR and then HAY and HAX radars

- Wideband Network Sensors (WNS)
  - High speed network demonstration with Radar Data >1gbit/sec
Deep Space Tracking Operations – Real time Multi-pulse Integration

• 30+ year history of deep space* tracking operations [7]
  – 1963 - Detected Syncom II in GEO using post-processing
  – 1965 – Real-time computer enables rudimentary multi-pulse processing in real time
  – 1971 – Experiments using Haystack planetary radar to observe GEO satellites
  – 1975 – Millstone begins routine operations tracking deep space objects for U.S. Space Surveillance Network

• Acquisition and tracking process [7,9]
  – Operate beyond unambiguous range of radar
  – Order of 1000 pulses integrated to gain 30 dB
  – 12 classes target models processed simultaneously
    3 levels of coherence
    4 options for polarization of returns
    Best model selected in real time

* Deep Space orbits here are defined to be those with periods > 225 minutes
Target Model Illustration

Three possible target spectra

Coherent

Quasi-coherent

Noncoherent

Four possible receive polarization characteristics

Left only

Right only

Joint

Polarimetric

7. Stone [2000]
HAX/HAY ROSA WNS Block Diagram
Remote Operations – Lincoln Space Situational Awareness Center

• Joint control room for shared site
  – Operators can view other sensor activities real-time
  – Direct communications among sensor operators
  – Cross-sensor familiarity

• Remote viewing of second shared site
  – Real-time viewing of sensor activities and cross-sensor familiarity
  – Best possible planning time

• Joint control room for multiple sites (notional)

Summary

• Radar Open Systems Architecture (ROSA) dramatically reduces the development time and cost of building radar sensors
  – Efficient use of engineering resources
  – Abstraction of hardware layer from software
  – Portable building block components

• ROSA has been applied to several large radar development and modernization programs
  – Kwajalein Missile Range - Common architecture for 4+ radars
  – LSSC - Common architecture for 3 radars & large cost savings

• ROSA implementations have demonstrated real-world benefits
  – Technology transfer efficiencies
  – Reduced development times and operations/maintenance costs
Bibliography


Lincoln Laboratory Space Surveillance Radars

**Frequency Bands**

- ALTAIR
- MILLSTONE
- TRADEX
- ALCOR
- HAY/HAX
- MMW

- VHF
- UHF
- L
- S
- C
- X
- Ku
- Ka
- W

Frequency (GHz)

0.1

1

10

100