Discoverer II:
Space-Based GMTI/SAR Demonstration Program

June 24, 1998

Presented by:
Col Mark T. Hughes
Program Manager
Discoverer II Joint Program
Overview

- Management Structure
- Program Elements
- Demonstration Objectives
- Risk Reduction Efforts
- Acquisition Strategy
Discoverer II
Program Management Structure

Senior Oversight Group
(DARPA – AF – NRO)

AF SAE

Dir, DARPA/TTO
PEO
(Through CDR)

Independent Review Team

AF PEO
(Post CDR)

DARPA
Program Manager

DARPA – Air Force – NRO
Joint Program Office

SAE, Air Force
Director, NRO
Director, DARPA

MOA Responsibilities:

AF
- Contract Authority (Core Program)
- Program Security
- Joint Concept Development Group
- Fund Launch Vehicles/Integration

DARPA
- Contract Authority (Risk Reduction)
- TPED Development

NRO
- FIA Coordination
- Architecture Trades
Discoverer II
CONOPS Development Structure

Senior Oversight Group
(DARPA - AF - NRO)

DII Joint Program Office

Joint Concept Development Group
- HQ USAF/XOR (OPR)
- Army DCSOPS
- Navy N8
- USMC
- DCI

Advance Warfighter Utility Panel ("O-6 Panel")
- Joint Staff/J-38
- DIA/J-2P
- CNO/N632
- HQ AF/XORB
- HQ AF/XORPB
- HQ USMC
- XVIIIth ABN Corps
- USA Armor Center
- Naval War College

Air War College

Air Force
- AFSPC/DR (OPR)
- ACC/DR
- ASC2A
Discoverer II
Joint Program Office Organization

**JPO Personnel:**
- 10 Government Staff
- 2 Government Adjunct Staff
- Small SETA team

**General Counsel Contracting Security**
- AF / DARPA

**Col Mark Hughes**
PM
- DARPA

**Lt Col (S) Ron Grundman**
Dep PM
- NRO

**Ms Christine Kaiser**
Exec Secretary

**Laboratory / FFRDC Support**

**JPO Adjunct Staff**

- Mr Thomas Revay (ASPO)
- Mr Emil Martinsek (AFRL)

**Dr Bill Jeffrey**
Dr John Smith
- DARPA

**Dr Allan Steinhardt**
- DARPA

**Dr Ron Repka**
- DARPA

**Lt Col Allan Netzer**
- AF

**Maj Phil Simonsen**
- AF

**Maj Dave Dzaran**
- NRO

**Mr Tom Tillotson**
- NRO

**Mr Ron Poussard**
- AF

**MIT/LL**

**John Hopkins/APL**

**Sandia NL**

**Aerospace Corp**

**Wright Lab**

**Phillips Lab**

**Rome Lab**
**Discoverer II Demonstration Program Elements**

**Core Program**

<table>
<thead>
<tr>
<th><strong>Space Segment</strong></th>
<th><strong>Ground Segment</strong></th>
<th><strong>Objective System Design</strong></th>
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</thead>
<tbody>
<tr>
<td>• Design/Build/Fly (2) GMTI/SAR Satellites</td>
<td>• Modify Existing Service CIG/SS-Compliant Ground Station(s)</td>
<td>• System performance allocated to component level</td>
</tr>
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</table>

**Risk Reduction Initiatives**

<table>
<thead>
<tr>
<th><strong>Space-Based Radar</strong></th>
<th><strong>Signal Processing</strong></th>
<th><strong>Small, Agile Satellite Bus</strong></th>
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<tbody>
<tr>
<td>• Two Independent Multi-Mode ESA Designs</td>
<td>• GMTI Algorithms</td>
<td>• Risk Analysis</td>
</tr>
<tr>
<td>• Environmental Testing (Subscale test articles)</td>
<td>• SAR Algorithms</td>
<td>• Risk Reduction Concepts</td>
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<tr>
<td>• Frequency Allocation</td>
<td>• Tracking Algorithms</td>
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<td></td>
<td>• Data Collection</td>
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<td></td>
<td>• Onboard Processing</td>
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**High-Data-Rate Communications**

- 2-4X Space Qualified CDL
- Bandwidth Compression

**High-Resolution Terrain Mapping**

- DTED Level 5 Generation
- Precision Geolocation Concepts

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DII: Briefing to Industry 06/24/98 (Hughes.2).ppt 6
Acquisition Strategy
DII Notional Interactions

Signal Processing

Tactical Radar Program
Active, low cost multi-mode ESA

Small Agile Bus

Data pkg

DII Core Program

HR-DTED

Data

Wide band Comm

Commercial, Services, NASA

Target recognition, tasking, image processing software

Data pkg

TES P3I

Software build

DARPA

Army

DJPO

Commercial, Services, NASA
Space Segment

- Develop the most capable, affordable radar on a space platform

Radar

- Multi-Mode, Electronically Scanned Array (ESA): GMTI - SAR - IFSAR
  - Small (e.g., \( \leq 8 \text{m} \times 5 \text{m} \))
  - Low Mass (e.g., \( \leq 500 \text{ kg} \))
- 2-D (-) Electronic Beamsteering:
  - Azimuth: \( >\pm 20^\circ - 45^\circ \)
  - Elevation: \( >\pm 1^\circ \)
- X-band (10 GHz)
- Integrated Sidelobe Level (ISL): -23dB
- Instantaneous Bandwidth: <1ft
- Duty Cycle: 20%
- Peak Radiated Power: >2.0 kW
- Average Power: <600W
- Employ STAP Signal Processing Techniques
- Employ ECCM Techniques
Space Segment (cont’d)

- Satellite Bus
  - Low-Mass: <1000 kg (w/o ESA)
  - Agile: Rapid Roll/Yaw and Settling Sequences
  - Existing, Proven Design, or Close Derivative

- Launch Mass and Form-Factor
  - (2) Satellites w/ Stowed Arrays per MLV

- Orbit
  - 770 km Altitude
  - Circular Orbit

- Transmission Encryption
  - TT&C: MIL-STD
  - Mission Data: UAV Equivalent

- TT&C
  - AFSCN Compatible
Discoverer II
Notional Characteristics (cont’d)

- **Ground Segment**
  - Modify CIG/SS-Compliant Tactical Ground Station (e.g., Army TES)
    - Mission/collection management and tasking SW
      - Update satellite models with Discoverer II ephemeris
      - Update collection planning S/W with Discoverer II agility constraints
    - Wide-band duplex datalink
    - Integrate backward-compatible upgrade to ≥548 Mbps (downlink)
    - Integrate backward-compatible upgrade to ≥ 200 Kbps (uplink)
      - Add common Imagery Processor (CIP) #2, for enhanced CIP performance >40 Gflops
      - Implement real-time GMTI signal processing algorithms in CIP
      - Integrate Discoverer II imagery formation processing S/W in CIP
  - Exploitation tools enhancement
    - Integrate with SAIP, MTE, etc.
    - Improve exploitation time by 4X
Discoverer II Demonstration Enhancements

CONOPS
- Joint Concept Development Group
- Army CONOPS Development
- Air Force Concept Development Group

Utility Assessment
- Determine Optimum “System of Systems” Employment

Enhanced Tasking, Processing, Exploitation & Dissemination (TPED)
- DDB (Dynamic Data Base)
- AIM (Advanced ISR Management)
- SAIP (Semi-Automatic IMINT Processing)
- MTE (Moving Target Exploitation)
- BADD (Battlefield Awareness and Data Dissemination)
Discoverer II Demonstration Objectives

- Affordability
- Tactical Warfighter Dynamic Tasking
- Direct Downlink to the Tactical Warfighter
- GMTI Collection
- SAR Imaging
- High-Resolution Terrain Mapping
Discoverer II
Demonstration Objectives
(Affordability)

- Produce two GMTI/SAR satellites substantiating the feasibility of achieving an objective system unit cost of $100M per satellite (24 unit average cost) and an affordable 20 year life-cycle cost
  - Innovative commercial manufacturing/practices and operations
  - Unique constellation deployment/replenishment strategies

Objective performance requires a large constellation, necessitating a revolutionary reduction in satellite per unit cost
Provide for tasking the constellation (GMTI and SAR collection) from a theater area of responsibility (AOR) in near-real-time (NRT) (AOR size is 500,000 km²)
Simultaneously broadcast GMTI/SAR information to any point in the AOR and transmit to CONUS in NRT.
Discoverer II
Demonstration Objectives
(GMTI Collection)

- Detect and track low-speed, HMMWV-sized ground targets
- Perform wide-area surveillance of an entire AOR: \( \leq 15 \) minutes
- Rapidly perform repeated GMTI collection against multiple “spots” of interest, randomly located within an AOR

Maritime Targets

Long-Range Reconnaissance

Sea Lane Reconnaissance

Littoral Reconnaissance

Ground Targets

“Go-Stop-Go” Tracking (Multi-mode GMTI/SAR)

Survey steep valleys (Angle Diversity)

Track Through Gaps (HR-GMTI)
Discoverer II
Demonstration Objectives
(SAR Imaging)

- Provide at least moderate resolution SAR imaging
- Provide “spot” (frame) and strip imaging modes
- Provide precise geolocation of stationary targets

Strip Mode
(e.g., > 1.0m IPR)

“Spot” Mode
(e.g., <1.0m IPR)

Precise Geolocation
(e.g., 3.0m TLE)

Target
Mission Image
Synthetic SAR Image
Terrain Database
Provide DTED Level 5 quality terrain mapping data (IFSAR- or stereo-derived)

DTED Accuracy Requirements

<table>
<thead>
<tr>
<th>DTED Level</th>
<th>Post Spacing (approx) (m)</th>
<th>CE (absolute)* (m)</th>
<th>LE (absolute)* (m)</th>
<th>CE (relative)* (m)</th>
<th>LE (relative)* (m)</th>
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<tbody>
<tr>
<td>2</td>
<td>30</td>
<td>50/15</td>
<td>30/10</td>
<td>- / 10</td>
<td>- / 7</td>
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<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>0.5</td>
<td>0.33</td>
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</table>

* x/y : Current requirement/Evolving Requirement

Battlefield Visualization
Technical Risk Reduction Efforts

- Spaceborne, Multi-Mode ESA
- GMTI/SAR Signal Processing
- Small, Agile Satellite Bus
- High-Data-Rate Communications
- High-Resolution Terrain Mapping

- Leveraging ongoing DARPA technology exploitation efforts
- Risk reduction effort results will transition to Discoverer II System Integrators
Technical Risk Reduction Efforts
(Spaceborne, Multi-Mode ESA)

- Awarded (2) sole source contracts for full-scale design of a small, low-mass, high-performance, spaceborne, multi-mode ESA
  - Northrop Grumman
  - Raytheon

- Subscale test article launch and space environmental testing

- Radar frequency allocation planning
Technical Risk Reduction Efforts
(Space-Based GMTI/SAR Signal Processing)

- Supporting waveform and signal processing algorithm development and laboratory evaluations
  - Space-based GMTI collection
  - Space-based SAR imaging
  - Simultaneous GMTI/SAR collection
  - Target tracking

- GMTI data collection

- Supporting technical evaluation of possible onboard processing options
- Issued RFI for existing low-mass, agile satellite buses
- Conducting risk analysis
- Developing risk reduction concepts
Technical Risk Reduction Efforts
(High-Data-Rate Communications)

- Feasibility analysis/options assessment for 2X-to-4X CDL
- Data bandwidth compression studies
- CDL frequency allocation planning
- Issued RFI for high-data-rate space-to-ground, ground-to-space and cross-link communications systems (1X-to-4X CDL data rate)
- CDL space qualification (planned)
Terrain-Aided SAR Targeting

- Mission image correlated with synthetic-SAR Image
  - High accuracy rapid targeting
  - No coverage impact
  - Requires high-quality terrain database

- Performance goal
  - 3-m TLE
  - Broad-area coverage
  - Precision terrain elevation data at 1, 3, or 10 m posting
Technical Risk Reduction Efforts
(High-Resolution Terrain Mapping)

Potential Terrain Mapping Performance

<table>
<thead>
<tr>
<th>2 Satellite pair performance</th>
<th>(400 km²) 20x20 km</th>
<th>(8100 km²) 90x90 km</th>
<th>(90,000 km²) 300x300 km</th>
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<tbody>
<tr>
<td>Regional Rqmts</td>
<td>18 hours</td>
<td>72 hours</td>
<td>12 days</td>
</tr>
<tr>
<td>10 m posting</td>
<td>0.17 hours</td>
<td>3.5 hours</td>
<td>1.6 days</td>
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<tr>
<td>3 m posting</td>
<td>0.8 hours</td>
<td>16.2 hours</td>
<td>7.5 days</td>
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<tr>
<td>1 m posting</td>
<td>13.7 hours</td>
<td>278 hours</td>
<td>129 days</td>
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</table>
Technical Risk Reduction Efforts
(High-Resolution Terrain Mapping)

Technical Challenges
- Baseline length and tilt measurement
- Phase unwrapping
- Scene Effects
  - Foliage
  - Urban Areas
  - Lakes
  - Snow/ice
- Accurate mission/reference image co-registration for targeting
- Collection concept
  - Orbit selection
  - Synchronization

Objectives
- Control relative, absolute errors to DTED 5 levels
- Correctly resolve $2\pi$ height ambiguities
- Identify and minimize errors and gaps due to
  - Shadowing
  - Layover
  - Decorrelation
  - Multipath
  - Low return areas
- Transfer full accuracy of terrain data to targeting solution
- Select orbits and phasing to ensure satisfactory coverage access and timeliness
The Discoverer II program develops the component-level design for the “objective system” – identifying growth paths needed.

The two R&D prototypes prove growth paths are achievable.
Discoverer II Program Touchstones

➢ Competition & Innovation
  • Empower, Enable, and Challenge industry
  • Want multiple “out of the box” high risk radar designs
    — Maximize viable offerors

➢ Acquisition reform/streamlined processes
  • “Other Transactions” agreements

➢ Capabilities
  • Cost As Independent Variable (CAIV)
    — Trade-space is performance and cost
## Discoverer II
### Notional Program Schedule

**As of: 22 June 98**

### Task

#### Technology Risk Reduction
- Space-Based Active ESAs

#### Demonstration Program
- **Phase I** (Studies/Trades/Prelim design)
- **Phase II** (Final Design/build/demonstrate)

#### System Design & Integration
- System SI Contract #1
- System SI Contract #2
- System SI Contract #3
- System SI Contract #4
- Antenna Build #1
- Antenna Build #2
- Ground Station integration/Test TES

### Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>FY99</th>
<th>FY00</th>
<th>FY01</th>
<th>FY02</th>
<th>FY03</th>
<th>FY04</th>
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<td>Freeze Architecture Start Subscale Array</td>
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<td>RA Awards</td>
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<td>Launch #2</td>
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### LEGEND:

- ▲ Planned Start
- ▼ Planned End
- ■ Planned Milestone
- ◇ Planned Critical Milestone
- ▲ Actual Start
- ▼ Actual End
- ■ Actual Milestone
- ◇ Actual Critical Milestone

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Phase I Agreement (RA award to IER3)

- Scope
  - Conduct up to 3 IERs w/deliverables
  - System trades, studies and reports (objective system & prototype)
    - Two design approaches/multiple radar vendors
    - Cost, risk, thermal, power, weight, reliability & performance
    - Operations concept
  - Risk mitigation program
  - Objective system H/W & S/W designs w/deliverables
  - Plan demonstrator test program
  - Submit and definitize Phase II proposal based on Phase I experience

- Milestone payments
Phase II Agreement Scope (Phase II award to Demo complete)

- Structure/definitize Phase II proposal based on Phase I experience
  - Demonstrator system design/TSPR
  - Conduct demonstrator system CDR w/deliverables
  - Software demos
  - Space craft integration & test/report
  - Space vehicle mate
  - TES integration
  - End to end ground system check-out
  - Launch support
  - Mission planning, tasking, TT&C
  - Conduct on-orbit operational demonstration
  - Final Report

- Cost reimbursement with incentives
- Long-lead provisions
Acquisition Strategy

- Use Section 845 Prototyping authority
  - 845 Agreement with System Integrator(s)
  - Award Multiple agreements in 1QFY99
  - Subsequent down selects to result in no more than two final System Integrator(s)
    - Affordability dependent

- Conduct program at Genser SECRET
  - General system description: UNCLASSIFIED
  - Detailed system characteristics and performance: SECRET
Discoverer II Joint Program: Funding

Total Joint Program planned funding
FY98-FY04: $593 M + AF funded launch

- Total then-year dollars
- DARPA, Air Force, and NRO share program costs
- Air Force separately funds launch vehicles and launch integration support
Discoverer II Near-Term Objectives

- Obtain feedback from industry representatives on program plan
  - Mid-June to early Aug
- Release for comment the Draft Solicitation for Discoverer II System Integration proposals
  - Mid-August
- Hold an “Industry Day” (release Draft RA)
  - Late August
- Consider comments on the Draft Solicitation
- Modify and release the Final Solicitation
  - Early October
- Award multiple System Integration agreements
  - Mid-December
Discoverer II is a joint demonstration program:

- Technical feasibility of attaining an affordable space-based GMTI/SAR capability using small, low-cost radar satellites
- Technical feasibility and operational utility of the tactical warfighter tasking, and receiving direct downlink from reconnaissance/surveillance satellites

- Design, build, and fly (2) space-based radar (SBR) R&D satellites; demo on-orbit for one year
- Modify one or more CIG/SS tactical ground stations
- Provide an objective system design