Project No. A-4050

Project Director: J. A. Bruder

Sponsor: Massachusetts Institute of Technology

Type Agreement: Purchase Order CX-6211 (Under Gov't Prime F19628-85-C-0002)

Award Period: From 11/20/84 To 12/31/84 (Performance) 12/31/84 (Reports)

Sponsor Amount:

<table>
<thead>
<tr>
<th>Estimated</th>
<th>Funded</th>
<th>Total to Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>$40,027</td>
<td>$40,027</td>
<td>$40,027</td>
</tr>
</tbody>
</table>

Cost Sharing Amount: None

Title: MMWave Radar Study

ADMINISTRATIVE DATA

1) Sponsor Technical Contact:
   Director of MIT-Lincoln Laboratory
   P. O. Box 73
   244 Wood Street
   Lexington, Massachusetts 02173-0073

2) Sponsor Admin/Contractual Matters:
   Nancy J. Alisow
   Associate Purchasing Manager
   MIT-Lincoln Laboratory
   P. O. Box 73
   244 Wood Street
   Lexington, Massachusetts 02173-0073

Defense Priority Rating: DO-A7

Military Security Classification: N/A

REQUIREMENTS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel:
- Foreign travel must have prior approval - Contact OCA in each case.
- Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment:
- Title vests with none proposed or anticipated

COMMENTS:
*Note: No cost extension through 2/15/85 has been requested.
SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 8/2/85

Project No. A-4050  XXXX/EnvLab  RAIL

Includes Subproject No.(s)

Project Director(s)  J. A. Bruder  WSMU/GIT

Sponsor  Massachusetts Institute of Technology, Lincoln Laboratory

Title  MMWave Radar Study

Effective Completion Date: 2/15/85 (Performance)  2/15/85 (Reports)

Grant/Contract Closeout Actions Remaining:

☐ None

☒ Final Invoice or Final Fiscal Report

☐ Closing Documents

☒ Final Report of Inventions

☒ Govt. Property Inventory & Related Certificate

☐ Classified Material Certificate

☐ Other

Continues Project No.  Continued by Project No.

COPIES TO:

Project Director  Library
Research Administrative Network  GTRC
Research Property Management  Research Communications (2)
Accounting  Project File
Procurement/GTRI Supply Services  Other
Research Security Services  Heyser
Reports Coordinator (OCA)  Jones

Legal Services

FORM OCA 89.285
BRIEFING MATERIAL

presented at

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Boston, Massachusetts

October 18, 1984

by

N. C. Currie
W. A. Holm
D. L. Odom
J. A. Scheer
R. N. Trebits

GEORGIA TECH RESEARCH INSTITUTE
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia
BRIEFING OUTLINE

EXECUTIVE SUMMARY
RADAR SYSTEM DESIGN CONSIDERATIONS
RF/IF HARDWARE REALIZATION
DATA ACQUISITION & SYSTEM CONTROL (AIRBORNE)
DATA PROCESSING, GROUND BASED
MEASUREMENT & CALIBRATION
PROGRAM ASPECTS
GTRI has developed a straightforward, low risk, compliant program in response to MIT/LL - DARPA need for an airborne instrumentation SAR data collection system.
<table>
<thead>
<tr>
<th>EXPERIENCE BASE</th>
</tr>
</thead>
</table>

| TEST AND INSTRUMENTATION | EXTENSIVE EXPERIENCE  
(>25 RECENT PROGRAMS) |
|--------------------------|------------------------|
| AIRBORNE                 | VARIOUS PROGRAMS USING  
GTRI AND CONTRACTOR AIRCRAFT |
| POLARIZATION             | RECOGNIZED AUTHORITY IN  
POLARIZATION RELATED PROCESSING |
| MILLIMETER WAVE          | 30 YEARS EXPERIENCE IN  
MILLIMETER WAVE R&D |
| HIGH RESOLUTION PROCESSING | PROVEN HIGH RANGE RESOLUTION  
TECHNIQUES |
|                          | STRAIGHT FORWARD, LOW RISK SAR  
APPROACH |
|                          | ALL AIRBORNE DATA RECORDED  
(NO PRE PROCESSING) |
<p>|                          | GTRI STAFF AUGMENTED |</p>
<table>
<thead>
<tr>
<th><strong>FLIGHT ENVIRONMENT:</strong></th>
<th><strong>SYNTHETIC ARRAY TIME:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>BENIGN, STRAIGHT &amp; LEVEL</td>
<td>SHORT (1500M)</td>
</tr>
<tr>
<td>UNCOMPENSATED ACCELERATION ALLOWABLE:</td>
<td>LARGE</td>
</tr>
<tr>
<td></td>
<td>$a &lt; \frac{\frac{\omega^2}{R^2}}{\frac{\lambda}{R^2}}$ ($\approx 0.04 \text{M/sec}^2$)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>RANGE:</strong></th>
<th><strong>RANGE SWATH:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>SHORT (1500M)</td>
<td>SMALL (150M)</td>
</tr>
</tbody>
</table>

**PROCESSING:**
- NON. REAL TIME
- POLAR PROCESSING NOT REQ'D
OUTLINE OF APPROACH

PULSED Ka - BAND RADAR:

70 WATT TWTA
CHIRPED/COMPRESSED PULSE
STEPPED FREQUENCY FOR ULTIMATE RANGE RESOLUTION
POLARIZATION DIVERSE ON TRANSMIT
DUAL POLARIZED ON RECEIVE    \{ FULL POLARIZATION MATRIX

SAR - STRIPMAP, SPOTLIGHT

ZERO DOPPLER PROCESSING
RECORD RADAR, NAV, MOCOMP DATA ON TAPE
DATA PROCESSING VAN FOR  \{ QUICK-LOOK PROCESSING
                      \{ PRODUCTION PROCESSING

RAR -

FORWARD LOOKING, SCANNING REAL BEAM
# System Enhancing Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Crosspolarization Isolation:</td>
<td>Not achievable w/o pencil (circular) beam which compromises performance</td>
</tr>
<tr>
<td>3-axis Positioner:</td>
<td>Cost -</td>
</tr>
<tr>
<td>Increased Range Swath:</td>
<td>Higher average data rate drives recorder cost</td>
</tr>
<tr>
<td>Increased Crossrange Swath:</td>
<td>No effect in stripmap</td>
</tr>
<tr>
<td>Reduced Crossrange Resolution (DBS):</td>
<td>Larger quantum angular steps in spotlight</td>
</tr>
<tr>
<td></td>
<td>Not advised</td>
</tr>
</tbody>
</table>
1. RANGE RESOLUTION APPROACH

2. SAR
   - ISSUES
   - STRIP MAP MODE
   - SPOTLIGHT MODE

3. RAR
<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. REAL PULSE</td>
<td>PEAK POWER LIMITED</td>
</tr>
<tr>
<td></td>
<td>DATA ACQUISITION SAMPLING PROBLEM</td>
</tr>
<tr>
<td>2. FMCW OR INTERRUPTED FWCW</td>
<td>SEVERE LINEARITY REQUIREMENTS</td>
</tr>
<tr>
<td>3. CHIRP COMPRESSION</td>
<td>DATA ACQUISITION SAMPLING PROBLEM</td>
</tr>
<tr>
<td>4. PULSE-TO-PULSE FREQUENCY STEPPING</td>
<td>SYNTHESIZER SWITCHING SPEED</td>
</tr>
</tbody>
</table>
RANGE RESOLUTION APPROACH

- PULSE-TO-PULSE FREQUENCY STEPPING
  - COMSTRON FREQUENCY SYNTHESIZER
  - DESIRED RANGE RESOLUTION

PROBLEM: SNR MARGINAL

SOLUTION: PRECEED FREQUENCY STEPPING WITH CHIRP PULSE COMPRESSION

(17 dB ADDITIONAL PROCESSING GAIN)
RANGE RESOLUTION APPROACH
(RECEIVED SIGNAL)

- Frequency
- Time
- Power
- 640 MHz
- 37 MHz
- 20 MHz
- 2 m
- 3 m
- 4 m
- 31 μs
RANGE RESOLUTION APPROACH
(AFTER RANGE FFT)

Power

1600a

Time

1.25ns
GENERAL SAR ISSUES

- HIGH X-RANGE RESOLUTION

- LOW INTEGRATED SIDELOBE LEVEL
  - MOTION COMPENSATION
  - RANGE WALK

- MOTION COMPENSATION

- PROCESSING SPEED
TEST MEASUREMENT CONDITIONS

- STRAIGHT, LEVEL, CONSTANT SPEED A/C MOTION (NO HIGH-G MANUVER)
  (HELPS MoCOMP COMPLEXITY)

- SHORT RANGES
  - SHORT APERTURE TIMES (REDUCES ISL)
  - NO "RANGE WALK" CORRECTION (REDUCES PROCESSOR COMPLEXITY, ISL)

- NO REAL-TIME PROCESSING REQUIREMENTS AT FULL RESOLUTIONS
RANGE WALK (STRIP MAP MODE)

\[ L_{\text{MAX}} = 2 \sqrt{R d_R} \]
SYNTHETIC APERTURE LENGTH
(STRIPE MAP MODE)

\[ d_A > \frac{\lambda R}{2L} \Rightarrow L_{\text{min}} = \frac{\lambda R}{2d_A} \]  
(To achieve X-range resolution requirements)

\[ L < 2\sqrt{Rd_R} \Rightarrow L_{\text{max}} = 2\sqrt{Rd_R} \]  
(To prevent "range walk")

Let \( R_{\text{max}} \) be maximum range before range walk processing is required

\[ L_{\text{min}} = L_{\text{max}} \Rightarrow R_{\text{max}} = 6.2 \text{ km} \]
SYNTHETIC APERTURE LENGTH
(STRIP MAP MODE)

\[ L_{\text{min}} = 50 \text{ ft} \]

\[ L_{\text{max}} = 119 \text{ ft} \]

\[ R = 1085 \text{ m} \]

\[ L = L_{\text{min}} = 50 \text{ ft} \]

\[ \therefore \text{ RANGE WALK IS NOT A PROBLEM IN STRIP MAP MODE} \]
\[
\frac{R\lambda}{\lambda} > L \quad \Rightarrow \quad \ell_{\text{max}} = \frac{R\lambda}{L}
\]

(TO ILLUMINATE LARGE ENOUGH PATCH ON GROUND FOR X-RANGE RESOLUTION)

\[
\frac{2V}{\lambda} < (f_{r_e}^{}) \quad \Rightarrow \quad \ell_{\text{min}} = \frac{2V}{(f_{r_e}^{})}
\]

(TO PREVENT DOPPLER AMBIGUITIES)

\[
\ell_{\text{max}} = 24 \text{ inches}
\]
MOTION COMPENSATION
(STRIP MAP MODE)

Meas. trajectory

Desired trajectory

\{Sr\}_x - Line of sight range differences between measured and desired trajectories.
• PHASE CORRECTIONS $\Delta \phi_R = 2\pi \Delta R_R / \lambda$

• RANGE BIN REGISTRATION & COMPLEX INTERPOLATION
RANGE BIN REGISTRATION AND INTERPOLATION

1. \( d_R \)
   \[ \begin{align*}
   &R \\
   &\text{time} \\
   &\text{NO MOTION ERROR}
   \end{align*} \]

2. \( R \)
   \[ \begin{align*}
   &\text{time} \\
   &\text{NO MOTION COMP}
   \end{align*} \]

3. \( d_R \)
   \[ \begin{align*}
   &R \\
   &\text{time} \\
   &\text{RANGE BIN REGISTERED}
   \end{align*} \]

4. \( R \)
   \[ \begin{align*}
   &\text{time} \\
   &\text{INTERPOLATED}
   \end{align*} \]
NO REAL-TIME IMAGING REQUIREMENT

THEREFORE, PERFORM "SLIDING WINDOW" AZIMUTHAL COMPRESSION

- NEW RANGE SWEEP IN, OLDEST RANGE SWEEP OUT OF BUFFER
- COMPLEX SUM IN AZIMUTH
- PRODUCES ONE HIGH X-RANGE RESOLUTION RANGE SWEEP
SAR GROUND PROCESSING STATION
(STRIP MAP MODE ONLY)

MOCOMP DATA

RECORER

RANGE COMPRSSOR 32:1

MOCOMP PHASE COR REGIST. INTERP.

SLIDING AZIMUTH WINDOW BUFFER

QUADRATIC PHASE COR WEIGHTING AZIMUTH COMPRESS.

STORAGE OF HIGH RES COMPLEX POLARIMETRIC MAPS

WEIGHTING

DIRECT TRAJECTORY LAT.,LONG ALT
SAR CONVENTIONAL SPOTLIGHT MODE

-45° ≤ θ ≤ 45°

ILLUMINATED PATCH

145.3 m

952 m

150 m
SYNTHETIC APERTURE LENGTH
(CONVENTIONAL SPOTLIGHT MODE)

\[ d_A > \frac{\lambda R}{2L} \Rightarrow L_{\text{min}} = \frac{\lambda R}{2d_A} \]  
(TO ACHIEVE X-RANGE RESOLUTION REQUIREMENTS)

\[ L < \frac{Rd_R}{L_{\text{min}}} \Rightarrow L_{\text{max}} = \frac{Rd_R}{L_{\text{min}}} = \frac{2d_A d_R}{\lambda} \]  
(RANGE WALK)

\[ L_{\text{min}} = 67 \text{ ft} \quad R = 1453 \text{ m} \]

\[ L_{\text{max}} = 71 \text{ ft} \]

"RANGE WALK EFFECTS BECOMING NOTICEABLE DUE TO"

1. \( L_{\text{max}} = L_{\text{min}} \)

2. UN-DOPPLER PROCESSED ILLUMINATED PATCH INCREASES ISL
ILLUMINATED PATCH

L_{MIN}

L_{MAX}
SAR ANTENNA X-RANGE DIMENSION
(SPOTLIGHT MODE)

\[
\frac{R\lambda}{\lambda} > W \rightarrow z_{\text{max}} = \frac{R\lambda}{W}
\]  
(TO KEEP ENTIRE SPOTLIGHT AREA ILLUMINATED)

\[
\frac{2V}{\lambda} < (f_{r'e}) \rightarrow z_{\text{min}} = \frac{2V}{(f_{r'e})}
\]  
(TO PREVENT DOPPLER AMBIGUITIES)

\[
z_{\text{max}} = 2.4 \text{ inches}
\]

IF \( z_{\text{min}} = z_{\text{max}} \)  
\( f_{re} = 2.1 \text{ kHz} \)  
(3.2 kHz 50% margin)
\( f_r = 136.5 \text{ kHz} \)  
(205 kHz 50% margin)

REQUIRED PRF TOO HIGH
MODIFIED SPOTLIGHT MODE
(SQUINT STRIP-MAP/SPOTLIGHT)

1. FIXED-ANGLE SQUINT STRIP-MAP AS REAL BEAM TRAVERSES SPOTLIGHT PATCH (SAME REAL BEAM GROUND ILLUMINATION AS IN STRIP-MAP MODE);

2. BACK-SCAN ANTENNA IN AZIMUTH TO PUT BEAM ON LEADING EDGE OF PATCH;

3. REPEAT (1) AND (2) UNTIL SQUINT ANGLE GOES FROM −45° TO 45°.
MODIFIED SPOTLIGHT MODE
MODIFIED SPOTLIGHT MODE

ADVANTAGES

- NO RANGE-WALK PROBLEM (BACK TO STRIP MAP MODE)

- NO HIGH PRF REQUIREMENT (ILLUMINATING SMALL PATCH ON GROUND AS IN STRIP MAP MODE)

- MINIMUM DIFFERENCES BETWEEN STRIP-MAP AND SPOTLIGHT MODES:
  
  ANTENNA IS STEPPED-SCANNED IN AZIMUTH

  (EVERY 2-3 SECONDS)

  ADDITIONAL RANGE REGISTRATION/INTERPOLATION

  QUADRATIC PHASE FACTOR IS FUNCTION OF SQUINT ANGLE
ADDITION RANGE CORRECTIONS REQUIRED WITH MODIFIED SPOTLIGHT MODE
## RAR Approach

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antenna:</strong></td>
<td>$1.5^\circ$ El</td>
</tr>
<tr>
<td></td>
<td>$3^\circ$ Az</td>
</tr>
<tr>
<td><strong>Scan:</strong></td>
<td>$\pm 30^\circ$ @ 1 Hz</td>
</tr>
<tr>
<td><strong>Range Coverage:</strong></td>
<td>150 M @ 1500 M up to $30^\circ$</td>
</tr>
<tr>
<td></td>
<td>(90 M @ $60^\circ$)</td>
</tr>
<tr>
<td><strong>Overlap:</strong></td>
<td>65 M/s Velocity</td>
</tr>
<tr>
<td><strong>Az Resolution</strong></td>
<td>40 M @ 1500 M</td>
</tr>
<tr>
<td><strong>PRF:</strong></td>
<td>500 Hz Effective</td>
</tr>
<tr>
<td><strong>Range Resolution:</strong></td>
<td>Same as SAR</td>
</tr>
</tbody>
</table>
COHERENT, FREQUENCY • STEPPED, CHIRPED/COMPRESSED WAVEFORM

TRANSMITTER:

FREQUENCY: 33.2 - 33.84 GHz
PEAK POWER: 70 WATTS
PRF: 32 KHz
PULSE: 2 µsec, 37 MHz LINEAR CHIRP
FREQUENCY STEP: 32, 20 MHz STEPS
**RECEIVER:**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.A.W. COMPRESSION:</td>
<td>50:1 TO 40 nsec</td>
</tr>
<tr>
<td>A-TO-D RATE:</td>
<td>32 MHz</td>
</tr>
<tr>
<td>NUMBER OF BINS:</td>
<td>32</td>
</tr>
<tr>
<td>FFT PROCESS/BIN:</td>
<td>32 POINT</td>
</tr>
<tr>
<td>NUMBER OF SYNTHETIC BINS:</td>
<td>1024</td>
</tr>
<tr>
<td>SYNTHETIC PULSE LENGTH:</td>
<td>≈2 nsec</td>
</tr>
<tr>
<td>EFFECTIVE PRF:</td>
<td>500 Hz/POLARIZATION</td>
</tr>
</tbody>
</table>
ANTENNA: HORN - FED LENS (SAR, RAR)

AZ: 1.5° (.43M)
EL: 3.0° (.22M)
GAIN: 38 dB
SIDELOBES: 30 dB PEAK
POLARIZATION: 25 dB ISOLATION, 1.0 dB ELIPTICITY
A-SANDWICH (3 LAYER) RADOME WALL — F/34.0 — 2 Half-wave Skins
SANDWICH (3 LAYER) RADOME WALL — F/34.0 2 Half-wave Skins
ADVANCED DETECTION TECHNOLOGY PROGRAM

AIRBORNE DATA ACQUISITION AND SYSTEM CONTROL
1. Record radar reflectivity, motion compensation data, time codes, status flags, etc.
2. Provide range gate delay to the analog-to-digital converters.
3. Control antenna pointing direction.
4. Provide built-in test capability.
5. Provide in-flight assessment of data quality.
1. Record digitized I and Q, range-gated, video returns for both receiver polarization channels.

2. Utilize 3-axis accelerometers, Doppler navigation radar, and inertial navigation systems to provide antenna position data to be used for motion compensation.

3. Utilize aircraft and target position data plus the beacon transponder return to provide proper antenna pointing directions.

4. Monitor transmitter power, receiver output levels, noise levels; provide for signal calibration.

5. Provide in-flight ability to assess data quality by displaying medium resolution radar imagery in "real time."
A/D Converters (4) → Buffer Memory → Data Formatter → High Speed Recorder

A/D Converters (4) → In-Flight Processing

CCT Recorder → TV Display

Navigation Computer → Antenna Servos

Ant, Accel, DOP, NAV, RAD, INER, NAV, SYS, Radar Alt, Beacon Transp, Target Pos.
o 8-bit, 32 MHz A/D converters are off-the-shelf items.

o Range gate delay will be provided by the navigation computer from stored target position data and calculated aircraft position data.

o Four A/D converters are required for full polarization matrix data collection capability.

o An oversampling of the range dimension data by a factor of 1-1/2 is provided.
The data rate from the A/D converters is slowed down from a burst rate to a steady rate into the recorder formatter.

Buffering is performed on all four receiver channels simultaneously at the pulse repetition rate.
<table>
<thead>
<tr>
<th>Navigation Sensors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antenna Accelerometers</strong></td>
<td>3-axis system provides ( \dot{x}, \dot{y}, ) and ( \ddot{z} ) on the gimbol.</td>
</tr>
<tr>
<td><strong>Doppler Navigation Radar</strong></td>
<td>True ground speed is provided from ( \dot{x}, \dot{y}, ) and ( \ddot{z} ) of the aircraft.</td>
</tr>
<tr>
<td><strong>Inertial Navigation System</strong></td>
<td>Latitude, longitude, and height plus roll, pitch, and yaw are provided.</td>
</tr>
<tr>
<td><strong>Radar Altimeter</strong></td>
<td>Relative height of the aircraft to the local terrain below the aircraft is provided.</td>
</tr>
<tr>
<td><strong>Beacon Transponder</strong></td>
<td>Specific target area locations are designated.</td>
</tr>
<tr>
<td><strong>Target Positions</strong></td>
<td>Stored target position information will be referenced to beacon transponder locations.</td>
</tr>
</tbody>
</table>
- Provides range gate delay to the A/D converters for sampling initiation.
- Calculates antenna pointing direction.
- Commands the gimbal position.
- Compares gimbal position to command position as part of built-in test.
0 Duplicate of the ground-based recorder, except possibly for playback capability.

0 Georgia Tech requests that high speed recorders be Government furnished equipment.

0 Provides a digital tape that contains all sampled radar video signals, motion compensation data, time code data, polarization status flags, range bin position, etc.
IN-FLIGHT DATA PROCESSING OBJECTIVES

- Processing provides an ability to assess the quality of the radar data in a "real time" manner.
- Processing provides a means of documenting radar scenes in a television compatible format.
IN-FLIGHT DATA PROCESSING

BUFFER MEMORY → STORAGE → 4:1 FFT RANGE COMP. → STORAGE → 64:1 FFT AZIM. COMP. → ADD 2 RANGES

RECOVER AMPLITUDE → LOG COMPRESS. → STORAGE → D/A CONVERTER → TV FORMATTER → TV DISPLAY

TV RECORDER

CCT RECORDER
NAV AND STABILIZATION PROCESSOR

INPUT BUFFER

BEACON
FLIGHT PLAN
RANGE INFOR.

TO GIMBAL

GIMBAL FEEDBACK

TO TAPE

TO R/T

PILOT
DISPLAY

RECORD FORMAT
INS Λ, λ, h, R, P, Y
D.N. \ddot{x}, \ddot{y}, \ddot{z}
ACCEL. \dddot{x}, \dddot{y}, \dddot{z}
ALT. ALT
GIMBAL COMM. AZ, EL
GIMBAL FEEDBACK AZ, EL
RANGE RATE DIGITAL COUNT
IN FLIGHT DATA PROCESSOR

DATA FROM R/T

DUAL PORT RAM

RAM

CPU

CONTROL CPU

GRAPHICS CONTROLLER

GRAPHICS CRT

TAPE CONTROLLER

TAPE UNIT

FPU
R/T DIGITAL SUBSYSTEM

- NAV PROC
- CTRL PROC

- INPUT BUFFER
- RANGE GATE
- FREQ/POL (RAIN TABLE)
- OUTPUT DATA SOURCE (R/T OR ROM)
- RF XMIT/REC TIMING AND ALIGNMENT

- OUTPUT BUFFER

STATUS AND INTERRUPT TO INFLIGHT PROC.

TO TAPE BUFFER
- Commercial 32-bit microprocessor based technology
- Real time processing approach
- Quick look processing
- Data base processing
- Inflight development system
- Processor commonalty
- Compact system
GROUND BASED ANALYSIS SYSTEM

INPUT BUFFER AND HI-D TAPE CONTROLLER
XTRA RAM
FPU (SKY)
AP (SKY)
CPU
DISK CONTROLLER
9 TRACK CONTROLLER
GRAPHICS CONTROLLER
SERIAL I/O

SMD DISK DRIVE
9 TRACK TAPE(S)
MEDIUM RESOLUTION COLOR DISPLAY
PRIMER/PLOTTER RS232
6 USER CRT'S
ANTENNA SQUINT ANGLE, A/C X-RANGE POSITION

MOCOMP DATA

RECORDER

RANGE COMPRESSOR 32:1

MOCOMP PHASE COR
REGIST.
INTERP.

WEIGHTING

DIRECT TRAJECTORY LAT., LONG
ALT

SLIDING AZIMUTH WINDOW BUFFER

RANGE REG. INTERP
QUADRATIC PHASE COR
WEIGHTING

PRE-AZIMUTH COMP. BUFFER

STORAGE OF HIGH RES.
COMPLEX POLARIMETRIC MAPS

AZIMUTH COMP.
GROUND BASED PROCESSING SUMMARY

- QUICK LOOK CALIBRATION VERIFICATION

- QUICK LOOK BITE ANALYSIS
  - GIMBAL POINTING
  - R/T TEST TARGET
  - R/T PERFORMANCE ANALYSIS

- QUICK LOOK SCENES
  11 MIN - SAR
  24 MIN - SPOTLIGHT

- CALIBRATED DATA BASE
SYSTEM CALIBRATION

AMPLITUDE

- Pre and Post Flight Calibrations (Ground)
- In Flight Calibration
- Calibration Assessment (Quick Look)

RESOLUTION

- In Flight Calibration
- Calibration Assessment
AMPLITUDE PRE AND POST FLIGHT CALIBRATION

- **Signal Injection (Receiver Transfer Curve)**
  + Inject transmitted signal into receiver at all frequencies
  + Vary power level from receiver saturation to noise

- **Calibrated Target Stare (Absolute Calibration)**
  + Stare at one or more odd bounce targets and one or more even bounce targets
  + Place targets at proper height to eliminate multipath
- **Fly Over Calibrated Target Array**
  - Even and Odd Bounce Targets
  - Varying Distances Between Targets
  - Optical Markers for TV Viewing
CALIBRATION ASSESSMENT

- Compare Injected Signal Transfer Curve to Absolute Ground Calibration Using Radar Equation

- Compare In Flight Array Calibration to Ground Calibration

- Two Independent Calibration Checks
INFLIGHT CALIBRATION

- Fly over radar reflector array with varying distance between reflectors

RESOLUTION ASSESSMENT

- Display calibration data on XY display
- Determine the resolvable reflector distance
0 System Check Out

0 Ground Calibration
  + Signal Generator
  + Absolute Stare

0 Flight Calibration (Fly Over Reflector Array)

0 Begin Flight Tests
  View Medium Resolution Display to Assess Data Quality Between Runs

0 Post Flight Ground Calibration
CLOSE SIGNAL GENERATOR AND ABSOLUTE GROUND CALIBRATIONS - COMPARE PRE- AND POST-FLIGHT CALIBRATIONS

PROCESS SELECTED DATA SCENES INCLUDING THE AIRBORNE CALIBRATION ARRAY

CHECK CALIBRATION ARRAY FOR CALIBRATION CLOSE WITH GROUND CALIBRATION AND FOR RESOLUTION

ENTER ASSESSMENT OF DATA QUALITY OF SAMPLED RUNS INTO DATA BASE

PRODUCE 35 MM IMAGES OF SCENES
DAILY PRODUCTION PROCEDURES

0  Determine Scenes to be Processed from Priority List
0  Load Calibration File for a Set of Runs
0  Process Scenes
0  Dump Processed Scenes to CCT
0  Evaluate Scenes
0  Compute Statistics/Register with Ground Truth
0  Enter Summaries into Data Base
0  Transcribe to Archival Storage Medium
0  Produce 35 mm Images of Scenes
With the proposed system a 1024 x 1024 scene can be processed in approximately eleven minutes to achieve a calibrated, complex, high resolution data set.

The time to process one 1024 x 1024 scene is thus

\[ 11 \text{ minutes/scene} \times 4 \text{ polarizations} = 44 \text{ minutes}. \]

Thus, the maximum number of 1024 x 1024 scenes that can be processed in an 8 hour day is

\[ 480 \text{ minutes/day} / 44 \text{ minutes per scene} = 11 \text{ scenes/day} \]

Thus the number of scenes that can be processed in the two year test period is

\[ 104 \text{ weeks} \times 5 \text{ days/week} \times 11 \text{ scenes/day} = 5720 = 24.0 \text{ Giga Pixals} \]

In practice it would be impossible to do more than glance at such a large number of scenes. Thus, a color display will be used as a basic analysis tool to assess the scene integrity. In this manner the scenes can be processed and viewed quickly and only useful scenes selected for permanent storage and logging in the data base. Thus, virtually all of the data could be looked at and a subset selected for additional analysis. As an option, an extra array processor could double the scenes that could be processed.
<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing Span</td>
<td>106 ft.</td>
</tr>
<tr>
<td>Length</td>
<td>79 ft.</td>
</tr>
<tr>
<td>Height</td>
<td>28 ft.</td>
</tr>
<tr>
<td>Empty Weight</td>
<td>32,000 lbs.</td>
</tr>
<tr>
<td>Gross Weight</td>
<td>53,200 lbs.</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>295 knots</td>
</tr>
<tr>
<td>Cruising Speed</td>
<td>220 knots</td>
</tr>
<tr>
<td>Initial Climb</td>
<td>1,230 ft./min.</td>
</tr>
<tr>
<td>Approximate Maximum Test Altitude</td>
<td>20,000 ft. msl.</td>
</tr>
<tr>
<td>Range</td>
<td>1,300 nmi</td>
</tr>
<tr>
<td>Radome Position</td>
<td>Must be able to elevate antenna 2° with unobstructed view on the ground</td>
</tr>
<tr>
<td>ITEM</td>
<td>SALARY COSTS</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>MANAGEMENT</td>
<td>451,371</td>
</tr>
<tr>
<td>SYSTEM ENGINEERING</td>
<td>350,366</td>
</tr>
<tr>
<td>SYSTEM INTEGRATION</td>
<td>365,636</td>
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<tr>
<td>GYMBAL</td>
<td>244,467</td>
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<tr>
<td>RADOME</td>
<td>61,395</td>
</tr>
<tr>
<td>TRANSMITTER</td>
<td>100,915</td>
</tr>
<tr>
<td>RF, IF, VIDEO, DATA ACQUISITION,</td>
<td>766,686</td>
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<tr>
<td>RADAR TIMING AND CONTROL</td>
<td></td>
</tr>
<tr>
<td>PEDESTAL</td>
<td>200,544</td>
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<tr>
<td>DATA ACQUISITION - NAV SYSTEM</td>
<td>116,511</td>
</tr>
<tr>
<td>DATA ACQUISITION - R/T DIGITAL</td>
<td>174,720</td>
</tr>
<tr>
<td>DATA ACQUISITION - INFIGHT PROCESSOR</td>
<td>117,190</td>
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<tr>
<td>DATA ACQUISITION - INTERCONNECT</td>
<td>76,520</td>
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<tr>
<td>DATA ACQUISITION - SYSTEM DESIGN</td>
<td>129,417</td>
</tr>
<tr>
<td>DATA ACQUISITION - DATA ANALYSIS VAN</td>
<td>300,991</td>
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**Total Preparation Cost** 4,790,238
<table>
<thead>
<tr>
<th>Item</th>
<th>Salary Costs</th>
<th>Materials</th>
<th>Travel</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Test Support</td>
<td>642,867</td>
<td>100,000</td>
<td>120,000</td>
<td>862,867</td>
</tr>
<tr>
<td>Quick Look Analysis</td>
<td>287,553</td>
<td>50,000</td>
<td>80,000</td>
<td>417,553</td>
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<tr>
<td>Production Image Processing</td>
<td>350,000</td>
<td>160,000</td>
<td>10,000</td>
<td>520,000</td>
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</table>

Total Test/Analysis Cost (2 years) 1,800,420
Cost Per Scene (10,000 scenes) 180
Total Cost 6,590,658

**OTHER ITEMS (ASSUMED GFE)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane</td>
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<tr>
<td>Installation</td>
<td>558,427</td>
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<tr>
<td>Test Support</td>
<td>2,164,520</td>
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<tr>
<td>INS &amp; Beacon</td>
<td>200,000</td>
</tr>
<tr>
<td>High Density Tape Recorder</td>
<td>200,000</td>
</tr>
<tr>
<td>Doppler Navigation System</td>
<td>75,000</td>
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Total GEF Items 3,197,947
<table>
<thead>
<tr>
<th>SPONSOR</th>
<th>DESCRIPTION</th>
<th>START DATE</th>
<th>DURATION</th>
<th>ACTUAL AMOUNT</th>
<th>% OF ESTIMATE OVERUN/UNDERRUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERADCOM</td>
<td>95 GHz Modulator</td>
<td>6/81</td>
<td>7 mos.</td>
<td>$99,000</td>
<td>0%</td>
</tr>
<tr>
<td>Gulf Interstate</td>
<td>Low Frequency Ground Penetration Radar</td>
<td>9/81</td>
<td>21 mos.</td>
<td>$500,000</td>
<td>0%</td>
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<tr>
<td>Corporation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teledyne Brown Corp.</td>
<td>Coherent Repeater</td>
<td>10/81</td>
<td>9 mos.</td>
<td>$290,000</td>
<td>0%</td>
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<tr>
<td>Westinghouse</td>
<td>Hi Res 35 GHz Radar Measurements</td>
<td>3/82</td>
<td>5 mos.</td>
<td>$410,000</td>
<td>0%</td>
</tr>
<tr>
<td>Corporation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MICOM</td>
<td>Snowman MMW Measurements</td>
<td>7/83</td>
<td>14 mos.</td>
<td>$2,400,000</td>
<td>0%</td>
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<tr>
<td>WSMR</td>
<td>AN/MPS-36 Radar Modification</td>
<td>9/82</td>
<td>24 mos.</td>
<td>$1,123,000</td>
<td>5%</td>
</tr>
</tbody>
</table>
A. The processed signal-to-noise ratio shall be 60 dB at 1.5 km for a 10 dBsm target. The signal-to-clutter ratio will be 33 dB for -13 dB $\sigma^0$.

B. The specified range and cross-range resolution shall be obtained in both the strip map and spotlight SAR modes.

C. All radar and navigation signals will be recorded in raw form to support SAR post-processing.

D. The absolute settling time of the synthesizer proposed is 1 $\mu$s which for the PRF rate of 32 kHz yields a maximum range of 4.5 km.

E. Polarization isolation shall be 25 dB over the main beam given the combined effects of antenna and radome.
F. The stabilities required for the desired sidelobe performance over the 0.25 second integration period are satisfied.

G. The cross-range swath shall be 150 m in the spotlight mode and up to 1500 m in the strip mode.

The range swath coverage shall be 100 m at 50° and 150 m at 10° depression angle.

H. The target location error shall not exceed 10 ft. range and cross range.