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KIRTLAND FEDERAL CREDIT UNION
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See our Ad - Inside Front Cover
SANDIA AREA FEDERAL CREDIT UNION
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WAGNER, DRS. MAX, REX & MICKEY/SCHUMAN, DR. WALLACE
201 Wyoming NE ALBUQUERQUE 266-5881
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2201 San Pedro NE ALBUQUERQUE 888-7944
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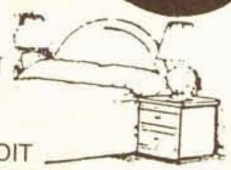
• Show Dog Handling • Hand Stripping
MON. - SAT. **299-1713** (Located in the Juan Tabo Villa Ctr.) 1720 JUAN TABO NE

CHOICE FURNITURE

CHOICE



• ALL THE FURNITURE YOU NEED FOR YOUR HOME AT THE BEST PRICE IN TOWN!

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WE ARE LOWER THEN LOWEST

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- **Albuquerque's only 30,000 cu. ft. showroom full of warehouse savings!**
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3900 Menaul NE,
two blocks east
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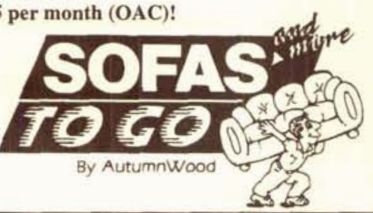

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Priced From The $190s.
823-9674

At Barstow And Signal, Just North Of Paseo del Norte.

Ridgefield

Priced From The $160s.
828-1112

At Ventura And Palomas, Just South Of Paseo del Norte.

Las Maravillas

Priced From The $80s.
865-HOME

Take I-25S To Broadway Exit, Then NM 47 South, And Follow The Signs.

THE VILLAGES OF
Park West

Priced From The $90s.
831-4000

Take I-40W, Exit Unser Boulevard North, And Follow The Signs.

RICHLAND HILLS

Priced From The $150s.
898-4000

Take Paseo del Norte, Across Coors NW, And Continue West A Short Mile.

SIVAGE THOMAS HOMES
NEW MEXICO'S BUILDER OF CHOICE.

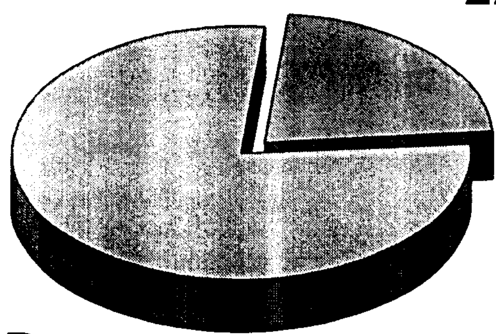
KIRTLAND REALIGNMENT
CONCEPT OF OPERATIONS
SUPPORT

Overview

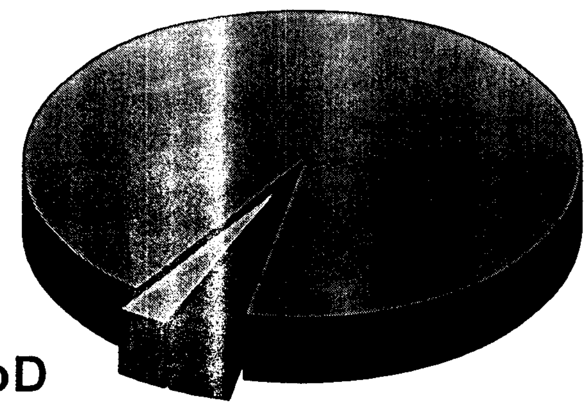
- Scope of Kirtland Realignment
- Support Concept / Impacts
- Transfer of Responsibility

SCOPE OF KIRTLAND REALIGNMENT
Acreage Control

Current Situation



Post Realignment



BOS GROUND RULES

- PL/TE/NMANG/RESERVE/KUMSC Remain in Cantonment
- "Back Forty" Under DoE Control
- NMANG or AIA Assumes Airfield Mgt. Responsibilities
- NMANG Provide Fuels Support
- KUMSC Emergency Services AF Provided
- Other DOD Remaining Agencies Receive DOE Support (FCDNA, DESA, NWI, ...)
- Co-Located Support Functions Where Appropriate (PL, TE, 898 MUNS)

CANTONMENT PROJECTS

PHILLIPS LABORATORY

Fac Maint Operations
Install Electric Meters
Isolate/Meter Sewer Sys
Perimeter Security
Reloc Adv Weapons Lab
Reloc H Pwr M-wave Lab
Alter Utilities

Reno Veh Maint Fac
Install Gas Meters
Facility Heating
Consolidated Spt Fac
Reloc Space Pwr Lab
Alter Secure Facility

CANTONMENT PROJECTS

KIRTLAND UNDERGROUND MUNITIONS STORAGE COMPLEX (KUMSC)

ADAL Perimeter Security

Add to Security Operations

Armory/Remote Arming Fac

Reserve Fire Team Facility

ADAL KUMSC-Code Defic.

CANTONMENT PROJECTS

AIR NATIONAL GUARD

Jet Fuel Storage

Civil Eng Maint Storage Fac

Isolate/Meter Utility Systems

Consolidated Support Facility

Perimeter Security

Dining Hall/Res Train Fac

CANTONMENT PROJECTS

BASE WIDE REQUIREMENTS

Facility Closure/Preservation/Security

SUPPORT CONCEPT/IMPACT
Current Support Structure

377 Service	PL/TE/KUMSC	NMANG	DoE/SNL
ADMIN	N	N	-
COMMUNICATIONS	N	R	-
SECURITY	N	N	N
FIRE PROTECTION	N	N	R
MEDICAL	N	N	R
PMEL	N	N	R
LOGISTICS	N	N	R
ENVIRONMENTAL	N	R	R
PERSONNEL	N	-	-
SAFETY	N	-	-
FAC MX & INFRA	N	R	R

N = Non Reimbursable
R = Reimbursable

Post Realignment Support

377 Service	PL/TE/KUMSC	NMANG	DoE/SNL
ADMIN			
COMMUNICATIONS			
SECURITY			
FIRE PROTECTION			
MEDICAL			
PMEL			
LOGISITICS			
ENVIRONMENTAL			
PERSONNEL			
SAFETY			
FAC MX & INFRA			
POSITIONS: 2669	709	82	288

1079

KIRTLAND REALIGNMENT CANTONMENT SUPPORT CONCEPT

AIR FORCE MATERIEL COMMAND

SUMMARY

- PL & TE CANTONMENT
  - BEEN THERE, DONE THAT
- KUMSC OSHA REQUIREMENTS
  - NOT COMPLETELY DEFINED
- DOE TRANSFER EAST SIDE
  - OWNERSHIP RESPONSIBILITY REMAINS WITH DOD
  - DOE OPERATING EXPENSE

Impacts to DOE from the Proposed KAFB Realignment

by

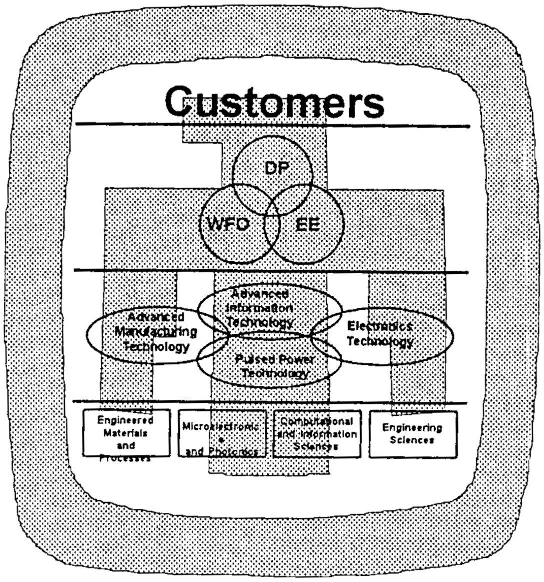
U.S. Department of Energy *and*
Sandia National Laboratories *for the*

Base Realignment and Closure Commission Site Visit

April 18, 1995

Agenda

- DOE Vision — **Victor Reis**, Assistant Secretary for Defense Programs
- Site Impacts and Program Considerations — **Al Narath, President**, Sandia National Laboratories; **Jeff Everett, Manager**, Site Planning
- Impacts to DOE — **Bruce Twining, Manager**, Albuquerque Operations Office



Sandia National Laboratories

Exceptional service in the national interest

Encroachment Concerns

- Continuing Mission Requirements
- Commingled Land Use and Infrastructure
- Public Expectations Regarding Land Use
- Potential SNL Liabilities

Realignment Cost Impacts

DOE / SNL

sandia.ppt/4/14/95

Global Assumptions

1. Realignment occurs, requires 3-5 years to accomplish

2. DOE/SNL becomes landlord for their cantonment(s) only

3. DOE/SNL will minimize land and facilities holdings and the size of their cantonment(s) to the extent practicable, consistent with missions and populations

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Cost Planning Scenario

- Cost estimates reflect cantonment boundaries that provide safety and security buffers for DOE/SNL operations
- Cost estimates assume existing USAF building within DOE/SNL cantonment are left in a mothballed ("pickled") state
- DOE/SNL will assess cost benefit of reactivating individual mothballed buildings over the next two years

Activity Areas Considered

- Public Safety
  - Security
  - Fire
  - Emergency Operations
- Physical Plant
  - Roads and Bridges
  - Traffic Lights and Controls
  - Gates, Intersections, Fencing, and Associated Demolition
  - Grounds Maintenance
- Utilities
  - Electrical Systems
  - Water Systems
  - Sanitary Sewer and Storm Drainage
  - Gas Lines
  - Steam System
  - Communications
- Other DOE Operations
  - Energy Technical Training Complex
  - Ross Aviation
  - AlliedSignal Kirtland Operations

Resource Impacts

Dollars in Millions

	Conversion	Operating	FTE's
Public Safety	15.1	14.9	202
Physical Plant	18.4	3.8	40
Utilities	28.6	10.1	40
DOE	2.0	0.4	6
Equipment O&M and Replacement		1.4	
Incremental Costs	$64.1M	$30.6M	288

Other DOE Issues

- Loss of Nuclear Operations Synergy
- Kirtland Underground Munitions Storage Complex

Conclusions

- Proposed Realignment Significantly Impacts Current DOE/SNL Operations
- Significant One Time and Recurring Costs
- DOD/DOE Infrastructures Closely Tied
- Costs to Other Tenants?

HQ AFOTEC BRIEFING

TO

BRAC COMMISSIONERS

18 APR 95

OVERVIEW

- MISSION
- RELOCATION GOALS
- CURRENT PLANNING STATUS
- CONCLUSION

PURPOSE OF OT&E

- TEST AND EVALUATE SYSTEMS UNDER REALISTIC OPERATIONAL CONDITIONS TO DETERMINE
  - OPERATIONAL EFFECTIVENESS
  - OPERATIONAL SUITABILITY
  - OVERALL DEGREE OF MISSION ACCOMPLISHMENT

EFFECTIVENESS

- PERFORMANCE
- SURVIVABILITY
- ORGANIZATION
- DOCTRINE
- TACTICS
- THREAT

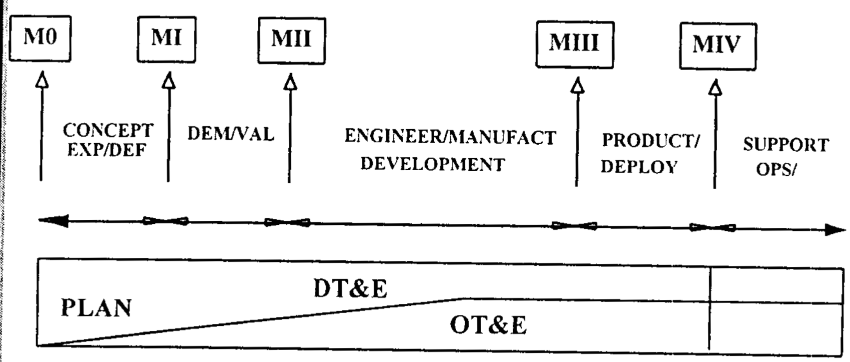
SUITABILITY

- RELIABILITY
- AVAILABILITY
- MAINTAINABILITY
- SUPPORTABILITY
- ENVIRONMENTAL

HQ AFOTEC MISSION

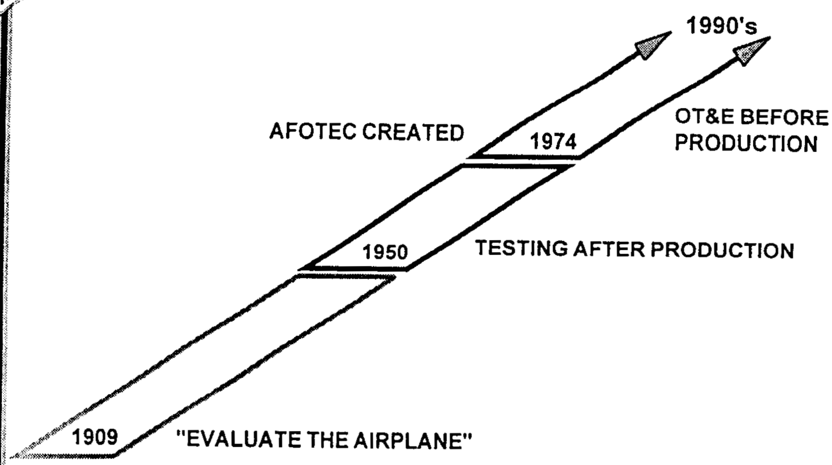
- MANAGE ALL USAF OT&E
- CONDUCT OBJECTIVE, IMPARTIAL OT&E
- TEST IN A REALISTIC OPERATIONAL ENVIRONMENT
- SUPPORT ACQUISITION DECISION-MAKING PROCESS

THE ACQUISITION CYCLE AND OT&E PHASES



OT&E INTEGRATED WITH ACQUISITION PROCESS

EVOLUTION OF OT&E

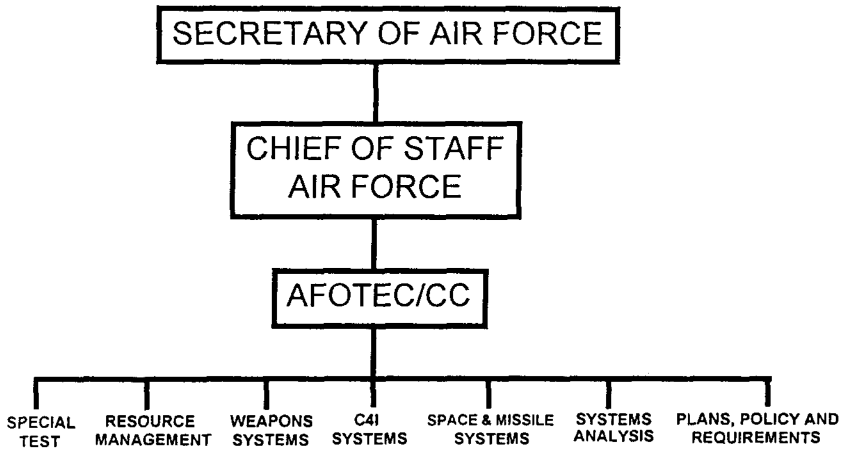


DIRECTION FOR OT&E

- **PERTINENT SOURCES**
  - U.S. CODE TITLE 10
  - DODI 5000.2
  - AFI 99-102, 99-103

- **FUNDAMENTAL GUIDANCE**
  - INDEPENDENT
  - IMPARTIAL
  - REALISTIC OPERATIONAL ENVIRONMENT
  - DIRECT REPORTING TO CSAF

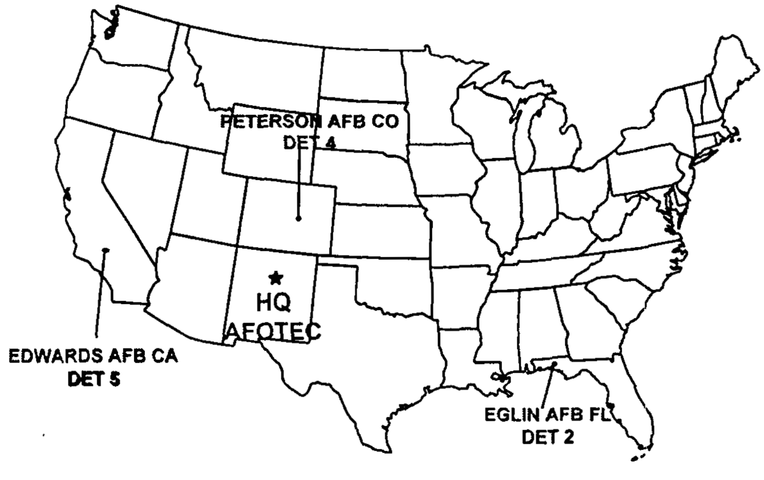
OT&E CHAIN OF COMMAND



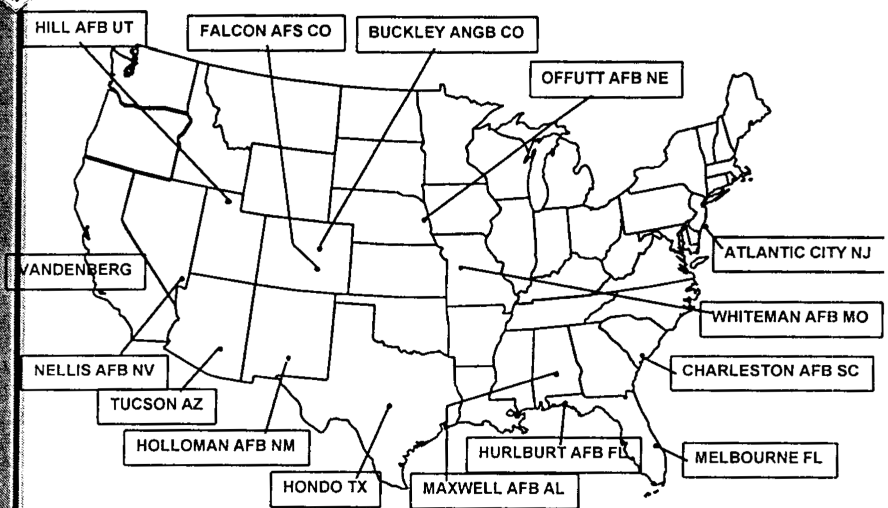
AFOTEC FUNCTIONAL SKILLS

- OT&E REQUIRES OPERATIONAL AND DIVERSE TECHNICAL SKILLS
- MULTI-FUNCTIONAL ACTIVITIES
  - HQ ADMINISTRATION
  - TEST PLANNING, EXECUTION, AND REPORTING
  - CUTTING EDGE OF TECHNICAL AND SCIENTIFIC METHODS
    - STATISTICAL METHODOLOGIES
    - WEAPON SYSTEM SOFTWARE EVALUATION
- EXTENSIVE COMPUTER OPERATIONS AND SUPPORT
  - TEST AND RESOURCE MANAGEMENT
  - DATA REDUCTION AND ANALYSIS
  - MODELING AND SIMULATION

DETACHMENTS



OPERATING LOCATIONS



RELOCATION GOALS

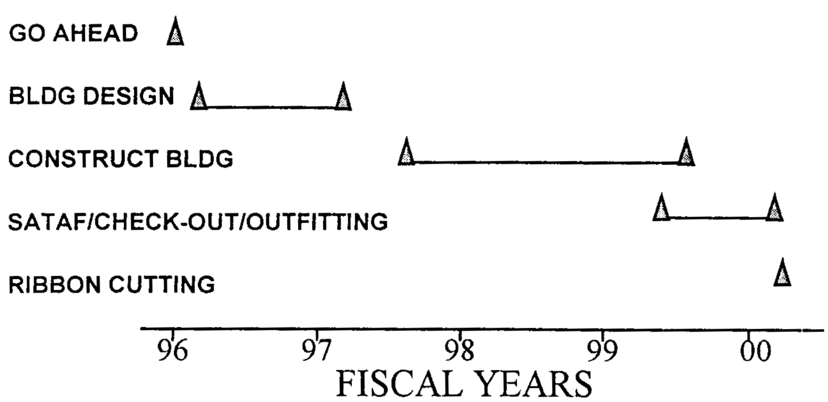
- CONTINUE MISSION WITH MINIMUM DISRUPTION
- ORDERLY TRANSITION TO EGLIN
  - NO INTERIM FACILITIES
  - SINGLE SITE
  - FUNCTIONAL LAYOUT
- ADEQUATE COMMERCIAL AIR TRANSPORTATION
- TAKE CARE OF OUR PEOPLE

CURRENT PLANNING STATUS

- FACILITY
  - 132,000 SF PROPOSED BUILDING AT EGLIN AFB
    - 648 PEOPLE
    - SPECIAL SPACE REQUIREMENTS INCLUDED
- OTHER AREAS BEING ESTIMATED
  - CIVILIAN PERSONNEL
  - TRANSPORTATION OF THINGS
  - COMMUNICATIONS - COMPUTERS
  - ENVIRONMENTAL

AFOTEC RELOCATION TO EGLIN

NOTIONAL TIMELINE



CONCLUSIONS

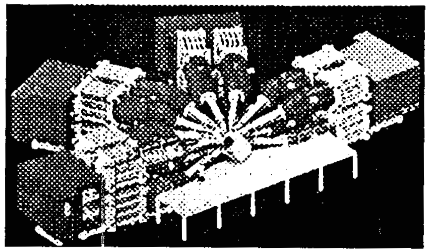
- AFOTEC MUST MAINTAIN INDEPENDENCE
- PROVIDED REALISTIC REQUIREMENTS
- ONGOING REFINEMENT OF ESTIMATES

FIELD COMMAND
DEFENSE NUCLEAR AGENCY

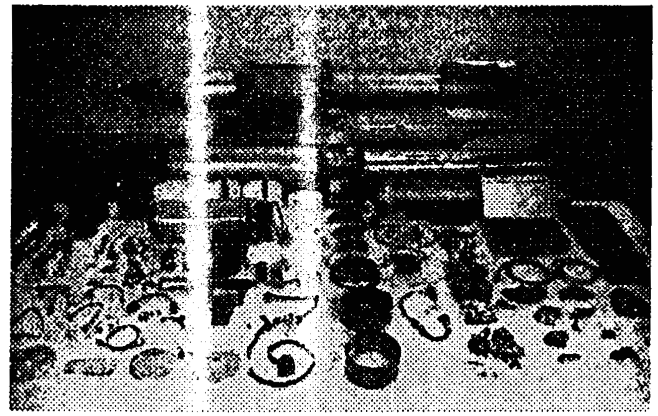
BRAC COMMISSION BRIEFING

DNA Missions Today

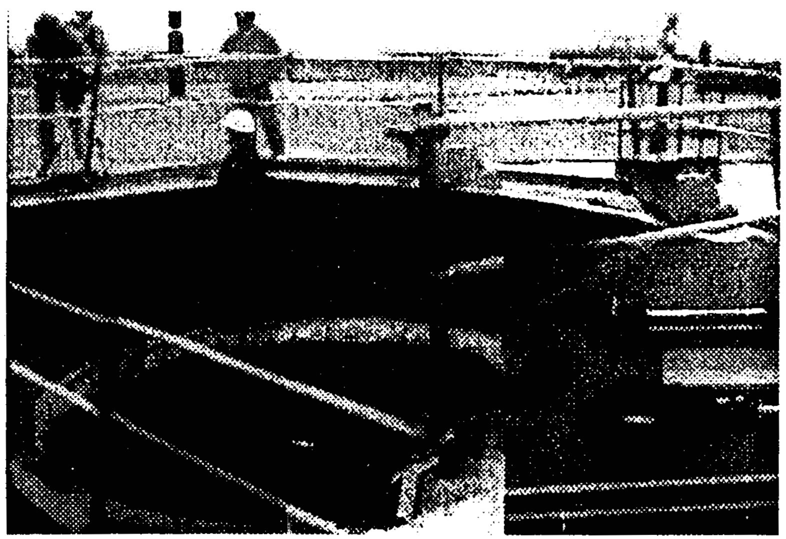
Weapon System Operability



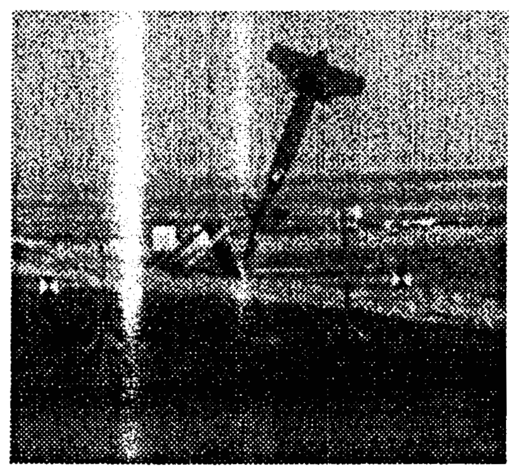
Nuclear Operations & Stockpile Support



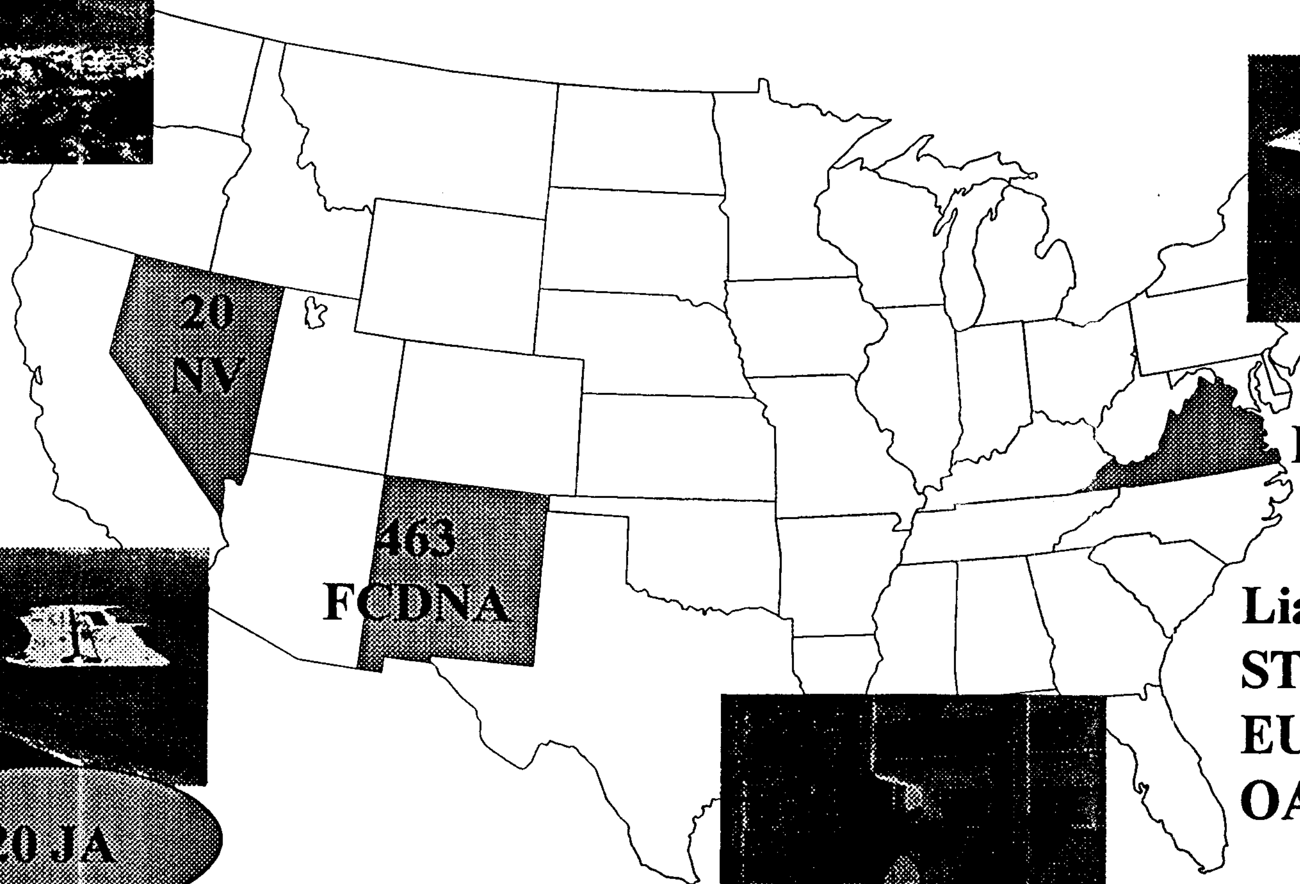
Arms Control/Cooperative Threat Reduction

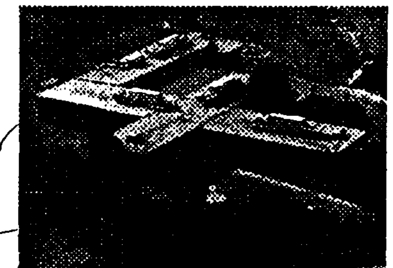


Weapon System Lethality



DNA Personnel Authorizations





20 JA

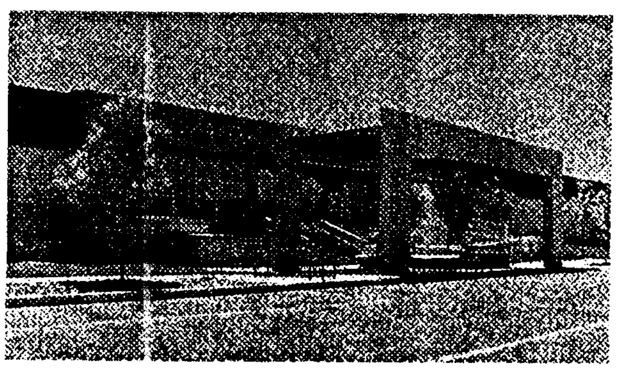
Liaison Offices
STRATCOM
EUCOM
OATSD(AE)

FCDNA MISSIONS

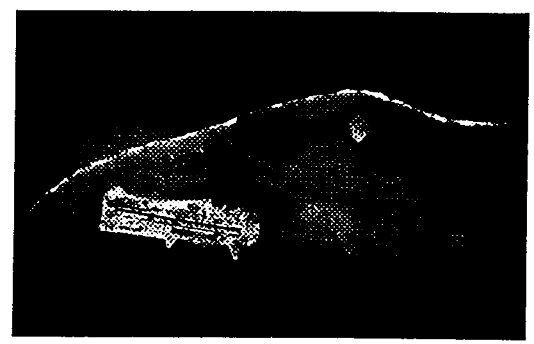
Nuclear Weapons Support

Special Weapon's Effects

Assessments and Training



Related National Security Programs



DNA PRIORITIES

- Retain Mission Capability
- No Additional Fiscal Impact on DNA
- Centralization of FCDNA to the Fullest Extent Possible

DoD PROPOSAL

- **Realign Kirtland Air Force Base**
  - Goal: Minimize Military Presence
- **Relocate Majority of Activities and Personnel**
  - Stockpile Operations and Assessments & Training to Kelly AFB (331 Personnel)
  - Test Activities to Nellis AFB (101 Personnel)
- **Retain LBTS, ARES and Ionization Testing at Kirtland AFB (25 Personnel)**

BASIS FOR DoD PROPOSAL

- **No Significant Military Presence Remains**
- **Military Expertise and Operational Perspective essential to FCDNA Mission**
  - Some Military to Civilian Conversion Possible
  - Minimum FCDNA Military Requirement (123) Exceeds Air Force Ceiling
- **Only Responsible Alternative: Relocate FCDNA**

RELOCATION ALTERNATIVES

- **Initial Time-Constricted Focus: Relocate FCDNA to a Single Site**
  - Adequate Space and Support
  - Close to Testing Areas
  - Supporting Military Infrastructure
  - Ideally, Tenants With Related Mission

(Continued)

RELOCATION ALTERNATIVES

- **Nellis/Holloman AFB Couldn't Accommodate**
- **Existing New Mexico Simulators (ARES/LBTS) not Relocatable**
- **<u>CONCLUSION:</u>**
  - Division of FCDNA Unavoidable if Relocated
  - Divide Between Nellis, Kelly, and Kirtland AFBs

PROPOSAL IMPACT

- **Same Mission--Different Means**
  - FCDNA Not Indivisibly Tied to a Location
  - Co-location with DOE/SNL Efficient but not Essential
  - New Means of Communication
- **Fiscal Impact to DNA**
  - FCDNA Requirements Provided to Air Force
  - Cost Estimates Made by Air Force
  - Costs to be Borne by Air Force
  - TDY to Increase an Undetermined Amount

PROPOSAL IMPACT

- **Centralization to the Fullest Extent Possible**
  - No Single-site Relocation Possible
  - Relocation to Just Two Sites Not Possible

SUBSEQUENT CONSIDERATIONS

- **Remaining at Kirtland Could be Reconsidered**
  - Military Manpower Ceiling Under Revision
  - FCDNA Could Remain if Ceiling Raised to Include Minimum FCDNA Military Requirement (123)
- **Two-site Relocation Could be Reconsidered**
  - Nellis and/or Holloman AFB May Accommodate FCDNA (LBTS and ARES Cannot be Moved)
  - Potential Environmental Concerns

(Continued)

SUBSEQUENT CONSIDERATIONS

- **INWS Should Remain at Kirtland**
  - Highly Advantageous Synergism With DOE/SNL
  - Unique Thorium-hydroxide Seeded Training Sites

DNA PREFERENCES

- **Remain at Kirtland AFB Under Increased Military Manpower Ceiling**
- **Two-site Option: Kirtland/Nellis AFB or Kirtland/Holloman AFB**
  - Simulators and INWS Remain at Kirtland
- **Three-site Option: Kirtland/Nellis/Kelly AFB**

KUMSC AFTER BRAC

To

Commissioner Robles

and

Commissioner Montoya

Lt Col Tom Risenhoover
MUNS Commander

Lt Col Dennis Cavit
SPS Commander

OVERVIEW

- Nuclear Operational Approaches
- Civilianizing Security and Munitions
  - Facts & Assumptions
- Total Civilianization

NUCLEAR OPERATIONAL APPROACHES

- DOE
  - Security Is Federal Marshals
  - Maintenance Is Contracted
  - Support Is Federal Civilians/Contractor
- Navy
  - Security Is Military
  - Maintenance Is DOD Civilians/Contractors
  - Support Is Military

NUCLEAR OPERATIONAL APPROACHES (Cont)

- **Air Force (KUMSC Today)**

	Enlisted	Officer	Civilian
Security Is Military	167	8	5
Maintenance Is Military	118	4	10
Total (312)	285	12	15

Support Is Military 377 ABW

CIVILIANIZATION SECURITY & MUNITIONS

- **Facts**
  - It's Legal, Meets DOD Requirements
  - Workforce Size Increases
  - Operational Cost Increases
  - OSHA Facility Conversion
- **Assumptions**
  - Suitable Grade Structure
  - Personnel Reliability Program Oversight Met
  - AF Accepts Nuclear Maintenance Technician (2W2) Career Field Impact
  - Sufficient Support Billets Added and Staffed

TOTAL CIVILIANIZATION

- KUMSC
  - Maintenance--DOD Civilian or Contracted
  - Security--DOD Civilian (Cannot Be Contracted)
  - Support--DOD Civilian/Contractor Mix
- Pros
  - Lowest Number of Residual Military
- Cons
  - Perception AF "Walked Away"
  - Cost for Equivalent Capability

TOTAL CIVILIANIZATION

- Civilianization Totals

Munitions	140
Security	177
BOS Tail	39
Total	356

SUMMARY

- New Paradigm Required
- Numerous Issues Must Be Resolved
- Total Civilianization Recommended

PHILLIPS LABORATORY PRESENTATION TO

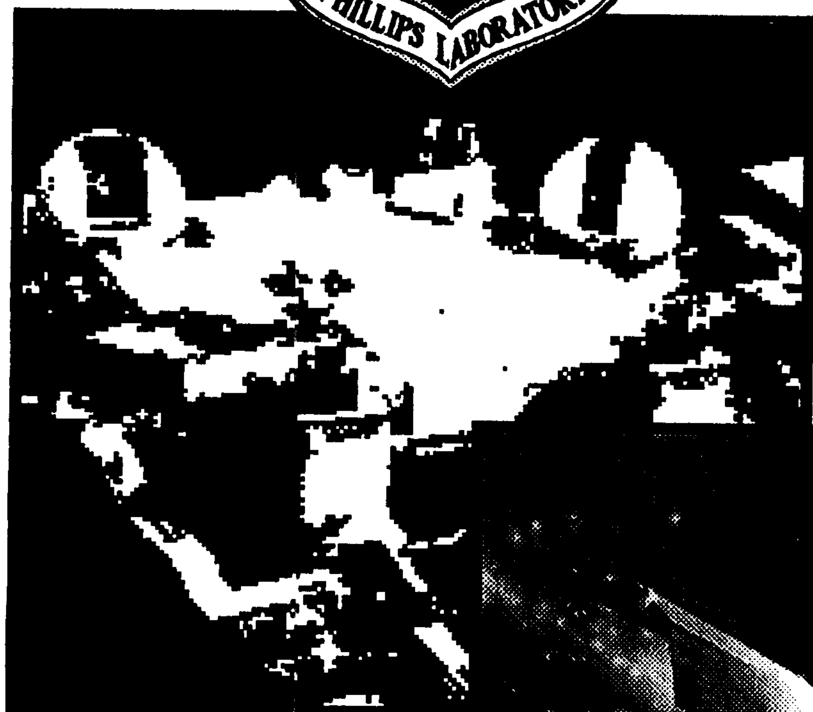
BRAC 1995 COMMISSION

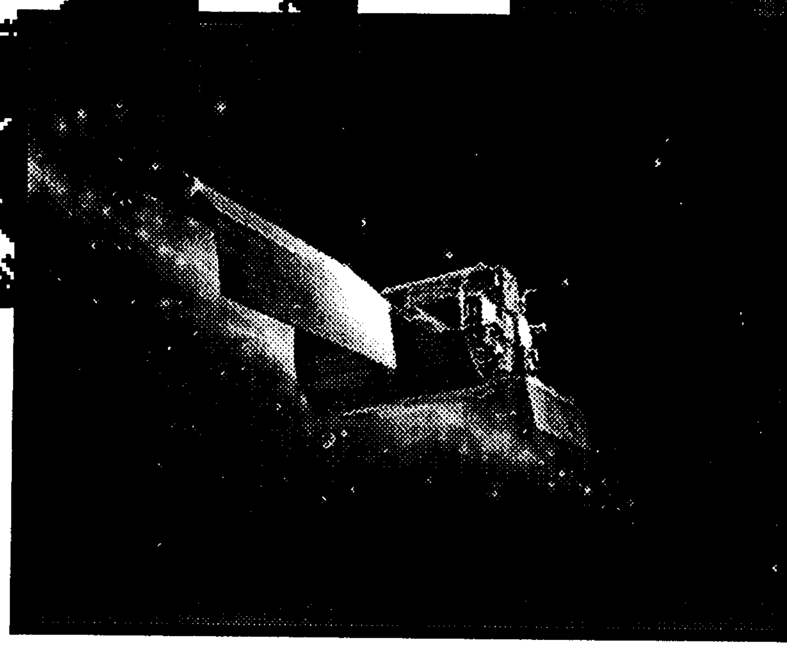
APRIL 18, 1995

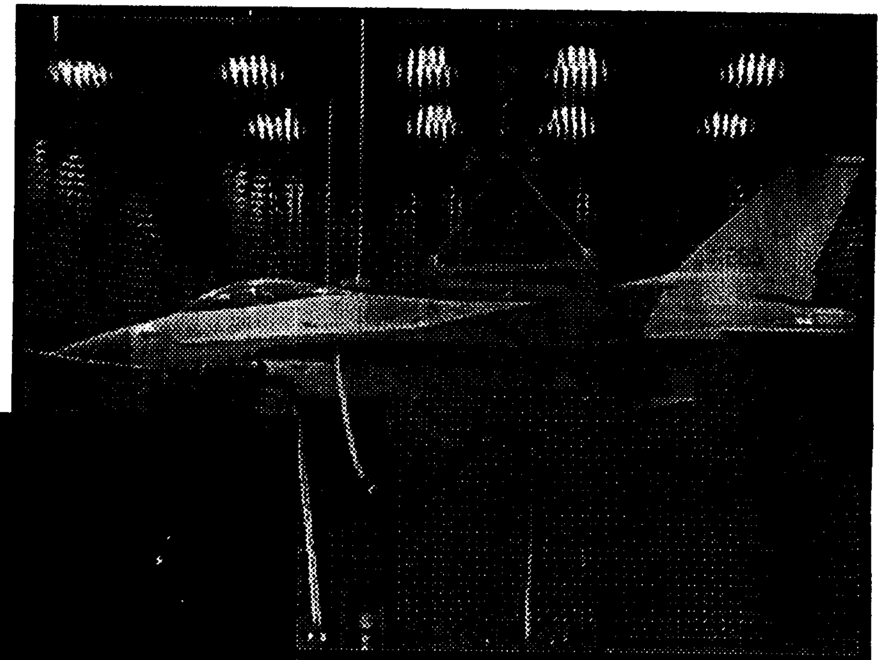
Dr R. Earl Good

Executive Director

Phillips Laboratory Overview



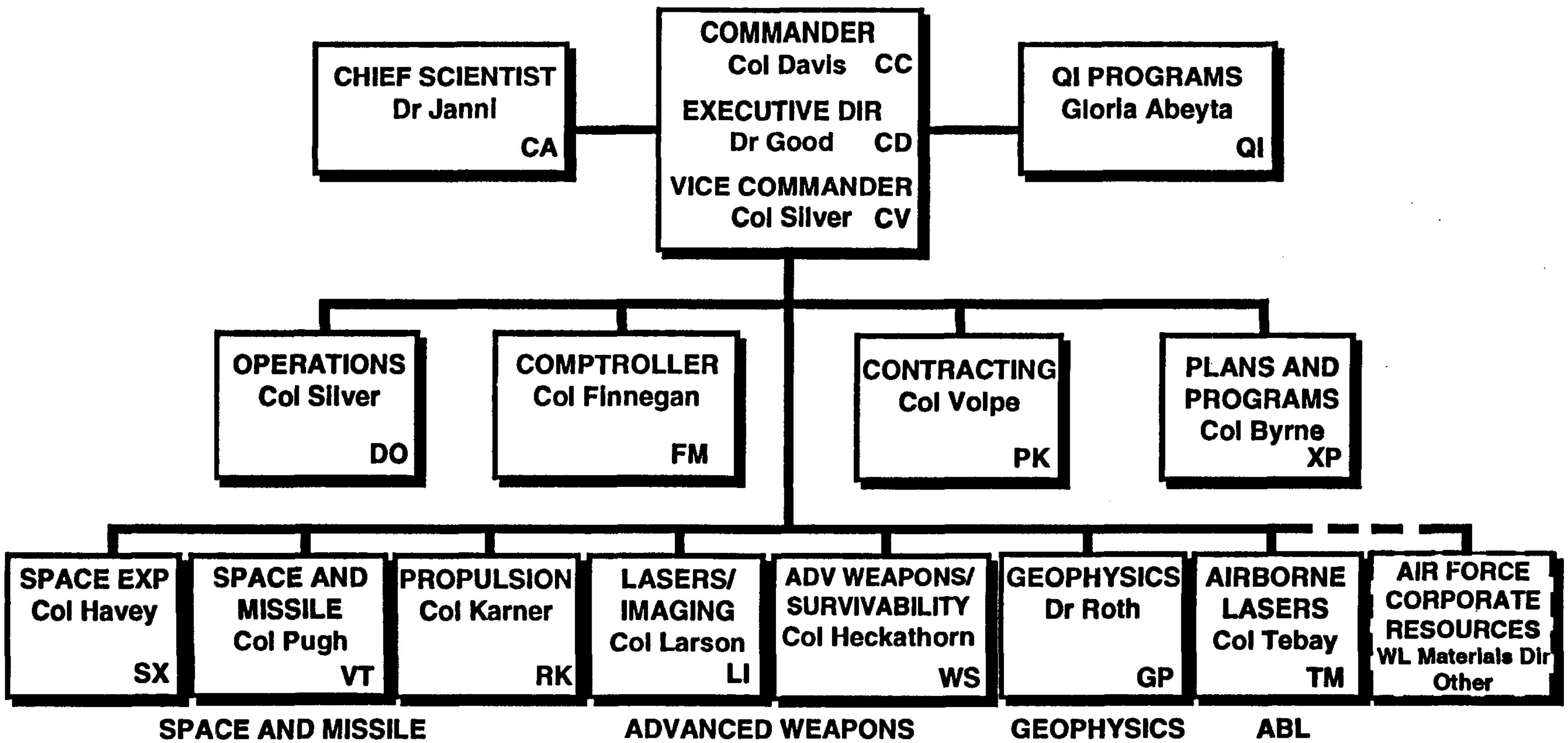




PHILLIPS LABORATORY MISSION

To Lead, Develop, Focus and Transition Military Space and Missile Technologies, including Directed Energy and Geophysics Extending Beyond their Space Applications

Phillips Laboratory
Organization



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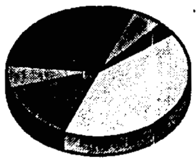
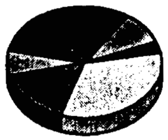
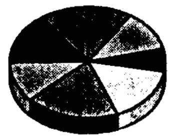
Plans and Programs Directorate



FY93
$785M



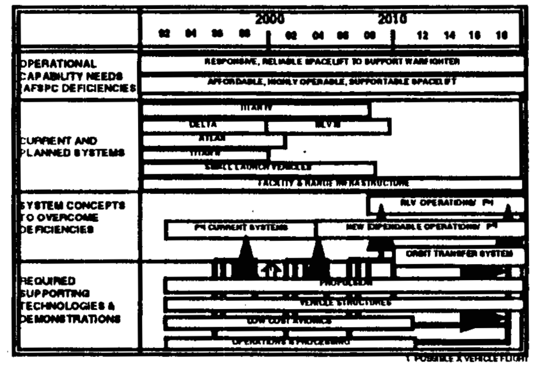
FY94
$586M



FY95
$556M

FUNDING BUDGETING AND ALLOCATION

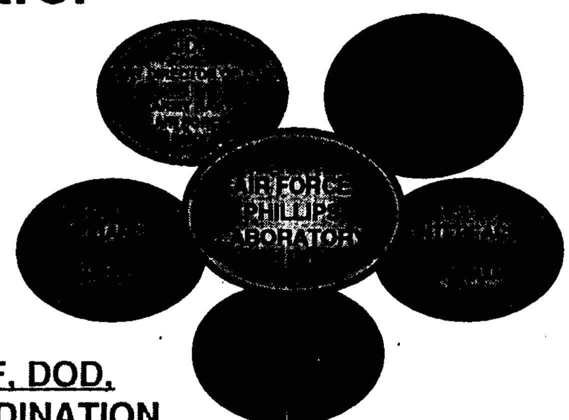
MAPs → TPIPTs → TAPs



Mission

Corporate Phillips technology planning, program coordination and funding control

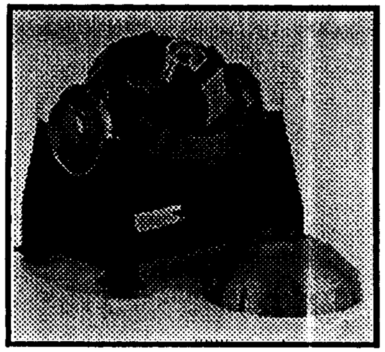
TECHNOLOGY TRANSFER



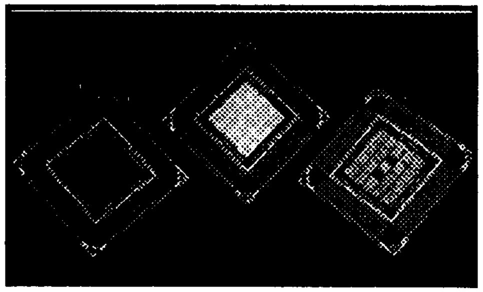
CORPORATE AF, DOD, NASA, ETC. COORDINATION

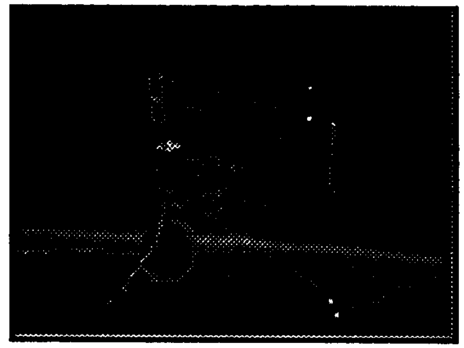
Space & Missiles Technology Directorate

SPACE & MISSILE DYNAMICS

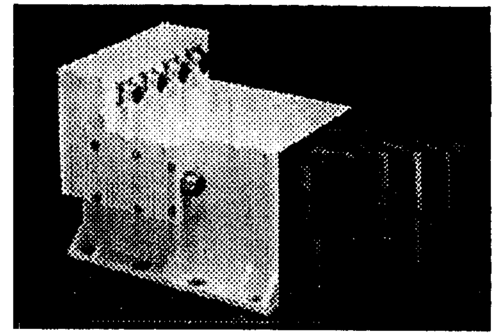


SPACE SENSORS & COMMUNICATION





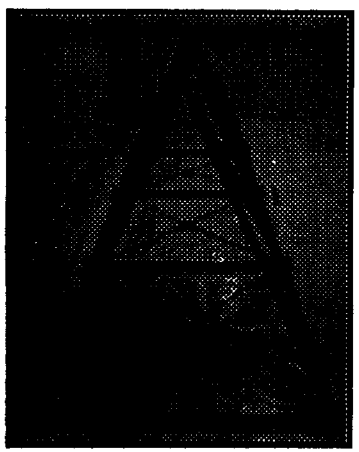
SPACE ELECTRONICS & SOFTWARE

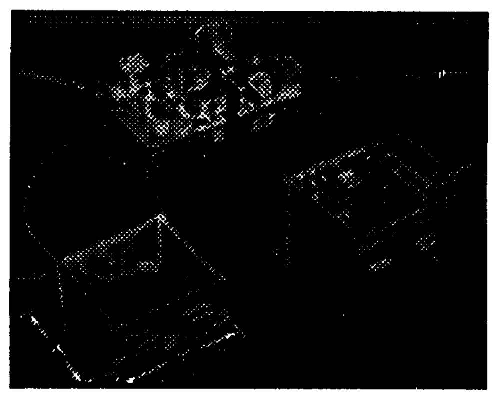


Mission

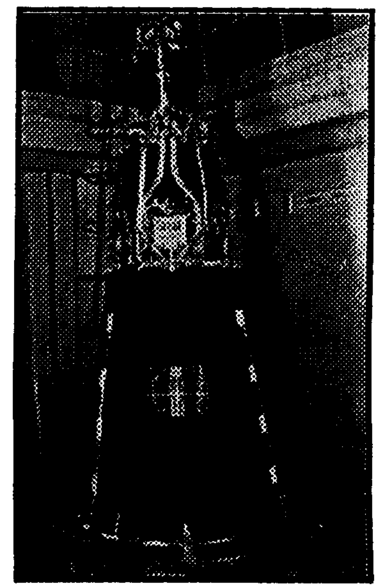
Explore, Develop, Integrate, Demonstrate, and Transition Space and Missile Technologies to Meet Our User's Needs

SPACE STRUCTURES & CONTROLS





POWER & THERMAL MANAGEMENT



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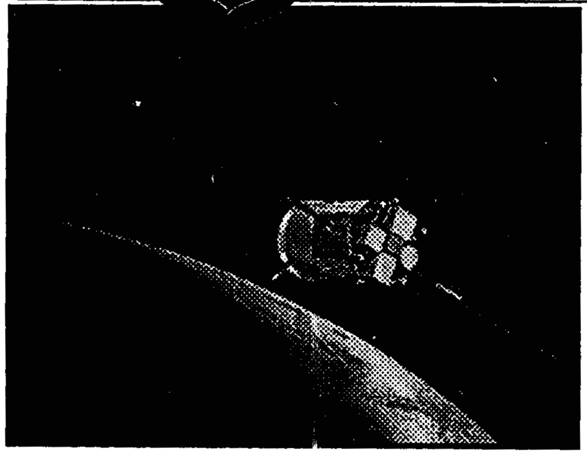
Space Experiments Directorate



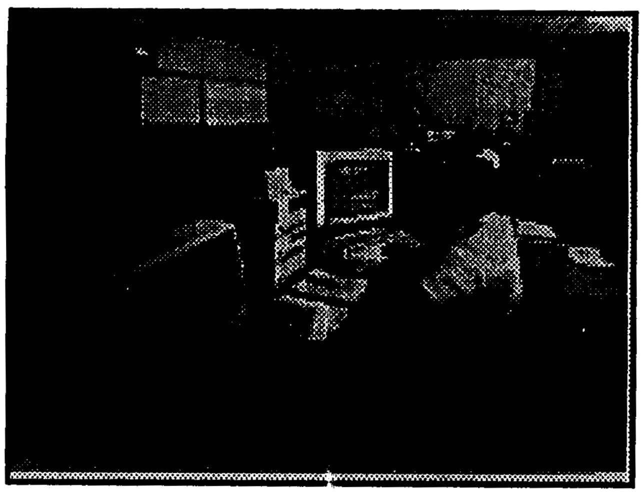
ADVANCED TECHNOLOGY INTEGRATION and DEMONSTRATION

BALLOON OPERATIONS

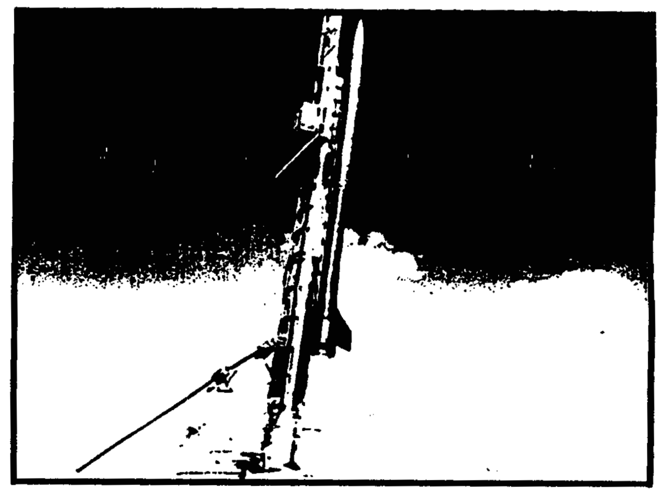
Mission

Performs Enabling Experiments and Integrated Demonstrations to Transition Advanced Space System Related Technologies to Our Users

PAYLOAD OPERATIONS



SPACE TEST ROCKET PROGRAM



TAOS

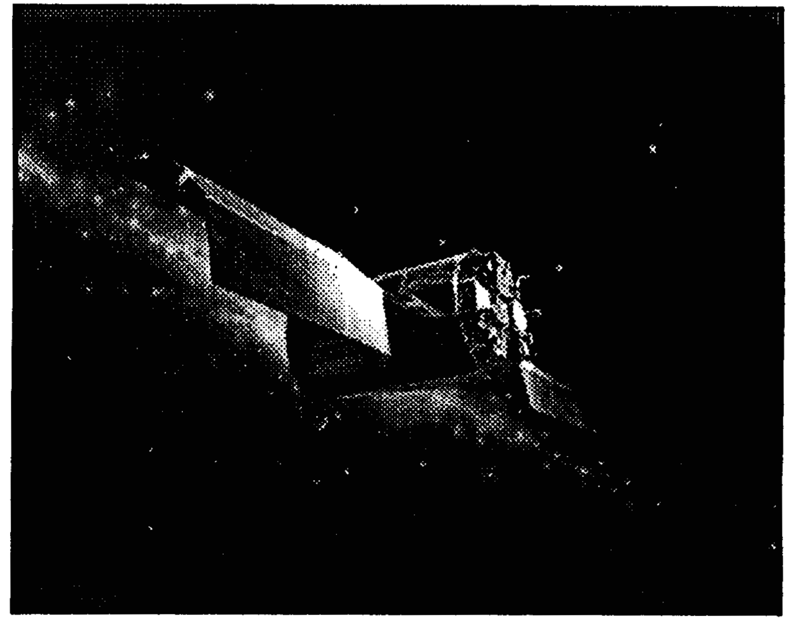
TECHNOLOGY FOR AUTONOMOUS OPERATIONAL SURVIVABILITY

OBJECTIVE

Develop & Demonstrate Satellite Autonomous Survivability Tech

GOALS

- Autonomous Space Navigation
- Standardized Space Bus
- Integrated Threat Warning Sensors



BENEFITS

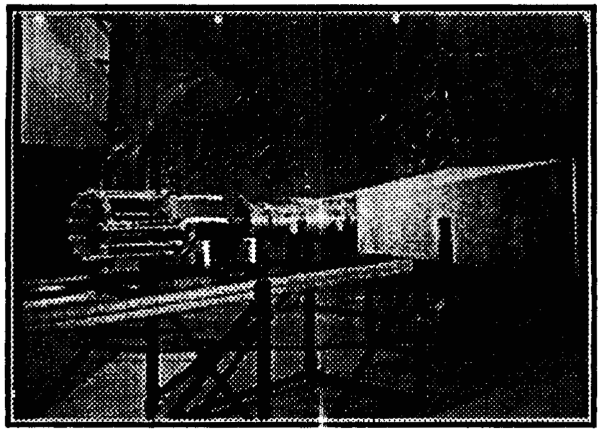
- Greatly Reduced Gnd Support
- Standardized Hardware
- Flexibility
- Reduced Weight
- Exercise/Test Space Ctrl Op's

THE NEW PARADIGM

FOCUSING ON THE WARFIGHTER . . .

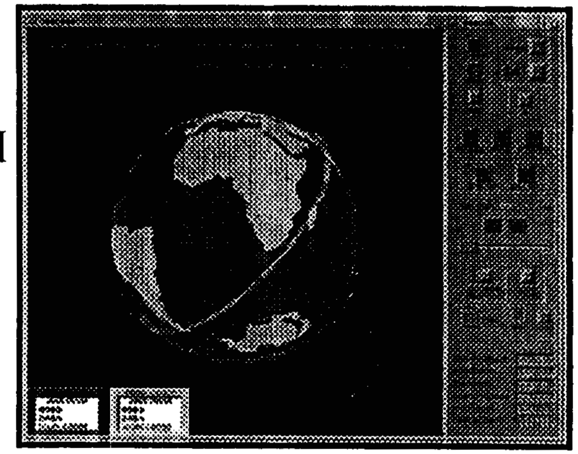
- With The View On Joint Utility
- An Eye on Supportability
- The Goal of Joint Commercial Devel
- . . . with Dual Use for Civilian Space

Advanced Weapons and Survivability Directorate



HPM SOURCES

SPACE DEBRIS RESEARCH

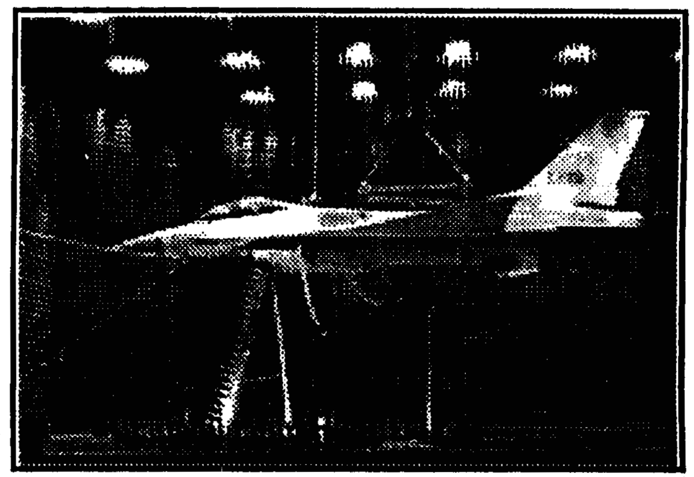


Mission

Dominate the Twenty-First Century Battlefield in Space, Air, and Land with Directed Energy Weapons and Countermeasures

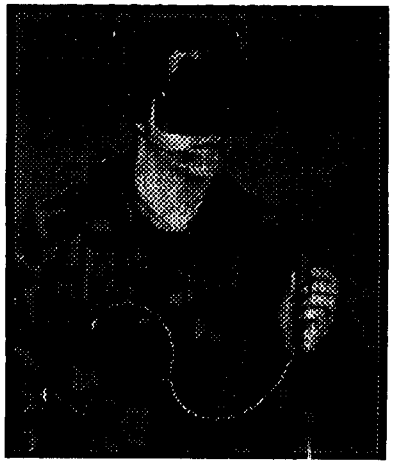
LASER EFFECTS EXPERIMENTS

RF TESTING

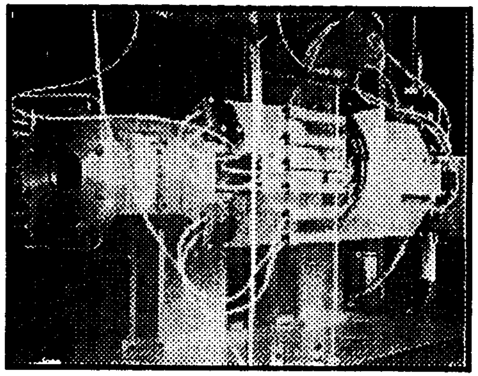


Lasers and Imaging Directorate

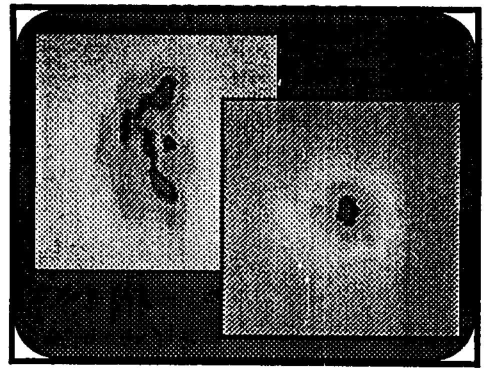
TACTICAL LASER APPLICATIONS



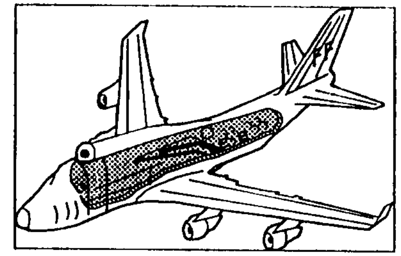
LASER TECHNOLOGIES



BEAM CONTROL TECHNOLOGIES



ABL / TMD

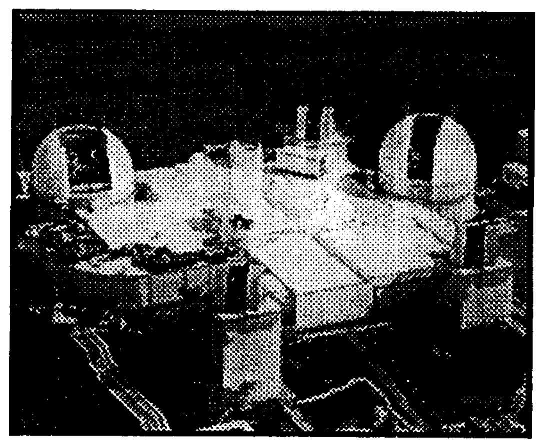


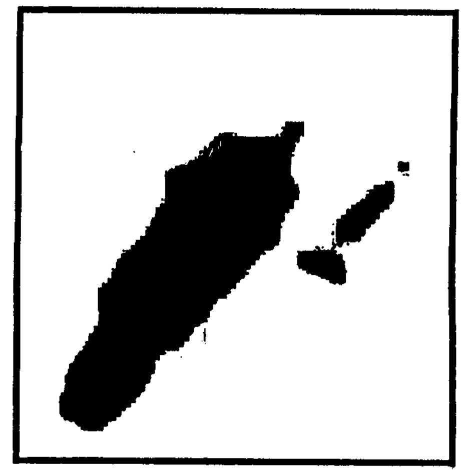
Mission

To Explore, Develop, and Apply Laser, Optical Sensing, and Beam Control Technologies to Meet Air Force and National Objectives

GBL / ASAT

SPACE SURVEILLANCE





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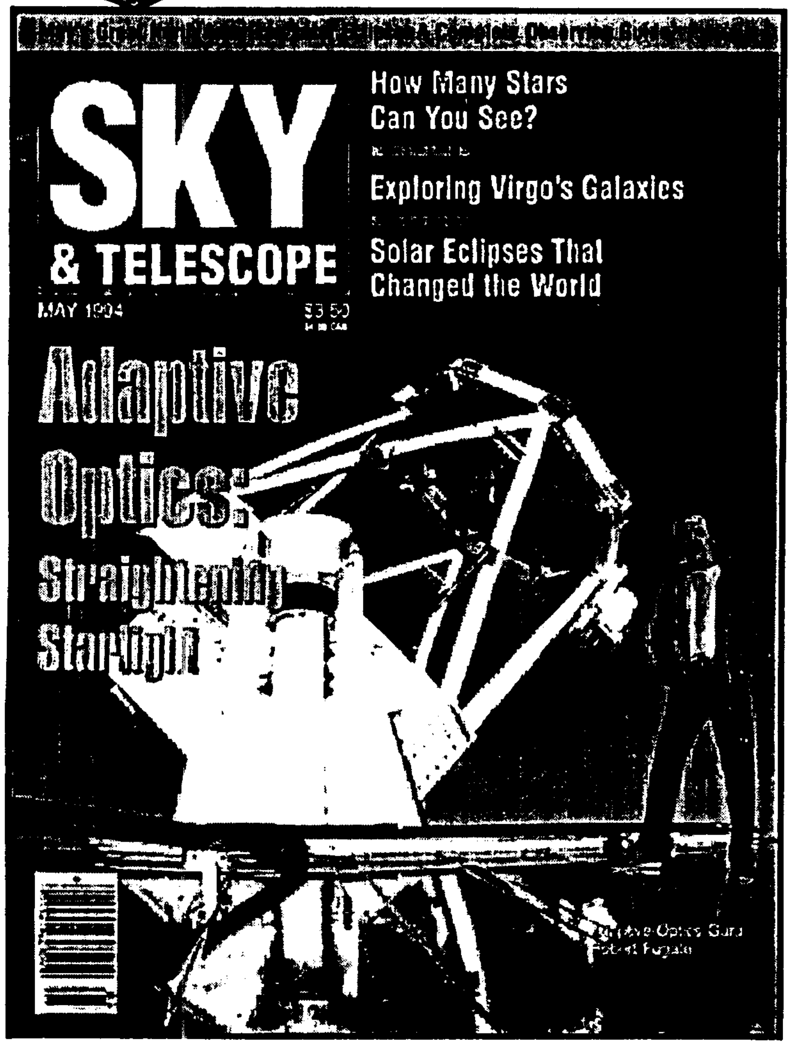
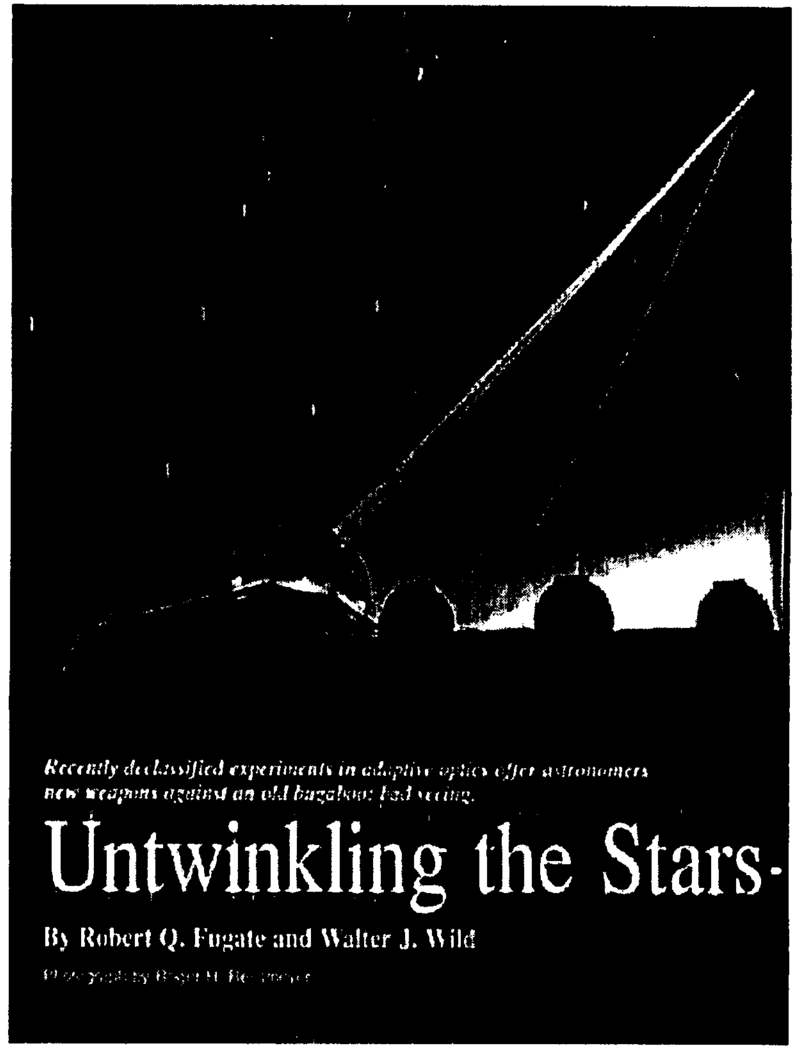
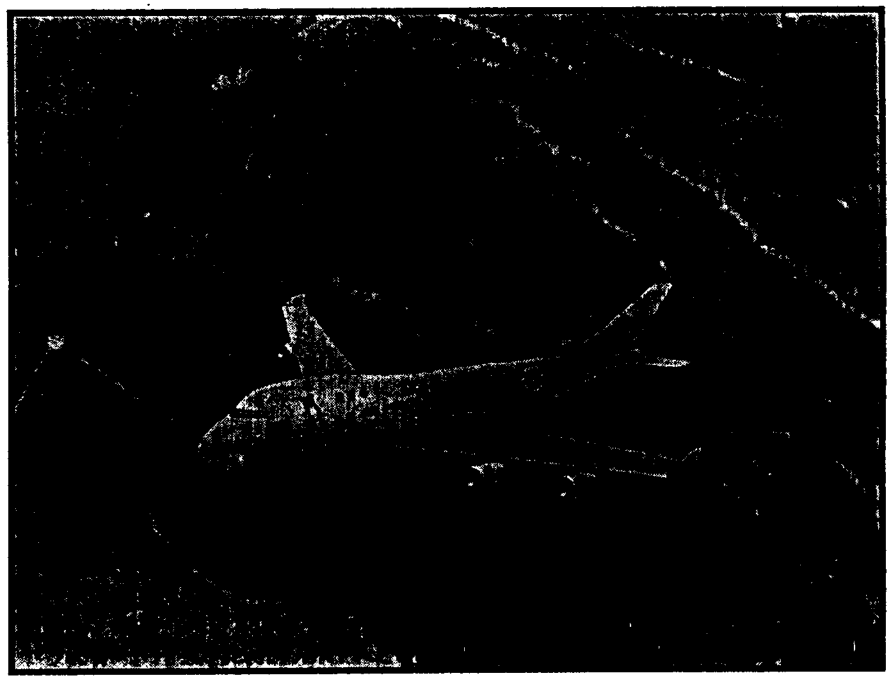
Starfire Optical Range (SOR)





Airborne Laser
(ABL)

- Special Project Office (SPO)
- Theater Missile Defense (TMD)
- Developing Design Concepts
- High-energy Laser Weapon
- Kill Missiles in Boost Phase
- Operates from Friendly Airspace

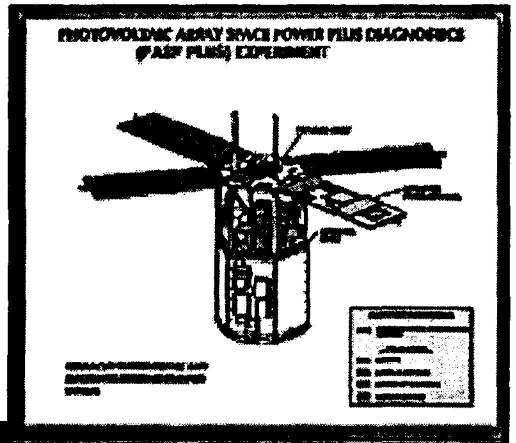


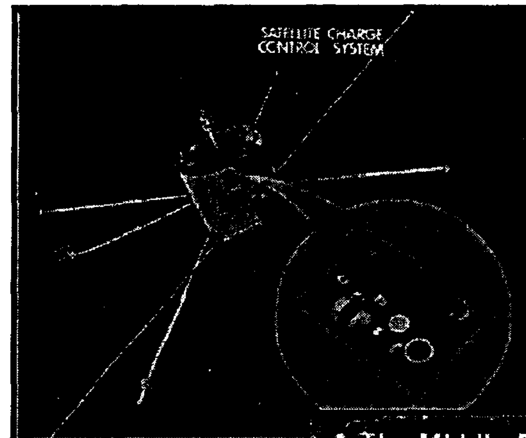
Revolutionary Capability when completed

Geophysics Directorate

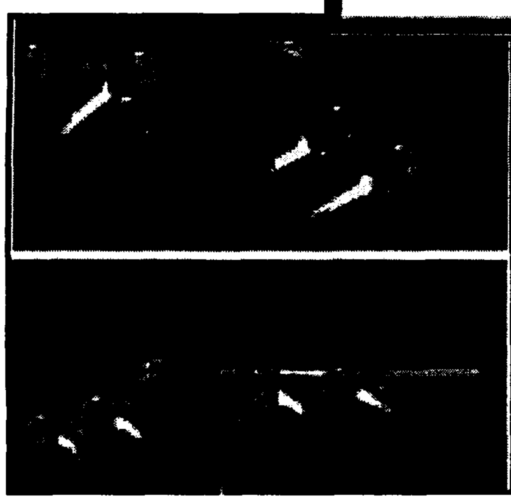
Mission

To Understand and Mitigate or Exploit the Interactions Between the Aerospace Environment and DoD Systems

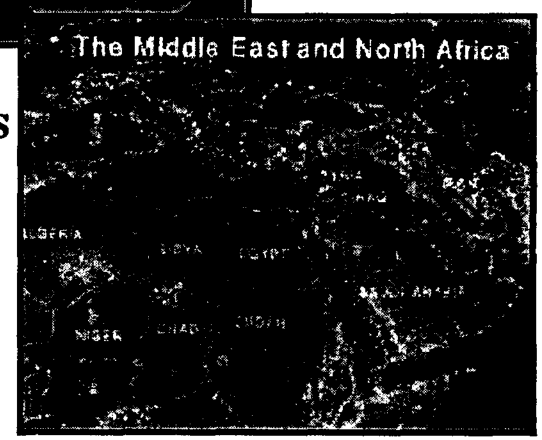




GEOPHYSICS for SPACE OPERATIONS and COMMUNICATIONS

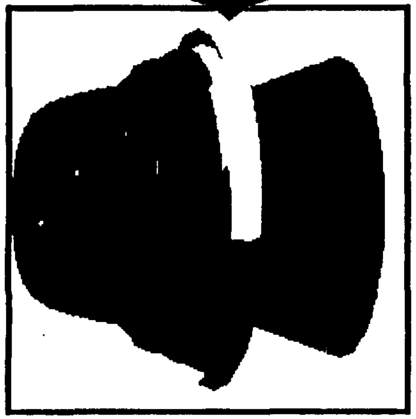


GEOPHYSICS for AIR and COMBAT OPERATIONS



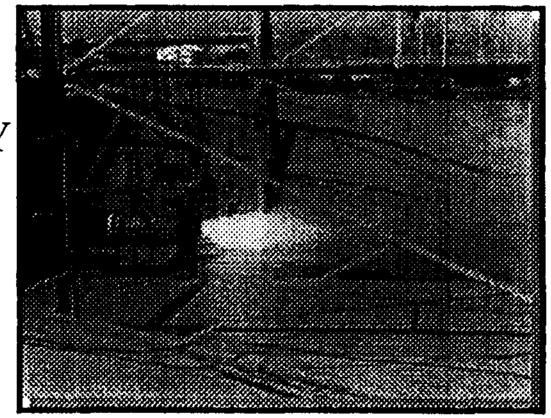
GEOPHYSICS with CORPORATE APPLICATIONS

Propulsion Directorate



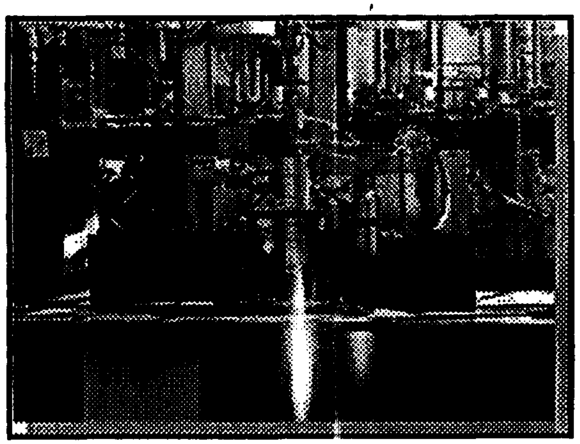
COMPONENTS
and
APPLICATIONS

MISSILE
PROPULSION
TECHNOLOGY



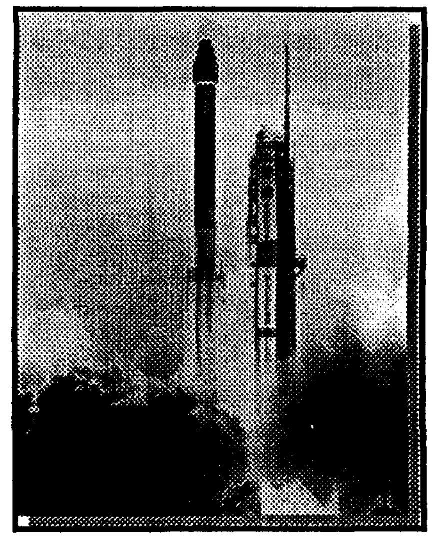
Mission

- Be the Center of Excellence in Rocket Propulsion Research and Development
- Formulate and Demonstrate Advanced Propulsion Concepts
- Develop a Broad, Advanced Technology Base for Future Propulsion System Designers
- Assist in Solving Operational Users' Problems



HIGH ENERGY
DENSITY MATTER

SPACE SYSTEM
PROPULSION

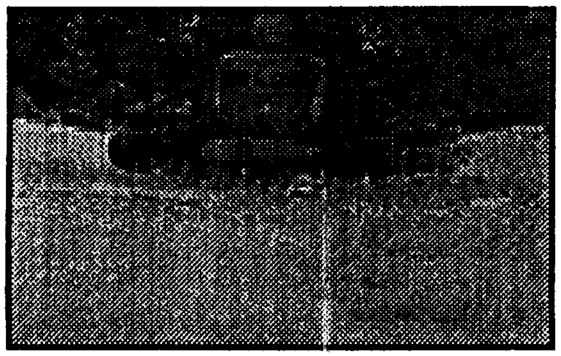


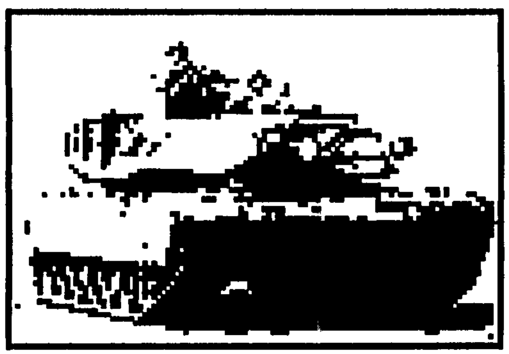
PHILLIPS LABORATORY SPACE EXPERIMENTS

- OVER 40 EXPERIMENTS CONDUCTED OR PLANNED JAN 94 TO 2000
- 28 FULL SATELLITE EXPERIMENTS JAN 94 TO 2000
- VARIETY OF LAUNCH VEHICLES/PLATFORMS USED
  - BALLONS -SOUNDING ROCKETKS -SHUTTLE
  - TAURUS -DMSP -COSMOS
  - DELTA II/MSC -STRV-1 / ARIANE -TITAN
- WIDE RANGE OF TECHNOLOGIES DEMONSTRATED
  - SMART STRUCTURES -COMMUNICATIONS SPACE DEBRIS
  - SPACE POWER -SPACE EFFECTS CRYOCOOLERS
  - ADV PROPULSION -RAD-HARD ELECT SPACE ENV

Phillips Laboratory Focus

Supporting the Warfighter





<u>Counterclockwise from Left:</u>

- K-Loader Laser Alignment System Under Evaluation at HQ/AMC
- Covert Beacons Tested with USMC Aviation and AF Special Ops Command
- Mid Infrared Laser to Army for Armor Defense System
- Laser Illuminator to US Navy Seals
- Saber 204 “Laser Shell” for USMC and AF Security Police Forces
- Laser Medpen for Battlefield Trauma Care
- TAOS Autonomous Support to the Warfighter at Space Command

AF MILITARY SPACE LAB

PHILLIPS LABORATORY

WE ARE A PREMIER MILITARY SPACE LAB

- • 7 Major Satellite Experiments Since 1990
- • Multiple Shuttle Missions/Space Surveillance Achievements

"FLY BEFORE YOU BUY" FOCUS

- • Demonstrate Technology in Partnership w/ SMC/TE, & in Concert w/ Warfighter
- • Allow Users/War Fighters to Actually Operate Demonstration Space Assets

STREAMLINED ACQUISITION FOR DEMOs

EXPLOITING CIVILIAN SPACE SYSTEMS

- • Space Equivalent of "CRAF" (Leveraging Non-DoD Systems for Military Use)

EVALUATING/USING FOREIGN TECHNOLOGIES

MILITARY IN KEY POSITIONS TO ENSURE OPERATIONAL INPUT INTO TECHNOLOGY PLANS

HISTORY OF KIRTLAND AFB

1941 Albuquerque Base, then Kirtland Field

1942 Sandia Base

1948 Kirtland AFB

1963 Air Force Weapons Lab Established

1971 Merged Sandia Army Base, Manazano Base and Kirtland AFB into one base

1982 Air Force Space Technology Center Established

1990 Phillips Laboratory Established

AFMC GROUND RULES

- **PL HAS" ...HIGH FUNCTIONAL VALUE ...." PREMIER SPACE LAB**

  BRAC 95 Language

- **REALIGNMENT MEANT TO BE TRANSPARENT TO PL DUE TO HIGH FUNCTIONAL VALUE**
  - Not a Personnel Reduction
  - Not a Change to Customer Relations
  - Not a Reduction in Quality

- **BUDGET ADJUSTMENTS REQ'D FOR CANTONED OPN'S**
  - Civilian Conversion and Hiring Expenses 3600
  - Stand-Alone O&M 3400

- **"MAINTAIN CHARACTER OF MILITARY SPACE LAB"**

  Gen Yates - HORIZONS

BRAC GUIDELINES

- PULL IN OUTLYING FACILITIES INTO CANTONED AREA WHERE EVER POSSIBLE, MINIMIZE RECURRING O&M

- DEVELOP PLANS TO OPERATE AS A STAND-ALONE ORGANIZATION

PL CANTONMENT PLANS

- MINIMIZE CANTONMENT AREAS
  - Determine which facilities can not move
  - Locate host buildings inside the cantonment for facilities that can move
- RETAIN AREA FOR GROWTH OF LAB MISSION

PL CANTONMENT PLANS

- FACILITIES THAT CAN NOT BE MOVED
  - STARFIRE OPTICAL RANGE (SOR)
  - HIGH ENERGY RESEARCH & TECHNOLOGY FACILITY (HERTF)

Starfire Optical Range
(SOR)

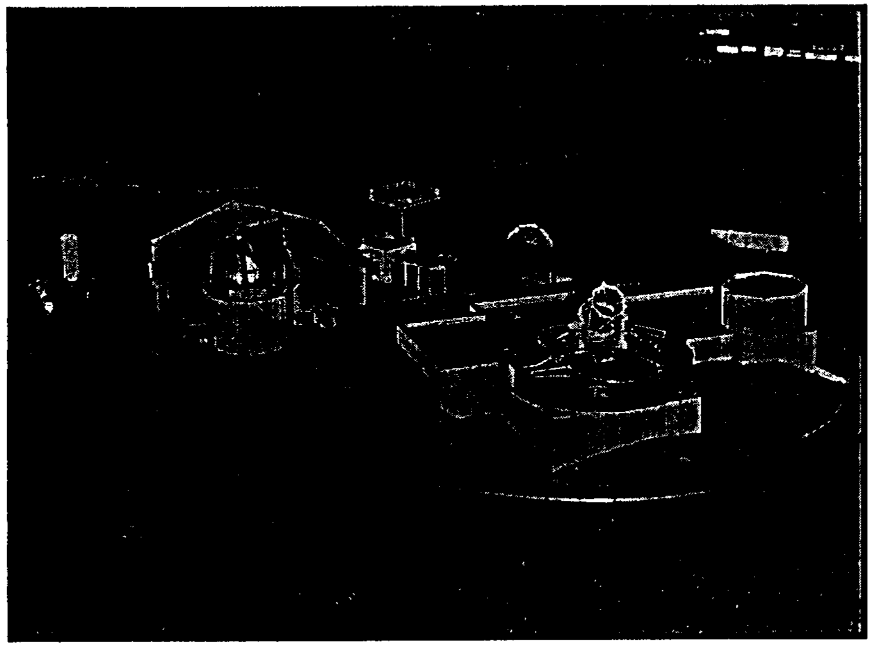
Power Beaming

Space Surveillance

Space Communications

Debris Detection

Daytime and High-Res Imaging



Remote Location:

- Seismic Stability
- Minimal Light
- Clear Weather

Unique Capability
Largest Telescope in DoD

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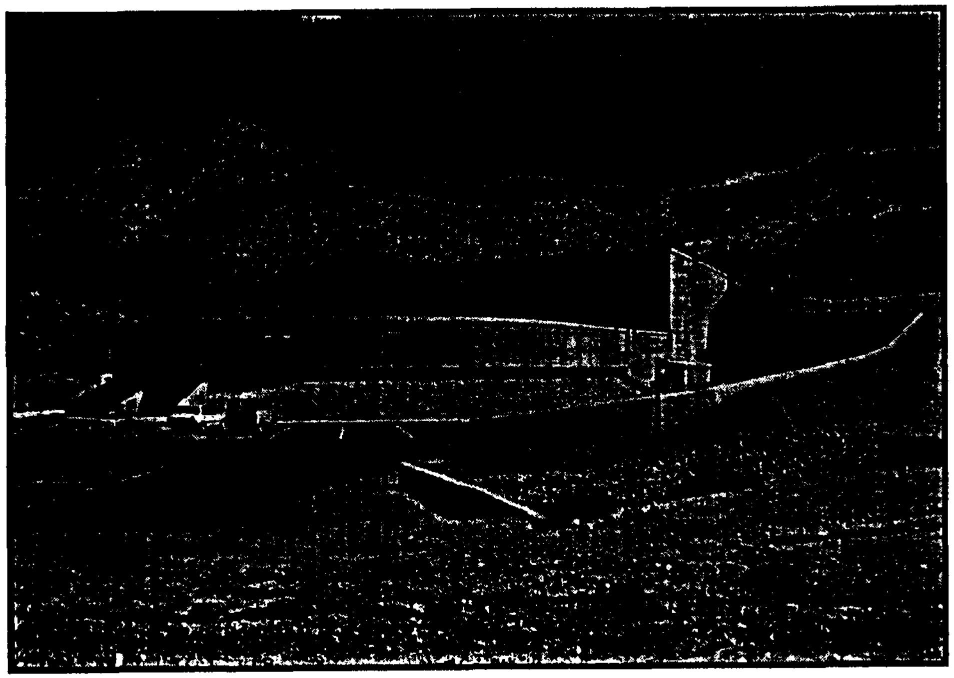
High Energy Research and Technology Facility
(HERTF)

Development of:

High-Power Microwaves

High-Energy Pulse Power

High-Energy Plasmas



Remote Location:

Withstand Blasts

Intense Radiation

Microwaves and X-Rays

Unique Capability

107XPPMA 2/95

PL FACILITIES THAT CAN MOVE
AT A COST

- SPACE POWER LAB
- PLANT 1 - HIGH POWER MW LAB
- PLANT 2 &3 - HPM SOLID STATE
- BUNKERS - EXPLOSIVE WORK
- COUNTERMEASURE SHOP
- COMMUNICATIONS SWITCHES
- MASKED DATA FACILITY

NOTE: Cost to move these facilities is paid back in 1 - 5 yrs reduced O&M

O & M COSTS

- **ONE TIME COSTS**
  - ASSOCIATED WITH ESTABLISHING A SUSTAINING CANTONED AREA

- **RECURRING O&M COSTS**
  - PL SUPPORT COSTS
    - » BASE OPERATING COSTS
    - » OTHER SUPPORT COSTS

NOTE: Recurring O&M costs higher if designated facilities not moved to the west side

ONE TIME COSTS

12-Apr-95 Facilities	Move	Move to:	One-time Other Costs
HERTF	No	N/A	N/A
SOR	No	N/A	N/A
760	No	N/A	N/A
Cobalt 60	No	N/A	N/A
COIL	No	Vacate FY99	N/A
LESLI	Yes	Pad at 728 Ramp	452,000
Space Power Lab Manzano	Yes	Bldg 333	125,000
CHOP Shop	Yes	Bldg 333	30,000
Plant 1&2 HPM Lab	Yes	Bldg 336	100,000
HPM Anechoic Chamber	New	Adv Wpn Lab	2,100,000
Plant 3 Adv Wpn Lab	Yes	New S of Runway	
Space Events Meas Lab	Yes	Bldg 333	50,000
Adv Laser Lab	Yes	FY98 Milcon 760	
Bunkers	Yes	700 Area	
CERF Warehouse	Yes	Bldg 1010	10,000
McCormick Ranch	Yes	Bldg 1010	
Perimeter Security		West/SOR/760	
Facility Maint Ops	Yes	Bldg 482	
Consolidated Support Fac	Yes	Bldg 425	
Sub-Total			2,867,000

[redacted]

12-Apr-95

Facilities	Move	Move to:	One-time Other Costs
Vehicle Maint	Yes	Bldg 381	
Move BOS/NonBOS	381	Bldg 482, 425, 381	$ 55,400
Move VT Admin	104	Bldg 333	$ 15,600
Move into Bldg 945	945	Bldg 945	$ 50,000
Alter Secure Facility		Bldg 945	
Fire Station Alarms	Yes	Bldg 482	
Water Wells		Existing Milcon	
Water Storage Tank- 760		Existing Milcon	
Gas Metering			
Electric Metering			
Water Metering		Existing Milcon	
Sanitary/Sewage Meter			
Alter Utilities			
Civilian Separation			$ 3,890,000
Communications/ Bldg498			$ 2,000,000
PCS Military Civilianization		130 positions	$ 4,810,000
Planning & Design 9%			$ 1,833,000
Environmental Analysis 1%			$ 204,000
Studio 1			$ 82,000

BRAC TOTAL **FY95 $15,807,000**

FY97 $17,024,000

RECURRING O & M COSTS

BOS Civilian Pay 134	4,958
Excluded BOS Civ Pay 247	9,139
Utilities	1,221
Real Property Maint	1,755
Maint for Pickled Space	100
Refuse	203
Custodial	164
Fac Maint O&M Supplies	940
Grounds Maintenance	627
Road Maintenance	305
Equipment Purchase	565
Equipment Rental	133
Equipment Maintenance	400
Security	354
Transportation	489
Communications	100
PMEL	364
Environmental, Safety, Health	990
Installation Restoration (IRP)	1,000
Postage	115
Training, Travel etc	128
BOS O&M supplies	25
DOE Services	400
Contingencies (5%)	1,299
Annual Recurring Costs:	$27,274M FY95

PL CANTONMENT ISSUES

- SECURE THE CANTONED AREA
- MAINTAIN A MINIMUM OF 212 MILITARY
- CONVERT 264 MILITARY TO CIVILIAN,
  INCREASE CIVILIAN S&E SALARY FUNDS
- FUND PLANNED MILCON TO AVOID HIGH RECURRING O&M COSTS
- IF DOE & PL ADJOINING CANTONMENT IS CHANGED:
  - SECURITY RISKS TO HIGH VALUE ASSETS
  - CIVIL ENCROACHMENT IMPACTS ON SOR & HERTF
  - RESTRICTIONS TO SPACE MISSION GROWTH

Space and Missile Test & Evaluation

Consolidation / Relocation

Col Thomas A. Imler
Deputy Director

DOCUMENTED T&E REQUIREMENTS

- DOD Test Resources Master Plan (Dec90):
  - "The space system test functional area is judged the most serious long term (DOD testing) deficiency"
- USAF Mission (Summer 93):
  - "To protect the USA by the exploitation of air *and space*"
- Space Test Capability Mission Need Statement (Apr94):
  - "Planned space requirements exceed the existing test support capability"

SMC/TE represents the only USAF DT&E capability for space and missiles; must be supported and expanded into the "AFFTC for Space"

VISION: "THE AFFTC FOR SPACE"

- Address the shortfalls in the Space Test Capability MNS
- Establish the center of excellence for space and missile T&E
- Consolidate a critical mass of space and missile T&E professionals
- Nurture core competencies of test and evaluation
- Provide single-face-to-the-customer for space and missile T&E
- Serve as DT&E liaison with developers, operators & AFOTEC
- Implement and host Combined Test Force (CTF)

Space and Missile Test and Evaluation Directorate (SMC/TE)

- 350-person government organization (250 moving to KAFB)
    - $120M per year budget
        - "AFFTC" for space and missiles
            - RDT&E spacecraft command and control
                - RDT&E launch and range support
                    - T&E for ICBM, RV, and decoys
                        - Tri-service RDT&E access to space
                            - High-altitude balloon support

Consolidation/Modernization complete by Sep 96!

ROCKET SYSTEMS LAUNCH PROGRAM (RSLP) PORTFOLIO

- Supporting MX deactivation
- Provides ballistic missile launch support for DoD flight test
- Stores deactivated Minuteman (MM) and MX assets
- Refurbishes MM motors/boosters for sounding rocket, ICBM test, and space launch (MSLS) use
- Ships MM motors/boosters
- Conducts aging and surveillance on MM II and MX assets
- Procures booster hardware
- Maintains MM booster support structure

4 ICBM Launches / Tests per Year

SPACE TEST & SMALL LAUNCH VEHICLE PROGRAMS PORTFOLIO

- Provides spaceflight opportunities for advanced DoD R&D experiments and certain operational payloads via Tri-SERB vetting process
- Specific Payload Services Provided:
  - Experiment integration (experiment to spacecraft and spacecraft to launch vehicle)
  - Integrated testing
  - One year of on-orbit experiment data
- Provides continuing capability for launch of small government payloads (ELV and STS)
- PEGASUS acquisition management and LV funding
- Spacecraft acquisition management and funding

13 RDT&E Missions per Year

SPACE TEST & EVALUATION DIRECTORATE PORTFOLIO

- Provides support for launch, early orbit C/O, on-orbit T&E, anomaly resolution, and routine TT&C of RDT&E spacecraft
- Provides spacecraft activation / transition to DoD / NATO operators (e.g. MILSTAR)
- Provides exploratory research, DT&E, and IOT&E for DoD space systems
- Provides acquisition management for the Tri-Service DoD global range
- Jointly manages Prototype Development Laboratory at NTF with CW
- Supports ACTD / ATTD military utility assessments and applications via CERES at FAFB

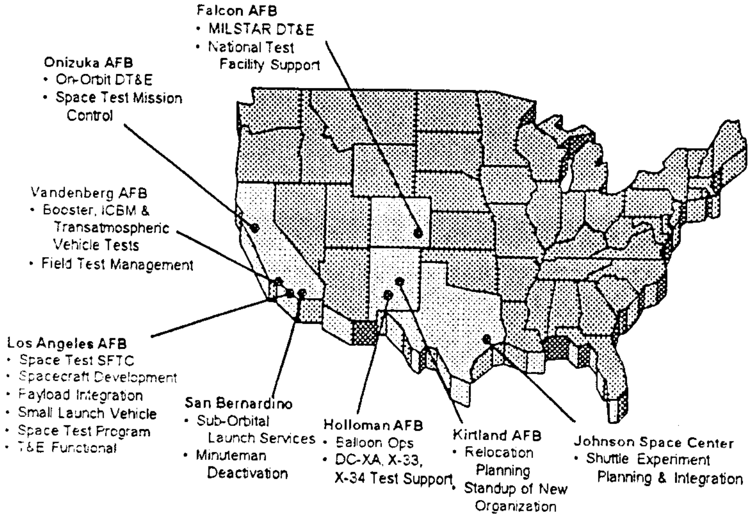
17 Spacecraft in Operation in 1996!

TEST INTEGRATION & LAUNCH DIRECTORATE PORTFOLIO

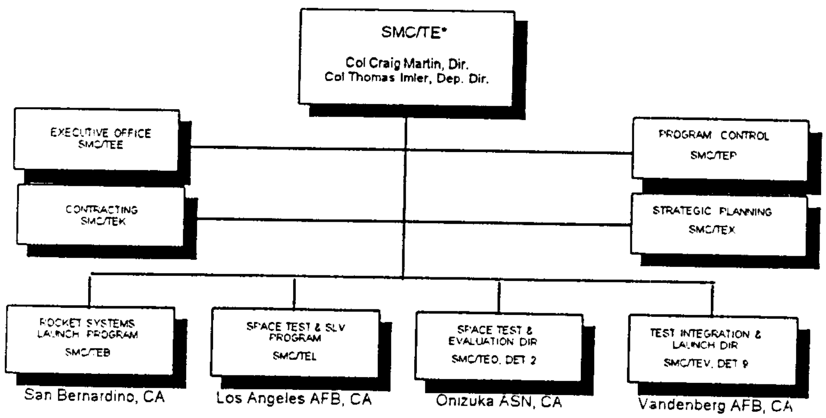
- Supports development testing of ballistic missiles, re-entry vehicles, space based systems and air-to-space cross-over systems
- Supervises design and development of R&D test facilities and launch complexes
- Supervises RDT&E spacecraft and ballistic missile payload integration to launch vehicles
- Provides independent T&E analysis and reporting

7 RDT&E Launches per Year

SPACE AND MISSILE TEST & EVALUATION DIRECTORATE (SMC/TE)

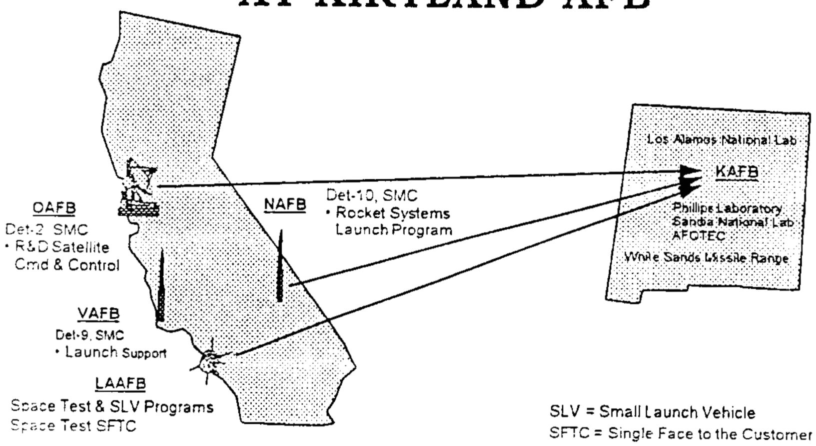


SPACE AND MISSILE TEST & EVALUATION DIRECTORATE (SMC/TE)

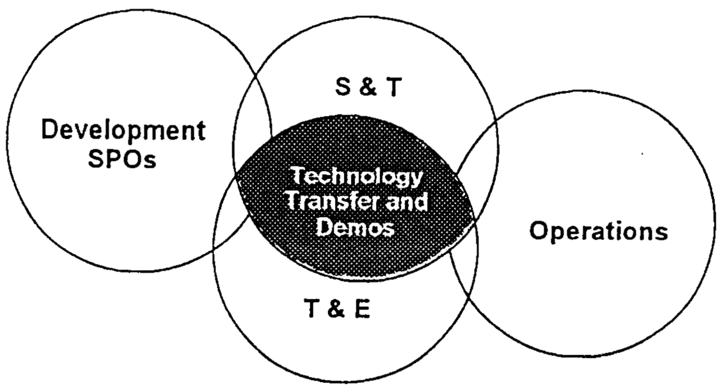


* Formerly known as SMC/CU

COLLOCATION OF SPACE AND MISSILE RDT&E FUNCTIONS AT KIRTLAND AFB



MISSION INTERACTIONS

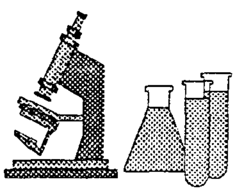


Collocate S&T and T&E missions to leverage overlap

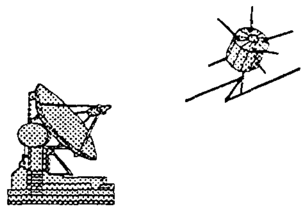
SYNERGY WITH PHILLIPS LABORATORY

- Phillips Laboratory (PL) is the USAF's space & missile laboratory
- PL is the primary Air Force customer for TE space test missions
- PL technology development provides continual improvement of satellite command & control capabilities
  - Software for satellite autonomy and control
  - Simulation, modeling and training concepts
  - Astrodynamics techniques and orbit planning
  - Debris survivability and space safety planning
- PL/SX jointly executes technology demonstrations with TE
  - RDT&E Support Complex (RSC) supports PL space experiments
  - Advanced Concept Transition Demonstrations (ACTD) speed new technologies to the warfighter

ADDITIONAL BENEFIT



Space & Missile
Research & Development



Space & Missile
Test & Evaluation

R&D + T&E

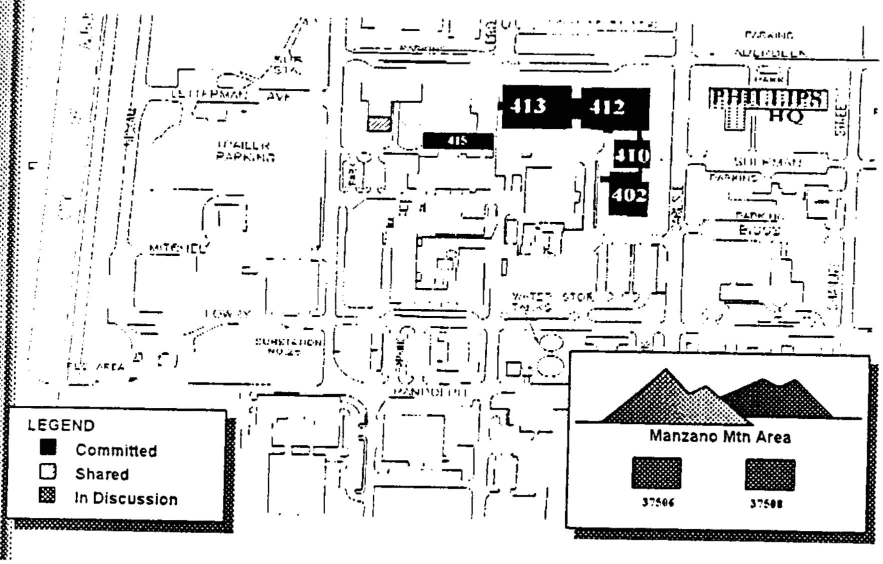
Pre-eminent DOD Center for Space & Missile RDT&E!

PROGRAMMED MOVES TO KAFB

Based on UMDs — JUN 94

UNIT	MIL	CIV	FFRDC	CONTR	TOTAL
TE (L,X) @ LA	66	32	23	0	121
TEB @ San Bern	17	22	0	18	57
TEO @ Onizuka	76	36	6	239	357
TOTAL	159	90	29	257	535

377 ABW / PL / TE BEDDOWN AGREEMENT



SMC/TE CONSOLIDATION STATUS

- AFMC/CC directed move 22 March 94
- 82 government positions moved
  - 44 government personnel in place; 11 in-bound
  - 27 government vacancies remain to be filled
- Facilities refurbishments essentially complete
- T-1 Comm link in place to Onizuka ASN
- RDT&E Support Complex (RSC) within 6 months of IOC (capable of autonomous satellite operations)
- AFMC/XPM approved new designation SMC/TE on 28 Feb 95

BRAC IMPACTS / RECOMMENDED APPROACH

Cantonment perimeter	All buildings within perimeter, IF Deployables sent to VAFB
Minimum military	Apply justification criteria, reduce 159 to 81 (62 @ KAFB)
Civilian salary "plus-up"	ZBT $4.8M (e.g. 78 @ $60K)
Civilian transfer costs	Add $2.1M (e.g. 58 @ $35K)
BOS tail	Add $6.7 M (18 BOS plus 53 other)
Proscriptive language	Clarify BRAC intent

Proposed Revision to the BRAC language concerning Kirtland AFB and Onizuka AS

- Kirtland AFB, New Mexico
  - "Recommendation: Realign Kirtland AFB...The Phillips Laboratory (PL), *the Space & Missile Systems Center Test & Evaluation Directorate (SMC/TE)*, and the 898th Munitions Squadron will remain in cantonment..."
  - "Justification: ...This realignment will close most of the base, but retains the Phillips Laboratory, which has a high functional value; *the Space & Missile Systems Center Test & Evaluation Directorate, which has a significant synergy with Phillips Laboratory;* and the 898th Munitions Squadron, which is not practical to relocate..."
- Onizuka AS, California
  - "Recommendation: Realign Onizuka AS... *The residual AFMC activity* -- Detachment 2, Space & Missile Systems Center *(CWO)* -- will relocate to Falcon AFB, Colorado, *and Los Angeles AFB, California, with a portion remaining in Sunnyvale, California to support national activities...*"

Directed Groundrules For TE Consolidation Under BRAC Considerations

- **Complete the <u>on-going</u> transfer of all SMC/TE military and civilian personnel from Los Angeles AFB to Kirtland AFB**
  - **SMC/TE Command Section**
  - **Tri-Service Space Test Program & AF Small Launch Vehicle Program**
  - **AFMC Space Test Single-Face-To-Customer Office**
- **Complete the <u>planned</u> transfer of all SMC/TEB (Rocket Systems Launch Program)**
  - **In accordance with the Brown Amendment to the Norton AFB closure**

Groundrules (cont)

- Minimize the transfer of SMC/TEO (Det 2, SMC) personnel pending final results of BRAC process
  - No more than 20 transferred from Onizuka ASN to KAFB
  - Delay any decision on where to locate Det 2's deployable telemetry systems
- SMC/TE will take no action which would prevent their ability to achieve a maximum military presence of 62 personnel at KAFB by 4QFY97

Summary

- SMC/TE collocation at KAFB with Phillips Lab provides maximum USAF space mission capability
- Move directed and underway since Mar 94
- Move scheduled for completion Sep 96
- Required military levels are acceptable

150th Fighter Group
New Mexico
Air National Guard

Col Henry S. Parker
Vice Commander

Mission

Train to develop and maintain the capability to execute fighter missions designed to destroy enemy air and ground forces through the use of F-16 LANTIRN equipped aircraft with mission ready pilots, mobility support equipment, and skilled personnel

Equipment

31 F-16C/D *Fighting Falcons*

1 C-26B *Metroliner*

Authorized Personnel

- Full-time - 404
  - AGR - 85
  - Technician - 295
  - State - 24
- Traditional Guardsmen - 1073
  - Officer - 126
  - Enlisted - 947

Support Provided by 377 ABW

- Wing/Group Staff Functions
  - Public Affairs
  - Social Actions Mediation
  - Chaplain and Chapel Support
  - Community Support
  - Accounting and Finance
  - Legal Services

Support Provided by 377 ABW

- 150th Operations Group
  - Command & Control
    - Command Post
    - Mobilization Support
  - Safety
    - Ground
    - Weapons
  - Weather Service
  - Base Operations
    - FAA Flight Following
    - Primary Crash Net

Support Provided by 377 ABW

- 150th Logistics Group
  - Explosive Ordnance Disposal
  - Installation/Retail Supply
  - Transportation Services
  - Munitions Maintenance/Storage Area
  - Test, Measurement, and Diagnostics
  - Equipment Operation, Maintenance and Repair
    - Special Purpose Equipment and Vehicles
  - Fuels (Defense Logistics Agency)

Support Provided by 377 ABW

- 150th Support Group
  - Fire/Crash/Rescue
  - Engineering Support
  - Disaster Preparedness
  - Security Police
  - Communications - ADP
  - Food Services
  - Military Personnel
  - Utilities and Distribution Infrastructure
  - Environmental Compliance Support
  - Roads/Grounds
  - Refuse Collection
  - Information Management
  - BOQ/VAQ
  - MWR
  - Mortuary Services

Support Provided by 377 ABW

- 150th Medical Squadron
  - Flight Surgeon
  - Emergency Response
  - Laboratory, Radiology, Optometry
  - Dental Support
  - Medical/Dental Supply
  - Air Transportable Clinic Support
  - Medical Equipment Repair/Calibration
  - Health Care Services for AGR Members and Families
  - Bioenvironmental Support

BRAC Recommendation

- ANG activities will remain in existing facilities

ANG MILCON

- Perimeter Security
- Composite Support Facility
  - Security Police Operations
  - Communications Facility
  - Disaster Preparedness
- Dining Hall/Reserve Training Facility
- Engineering Maint Storage Facility
- Jet Fuel Storage Facility
- Isolate & Meter Utility Systems

Full-time Personnel

Communications	+ 5
Precision Measurement Eq Lab	+ 4
Supply	+ 5
Security Police (12 State O&M)	+ 28
Civil Engineering (10 State O&M)	+ 14
Medical Services	+ 2
Fire/Crash Rescue (24 State O&M)	+ 24
Total	+ 82

ANG Training Sites

- Firearms Qualification Facilities
  - Small Arms (M-16 & 9mm)
  - M-60 (machine gun)
  - M-203 (grenade launcher)
- Prime BEEF/RIBS & Security Police Training Area (Archuleta Field)
  - Overnight Bivouac
  - Field Sanitation
  - Rapid Runway Repair
  - Security Police Tactics
- Chemical Warfare Confidence Facility

Questions ?

Air Force Inspection Agency (AFIA)

Air Force Safety Agency (AFSA)

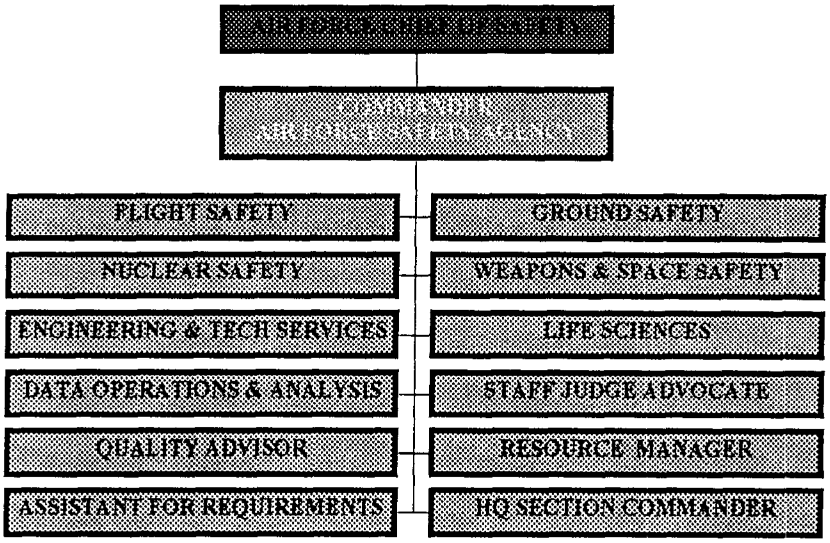
Col Bernard Burklund, Jr.
Commander, AFIA

Col Jay Sweetnam
Vice Commander, AFSA

Air Force Safety Agency AFSA Mission

Establish and execute mishap prevention programs to enhance Air Force mission capability

AFSA Organization



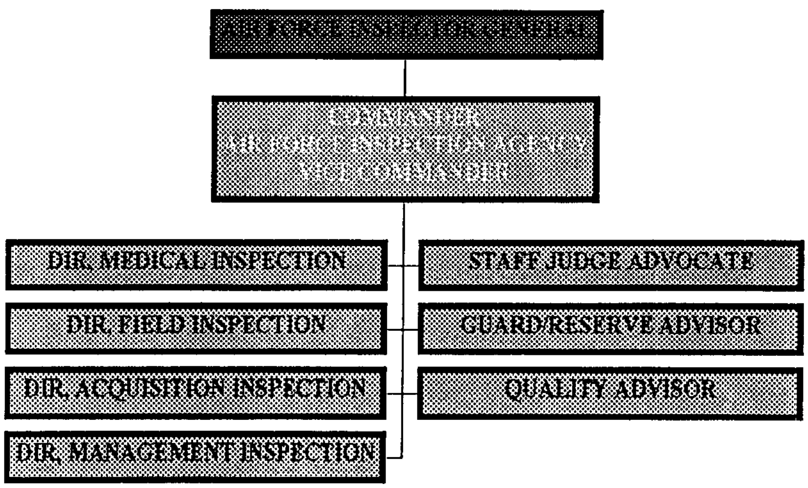
AFSA - What we do

- Implement, execute and evaluate Air Force safety and mishap prevention programs
  - Flight
  - Ground
  - Weapons
  - Space
  - Nuclear
- Oversee mishap investigations--cause, findings, recommendations
- Provides technical assistance--develop regulatory guidance

Air Force Inspection Agency
AFIA Mission

AFIA provides Air Force leadership an assessment of Air Force readiness, discipline, and management efficiency and effectiveness

AFIA Organization



AFIA - What we do

- We provide:
  - Independent assessments to leadership on issues of concern
- Through:
  - Health Services Inspections
  - Quality Air Force Assessments of DRU/FOAs
  - Functional Management Reviews
  - Acquisition Management Reviews
  - TIG Brief Magazine
  - USAF IG School
  - Reports of Inquiry

AFIA/AFSA Relocation Factors

- Scheduled to move to Kelly AFB TX
- Personnel Involved
  - AFSA 62 Military 70 Civilian
  - AFIA 116 Military 22 Civilian
- Minimum Facility Requirements
  - 77,751 Sq Ft Admin Space
  - 30 Acre Crash Lab (2250 Sq Ft Facility)

AIR FORCE SECURITY POLICE AGENCY (AFSPA)

Col Jerry Riordan
AFSPA

AFSPA

- FIELD OPERATING AGENCY
  - SUPPORTS 34,000 USAF SECURITY POLICE
  - REPORTS TO AIR FORCE CHIEF OF SECURITY POLICE
  - 64 AUTHORIZATIONS AT KIRTLAND AFB
    - 78 AT 3 DETACHMENTS
  - $2.8M O&M (FY 95)

AFSPA (CONTINUED)

- MISSIONS
  - CENTER OF EXPERTISE AND IMPLEMENTATION OF POLICY
    - SECURITY OF WEAPONS SYSTEMS
    - AIR BASE DEFENSE
    - LAW ENFORCEMENT
    - COMBAT ARMS TRAINING AND MAINTENANCE
    - CORRECTIONS
    - ANTITERRORISM

AFSPA (CONTINUED)

- FUNCTIONS
  - PROGRAM OFFICE (STUDIES/TESTS/ REVIEWS)
  - FIELD AGENT (FIELD VISITS/DATA GATHERING/ANALYSES)
  - PROGRAM MANAGER (DOD MILITARY WORKING DOG, SECURITY POLICE AUTOMATED SYSTEM, INTRUSION DETECTION SYSTEM, SP TRAINING AND SP EQUIPMENT)

AFSPA (CONTINUED)

- PROGRAM MANAGER (CONTINUED)
  - DEVELOPS/WRITES SP INSTRUCTIONS, HANDBOOKS, PAMPHLETS, CATALOGUES, DIGESTS
  - USAF PEACEKEEPER CHALLENGE COMPETITION
  - FUTURE TECHNOLOGY, CONCEPTS, EQUIPMENT
  - MANAGEMENT OF TESTS AND EVALUATIONS

AFSPA (CONTINUED)

- IMPLEMENTATION OF USAF BRAC DECISION
  - RELOCATE ALL KIRTLAND AFB FUNCTIONS TO LACKLAND AFB IN FY 98
    - CONSTRUCT NEW HEADQUARTERS
    - CONTINUE OPERATIONS

58th SPECIAL OPERATIONS WING

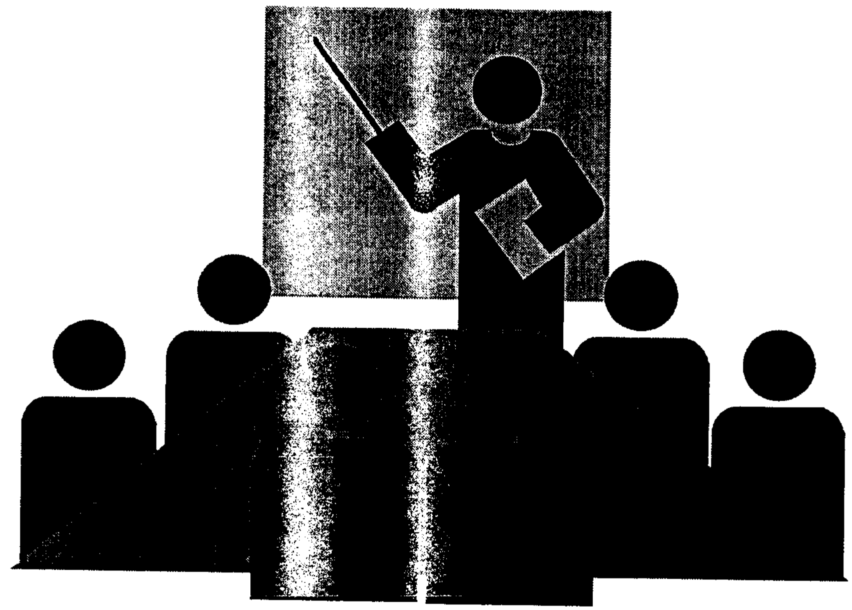
BRAC COMMISION BRIEF

18 April 95

Colonel Bob Pyeatt
Vice Commander

WHAT WE'LL TALK ABOUT

- Mission
- Resources
- Training



Mission

To Train

Mission-Ready

Special Operations & Combat Rescue

Aircrews, Maintenance Personnel,

Pararescuemen and Combat Controllers

for the

World's Best

Air Force

STATUS

For Our Customers, We Train:

More Personnel in
More Crew Positions in
More Aircraft than

Any Other Schoolhouse in AETC

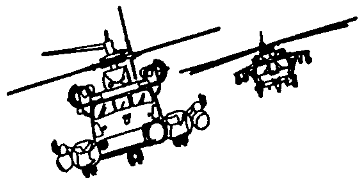
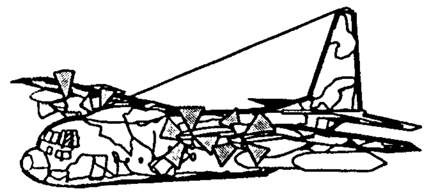
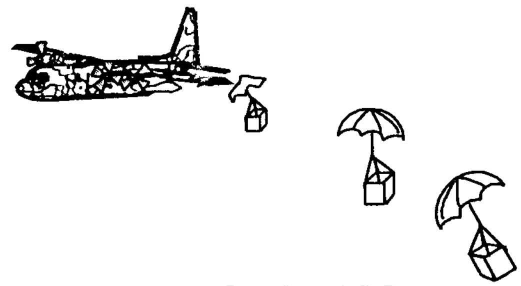
PERSONNEL

	AUTHORIZED				ASSIGNED
	STAFF	OG	LG	TOTAL	PERM
OFFICERS					
FLYING	7	136	0	143	136
NONFLYING	2	15	8	25	26
(TOTAL)	9	151	8	168	162
ENLISTED					
FLYING	0	172	0	175	174
NONFLYING	35	510	326	868	936
(TOTAL)	35	682	326	1,043	1,110
CIVILIANS	5	40	39	84	66
TOTAL	49	873	373	1,295	1,338

TOTAL POPULATION ASSIGNED: 1,338

As of 17 April 1995

ATD CONTRACTOR SUPPORT

MARTIN MARIETTA	CAE-LINK	LORAL
		
MH-53J, TH-53A M/HH-60G 120	HC-130P 43	MC-130H 31

→ 194

LORAL ADDS 52 PERSONNEL TO SUPPORT MC-130H WST IN FY95/96

AIR EDUCATION & TRAINING COMMAND

58TH SPECIAL OPS WING

FORMAL SCHOOL COURSES

AIRCRAFT TYPE	CREW POSITIONS OFFICER	CREW POSITIONS ENLISTED	COURSES
H-1	1	1	7
H-53	1	2	8
H-60	1	1	6
HC-130	2	3	12
MC-130H	3	2	6
PJs	0	1	8
CCT			2
FORT RUCKER			1
REFRESHER			9
MISC			3
TOTAL	8	10	62

As of 17 April 1995

FORMAL SCHOOL STUDENTS

TYPE	FY 94 STUDENTS GRADS	FY 95 STUDENTS** PROG	FY 95 STUDENTS** PROG NOW	FY 95 STUDENTS** GRADS NOW
H-1	47	84	49	43
H-53	74	102	40	35
H-60	80	112	49	41
HC-130	129	165	78	72
MC-130H	75	72	32	26
PJs	60	308	99	58
CCT	92	95	36	35
FORT RUCKER	72	90	30	27
MISC	91	165	70	39
TOTAL	720	1,193	483	376

As of 7 April 1995

AIRCRAFT

TYPE	ASSIGNED (HEADQUARTERS ALLOCATION)	POSSESSED (PHYSICALLY RESPONSIBLE)	DEPOT/ OTHER
UH-1N	6	5	1/0
TH-53A	6	5	1/0
MH-53J*	4	3	2/0
HH-60G*	7	7	1/0
HC-130P	5	4	1/0
MC-130H	5	5	0/0
HC-130N	1	1	0/0
TOTAL	34	30	6/0

* 2 Loaner aircraft
HH-60G, 1; MH-53J, 1

As of 7 April 1995

FLYING HOUR PROGRAM

AIRCRAFT	FY94 FLOWN	FY 95 PROG	FY 95 FLOWN
UH-1N	2,256	2,304	1,211.0
TH-53A	1,104	1,632	760.2
MH-53J	1,968	1,728	808.8
HH-60G	3,540	3,420	1,500.5
HC-130P	2,520	2,580	1,296.6
MC-130H	2,016	2,112	1,010.8
TOTAL	13,404	13,776	6,587.9

As of 7 April 1995

LOCAL TRAINING AREAS

REQUIREMENTS	AVAILABILITY
HELO AUX FIELD (FIRE STATION)	1
DIRT & PAVED STRIPS & PADS	12
TREE JUMP AREA	0
WATER TRAINING AREA (CONFINED/OPEN)	1/0
GUNNERY RANGES	3
ELECTRONIC WARFARE RANGE	2
DROP ZONE (PERSONNEL & EQUIPMENT)	3
C-130 ASSAULT LANDING STRIPS (NORMAL/NVG)	3/2
PARARESCUE GROUND TRAINING AREAS	4
LOW-LEVEL FLYING AREAS	32,000 SQ MI
REMOTE LANDING SITES	38
MOUNTAIN TRAINING AREAS	3
AIR REFUELING TRACKS	1 HIGH; 3 LOW
WEAPONS RANGES	4

QUESTIONS

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

JOSUE (JOE) ROBLES, JR., Commissoner

Biography

Joe Robles is Senior Vice President, Chief Financial Officer/Corporate Controller for USAA Financial Services. He directs USAA's activities in the areas of Payroll and Compensation Accounting, Accounting Policy, Corporate Financial Analysis, Internal Audit and Taxes. He joined USAA in July 1994 as Special Assistant to the Chairman after retiring from the U.S. Army as a Major General after 28 years of service. He assumed the role of CFO/Controller in September 1994.

General Robles was born in Rio Piedras, Puerto Rico, January 24, 1946. He joined the U.S. Army in 1966 and received his commission as a second lieutenant through the Artillery Officer Candidate School at Fort Sill, Oklahoma in 1967. He received a Bachelor of Business Administration degree in Accounting from Kent State University in 1972. He also holds a Master of Business Administration from Indiana State University. His military education included Field Artillery Basic and Advanced courses, U.S. Army Command and General Staff College, Spanish General Staff College, and U.S. Naval War College.

Robles served in a variety of important command and staff positions, culminating in his assignment as Commander General, 1st Infantry (Mech) at Fort Riley, Kansas. Prior to that position, General Robles served as Director of the Army Budget, and as the assistant division commander, 1st Cavalry Division, Fort Hood, Texas. The latter included participation in Operations Desert Shield/Desert Storm. His early troop assignments included command and staff positions in Field Artillery units in Korea; Fort Knox, Kentucky; Vietnam; and Germany.

Robles' mid-level assignments included work with the Resource Management Department, U.S. Army Institute of Administration, Fort Benjamin Harrison, Indiana. He also served as special assistant to the G-3, 1st Infantry Division (Mech), and battalion commander, 1st Battalion 7th Field Artillery, 1st Infantry Division, both at Fort Riley, Kansas.

Recent assignments included Chief, programming and budget office with Headquarters, U.S. Army, the Pentagon, and Division Artillery commander of the 1st Infantry Division (Mech), Fort Riley, Kansas.

Robles' military awards include the Distinguished Service Medal with Oak Leak Cluster, the Legion of Merit with two Oak Leaf Clusters, the Bronze Star Medal with Oak Leak Cluster, the Meritorious Service Medal with Oak Leaf Cluster, the Air Medal, the Army Commendation Medal with Oak Leaf Cluster, the Army Good Conduct Medal, and the Army General Staff Identification Badge.

General Robles is married to the former Patricia Ann Gavin of East Greenwich, Rhode Island and has three sons, Joseph (deceased), Andrew and Christopher, and a daughter, Melissa.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

BENJAMIN F. MONTOYA, Commissioner

Biography

Benjamin F. Montoya is currently the President and Chief Executive Officer of Public Service Company of New Mexico, an investor-owned public utility serving gas, electricity and water throughout the State.

His private sector career, which began in 1989 when he retired from the Navy, has included the positions of Manager, Vice President, and Senior Vice President of Pacific Gas and Electric company, San Francisco.

Mr. Montoya enjoyed a distinguished and decorated U.S. Navy career spanning 31 years, rising to the rank of Rear Admiral. He served as Commanding Officer of the Navy Public Works Center in San Diego, California; Commander of the Western Division Naval Facilities Engineering Command in San Bruno, California; and Director of the Shore Activities Division in the Office of Deputy Chief of Naval Operations (Logistics) in Washington, D.C. From 1987-1989, he assumed the duty as Commander of the Naval Facilities Engineering Command and Chief of Civil Engineers. Mr. Montoya was selected to the rank of Rear Admiral in March, 1987.

His awards include the Legion of Merit, Bronze Star Medal with Combat "V," Meritorious Service Medal, Navy Commendation Medal and the Navy Achievement Medal.

Mr. Montoya is a graduate of the U.S. Naval Academy. He also holds a Bachelor of Science degree in civil engineering from Rensselaer Polytechnic Institute, a Master of Science degree in sanitary engineering from Georgia Institute of Technology.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

ALAN J. DIXON, Chairman

Biography

Alan J. Dixon was confirmed by the U.S. Senate October 7, 1994, as chairman of the Defense Base Closure and Realignment Commission, adding another chapter to a distinguished 45-year career in public service.

Dixon, 67, is a senior partner in the corporate and business department of the St. Louis-based law firm of Bryan Cave, which he joined in 1993 after representing Illinois in the U.S. Senate for 12 years. Until his defeat in the Democratic primary election in 1992, Dixon had enjoyed an unbroken string of 29 election victories dating from 1949 when, while attending law school, he was elected police magistrate in his hometown of Belleville, Illinois.

In 1988 and again in 1990, Democratic Senators elected him unanimously to serve as chief deputy whip, their number three leadership post.

During his Senate career, Dixon held important positions on the committees on Armed Services, Small Business, and Banking, Housing and Urban Affairs.

On the Armed Services Committee, he chaired the Subcommittee on Readiness, Preparedness and Sustainability, which oversees 38 per cent of the U.S. defense budget. The subcommittee was one of those responsible for making sure U.S. manpower and weapons systems employed in the Persian Gulf War were adequate for the task. In 1990, he co-authored the legislation that created the commission he now chairs and the process under which the federal government operates to close and realign military bases in the United States.

Dixon began a 20-year career in the Illinois General Assembly with election to the House of Representatives in 1950. As a legislator, he wrote or co-sponsored legislation that produced or nurtured the state's modern criminal code, the modern judicial article to the Illinois Constitution, the state's community college system and its open meetings law.

He served as Illinois Treasurer from 1971-77, during which time his policies earned hundreds of millions of dollars for Illinois taxpayers and he established investment incentives for Illinois banks to encourage them to invest locally.

He was elected Illinois Secretary of State by a margin of 1.3 million votes in 1976. In 1978, he was re-elected by 1.5 million votes, becoming the first candidate in Illinois history to carry all 102 counties in the state, including all 30 townships in suburban Cook County and all 50 wards in the City of Chicago.

He was the first Democratic statewide candidate to disclose the sources and amounts of all campaign contributions, and since 1970, his personal financial assets and liabilities were a matter of public record.

Dixon is a graduate of the University of Illinois and holds a law degree from Washington University in St. Louis. He and his wife, Jody, have three children and seven grandchildren.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

WENDI L. STEELE, Commissioner

Biography

Wendi L. Steele served as the Senate liaison for the Defense Base Closure and Realignment Commission in 1991. She began her career in the Reagan Administration, working in the legislative affairs offices of both the Office of Management and Budget and the White House. Following her service in Washington, Mrs. Steele was a congressional and economic analyst for the Defense and Space Group of the Boeing Company in Seattle, Washington. She returned to D.C. during the Bush Administration and worked for the assistant secretary for legislative and intergovernmental affairs of the U.S. Department of Commerce. In 1993, she staffed defense, veterans' affairs, foreign policy and trade issues for Senator Don Nickles (R-OK).

Mrs. Steele currently resides with her husband Nick in Houston, Texas, where she is a writer.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

S. LEE KLING, Commissioner

Biography

S. Lee Kling serves as Chairman of the Board of Kling Rechter & Company, a merchant banking company. The company was formed in 1991. Additionally, he serves as a Special Advisor and Managing Director of Willis Corroon Corp. of Missouri.

Mr. Kling served as Chairman of the Board of Landmark Bancshares Corporation, a St. Louis based bank holding company located in Missouri and Illinois, from 1975 through December 1991 when the company merged with Magna Group, Inc. He served additionally as the company's Chief Executive Officer from 1974 through October 1990, except for the year 1978 when he served as Assistant Special Counselor on Inflation for the White House, and in that capacity as Deputy for Ambassador Robert S. Strauss.

From 1953 until 1974, Mr. Kling was in the insurance brokerage business. He founded his own insurance firm in 1965, which was sold in 1969 to a publicly traded manufacturing company, Weil McClain Co., Inc. He remained with the company as Chairman and CEO of the insurance division until 1974, when the company was sold to Reed Stenhouse of Canada. He then continued on a part-time basis for a number of years.

From 1974 to 1977, Mr. Kling served as Finance Chairman of the Democratic National Committee and a member of its Executive Committee. In 1976, he was Treasurer of the Democratic National Convention. He founded and chaired for two years the Democratic Congressional House and Senate Council. He was Co-Chairman in 1977 of the Democratic Congressional Dinner, and in 1982 was the recipient of the Democratic National Committee Distinguished Service Award. He served as National Treasurer of the Carter-Mondale Election Committee, and in 1987-88 Mr. Kling served as National Treasurer of the Gephardt for President Committee.

Mr. Kling was Co-Chairman of the Citizens Committee for the Ratification of the Panama Canal Treaties. In 1979 he served as United States Economic Advisor representing the private sector during the peace negotiations between Israel and Egypt. In 1982-83 he was Co-Chairman of the Coalition for Enactment of the Caribbean Basin Initiative legislation. Mr. Kling serves on the boards of a number of public and private corporations, civic and charitable organizations.

He received the Distinguished Business Alumni Award from Washington University in 1989 and was the Missouri Building & Construction Trade Counsel "Construction Man of the Year" in 1990.

Mr. Kling and his wife, Rosalyn Hauss, have four children. Their residence is at Grayling Farms in Villa Ridge, which is just west of St. Louis, Missouri. He attended New York Military Academy, Cornwall-on-Hudson, New York, and received his B.S.B.A. degree from Washington University in St. Louis. From 1950 to 1952, he served in the Army as a 1st Lieutenant and aide-de-camp to General Buy O. Kurtz. Mr. Kling was born in St. Louis, Missouri on December 22, 1928.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

JAMES B. DAVIS, Commissioner

Biography

In August of 1993, General J.B. Davis concluded a thirty-five year career with the United States Air Force as a combat fighter pilot, commander and strategic planner and programmer. He has served as a commander of a combat fighter wing, of the U.S. Air Force's Military Personnel Center, Pacific Air Forces, and United States Forces Japan. On the staff side, he served as the Director and Programmer of the U.S. Air Force's personnel and training, Deputy Chief of Staff for Operations and Intelligence Pacific Air Forces, and served his last two years on active duty as the Chief of Staff, Supreme Headquarters Allied Powers Europe (NATO).

During his career he has had extensive experience in operations, intelligence, human resource management, and political/military and international affairs. He has commanded a nuclear capable organization of about six thousand personnel and a joint service organization of about sixty thousand personnel and several sizes in between.

In the 1990's, he was deeply involved in the successful multimillion dollar negotiations for support of U.S. Forces in Japan and the Japanese financial support of U.S. Forces in Desert Storm. In NATO, he was the chief negotiator with the North Atlantic Council and the United Nations for NATO's participation in the Yugoslavian conflict.

General Davis has lived overseas for more than ten years almost evenly split between the Pacific and Europe. Because of his official duties, he has traveled extensively to all the ASEAN and NATO countries and many of the Central and Eastern European countries, including Hungary and Albania, meeting with Ministers of State and Defense, Prime Ministers and Presidents.

General Davis has a B.S. degree in Engineering from the U.S. Naval Academy, a Masters degree in Public Administration from Auburn University at Montgomery, and has attended multiple professional schools.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

REBECCA G. COX, Commissioner

Biography

Rebecca G. Cox is currently a Vice President of Continental Airlines, Inc. She joined Continental in January, 1989. In 1993, she served as a Member of the Defense Base Closure & Realignment Commission.

Before joining Continental, Rebecca served as Assistant to the President and Director of the Office of Public Liaison, President Reagan's primary outreach effort to the private sector. She was also appointed by the President to serve as Chairman of the Interagency Committee for Women's Business Enterprise.

Prior to her 1987 White House appointment, Ms. Cox had served as Assistant Secretary for Governmental Affairs at the Department of Transportation. As Assistant Secretary, she was responsible for coordinating legislative strategies and non-legislative relationships between the Department and Congress, as well as ensuring a continuing Departmental program for effective communication and policy development with other Federal agencies, state and local governments and national organizations.

Ms. Cox had previously served at the Department of Transportation as Counselor to Secretary Elizabeth Dole and as Deputy Assistant Secretary for Government Affairs.

Before coming to the Department of Transportation, Ms. Cox worked in the U.S. Senate first as staff assistant, then legislative assistant and, finally, as Chief of Staff to U.S. Senator Ted Stevens. As Chief of Staff, she was responsible for managing the Senator's Alaska staff, the leadership duties of the Office of the Assistant Majority Leader and the oversight of his Subcommittee assignments including those involving the Commerce, Appropriations, and Governmental Affairs Committees.

In 1976, she received a B.A. degree from Depauw University in Greencastle, Indiana and a Juris Doctorate degree from the Columbus School of Law, Catholic University, Washington, D.C. in 1981.

Ms. Cox resides in Newport Beach, California with her husband Chris and their two children.

DEFENSE BASE CLOSURE AND REALIGNMENT COMMISSION
1700 NORTH MOORE STREET SUITE 1425
ARLINGTON, VA 22209
703-696-0504

AL CORNELLA, Commissioner

Biography

Al Cornella is the President of Cornella Refrigeration Inc., a Rapid City, South Dakota firm specializing in commercial and industrial refrigeration. He is a U.S. Navy Veteran with service in Vietnam and has been active in military issues for over a decade.

Cornella has also served on a number of boards and commissions in South Dakota including the Rapid City Chamber of Commerce. During his tenure with the Chamber, he served as Chairman of the Board of Directors from 1991-1992 and as Chairman of the Military Affairs Committee.

In 1992, Mr. Cornella was appointed by former South Dakota Governor George Mickelson to serve on the State Commission on Hazardous Waste Disposal.

Mr. Cornella currently serves on the boards of the South Dakota Air and Space Foundation and the Rapid City Economic Development Loan Fund.

BIOGRAPHY

UNITED STATES AIR FORCE

Secretary of the Air Force
Office of Public Affairs
Washington, D.C. 20330-1690

MAJOR GENERAL GEORGE B. HARRISON

Major General George B. Harrison is commander, Air Force Operational Test and Evaluation Center, a direct reporting unit with headquarters at Kirtland Air Force Base, N.M. He reports directly to the chief of staff of the Air Force on the testing of more than 250 major programs at 20 different locations. He also directs nearly 900 permanent civilian and military personnel. As a member of the test and evaluation community, he works directly with the offices of the secretary of defense and Headquarters U.S. Air Force, Washington, D.C., to ensure that realistic, objective and impartial operational testing is conducted on Air Force systems.

The general entered the Air Force in 1962 as a graduate of the U.S. Air Force Academy. He has commanded a test squadron, tactical training wing, tactical fighter wing, and served as chief of the joint operations division, J-3, Organization of the Joint Chiefs of Staff. Before assuming his current position, the general commanded the U.S. Air Force Air Warfare Center, Eglin Air Force Base, Fla. He is a command pilot, having flown more than 4,300 hours in a variety of tactical aircraft. More than 500 of those hours were flown in combat over Southeast and Southwest Asia.

General Harrison and his wife, Pennie, of Fort Bragg, N.C., are the parents of two daughters and a son.

EDUCATION:

1962 Bachelor of science degree in public policy, U.S. Air Force Academy, Colorado Springs, Colo.
1967 Distinguished graduate, Squadron Officer School, Air University, Maxwell Air Force Base, Ala.
1970 Master of business administration degree, with distinction, Wharton School of Finance and Commerce, University of Pennsylvania, under sponsorship of Air Force Institute of Technology
1974 Armed Forces Staff College, Norfolk, Va.
1979 Air War College, Air University, Maxwell Air Force Base, Ala.
1990 Program for Executives in National Security, Harvard University, Mass.

ASSIGNMENTS:

1. June 1962 - August 1963, student, flight training, Moody Air Force Base, Ga.
2. August 1963 - October 1965, fighter pilot, 557th Tactical Fighter Squadron, 12th Tactical Fighter Wing, MacDill Air Force Base, Fla. (Feb. 1965 - April 1965, temporary duty as O-1F pilot and forward air controller, 2nd Division, Army of the Republic of Vietnam)
3. November 1965 - September 1966, F-4 fighter pilot, 12th Tactical Fighter Wing, Cam Ranh Bay Air Base, South Vietnam
4. September 1966 - April 1969, F-4 replacement training instructor, 4531st Tactical Fighter Wing, Homestead Air Force Base, Fla.
5. April 1969 - December 1970, Wharton School of Finance and Commerce, University of Pennsylvania

Biography
United States Air Force
Secretary of the Air Force, Office of Public Affairs, Washington, D.C. 20330-1000

MAJOR GENERAL KENNETH L. HAGEMANN

Major General Kenneth L. Hagemann is director, Defense Nuclear Agency, Washington, D.C.

General Hagemann was born April 20, 1942, in Holyoke, Colo., where he graduated from Holyoke High School in 1960. He earned a bachelor of science degree in mathematics from Colorado State University in 1964. The general completed Air Command and Staff College in 1979, and Air War College in 1983.

A distinguished graduate of the Reserve Officer Training Corps program, he was commissioned as a second lieutenant in the Air Force in 1964. General Hagemann then attended navigator training at James T. Connally Air Force Base, Texas, and received wings in July 1965. He next was assigned to the Electronic Warfare Officer Training Squadron, Mather Air Force Base, Calif., as an instructor, and a standardization and evaluation examiner.

In July 1969 he entered undergraduate pilot training at Williams Air Force Base, Ariz., and earned pilot wings in July 1970. General Hagemann then was assigned with the Pacific Air Forces in Southeast Asia, where he flew C-123Ks at Phan Rang Air Base, South Vietnam. He flew 115 combat missions in support of allied forces and instructed South Vietnamese air force pilots in C-123K systems during the Vietnamization Program.

He entered combat crew training in B-52s at Castle Air Force Base, Calif., in November 1971. The general subsequently was assigned to the 416th Bombardment Wing, Griffiss Air Force Base, N.Y., serving as a combat-ready co-pilot, aircraft commander, wing bomber scheduler, instructor pilot, and chief of the Standardization and Evaluation Division.

From July 1976 to April 1981 General Hagemann was assigned to Headquarters Strategic Air Command, Offutt Air Force Base, Neb., where he served successively as an action officer, branch chief, and deputy chief of the Bases and Units Division, Directorate of Plans and Programs, Office of the Deputy Chief of Staff for Plans. During that time the general was involved in several significant projects, including the reactivation of Royal Air Force Station Fairford, England; B-52 wartime basing; and B-1 basing. General Hagemann then became commander of the 20th Bombardment Squadron, Carswell Air Force Base, Texas. In August 1982 he entered Air War College.

General Hagemann's next assignment was to Headquarters U.S. Air Force, Washington, D.C., in the Directorate of Plans, Office of the Deputy Chief of Staff for Plans and Operations. He first served as deputy chief of the Strategic Offensive Forces Division. Later he became division chief with the responsibility for the development of the strategic offensive force structure for the Air Force. His division established strategic aircraft and missile force requirements, and coordinated Air Staff actions on nuclear weapons employment policy and force-level considerations for strategic arms reduction negotiations.

(Current as of April 1992) OVER

BIOGRAPHY

UNITED STATES AIR FORCE

Secretary of the Air Force
Office of Public Affairs
Washington, D.C. 20330-1690

BRIGADIER GENERAL CHARLES H. PEREZ

Brigadier General Charles H. Perez is commander, 377th Air Base Wing, Kirtland Air Force Base, N.M. The wing, a major unit of the Air Force Materiel Command and the host organization at Kirtland, supports the nearly 20,500 employees who work for 150 tenant organizations. Major organizations include the Air Force Operational Test and Evaluation Center, Air Force Phillips Laboratory, 58th Special Operations Wing, Defense Nuclear Agency's Field Command, Air Force Safety Agency, Air Force Inspection Agency, Air Force Security Police Agency, U.S. Department of Energy and Sandia National Laboratories.

The general entered the Air Force in January 1968 through Officer Training School, Lackland Air Force Base, Texas, and was commissioned in March 1968. He spent five years as a weapons controller, including a tour in Vietnam, then served as a logistics staff officer and chief of numerous logistics divisions in the Tactical Air Command. From 1982 through 1985 he was the chief Air Force logistician, Joint U.S. Military Assistance Group, Madrid, Spain. He then was assigned as commander of Detachment 19, where he managed the programmed depot maintenance of U.S. Air Forces in Europe-based F-4 and F-15s, and the coproduction of the Spanish air force's and the U.S. Navy's F-18s. In 1988 he became the deputy for Pacific, Asian American and Arabian programs at the U.S. Air Force's International Logistics Center, Wright-Patterson Air Force Base, Ohio. He was assigned to Ogden Air Logistics Center, Hill Air Force Base, Utah, in 1989, where he served successively as director of the contracting and manufacturing directorate, director of the commodities directorate and as vice commander.

General Perez was born in Cuba and moved to Miami in 1956. He and his wife, Miriam of Miami, have a daughter, Renee Nicole.

EDUCATION:

1967 Bachelor of science degree in chemistry, Florida Atlantic University
1974 Master of science degree in systems and logistics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio
1975 Squadron Officer School, Maxwell Air Force Base, Ala.
1977 Air Command and Staff College, Maxwell Air Force Base, Ala.
1978 Education-with-Industry Program, General Dynamics Corp., Fort Worth, Texas
1981 Industrial College of the Armed Forces, Fort Lesley J. McNair, Washington, D.C.
1982 Armed Forces Staff College, Norfolk, Va.
1988 Air War College, Maxwell Air Force Base, Ala.
1991 DOD Program Management Course, Defense Systems Management College, Fort Belvoir, Va.

U.S. Department of Energy
Office of Public Affairs
Washington, D.C. 20585
202/586-3640

BIOGRAPHY

DR. VICTOR H. REIS

Dr. Victor H. Reis has served as the Assistant Secretary for Defense Programs in the U.S. Department of Energy since August 1993. In this position, Dr. Reis directs all aspects of the Department of Energy's post-Cold War nuclear weapons programs. These responsibilities include maintaining U.S. nuclear weapons in a safe, secure, reliable, and environmentally sound manner; dismantling retired nuclear weapons to meet international arms control obligations; providing efficient and forward-looking management of nuclear materials; reducing substantially the size of the nuclear weapons complex to one that is smaller and more cost efficient; ensuring the continued science and technology base of the Nation's nuclear weapons program; and fostering technology transfer through cooperative research and development with academia and the private sector. Dr. Reis was nominated for his position by President Clinton in May 1993 and was confirmed by the U. S. Senate on August 6, 1993.

Prior to accepting his present position, Dr. Reis was the Director of Defense Research and Engineering at the Pentagon, a position he held since late 1991. As Director, Dr Reis was the principal advisor in the Office of the Secretary of Defense for scientific and technical matters, basic and applied research, laboratories, and early development of defense weapons systems. While serving at the Department of Defense, Dr. Reis was also Chairman of the Nuclear Weapons Council and the Strategic Environmental Research and Development Program -- a joint project of the Departments of Defense and Energy and the Environmental Protection Agency.

Prior to assuming the directorship of Defense Research and Engineering, Dr. Reis served as the Deputy Director and then Director of the Defense Advanced Research Projects Agency beginning in December 1989. Dr. Reis also has served as Special Assistant to the Director, Lincoln Laboratory, Massachusetts Institute of Technology; Senior Vice President for Strategic Planning, Science Applications International Corporation; Assistant Director for National Security and Space, Office of Science and Technology Policy, Executive Office of the President; and other positions in industry, academia and Government.

Department of Energy
Albuquerque Field Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

BRUCE G. TWINING

Bruce G. Twining is Manager of the U.S. Department of Energy's (DOE) Albuquerque Field Office.

Appointed to this position in March 1988, Mr. Twining is responsible for field coordination and direction of the nation's nuclear weapons research and development production effort; energy research and development programs; the Waste Isolation Pilot Plant; the Uranium Mill Tailings Remedial Action Project; and the national nuclear weapons materials transportation system.

Prior to his current position, he served as DOE's Acting Deputy Assistant Secretary for Nuclear Materials, Office of Defense Programs (August 1987 to March 1988). Here he was responsible for ensuring that nuclear materials were produced safely and efficiently, in quantities sufficient to meet the nation's requirements, and to assure that defense nuclear wastes were safely handled, treated, stored, utilized, transported, and disposed of to protect the public health and safety.

Mr. Twining also served as Deputy Manager of DOE's Savannah River Operations Office in Aiken, South Carolina (1984 to 1987). Savannah River has been a major nuclear materials production site for the DOE.

Other assignments included Assistant Manager for Energy Research and Technology in DOE's San Francisco Operations Office (SF) (June 1982 to December 1984), and Project Manager of the SF Mirror Fusion Test Facility Project (November 1977 to May 1982).

Mr. Twining began his federal career by participating in the Atomic Energy Commission Intern and Fellowship programs. He held various positions in government reactor development and magnetic fusion research programs (June 1964 to November 1977).

Mr. Twining is a 1963 honor graduate in engineering from California Polytechnic State University, San Luis Obispo, California. In 1970, he earned an M.S. degree in nuclear engineering from the University of Washington in Seattle, Washington, and in 1982, he received an M.B.A. degree from St. Mary's College in Moraga, California.

Mr. Twining and his wife, Becky, have two children, Kimberly and Scot.

July 1992

Al Narath is president, Sandia National Laboratories, a Department of Energy multiprogram laboratory with principal locations in Albuquerque, NM, and Livermore, CA.

Dr. Narath joined Sandia in 1959 as a member of technical staff in the research organization. Following promotions to supervisor, department manager, and director of Solid State Sciences Research, he was promoted to managing director, Physical Sciences, in 1971 and to vice president, Research, in 1973. In 1982 he was appointed executive vice president responsible for Research, Advanced Weapon Systems and Components, and Administration. In April 1984 he transferred to Bell Laboratories, Whippany, NJ, and as vice president of Government Systems, assumed responsibility for all Bell Laboratories systems engineering and development activities for the federal government. He assumed his present position on April 1, 1989.

A native of Germany, Dr. Narath received a B.S. degree in Chemistry from the University of Cincinnati in 1955 and a Ph.D. in Physical Chemistry from the University of California at Berkeley in 1959. He is a member of Phi Beta Kappa and has published approximately 80 scientific papers in the field of solid-state physics. He was elected to the National Academy of Engineering in 1987, is a Fellow of the American Physical Society, and received that society's 1991 George E. Pake Prize.

He is a member of the Defense Science Board; member of the Strengthening of America Commission (Center for Strategic and International Studies); member of the Executive Committee of the National Research Council Board on Physics and Astronomy; member of the Executive Committee of the Superconducting Super Collider Board of Overseers; member of the Critical Technologies Panel of the Competitiveness Policy Council; member of the Leadership Steering Committee of the Agile Manufacturing Enterprise Forum; member of the DOE Energy Advisory Council; member of the New Mexico Council to Advance Math and Science Education; member of the New Mexico Governor's Technical Excellence Committee; member of the University of New Mexico College of Engineering Advisory Council; member of the Coalition to Increase Minority Doctorates; and member of the University of Texas System-Wide Alliance for Minority Participation.

He is a former member of the New Mexico Symphony Board; past member of the Executive Committee of the APS Division of Condensed-Matter Physics; past member of the APS Nominating Committee; former member of the Advisory and Steering Committees, Annual Conference on Magnetism and Magnetic Materials; past member and chair of the Oak Ridge National Laboratory Advisory Board; past member of Brookhaven National Laboratory's Synchrotron Light Source Program Advisory Committee; past chair of Lawrence Berkeley Laboratory's Advanced Light Source Science Policy Committee; past member and chair of the National Research Council's Solid State Sciences Committee; past member of the Major Facilities Study (Seitz-Eastman Panel); past co-chair of the Steering Committee, Materials Science and Engineering Study of the National Research Council; past chair of DOE's Basic Energy Sciences Advisory Committee; past member of the Naval Research Advisory Committee; past member of the Defense Nuclear Agency's Scientific Advisory Group on Effects; and participant on various other government panels and study groups.

July 1992

United States Air Force
AIR FORCE MATERIEL COMMAND
Office of Public Affairs, Phillips Laboratory
3550 Aberdeen Ave SE, Kirtland AFB, NM 87117-5776

DR. R. EARL GOOD

Doctor R. Earl Good is Deputy Director for the Phillips Laboratory at Kirtland AFB NM

Dr Good was born June 2, 1936, in Sterling, Illinois. He graduated from the University of Texas earning a bachelor of science degree in aeronautical engineering in 1958. He holds a master of science in aeronautical engineering from Massachusetts Institute of Technology. He completed a PhD in astro-geophysics in 1974 from the University of Colorado with emphasis on upper atmosphere physics and radiation processes. He graduated from the Industrial College of the Armed Forces in 1980.

In 1960 he became a member of the research staff at the MIT Naval Supersonic Laboratory participating in research on the infrared radiation from missile boundary layers and shock waves, infrared fuses and infrared radiation produced by satellite reentry. In 1963 he joined colleagues in the formation of MITHRAS, Inc pioneering the use of shock tubes and plasma arc facilities to study techniques to alleviate blackout and signatures in missile and satellite reentry.

Dr Good joined the Phillips Laboratory (formerly Geophysics Laboratory) in 1967, participating in numerous rocket experiments to study the upper atmosphere aeronomy and emissions. Dr Good served as the Director of the Stratospheric Environment Program (1974) and the Optical Turbulence Program (1978).

As Director of the Optical and Infrared Technology Division, Dr Good saw the successful launch of the EXCEDE rocket program producing artificial aurora for controlled study of new emission sources. The STS-39 shuttle launch of CIRRIS-1A cryogenic infrared telescope produced new discoveries in the strategic infrared backgrounds. The CIRRIS-1A and the SKIRT shuttle glow payload have yielded unprecedented phenomonology and surveillance knowledge now being applied to Air Force and DoD space systems.

Dr Good is a member of AIAA, AGU, Sigma Xi, and professional societies. He has served as a member of the AIAA Technical Committee on Atmospheric Environment, NASA, and NAS technical panels and federal interdepartmental committees. He was selected for Senior Executive Service, USAF, April 28, 1988.

Dr Good held the position of Director of Geophysics, Phillips Laboratory, from August 1991 until August 1993.

Dr Good assumed his present position as Deputy Director of Phillips Laboratory on 22 August 1993.

UNITED STATES AIR FORCE

AIR FORCE SAFETY AGENCY

COLONEL BERNARD B. BURKLUND, JR.

Colonel Bemard B. Burklund, Jr., is the Commander, Air Force Safety Agency, Kirtland Air Force Base, New Mexico.

Colonel Burklund was bom February 28, 1948, in Newport, Rhode Island, and graduated from Riviera Beach High School, Riviera Beach, Florida, in 1966. He received a Bachelor's Degree in Political Science from the University of Florida and was commissioned through the AFROTC program in December 1970. Colonel Burklund entered Undergraduate Pilot Training (UPT) at Craig AFB, Alabama, and received his pilot's wings in February 1972.

Following UPT, Colonel Burklund completed B-52 Combat Crew Training Squadron (CCTS) at Castle AFB, California and was assigned to the 320th Bombardment Wing, Mather AFB, California in September 1972. From December 1972 until October 1973, Colonel Burklund flew B-52 combat missions in support of the Strategic Air Command's ARC Light/Bullet Shot operations in Southeast Asia. In October 1973, Colonel Burklund returned to Mather AFB and served as a B-52 copilot, aircraft commander, and instructor pilot with the 441st Bombardment Squadron. In April 1977, Colonel Burklund was selected for the Strategic Air Command (SAC)-Air Training Command (ATC) exchange program and was assigned to Williams AFB, Arizona, as a T-38 instructor pilot. From 1977-1981, he served as assistant flight commander, chief of the student branch and UPT school secretary for the 82nd Flying Training Wing and flew over 1100 hours in the T-38.

Following his tour in ATC, Colonel Burklund retumed to SAC and was selected for FB-111 training. He completed the FB-111 CCTS in October 1981 and was assigned to the 528th Bombardment Squadron at Plattsburgh AFB, New York. He served as aircraft commander, instructor pilot, flight commander, and Stan/Eval instructor pilot and accumulated over 1000 flying hours in the FB-111. The tour at Plattsburgh AFB was highlighted by the 528th Bomb Squadron winning SAC's Ryan Trophy for best bomb squadron and the 380 Bomb Wing winning SAC's Fairchild Trophy. While at Plattsburgh, Colonel Burklund earned a Master's Degree in Systems Management from the University of Southern California. He departed Plattsburgh In June 1985 for Offutt AFB, Nebraska.

From June 1985 until July 1988, Colonel Burklund was assigned to the B-1B Division, Aeronautical Requirements Directorate, Deputy Chief of Staff/Plans, Headquarters Strategic Air Command, where he was a B-1B Systems Acquisition manager and helped develop flight performance parameters for integrating the B-1B into the Single Integrated Operational Plan (SIOP). On 19 August 1988, Colonel Burklund returned to fly the FB-111 when he assumed command of the 393rd Bombardment Squadron at Pease AFB, New Hampshire. Over the next two years, the 393rd Bomb Squadron won both of SAC's conventional bombing competitions; 8AF "Duel in the Sun" and 15AF "Shootout," received "Outstanding" on the Operational Readiness Inspection and was awarded the Air Force Outstanding Unit Award.

UNITED STATES AIR FORC

77TH AIR BASE WING (AFMC)

PUBLIC AFFAIRS DIVISION, 2000 WYOMING BLVD SE, KIRTLAND AIR FORCE BASE, N M 87117-5606 (505) 846-59

COLONEL MICHAEL A. CUDDIHEE

Colonel Michael A. Cuddihee is Base Civil Engineer and Commander, 377th Civil Engineer Squadron, Kirtland Air Force Base, NM. On this 52,587 acre base he directs all civil engineering programs, which include the construction, maintenance and repair of 806 major facilities, the operation of utilities services, and plans, budgets, constructs and maintains 2,121 military family houses. He is also the Base Fire Marshall and provides fire protection support to the base, over 150 tenant units and aircraft rescue firefighting (ARFF) support to Albuquerque International Airport. The fire protection value at risk is estimated to be 35 billion dollars. Colonel Cuddihee is also responsible for explosive ordnance disposal, disaster preparedness and prepares the Prime BEEF team for worldwide mobility. The 377th Civil Engineer Squadron has a workforce of over 550 people.

Col Cuddihee was born 14 October, 1949, in Peteboro, NH. He was commissioned into the Air Force in 1971. He is married to the former Vicki Brown of Wendell, ID. They have three children, Tiffany, Alexandra and Patrick.

EDUCATION:

1971 Bachelor of Science Degree in Civil Engineering, Tufts Univ
1980 Masters Degree in Logistics Mgt, Central Michigan Univ
1989 Air War College, Maxwell AFB, AL

ASSIGNMENTS:

Aug 1971-Nov 1974	347 CES, Mountain Home AFB, ID, Chief, Construction Management. 366 CES, Base Facilities Engineer.
Dec 1974-Dec 1975	432 CES, Chief, Programs Division Udorn Royal Thai AFB, Thailand
Jan 1976-Feb 1980	AF Systems Command, Aeronautical Systems Div,. Wright-Patterson AFB, OH. Aero Propulsion Lab Compressor Research Fac.
Jan 1976-Mar 1977	Construction Project Manager
Mar 1977-Mar 1978	A-10 Systems Program Officer
Mar 1978-Feb 1980	F-16 Facilities Systems Program Manager.
Mar 1980-Sep 1982	HQ AFSC, Andrews AFB, MD Exec Officer, Engrg and Services Deputate

AFMC

BIOGRAPHY

UNITED STATES AIR FORCE

377th AIR BASE WING (AFMC)

377th SECURITY POLICE SQUADRON, Kirtland Air Force Base, NM 87117-5527 (505) 846-6122

LIEUTENANT COLONEL DENNIS D. CAVIT

Lieutenant Colonel Cavit is the Commander, 377th Security Police Squadron, Kirtland AFB, NM.

Colonel Cavit was born 12 August 1949 in Wichita, Kansas. He graduated from Westmont Hig School, San Jose, California, in 1967 and enlisted in the Air Force in 1969. He has sinc earned a Bachelor's Degree in Criminal Justice Administration from California Stat University at Sacramento and a Master's Degree in Psychology/Sociology from Pepperdin University. He is also a graduate of Squadron Officer School, Air Command and Staff Colleg and Air War College. Following basic training at Lackland Air Force Base, Texas, he serve as an Electronics Intelligence Specialist at Eielson Air Force Base, Alaska, and as a Dat Computer Repairman at Travis Air Force Base, California.

Colonel Cavit was selected for the Air Force Airmen Education and Commissioning Progra (AECP) in 1973. Following graduation from Sacramento State University Sacramento, California, he attended Officer Training School and received a commission as a Secon Lieutenant in October 1974. Following commissioning, his first assignment was to Cannon Ai Force Base, New Mexico, as Operations Officer for the 27th Security Police Squadron. In Ma 1978, Colonel Cavit was transferred to Charleston Air Force Base, South Carolina, where h served as the 437th Security Police Squadron Operations Officer. He was assigned to Araxos Air Base, Greece, in June 1980, as Chief of Security Police/Officer in Charge of the Custodial Branch for the 7061st Munitions Support Squadron.

Colonel Cavit returned to the United States in July 1981 and was assigned to Headquarters Air Force Office of Security Police, Kirtland Air Force Base, New Mexico, as an Air Staff Training Officer (ASTRA). After a one-year rotational assignment to each directorate within the Security Police Air Staff, he was appointed as Chief, Data Automation Branch, where he directed the development of the Security Police Automation System (SPAS). In November 1984, Colonel Cavit assumed command of the 6960th Security Police Squadron, Kelley Air Force Base, San Antonio, Texas, directing the security efforts of Electronics Security Command (ESC) in safeguarding critical intelligence and cryptologic systems. In August 1986, he attended Air Command and Staff College at Maxwell Air Force Base, Alabama. Following graduation in June 1987, Colonel Cavit became Chief, Security Police Assignments, at the Air Force Military Personnel Center, Randolph Air Force Base, Texas. He was responsible for ensuring the worldwide assignments and professional development of over 1,000 security police officers in the grade of Second Lieutenant through Lieutenant Colonel.

In July 1989, Colonel Cavit became the Director of Information Security for MAC at Scott Air Force Base, Illionis. His duties included the formation of directives and administration for the protection of all classified handled and maintained by MAC.

Colonel Cavit's military awards and decorations include the Meritorious Service Medal with Four Oak Leaf Clusters, the Air Force Commendation Medal, the Air Force Outstanding Unit Award with Two Oak Leaf Clusters, and the Air Force Organizational Excellence Award with One Oak Leaf Cluster. He has been awarded the Master Security Police Functional Badge. He was awarded the 1992 Air Mobility Command Security Police Field Grade Officer of the Year and subsequently, the 1992 The Air Force Security Police Field Grade Officer of the Year Award.

Colonel Cavit is married to the former Erin T. Casey of Northridge, California. They have two sons, Michael and Marshall. (Current as of 1 April, 1993)

STEVEN SCHIFF
FIRST DISTRICT, NEW MEXICO

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BIOGRAPHY OF CONGRESSMAN STEVE SCHIFF
FIRST DISTRICT OF NEW MEXICO

CAREER:

MEMBER OF CONGRESS, 1989-
DISTRICT ATTORNEY OF BERNALILLO COUNTY, NEW MEXICO, ELECTED 1980, RE-ELECTED, 1984.
ASSISTED CITY ATTORNEY AND COUNSEL FOR THE ALBUQUERQUE POLICE DEPARTMENT, 1979-81.
TRIAL ATTORNEY IN PRIVATE PRACTICE, 1977-79.
ASSISTANT DISTRICT ATTORNEY OF BERNALILLO COUNTY, 1972-77.

EDUCATION:

B.A. IN POLITICAL SCIENCE FROM THE UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE, 1968.
J.D. FROM THE UNIVERSITY OF NEW MEXICO LAW SCHOOL, 1972.

SERVICE AND MEMBERSHIPS:

CIVITAN INTERNATIONAL
NEW MEXICO AND NATIONAL DISTRICT ATTORNEYS ASSOCIATION
FORMER PRESIDENT, ALBUQUERQUE LODGE OF B'NAI B'RITH
VOLUNTEER COUNSEL, ALBUQUERQUE HUMANE SOCIETY

MILITARY:

LIEUTENANT COLONEL AND STAFF JUDGE ADVOCATE, NEW MEXICO AIR NATIONAL GUARD. ENLISTED AS AN AIRMAN BASIC, 1969.

PERSONAL:

BORN MARCH 18, 1947 IN CHICAGO, ILLINOIS
MARRIED TO THE FORMER MARCIA LEWIS; TWO CHILDREN, JAIMI, 11, AND DANIEL, 7.

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MARTIN J. CHAVEZ
MAYOR

MARTIN J. CHAVEZ
BIOGRAPHY

PERSONAL

-- Born March 2, 1952, Albuquerque, New Mexico
-- Married to Margaret Chavez de Aragon
  -- Daughter, Martinique Chavez, age 3
  -- Son, Ezequiel (Zeke) Chavez, 10 months
-- Parents, Lorenzo A. Chavez, Esq. and Sara Baca Chavez

EDUCATION

-- St. Charles Borromeo School, grades K - 4
-- Holy Ghost School, grades 5 - 8
-- Van Buren Middle School, grade 9
-- Manzano High School, 1970
-- University of New Mexico, B.U.S., 1975
-- Georgetown University Law Center, J.D. 1978

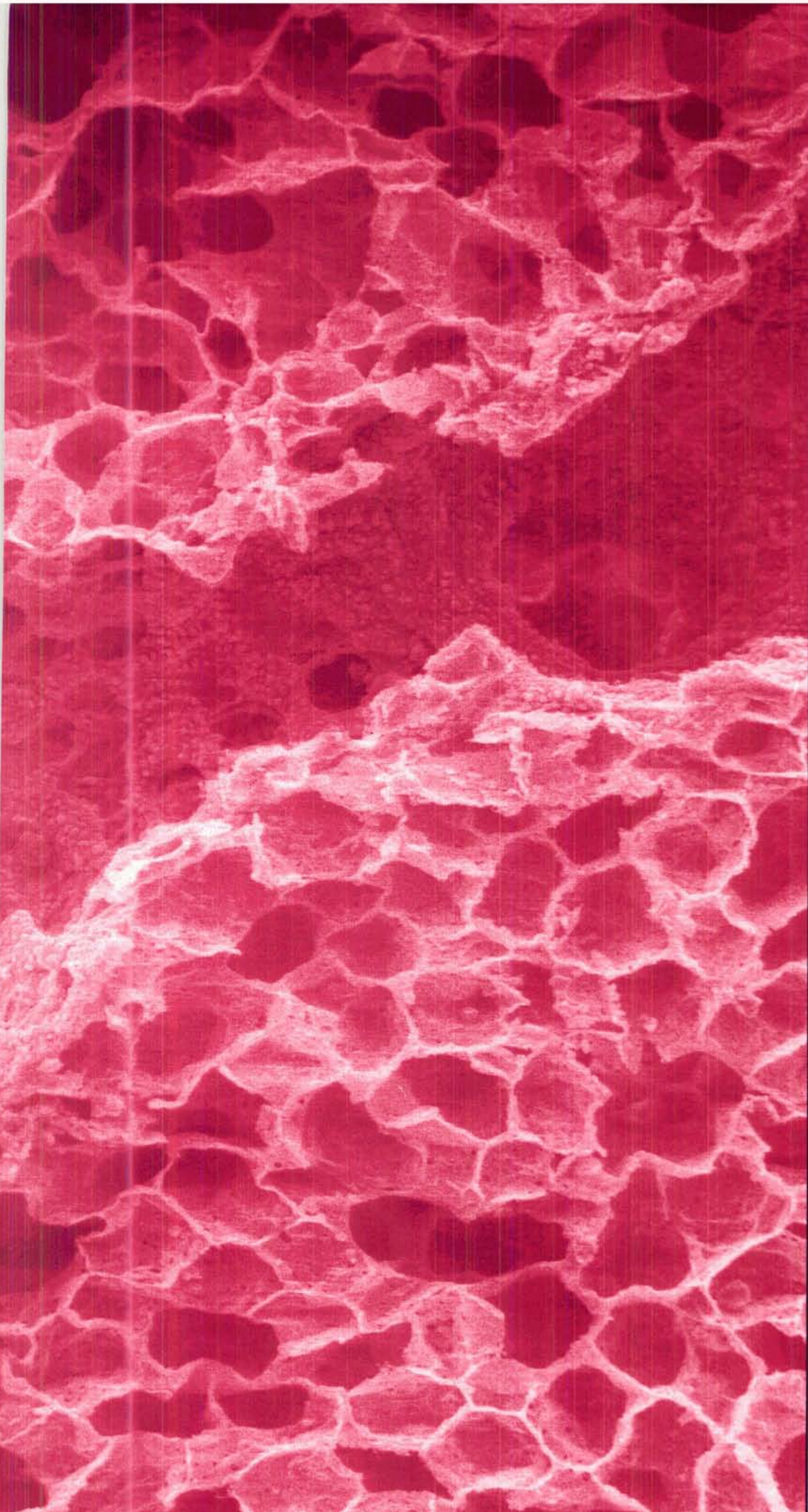
PROFESSIONAL EMPLOYMENT

-- 1976-1977, Staff Assistant, United States Senate, Washington, D.C.
-- 1977-1978, Deputy Director, LULAC National Scholarship Fund, Washington, D.C.
-- 1978-1979, Law Clerk, New Mexico Attorney General
-- 1979-1986, Private Civil Trial Practice, Chavez Law Offices
-- 1986-1987, First and Founding Director, N.M. Workers' Compensation Administration
-- 1987-1993, Private Civil Trial Practice, Chavez Law Offices
-- 1993-Present, Mayor, City of Albuquerque

- FHP of New Mexico, Inc. 1990, Appreciation for Efforts to Improve Quality of Health Care in New Mexico
- Excellence in Education Award, 1990, Friend of Education
- West Mesa Little League, 1989, Appreciation for Support and Dedication
- State Bar of New Mexico, 1989, In Recognition of Public Service
- N.M. Dietetic Association, 1989, Distinguished Service Award
- American Merchant Marines, 1989, Certificate of Appreciation
- Friends of the Albuquerque Petroglyphs, 1989, Award of Appreciation
- N.M. State Senate Memorial 65, 1987, Exemplary Service as First Director of the N.M. Workers' Compensation Administration
- Outstanding Young Men of America, 1984

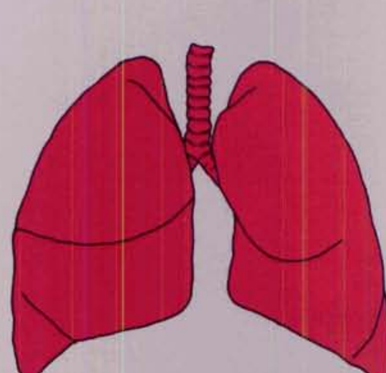
LEGISLATIVE SPONSORSHIPS AND CO-SPONSORSHIPS (Partial list)

- N.M. FOREST RE-LEAF ACT, first statewide tree planting initiative, over one-million dollars worth of trees planted to date
- WORKERS' COMPENSATION REFORM ACT, complete overhaul of workers' compensation act - a compromise between business and labor
- OFFICE OF ECONOMIC ENTERPRISE, one stop shopping for businesses seeking all regulatory, permitting and other requirements for opening or expanding businesses as well as the provision of economic and demographic data to businesses
- CAMPAIGN FINANCE DISCLOSURE, requirement that contributions be reported, even those in off years
- SPOUSAL RAPE, making the rape of spouses illegal
- PLANTING IN MEDIANS AND RIGHTS OF WAY, providing for median and right of way indigenous tree planting by the state
- INSURANCE FRAUD REPORTING, "whistle blower" protection for reporters of insurance fraud
- MOTOR VOTER, allowing New Mexicans to register to vote at the Department of Motor Vehicles
- SMALL BUSINESS GROUP HEALTH INSURANCE, facilitating procurement of health insurance by small businesses
- UNSER BOULEVARD PARKWAY DESIGN, providing for four lane parkway design, reduced speed, truck limitations and landscaping for Unser Boulevard
- MEDICARE SUPPLEMENT ACT AMENDMENTS, providing for uniform coverage for senior citizens
- ABSENTEE VOTING, allowing New Mexicans to vote early by absentee ballot for any reason
- POST CARD VOTER REGISTRATION, allowing New Mexicans to register to vote by post card
- CHILDREN'S TRUST FUND INCOME, reauthorizing funding for the Children's Trust Fund which addresses child abuse and neglect problems
- FELONY CONVICTION FINES, increasing fines for white collar felonies
- PINON-JUNIPER ECOSYSTEMS, encouraging preservation and development of pinon trees and production as a cash crop



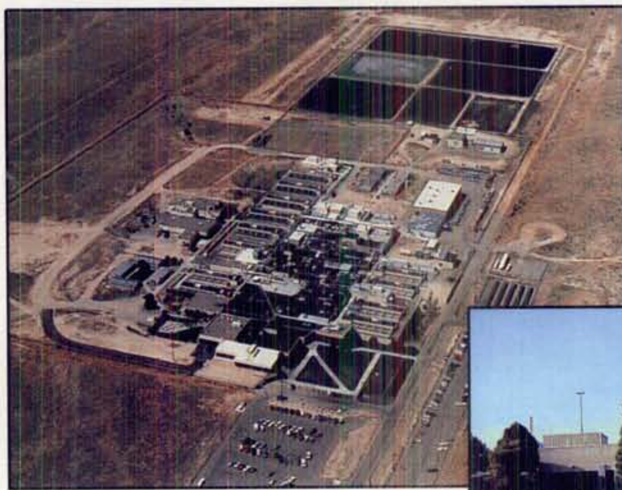
ITRI

INHALATION TOXICOLOGY RESEARCH INSTITUTE



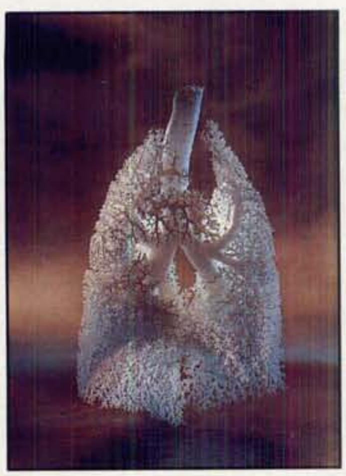
ITRI

The Inhalation Toxicology Research Institute (ITRI, pronounced "I-try") is a Federally Funded Research and Development Center that serves as an international research resource for government and industry. The facilities are owned by the Department of Energy (DOE) and staffed and operated by the private, non-profit Lovelace Biomedical and Environmental Research Institute, Inc., a subsidiary of Albuquerque's Lovelace Medical Foundation.



The Institute began in the early 1960s as a joint effort between the Lovelace organization and the Atomic Energy Commission to assemble a research team for determining the long-term health impact of inhaling radioactive particles. This team and the facilities it occupies have evolved to become a premier center for inhalation toxicology and associated fields. Today, ITRI is broadly recognized for its expertise in aerosol science, toxicology, radiobiology, respiratory tract structure and function, dosimetry and metabolism of inhaled agents, and the pathogenesis of cancerous and non-cancerous respiratory disease.

Mission



ITRI is dedicated to protecting human health by conducting basic and applied research to improve our understanding of the respiratory tract and the health effects that might occur in humans from inhaling airborne toxicants in the home, workplace, or environment. The Institute's tripartite mission includes research, education, and technology transfer. Its primary goals are to conduct high quality, unbiased research and to link laboratory results with epidemiological findings in order to identify, define, and reduce human health risks. The Institute is oriented toward collaborating with other

scientists, developing research partnerships with industry for problem solving and technology transfer, and serving the scientific community through advisory roles, leadership in professional societies, and research training.

ITRI fills a unique scientific niche that complements resources in universities, industry, and testing laboratories. The uniqueness of the Institute stems from its combination of diverse and highly qualified staff and its specialized facilities. A hallmark of ITRI is its ability to readily assemble multidisciplinary teams of internationally recognized investigators in order to develop research strategies and address sponsor needs. The ITRI staff serves freely as a resource of information and advice. ITRI is oriented toward building bridges between the biological and physical sciences, basic and applied research, animal and human research, and hazard identification and risk assessment. ITRI

management and staff place high value on communicating, collaborating, and integrating study results into the broader context of solving problems and minimizing health risks.

No classified research is conducted at the Institute, and the staff is oriented toward rapid publication of research results; however, confidentiality is maintained to suit sponsor needs.

Unique Scientific Strengths

The breadth of ITRI's capability for integrative research is unmatched in the field of inhalation toxicology and pulmonary disease research. At ITRI, a broad spectrum of clinical and bioassay capabilities coexists with capabilities for working with innocuous and hazardous materials of all types, expertise in evaluating airborne materials, dosimetry and toxicokinetics, health effects from the molecular level to the intact individual, and risk assessment.

Some of ITRI's most broadly recognized scientific strengths include:

Basic aerosol science, air sampling technology and monitoring strategies, evaluation of the generation of airborne materials from environmental sources, industrial processes, and waste handling.

Generation and delivery of aerosols, gases, and vapors for experimental and medical applications, and for testing and demonstration of instrumentation.

Novel and conventional methods for acute to chronic inhalation exposures of all laboratory animals to all physical forms of hazardous and nonhazardous chemicals and radionuclides, including the use of chemical and radioactive tracers.

Routine and novel clinical evaluation and treatment of laboratory animals by procedures applied in human clinical medicine, including clinical

pathology, cardiorespiratory physiology, immunology, x-ray and gamma imaging, bronchopulmonary lavage and endoscopy, and cellular and molecular assays.

A genetically defined dog colony with an ongoing breeding program, multigeneration capability, and broad age availability.

Dosimetry and toxicokinetics of chemical and radioactive agents using tissue and fluid sampling, metabolic collections, radiotracer

ITRI

studies, extensive analytical and radioanalytical capability, and computer modeling and simulation.

Cellular and molecular biology of cancerous and noncancerous responses, including access to animal and human tissues, tissue culture and banking capability, cytotoxicity and transformation assays, transplant and repopulation studies, and routine and novel molecular biology approaches for relating gene alterations to disease development.

Experimental pathology, including necropsy, microdissection and cell isolation, routine and special fixation techniques, qualitative and morphometric light and electron microscopy, slide preparation with routine and special stains, histochemistry, immunohistochemistry, autoradiography, and in situ hybridization.

Commitment to quality assurance and quality control with incorporation of Good Laboratory Practices (GLP) principles in all studies and the capability for full GLP compliance as required.

Staff

The approximately 180 full-time employees of ITRI include a research staff of about 30 principal investigators and 60 technicians who encompass a broad range of disciplines and experience including aerosol science, chemistry, toxicology, cellular and molecular biology, radiobiology, pathology, veterinary medicine, biomathematics, and risk assessment. The research is supported by an animal care staff of approximately 20 and the full range of administrative support staff. The hallmarks of the staff are its diversity, qualifications, motivation and productivity, orientation toward excellence, readiness to communicate and collaborate, and culture of teamwork that not only crosses disciplinary lines, but also bridges between the research and support staff.

The combined professional expertise and outstanding individual qualifications of the ITRI staff constitute a remarkable resource. ITRI scientists are highly visible in the scientific mainstream and have a strong reputation for scientific credibility. They hold over 50 positions on national and international advisory boards, review panels, and study sections, 15 positions as scientific editors or on editorial boards of scientific journals, and numerous offices in leading professional scientific societies.

Professional certifications include the American Board of Toxicology (6), American Board of Veterinary Toxicology, American College of Pathologists, American College of Veterinary Pathologists (3), American Board of Health Physics (2), American Board of Industrial Hygiene, American Academy of Microbiology, and American College of Laboratory Animal Medicine. Most ITRI researchers have at least one academic appointment and are active lecturers and graduate and postdoctoral mentors.

Facilities

ITRI encompasses 290,000 square feet of laboratory, office, animal housing, clinical, and research support space with a replacement value of over $62M and containing capital equipment valued at over $14M. The Institute is located on a 40-acre site near Albuquerque, NM. These resources include:

State-of-the-art facilities for the housing, care, and breeding of over 1000 dogs, 10,000 rodents, and other species of all sizes.

Inhalation exposure facilities for acute to life-span exposures of all species by whole-body, nose-only, or intra-airway routes to innocuous, hazardous, and radioactive airborne materials in all physical forms, including single agents and mixtures such as tobacco smoke and engine exhaust.

Specialized aerosol laboratories supporting inhalation studies, basic and applied laboratory research, and field studies, including environmental chambers, wind tunnels, exhaust dilution tunnels, and respiratory tract casts and models.

A well-equipped veterinary clinic for examination and treatment of animals, including clinical chemistry and microbiology laboratories, x-ray and gamma imaging, surgery, respiratory physiology, electrocardiology, electroencephalography, and bronchoscopy.

High-capacity necropsy and histopathology laboratories, light and electron microscope suites, and facilities for video imaging and image analysis.

Cellular and molecular biology laboratories with capability for tissue and cell collection and banking, flow cytometry, cell and tissue culture, and tumor transplantation. DNA, RNA, and protein evaluations, including gel and capillary electrophoresis, PCR, DNA adduct analysis, fluorescent microscopy, and immunocytochemistry.

Analytical organic and inorganic chemistry and radiochemistry laboratories.

Facilities and procedures for the safe collection, segregation, packaging, and temporary storage of all research-generated chemical and radioactive wastes in compliance with DOE, EPA, and state regulations, and for onsite disposal of uncontaminated biological wastes.

Quality assurance facilities including data and experimental sample archives and instrumentation calibration laboratories with traceable standards.

An extensive research library containing 280 journal subscriptions, 10,500 bound journals, 10,000 books, and 20,000 documents, with full on-line search capability.

ITRI

Animal Care and Use

ITRI management and staff are deeply committed to the humane care and proper use of laboratory animals. All protocols involving animals are reviewed and approved by the Institute's Animal Research Committee, composed of staff at all levels and a non-employee community member.

The Institute has maintained full accreditation by the American Association for the Accreditation of Laboratory Animal Care since 1971, is registered under the Animal Welfare Act (Reg. No. 85-R-003), and is in full compliance with the Act's provisions. All animals are maintained and used according to the recommendations in NIH Publication 85-23, "Guide for the Care and Use of Laboratory Animals." ITRI has an approved Public Health Service Animal Welfare Assurance (NIH Assurance No. 3083-01).

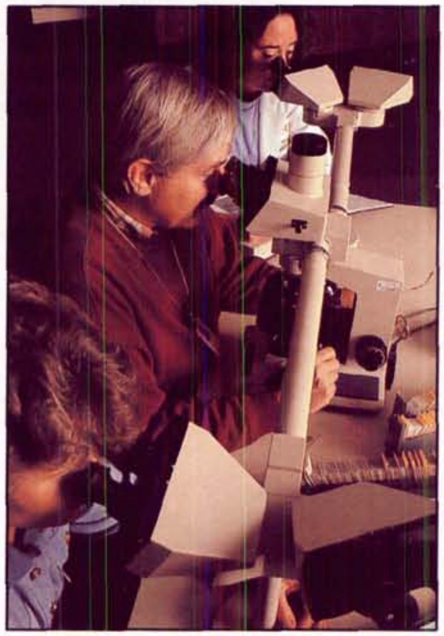
Quality Assurance

ITRI holds an excellent reputation for scientific integrity and for the quality of its research and the resulting publications, and presentations. The Quality Assurance (QA) Unit, reporting to the Director, administers a comprehensive site-wide QA program, integrating a culture of quality into research and support operations alike. All studies are conducted in the spirit of Good Laboratory Practices (GLP) and in strict accordance with FDA or EPA GLP regulations as required. All research is conducted under approved, rigorously reviewed protocols. Standard operating procedures and calibration logs are in place. Research and results are recorded using standardized notebooks, forms, and electronic media, and both data and experimental samples are archived as needed. The QA Unit conducts critical phase inspections, data audits, and report audits according to a QA plan developed for each study.

Stewardship of the Environment and Human Safety

Safeguarding the safety and health of staff and avoiding adverse impacts on the environment are top priorities at ITRI. The Health Protection Operations (HPO) Unit, reporting to the Director, provides direction and oversight to ensure that research and support activities are in compliance with applicable regulations and good practices. The HPO Unit maintains progressive programs in health physics, industrial hygiene, environmental compliance, laboratory safety, and emergency preparedness to meet requirements of DOE, OSHA, state, and local regulations. Located 10 miles from the nearest residential area, and isolated from other nonresidential facilities, ITRI presents no offsite contamination hazards. Hazardous and radioactive wastes are managed according to RCRA and DOE regulations. All hazardous wastes are shipped offsite to EPA-permitted disposal facilities. ITRI participates actively in the DOE Environmental Restoration and Waste Management Five-Year Plan, ensuring identification and remediation of contaminated sites and safe management of current waste streams.

Educational Programs



ITRI takes pride in its broad involvement in education and serves as a key national research training resource. Long a Lovelace tradition, education is now also a DOE mission, lending a strong element of academia to the ITRI culture. Educational programs are aimed at all levels, from elementary school to senior scientists. Individuals and organizations interested in ITRI educational programs are encouraged to contact the Institute.

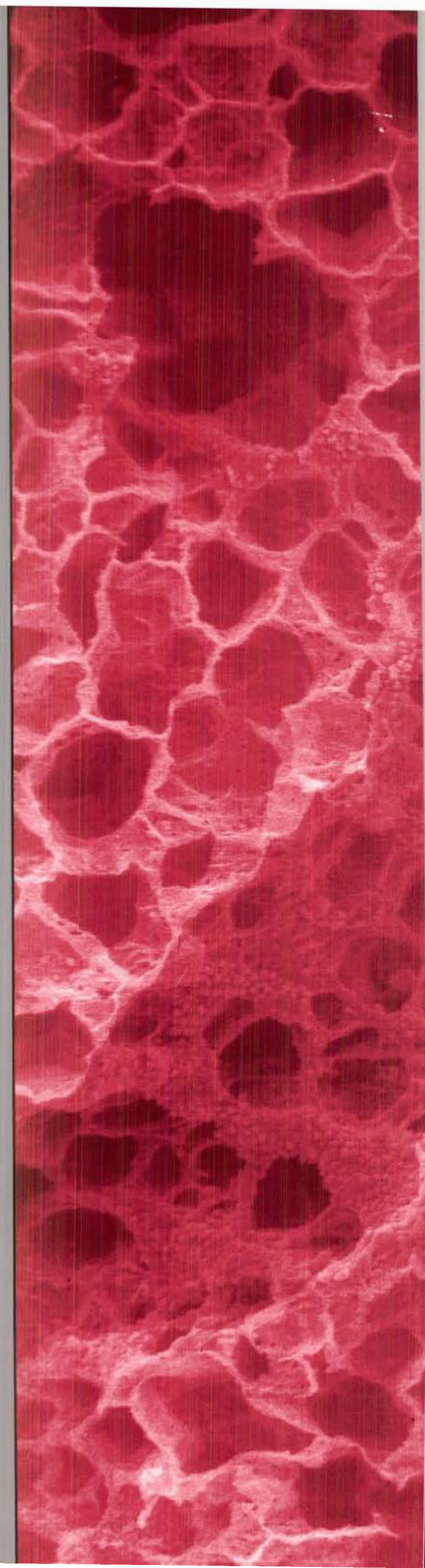
ITRI has a long reputation for the high quality of its summer research internship programs which engage participants as true co-investigators in studies from experimental design to reporting of results. Over 570 individuals have participated in summer programs aimed at minority high school students, undergraduate university students, and secondary school science and math teachers.

With the University of New Mexico (UNM) College of Pharmacy, ITRI conducts a doctoral-granting graduate program in inhalation toxicology that is funded by the Lovelace-Anderson Endowment Foundation, the DOE, and industry sponsors. The combined ITRI-UNM toxicology programs constitute one of the larger toxicology graduate training centers in the US. Students entering with bachelors, masters, and professional degrees conduct research at ITRI in selected areas of focus and complete coursework at UNM.

ITRI is also active in postgraduate training. Postdoctoral fellowships are offered in all of the Institute's scientific disciplines. The Institute also hosts pulmonary fellows for research training and visiting scientists on sabbatical leave or other temporary collaborative or training assignments.

Opportunities for Research Sponsorship

As a Federally Funded Research and Development Center (FFRDC), ITRI is available to conduct research for all government and industry sponsors. Although the largest single sponsor is DOE, ITRI research is funded by other agencies, private industry, and industry and government-industry consortia. Non-DOE government sponsors fund ITRI research through interagency agreements and grants, while non-government sponsors fund research through contracts and Cooperative Research and Development Agreements (CRADAs). FFRDCs are not allowed to submit bids or respond competitively to Requests for Proposals (RFPs), but may respond to Requests for Applications (RFAs) or to sole-source inquiries. ITRI collaborates in research under grants and contracts with other institutions through subcontracts. We invite inquiries about research needs.



Inhalation Toxicology Research Institute
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Exploring Virgo's Galaxies

Solar Eclipses That Changed the World

Adaptive Optics: Straightening Starlight

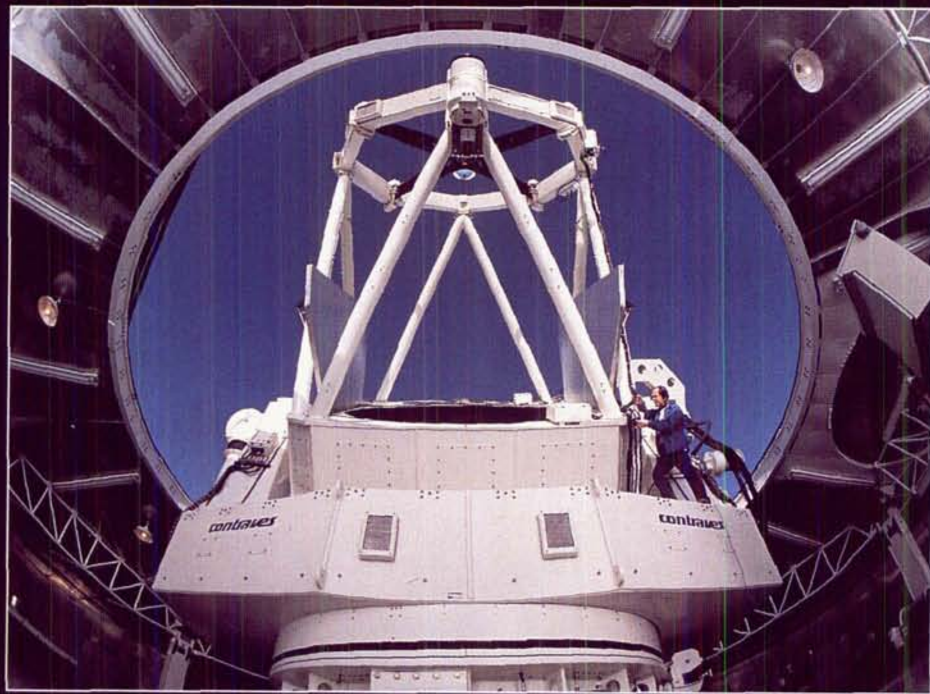
Adaptive-Optics Guru
Robert Fugate

Recently declassified experiments in adaptive optics offer astronomers new weapons against an old bugaboo: bad seeing.

Untwinkling the Stars–

By Robert Q. Fugate and Walter J. Wild

Photograph by Roger H. Ressmeyer



Twinkle, twinkle, little star,
How I wonder what you are!
Up above the world so high,
Like a diamond in the sky. . . .

WE ALL KNOW this little children's rhyme, which recalls how a twinkling star can be pretty, even romantic to behold. When it comes to serious work, however, astronomers are not inclined to be romantic. The twinkling is caused by the Earth's atmosphere, which, even on the clearest and most transparent of nights, is constantly in a state of turmoil.

Throughout the centuries, telescopes have had to cope with the atmosphere — so necessary for life but a hindrance for astronomers. In fact, while the largest telescopes in the world collect a lot of light, they typically cannot resolve double stars or the divisions in the rings of Saturn any better than a humble 6-inch reflector. For cosmological studies a mere hundred miles of atmosphere ruins untold light-years of flawless wave propagation through intergalactic space!

The culprit is the presence of random temperature variations in the air, causing slight local changes in its refractive index. Turbulent pockets of air act like little transient lenses, redirecting portions of the incoming plane wavefronts from a star. When focused by a telescope the star's image becomes a spread-out blob that churns and boils, frequently flaring out and perhaps occasionally settling down.

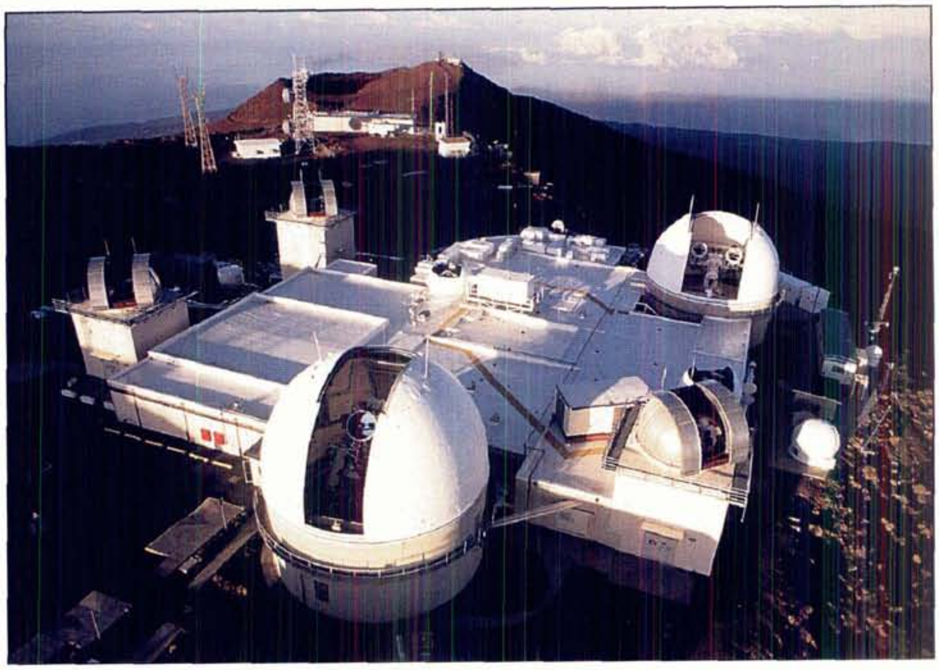
Each distorted wavefront consists of many contiguous segments whose sizes are governed by those of the cells of turbulence. A crinkled piece of chicken wire offers a good analogy. The whole thing is certainly distorted, yet the individual openings remain flat — they are merely tilted in a random fashion relative to their neighbors.

An emerging technology called adaptive optics will soon revolutionize ground-

—Part I

***Facing page:* High over the Starfire Optical Range in New Mexico, beams from powerful copper-vapor and sodium lasers converge at a point in Draco where the 1.5-meter telescope (large dome) is aimed. During much of the last decade the technique remained a military secret of the U. S. Strategic Defense Initiative, but soon it will help astronomers gain views of the universe with a clarity hitherto impossible with ground-based telescopes. In February, this photograph won first-place awards from both the World Press Photo Foundation and the University of Missouri/NPPA Pictures of the Year competition. All photographs on pages 24–26 are ©1994 Roger H. Ressmeyer–Starlight/MP©A.**

***Above:* Starfire's new 3.5-meter reflector, which saw "first light" on February 10th of this year, may soon offer celestial views that are sharp right down to the instrument's 0.04-arc-second diffraction limit. Next to the primary mirror cell and surrounded by the open-air, retractable dome is range director and coauthor Robert Q. Fugate.**



Above: **Photographer Roger Ressmeyer recorded a nightful of laser-beam experiments at Hawaii's Haleakala Crater in this time exposure from an adjacent air-traffic-control tower.**

Left: **Long cloaked in secrecy, the domes at Science City on Haleakala greet the sunrise in this Ressmeyer photograph.**

based astronomy. It will enable astronomers to attain full diffraction-limited performance — almost as if corrective eyeglasses were placed upon their telescopes. Features 10 to 100 times smaller than are currently observed from Earth will be clarified, whether the target is a comet's nucleus, a chunky asteroid, distant interacting galaxies, or the heart of the Milky Way.

Adaptive optics work by what is popularly termed a "rubber mirror" — a reflector inserted in the telescope's light path that can rapidly alter its shape to counteract the distortions of the atmosphere. The most common design employs a thin faceplate mounted on an array of pistons. In effect, this deformable mirror flattens the chicken wire out again.

But how can a high-speed computer controlling a deformable mirror get the information it needs to undo the distortions? That central question has occupied many teams of researchers for more than two decades. A bright star readily furnishes its own beacon, or reference wavefront, but an extended object like a planet or nebula generally will not suffice. Unfortunately, most natural point sources (stars) are much too faint to provide sufficient signal levels for an adaptive-optics system to drive a deformable mirror effectively.

Furthermore, the angle over which light from astronomical bodies encounters essentially the same atmospheric turbulence is only about 2 arc seconds at visible wavelengths. This small cone of sky is called the *isoplanatic patch*, a fundamental limit on how big an image area the adaptive optics can fully correct at any one time. The size of the patch increases with wavelength, so a larger area of sky can be corrected in infrared than in visible light.

Two arc seconds is an incredibly small angle — equal to the separation of a car's headlights seen 100 kilometers away — giving some idea of what we are up against when dealing with the atmosphere. Not only does an astronomical image change randomly on a time scale of milliseconds, but in a very short exposure that freezes the turbulence even stars 10 arc seconds apart will look totally different!

Despite these seemingly overwhelming difficulties, scientists were making steady progress in their quest for suitable wavefront correctors when a bit of serendipity in Hawaii profoundly enhanced the prospects for a workable adaptive-optics system.

THE LASER BEACON

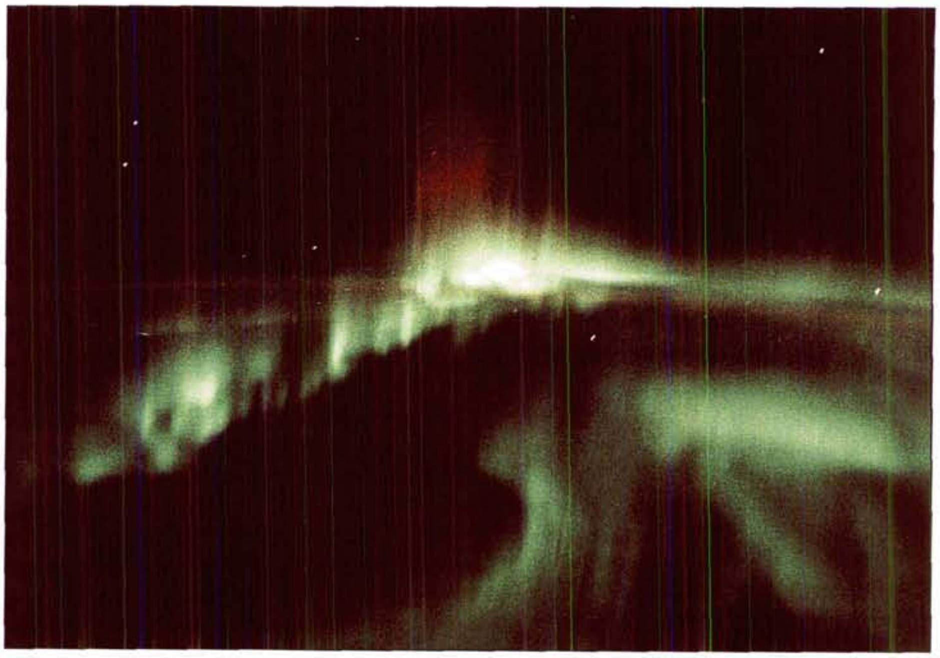
Back in the summer of 1981 Julius Feinleib, president of Adaptive Optics Associates in Cambridge, Massachusetts, happened to visit the U. S. Air Force's Maui Optical Station at Haleakala Crater in Hawaii. He observed some lidar (light detection and ranging) experiments that used a laser beam transmitted by one of the telescopes there. He also knew that the Defense Advanced Research Projects Agency (DARPA) of the Department of Defense was interested in the use of adaptive optics for viewing faint military targets, and that Richard Hutchin (Itek) and Donald Hanson (Air Force Rome Development Center) were already at work on this problem. Indeed, the Rome-Itek team had built the Compensated Imaging System in use on the Maui 1.6-meter telescope.

As Feinleib watched the pulsed laser beam shooting into the night sky, a concept jelled. Why not use this beam as a kind of probe by which an adaptive-optics system could measure the atmospheric distortions independently of the object being viewed?

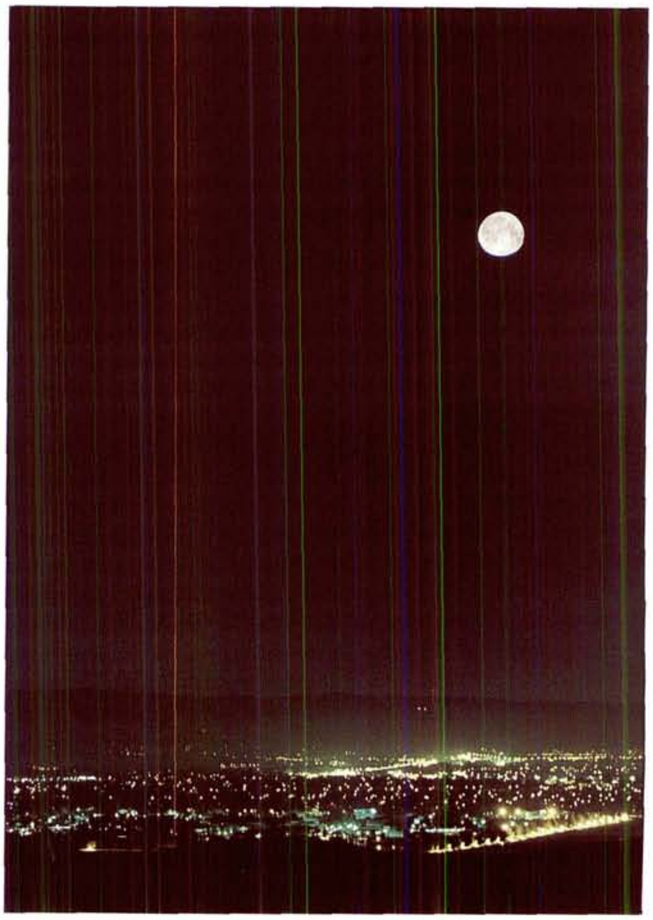
In October, after refining his concept, Feinleib prepared a proposal for further development. Rett Benedict at DARPA was interested in the idea and called a meeting of researchers to discuss it. Among those attending was David L. Fried, a major contributor to our understanding of atmospheric turbulence and astronomical seeing.

Fried was initially skeptical of the concept, which involved focusing a laser to create a point source in the lower atmosphere that would be visible by the mechanism of Rayleigh backscatter from air molecules. While this artificial source could be positioned almost exactly in any desired line of sight (that is, on virtually any celestial target), it would not sample the air turbulence *beyond* the beacon and would therefore lead to incomplete compensation at best. Nevertheless, the very night after that pivotal meeting, Fried burned the midnight oil and derived the equations needed to predict how well such an artificial beacon would work.

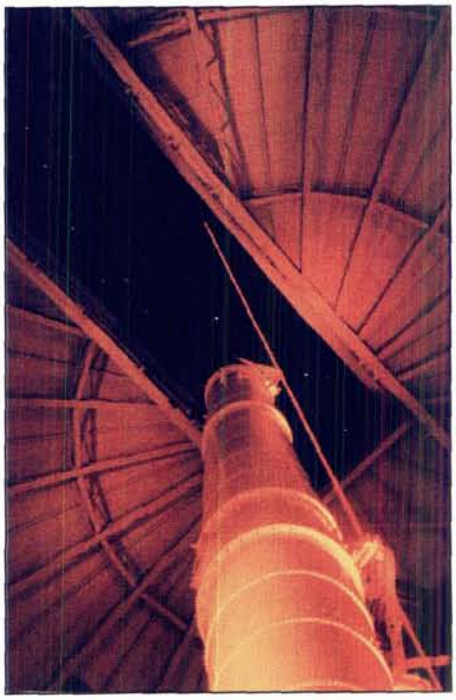
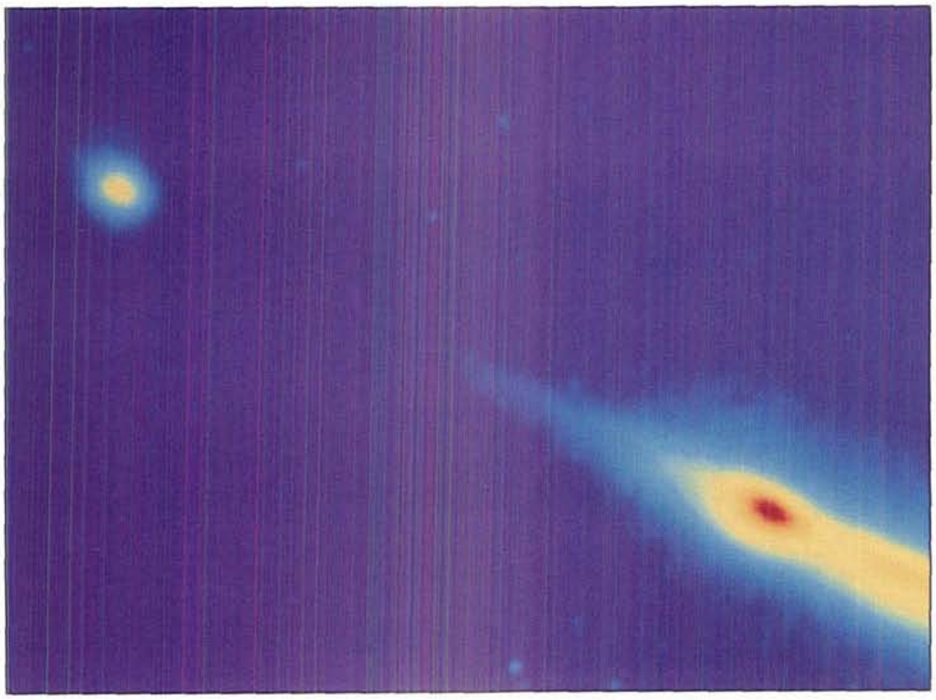
Over the next several months Fried set about evaluating the complicated mathematical integrals in the theory. When he and colleague John Belsher completed this work they found that the wavefront-sensing error, due mainly to the finite range of the laser beacon, should increase with the aperture of the viewing telescope. Even so, their results predicted the beacon *should* be useful for adaptive optics. The engineers and scientists at Adaptive Optics Associates began to de-



During the September 1992 flight of Space Shuttle *Endeavour*, astronaut Jay Apt captured this view of the aurora australis with its green curtains and reddish fringe. The faintly visible yellow arc curving along the Earth's limb is the thin layer of sodium atoms roughly 90 kilometers up that offers astronomers such promise for laser-controlled adaptive optics. Photograph courtesy NASA/Starlight.



A beam rises skyward over California from one of the world's most powerful dye lasers. Each such test, conducted by the Lawrence Livermore National Laboratory to produce a sodium "guide star," attracts wide notice in the local press. To make this photograph Joe Galkowski opened his camera for 10 minutes and captured the laser beam and lights of Livermore Valley, then added the Moon in a separate brief exposure.

Left: In their experiments with a half-watt dye laser in 1992, University of Chicago astronomers used the Yerkes 40-inch refractor to view the return when the laser beam was sent skyward through the piggyback 5-inch guidescope. Photograph by Walter Wild. _Right:_ In this highly foreshortened side view of the return, the streak at lower right is produced by low-altitude Rayleigh backscatter and becomes most intense (red spot in this false-color image) when at 23 kilometers the beam encounters volcanic dust that was lofted by Mount Pinatubo in 1991. Farther up the backscatter fades in the rarefied air. Finally, at upper left the expected 12th-magnitude guide star appears as the laser beam excites free sodium atoms in the mesosphere.

velop the hardware required to test this prediction.

By the summer of 1982 there was considerable excitement in the defense community about the laser-beacon concept. When a special advisory group held its annual meeting in La Jolla, California, Fried and other atmospheric scientists were invited to discuss the subject. Princeton University's Will Happer, a member of the group that reviewed the theory, expanded the concept by suggesting an entirely new source for the artificial beacon: the free sodium atoms located some 90 km (60 miles) high in the layer of the upper atmosphere called the mesosphere. Situated outside nearly all the Earth's air, such a beacon would offer much better wavefront sensing than a low-altitude Rayleigh beacon.

If a laser could be built to resonate at the wavelength of one or both of the yellow sodium D lines in the visible spectrum, Happer realized, it would excite those atoms. The light they then emitted would become an ideal beacon for adaptive optics.

THE FIRST BEACON TRIALS

With the stage thus set, DARPA's Benedict immediately sponsored two experiments — one to test the Rayleigh concept and the other to try out the sodium layer. The first was carried out by the Air Force Phillips Laboratory at the Starfire Optical Range near Albuquerque, New Mexico. The sodium experiment was designed at the Massachusetts Institute of Technology's Lincoln Laboratory and conducted at White Sands Missile Range, also in New Mexico.

The purpose of the Rayleigh experiment was to find out whether the laser-beacon concept would work at all, and then to verify Fried's theoretical predictions. Researchers pointed a laser at a bright star and fitted a 40-centimeter viewing telescope with a mask having 18 small openings. The real star and the artificial "guide star" permitted simultaneous measurement of the two wavefronts. Even without bringing adaptive optics into play, we would learn whether the wavefront distortions from the two very different point sources were similar enough for the technique to work. Performed in the summer and fall of 1983, this experiment definitively confirmed Fried's theory. The results were reported to an audience of nearly 200 people at a classified conference held in February of 1984.

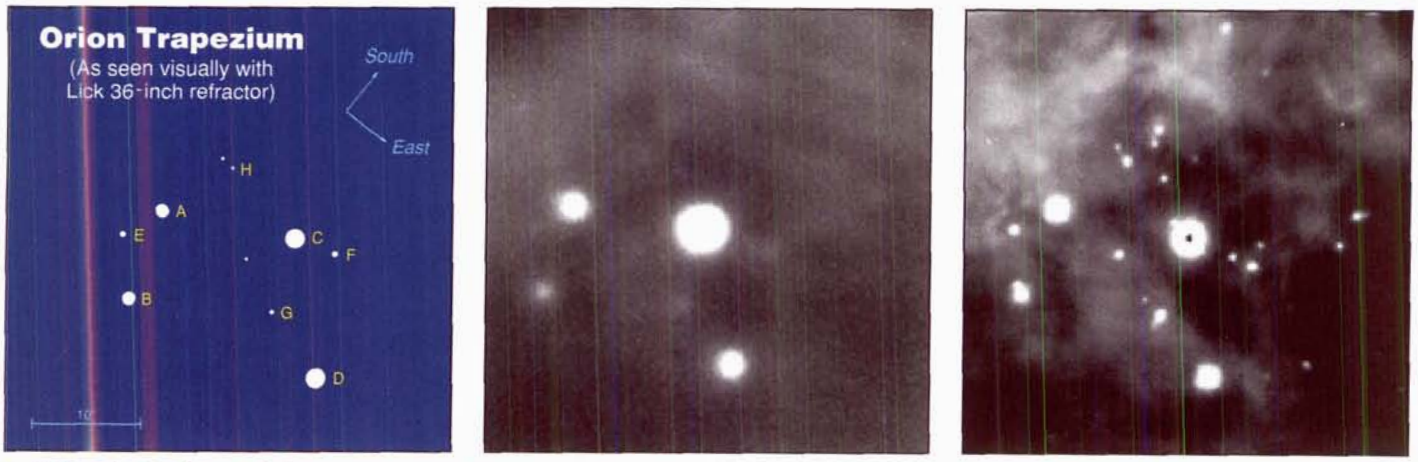
The Lincoln Lab sodium experiment used just two subapertures separated by 76 cm and compared the tilt differences between them when focusing on a sodium laser beacon and a bright star. Completed in early 1985, this test confirmed that the error incurred by using such an artificial beacon decreases as its altitude gets higher, just as Fried's theory said it should.

These two pioneering experiments validated our understanding of the physics and established the limitations of using a single, focused laser beam as an artificial beacon for adaptive optics.

ASTRONOMERS DISCOVER THE LASER-BEACON CONCEPT

Independently of the work being done by the U. S. Department of Defense, two French astronomers, Renaud Foy and Antoine Labeyrie, introduced the laser-beacon concept in a letter published in *Astronomy & Astrophysics* in the summer of 1985. They discussed the use of both Rayleigh and sodium beacons for astronomical seeing correction. Since that time a number of civilian groups in both the United States and Europe have gotten into the act. They include astronomers in France, at the European Southern Observatory in Germany, and at the Universities of Illinois, Chicago, and Arizona, as well as the Lawrence Livermore National Laboratory in California.

While the experimental results of these groups have lagged considerably behind those of the defense community, the latter began making information and hardware available to assist astronomers in their particular applications. Laird Thompson and Chester Gardner (Uni-



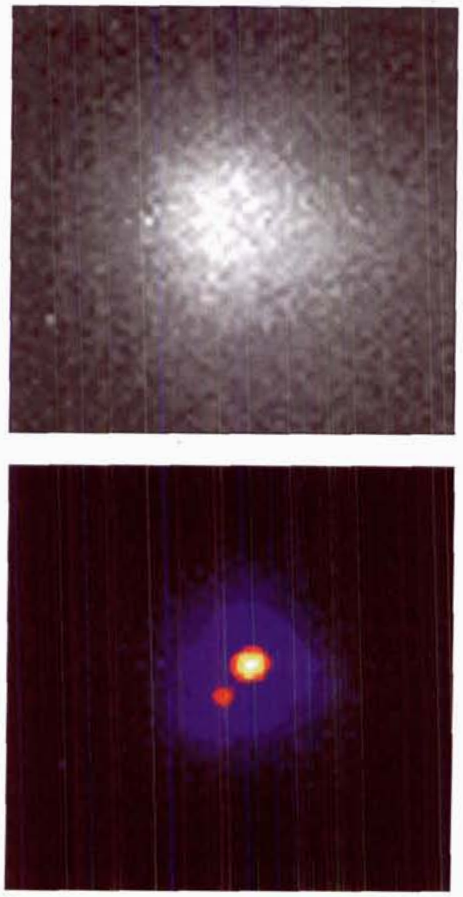
Left: Deep in the heart of the Orion Nebula, the famous Trapezium is a tight clump of four stars visible in modest telescopes and commonly denoted A, B, C, and D. In 1889 S. W. Burnham identified the six additional companions marked here, a few of which taxed even the most skilled observers using the 36-inch Lick refractor. *Center:* Because of glare from the brighter stars and unsteady air, conventional photographic or electronic techniques seldom do much better on this difficult object, as illustrated by this image taken with the Starfire 1.5-meter reflector in 3-arc-second seeing. *Right:* This laser-compensated Starfire view is a spectacular improvement. In a 4-minute exposure made in red hydrogen-alpha light, the adaptive-optics system has sharpened the entire 40-arc-second field, but the correction is best near the C component at which the laser was aimed. This luminous star is believed responsible for the faint "comet tails" — ionized gaseous envelopes — that project away from a few of the surrounding stars. Peter McCullough (University of Illinois) suggested the observation, which is discussed in a paper submitted to the *Astrophysical Journal.*

versity of Illinois) generated a sodium laser beacon at Mauna Kea, Hawaii, in 1987 and photographed it in an 8-minute exposure with the 2.2-meter University of Hawaii telescope. While their beacon was too weak and too unfocused to be useful for adaptive optics, it did verify the concept and the expected strength of the return signal.

Thompson also succeeded in generating high-quality Rayleigh laser beacons more than 15 km above the 1-meter Mount Laguna telescope in California, using an excimer laser operating at the ultraviolet wavelength of 3510 angstroms. A team of French workers has done similar Rayleigh-beacon experiments with the 1.52-meter telescope at the Observatoire de la Côte d'Azur in southern France.

A significant adaptive-optics program dubbed CHAOS, for *Ch*icago *A*daptive *O*ptics *S*ystem, is being led by Edward Kibblewhite (University of Chicago) to produce a sodium-beacon system for infrared work with the 3.5-meter Astrophysical Research Consortium telescope at Apache Point, New Mexico. In its preliminary trials, as pictured on the facing page, this group beamed a low-power laser through a small telescope and successfully observed the beacons with the Yerkes 40-inch refractor.

Several California amateurs have noticed, and even photographed, a sodium-layer beacon that is occasionally visible to the naked eye in the sky over San Francisco Bay. It is part of an experiment by researchers at Lawrence Livermore with a powerful dye laser (about 1,000 watts) tuned to the sodium resonance frequency. They hope to achieve full wavefront compensation in the visible part of the spectrum.

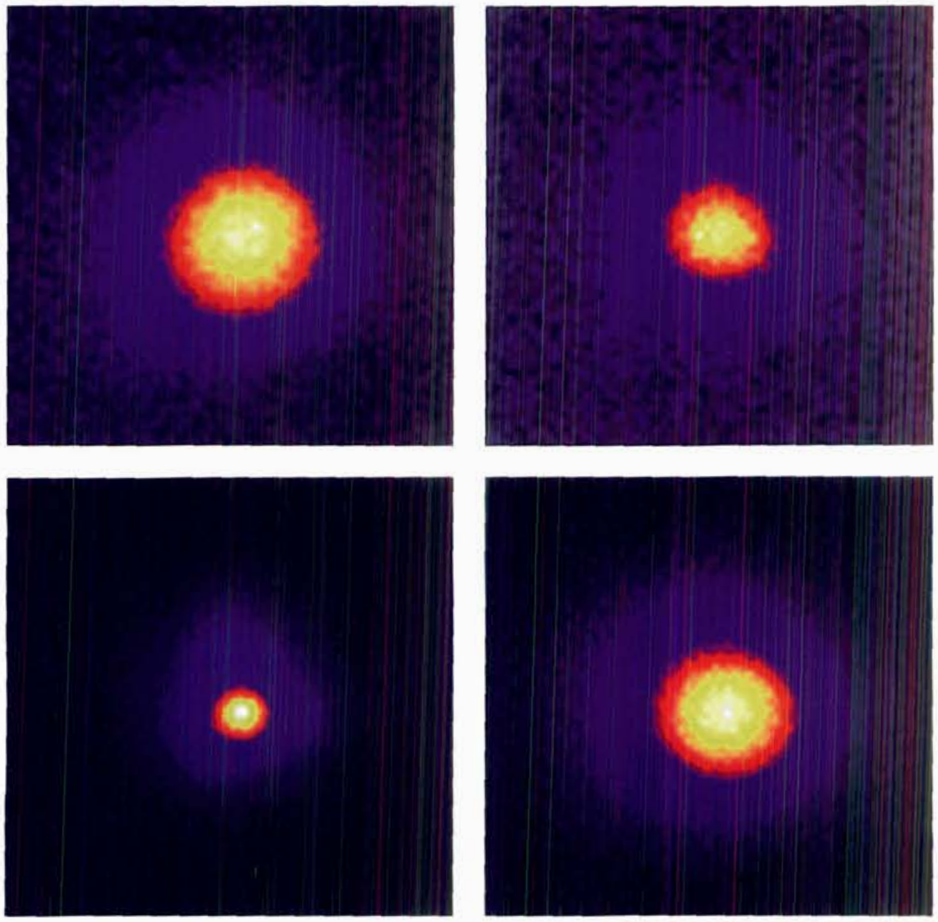


Beta Delphini is a huge blob in the uncompensated image (*top*) obtained with the Starfire 1.5-meter telescope. Switching on the laser beacon and adaptive optics brings out the star's binary nature, with components just 0.20 arc second apart (*bottom*). Furthermore, the intensity at the image core is enhanced 8 times. These are 1-minute exposures in the near infrared (8500 angstroms), and the frames are 1.7 arc seconds across.

During 1993 researchers at the Multiple Mirror Telescope (MMT) in Arizona made significant advances in work with sodium-layer beacons, testing concepts to be used for full adaptive correction of the 6.5-meter mirror to be installed in the MMT in 1996. Working first with Kibblewhite's team and James Beletic (Georgia Tech), and later with Steve Benda (Coherent Inc.), Roger Angel and Michael Lloyd-Hart (University of Arizona) projected the light from a commercial continuous-wave dye laser through a small telescope on the central axis of the MMT array. This created an 11th-magnitude sodium guide star as sharp as 1.3 arc seconds. The team found very close agreement between the wavefront distortions of this guide star and a natural star over the full 6.9-meter aperture of the MMT's present six mirrors. These are the first such measurements with a very large astronomical telescope. Furthermore, adaptive corrections made 20 times a second produced a clear reduction in the atmospheric jitter of natural star images.

REAL-TIME CORRECTION

Creating bright beacons at a suitable altitude is just the first step — making them work for adaptive optics is quite another matter. To date, the most impressive demonstrations of real-time compensation with lasers have come from two research teams working for the



Three asteroids show their true disks in these near-infrared images made with the Starfire 1.5-meter reflector and a laser beacon. The false-color frames are 1.7 arc seconds across and show (*clockwise from upper left*) Ceres, Pallas, Vesta, and the 7th-magnitude star SAO 110603 for comparison. The exposure times ranged from 20 to 60 seconds. Note that Pallas appears slightly elongated, confirming a finding from ground-based occultation observations in 1983.

U. S. Department of Defense.

In mid-1988 Lincoln Lab became the first group to succeed. Their deformable mirror with 241 actuators was mounted on a 60-cm telescope at Haleakala and teamed with a dye laser emitting blue-green pulses 2.5 times a second. But since any correction is only valid for a few milliseconds at visible wavelengths, the slow pulse rate meant that the aperture was effectively compensated less than one percent of the time — an obvious limitation if faint astronomical objects are to be studied.

The Lincoln Lab experimenters obtained star images whose peak intensities were 40 percent of their theoretical value — a sign they were well on their way to diffraction-limited performance. (Ground-based telescopes normally achieve a ratio of only 1 to 5 percent; the repaired Hubble Space Telescope gets 60 to 85 percent.) They also demonstrated how data could be combined from more than one artificial beacon, a technique that will ultimately be required if telescopes of very large aperture are to be successfully compensated.

Then in February 1989 the Phillips Lab team struck pay dirt with its 1.5-meter telescope and a copper-vapor laser emitting 5,000 pulses per second. The high repetition rate meant the atmosphere could be sampled often enough, and the deformable mirror's shape adjusted in step, to operate in a continuous, real-time mode. Working at 8800 angstroms in the infrared, this system intensified the cores of star images more than 10-fold and reduced their seeing disks from 2 arc seconds to only 0.18 arc second.

The Phillips Lab team has since acquired a new deformable mirror and wavefront sensor. Stellar images are now as small as 0.13 arc second across, measured to where the intensity has fallen to half its central value. Distortion has been reduced to $1/10$ wave, averaged over the aperture, making possible extremely sharp images of such complex regions as the Orion Trapezium (see the pictures at the top of page 29).

BEACON REQUIREMENTS

A laser beacon should have, as nearly as possible, the characteristics of a real star — a bright point source well outside the atmosphere. It must also be bright enough for the wavefront sensor to operate in the required sample time.

A beacon at 20 km is already above, and thus useful for correcting, 95 percent of the atmospheric turbulence. But an even higher beacon is desirable for a more important reason. Because the beacon is formed a finite distance away, its light rays arriving at the center and edge of the telescope aperture must diverge by a very small angle. When this angle reaches about twice the size of the isoplanatic patch mentioned earlier, wavefront correction deteriorates.

For example, in visible light the deviation should not exceed about 3 arc seconds, corresponding to 2.5 meters for a beacon as high as 90 km. Thus, such a beacon could not help a telescope any larger than the Palomar 5-meter reflector. Current theories predict that a 10-km beacon allows the same level of correction in a 0.6-meter telescope as a 90-km beacon with a 2.4-meter instrument. The useful aperture is also proportional to the observing wavelength raised to the $6/5$ power. The bottom line: If we want to correct an 8-meter telescope, we will probably need more than one beacon positioned over the aperture.

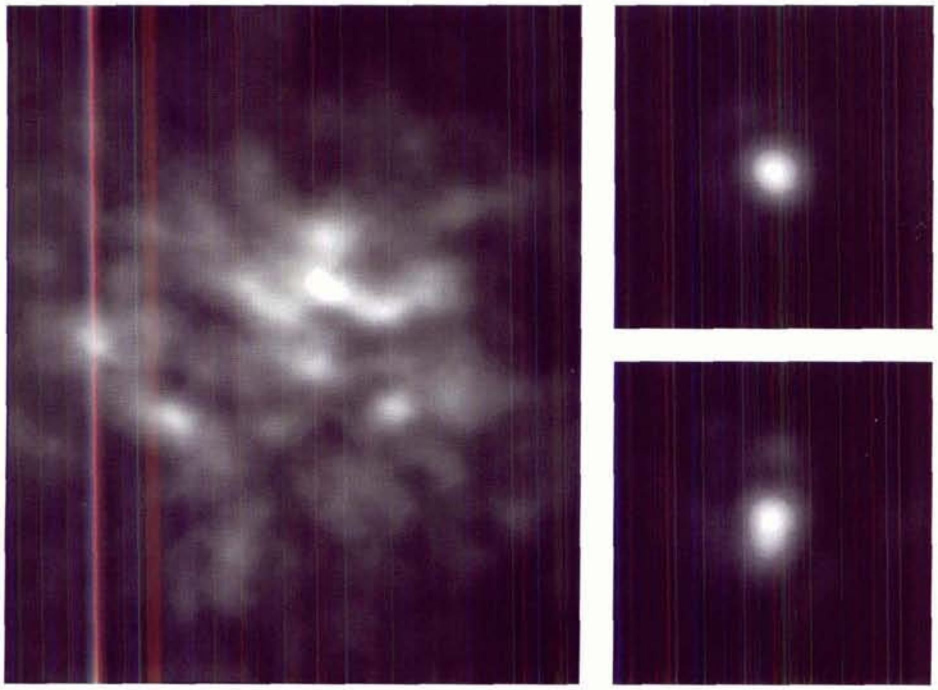
Extremely small angular size is another beacon requirement. If the laser's natural beam divergence is too great, the beacon can be sharpened by expanding the beam and feeding it through a large-aperture telescope. Typically we want the beam divergence to be less than that caused by atmospheric turbulence.

A very desirable location for the transmitting aperture is just beyond the imaging telescope's secondary mirror, where the outgoing beam is perfectly coaxial with the telescope but blocked from view. In this case the beacon is brightest and smallest because it is viewed end on, rather than from slightly to one side.

The laser beacon must also be fairly intense to be at all effective, at least as bright as 6th magnitude at visual wavelengths and 12th magnitude for infrared operation.

UNWANTED LASER LIGHT

Furthermore, how can we keep the laser's light from blinding the scientific camera? We want it to go only where it belongs: into the wavefront sensor. A straightforward approach is to use a pulsed laser and turn the sensor on just long enough to receive the backscattered



Left: The light of Betelgeuse spreads completely across the 3.1-arc-second width of this frame, which shows an uncompensated 1/30-second exposure obtained with the Starfire 1.5-meter telescope. Reproduced at the same scale, but cropped in, are two images showing the great improvement when this 1st-magnitude star serves as its own beacon (*upper right*), or when a laser beacon 10 kilometers away is used (*lower right*). The star-compensated image is best, having a peak intensity 12 times that of the raw image, but the laser-beacon image is still an exceptional improvement.

light from each pulse. An electro-optical switch or mechanical chopper can be used to block out the offending laser light from the camera during the time it is most intense.

If the scientific camera operates in a different spectral region than the laser, special filters may create enough isolation. For example, the infrared camera at Starfire contains a polarizing beamsplitter and filter. It shares the 1.5-meter telescope 100 percent of the time with a pulsed copper-vapor laser emitting blue-green and yellow light, yet exposures lasting tens of seconds show no detectable light from the laser.

Most observatories have several telescopes in use simultaneously. If one of these instruments is emitting laser light, another telescope could pick up side scatter if it tries to look through that beam. In the future, observing plans may need coordination to minimize such interference.

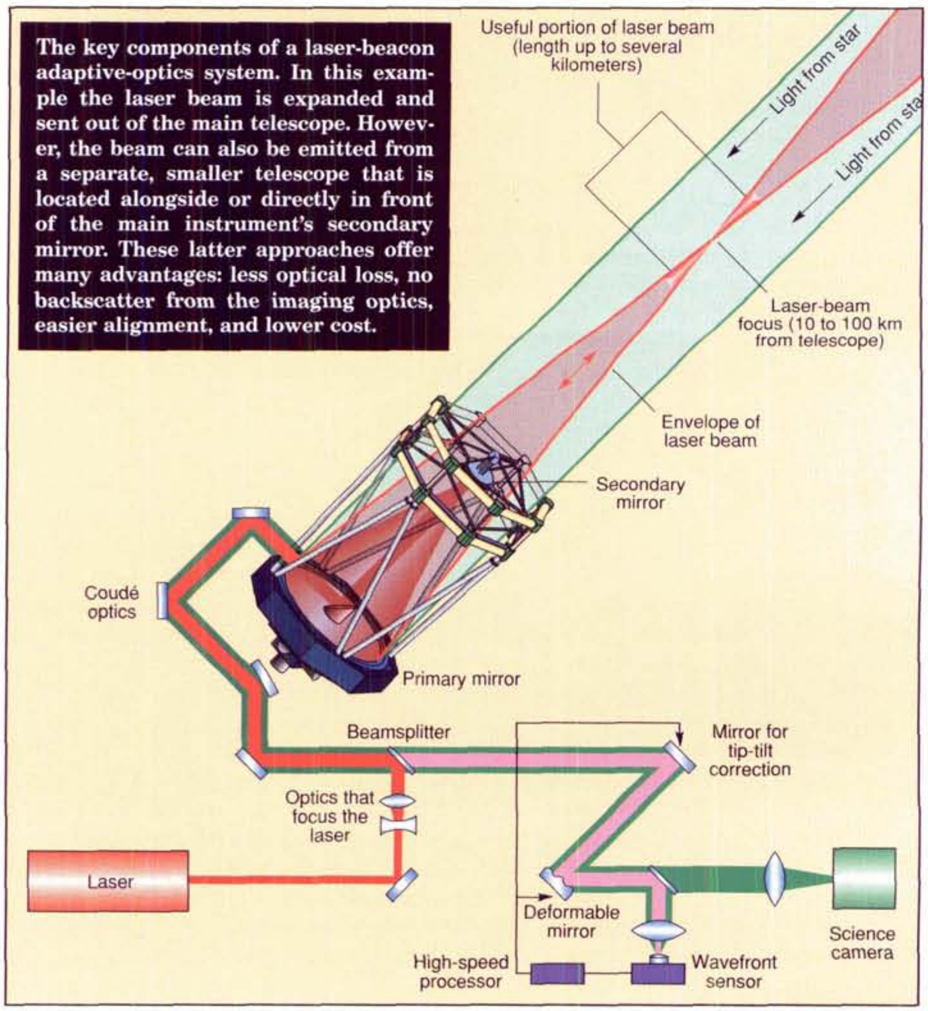
TILT CORRECTION

Despite the early successes with laser beacons there remains a final, serious limitation to their effectiveness for adaptive optics. Although these beacons reveal much about the higher-order details of atmospheric turbulence, they can't provide any information about what is called *full-aperture tilt.* On its upward propagation through the atmosphere the beam wanders randomly, and the unknown final offset from the aim point at the beacon's altitude leads to an unknown overall tilt to the returned wavefront.

As a result, while the beacon may indeed help correct a natural star for wavefront error, there is nothing to prevent the newly sharpened image from jittering around so badly as to ruin a long exposure. The final image would be hardly any better than without the adaptive optics! All this means a laser beacon cannot be the ultimate cure-all; the Starfire system uses a natural star *in addition to* a laser beacon to correct for both wavefront distortion and aperture tilt.

Meanwhile, other groups of astronomers are continuing to pursue seeing-compensation techniques that use no lasers at all. One even provides close-up views of fine structure on the surface of the Sun. We'll explore these alternate approaches in a future issue of *Sky & Telescope.*

After several years at the Starfire Optical Range Walter Wild is now part of the Kibblewhite adaptive-optics group at the University of Chicago. A glimpse at Robert Fugate's pioneering role in the field begins on page 20.



The key components of a laser-beacon adaptive-optics system. In this example the laser beam is expanded and sent out of the main telescope. However, the beam can also be emitted from a separate, smaller telescope that is located alongside or directly in front of the main instrument's secondary mirror. These latter approaches offer many advantages: less optical loss, no backscatter from the imaging optics, easier alignment, and lower cost.

JOSÉ R. DÍAZ

Meet the man in charge of the most revolutionary telescope in the world.

Robert Q. Fugate: Starfire's Magician Optician

Text and Photographs by Roger H. Ressmeyer

AS TECHNICAL DIRECTOR of the Starfire Optical Range (SOR) in New Mexico, physicist Robert Q. Fugate commands the most advanced adaptive-optics facility in the world. The man is consumed by his mission, one so secret that for 20 years he couldn't even mention it to his wife, Marilyn. "I couldn't tell her what I was doing or who I was meeting or why I had to go back to work at night." Things got so bad that one day their two children, Jeffrey and Elizabeth, declared, "We should buy a cardboard daddy and put him in the living room."

The Starfire project was finally declassified in May 1991, a day Fugate remembers vividly. "It was amazing, just incredible. Previously we had been talking to such a small audience, and suddenly I was sharing our work with a group of 600 at an open meeting of the American Astronomical Society in Seattle."

And the family? "Declassification has made our life together much better," he admits. "I was working no less than 80 hours a week. I'd get home after sunrise, sleep for four or five hours until noon, and go right back out to prepare for the coming night. I still do that now, sometimes."

Working at SOR takes a lot of energy, stamina, and dedication, and Fugate is the embodiment of these qualities. As team leader in the early 1980s his experiment proved the concept of laser-beacon adaptive optics. Today, he presides over a huge, state-of-the-art telescope dedicated to refining the technique. It's perched on the windward edge of a 1,950-meter rise deep within Kirtland Air Force Base, only 30 kilometers from downtown Albuquerque. The instrument received its 3.5-meter f/1.5 primary mirror (spin-cast by Roger Angel) just last August — yet made its first-light images in February!

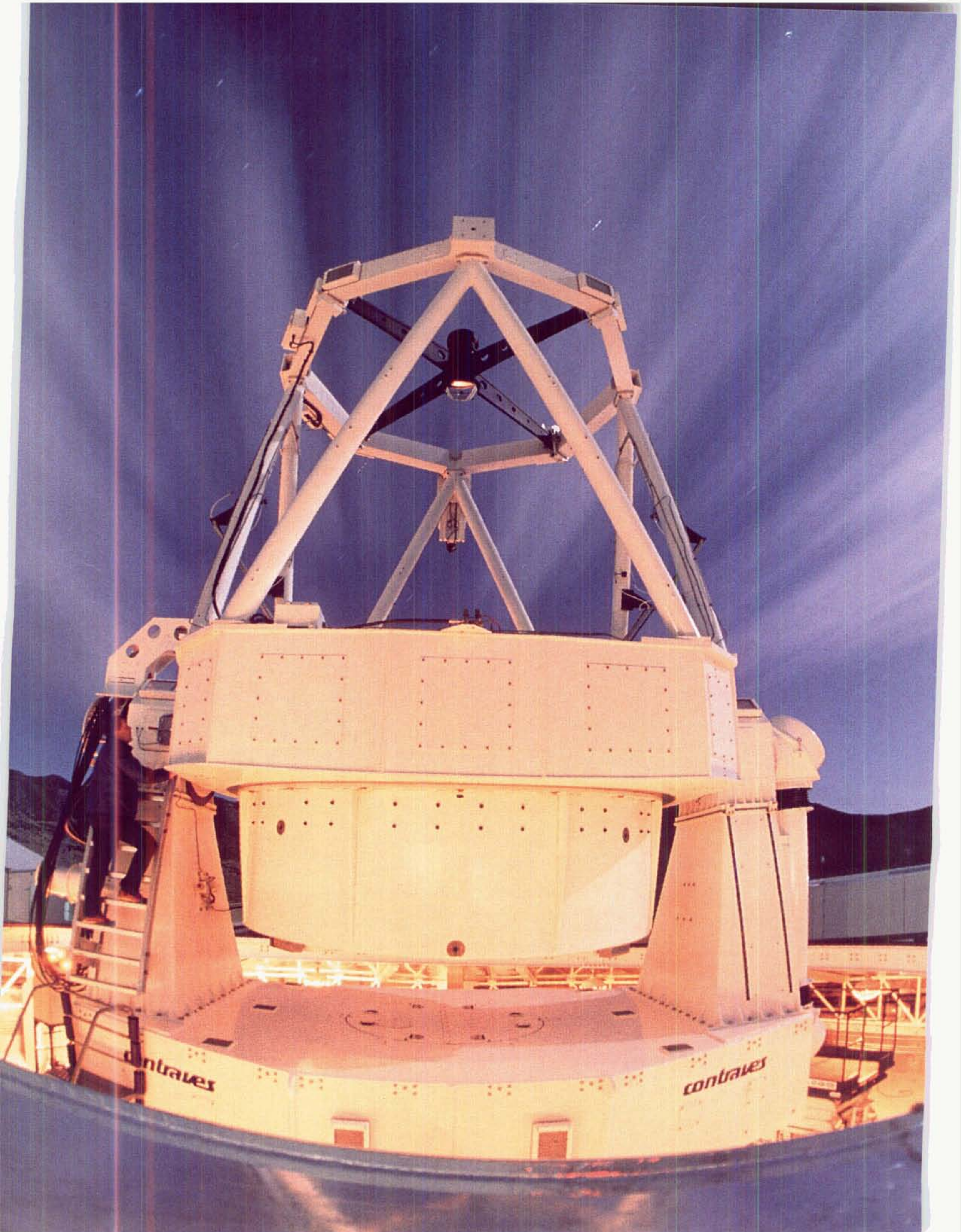
Surveying the scene at night, I am surprised to find "spotter" platforms next to Starfire's main and smaller (1.5-meter) telescopes. These, I learn, are used by sentries watching for incoming aircraft — so that Starfire's brilliant laser beacons can be shut down if a plane accidentally strays toward the blinding light.

Fugate describes the 3.5-meter's revolutionary enclosure as a "Boy Scout cup" whose three concentric cylinders collapse around the telescope, leaving the instrument completely exposed to the night air. "This has two advantages," he explains. "It provides complete ambient-air ventilation all around the telescope, and you don't have to turn a heavy dome when you move the telescope at 12° per second. This is the largest telescope around that slews at high speed with extremely low jitter." That also makes it the largest spyglass on Earth for tracking and imaging low-orbit satellites.

The SOR staff of 40 or 50 is a mix of Air Force personnel attired in military garb and civilians, like Fugate, in jeans and sweaters. During my tour of the facility I ask to see some of the pictures of orbiting spacecraft taken here. "Sorry," Fugate re-

Facing page: The Starfire Optical Range's 3.5-meter telescope, the brainchild of SOR director Robert Q. Fugate, has a spin-cast f/1.5 primary mirror and uses adaptive-optics technology to counter atmospheric turbulence. Moonlight, dusk, and dawn aid in the scene's illumination. All photographs with this article are ©1994 Roger H. Ressmeyer–Starlight/MP©A.

Above: No one can accuse Fugate, now 49, of lacking vision. For observations at visible and near-infrared wavelengths, he asserts, "our goal is diffraction-limited imaging at the sky background — around 20th or 21st magnitude."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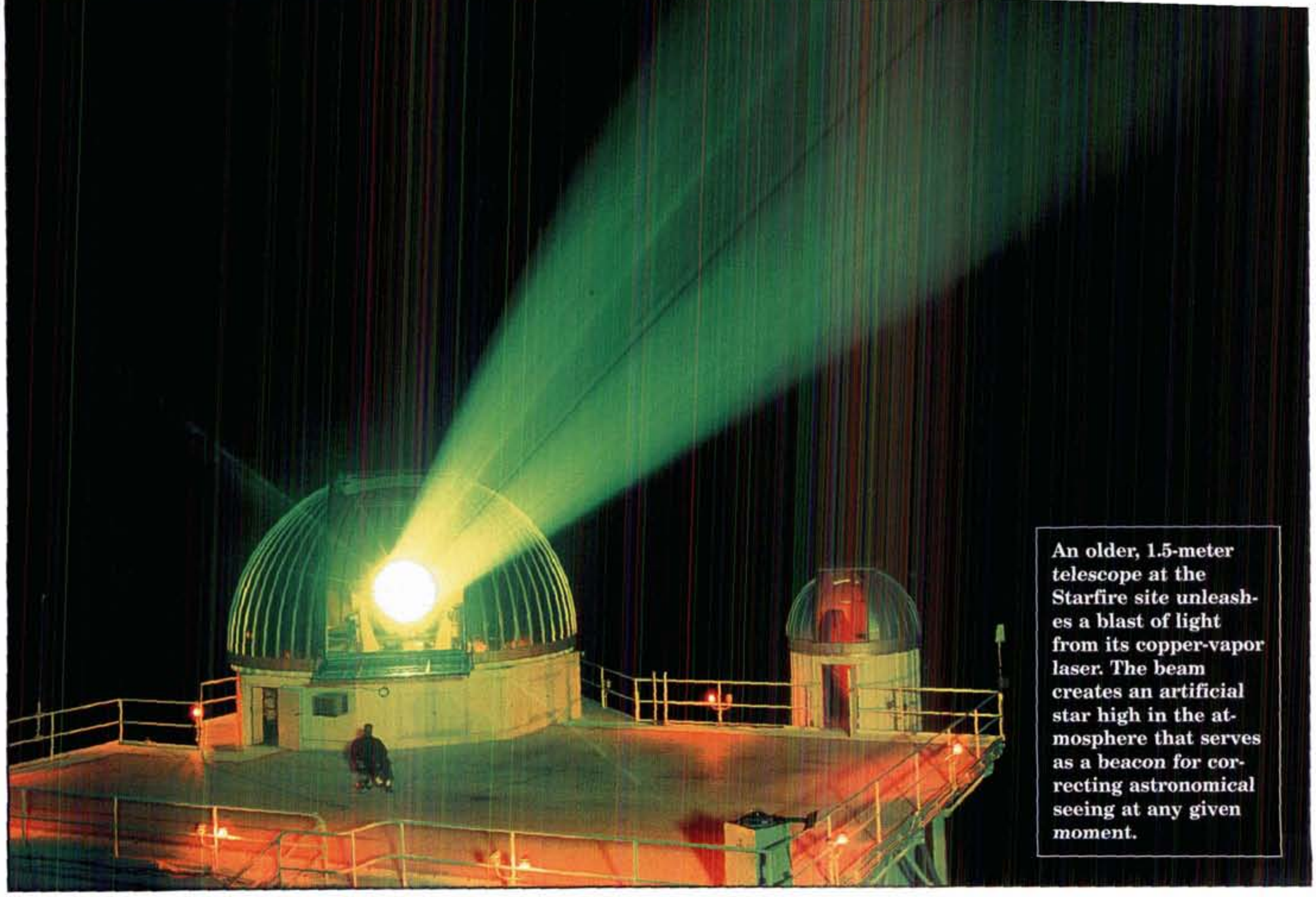

An older, 1.5-meter telescope at the Starfire site unleashes a blast of light from its copper-vapor laser. The beam creates an artificial star high in the atmosphere that serves as a beacon for correcting astronomical seeing at any given moment.

sponds. "All the astronomy stuff is unclassified, but they're real persnickety about satellite imagery." Sensing my disappointment, he adds, "Today 5 percent of our work is in astronomy, but we want it to grow. We want to share this technology fully with the astronomy community, and we're doing everything we can in the world to do that."

I ask him about the strange, dark blockhouse a few hundred yards downhill from the telescope and connected to the observatory with large pipes. He explains that it's a high-tech icehouse. "During the daytime we manufacture and store up to 4½ million pounds of ice in that reservoir. At night we circulate water through it, chilling the water. Then we pump the water up here to remove heat from the building. A fan pulls air through the telescope structure and primary mirror, and we exhaust the warm air alongside the icehouse."

Despite Fugate's quiet, calm humility, his story could have come straight from the pages of a Tom Clancy novel. In 1970, with his newly minted Ph.D. from Iowa State University in hand, Fugate joined a glut of physics graduates who were having a difficult time finding work. Then his mother-in-law, a hairdresser, learned over soapsuds from one of her customers that a scientist at Wright-Patterson Air Force Base in Ohio was looking to hire a brilliant young physicist. Fugate called for an interview, and the rest is history.

He went right to work in lasers and electro-optics, his assignment being to detect "hostile" aircraft-threatening lasers. By 1978 he'd become an acknowledged expert in laser detection, and one day he was asked to visit a top-secret project at Kirtland in New Mexico known as the Sandia Optical Range. (Eventually he would personally rename it the Starfire Optical Range.) Fugate's clandestine trip to the air base came about because five years earlier scientists at SOR had used a potent, carbon dioxide laser to blast an airplane out of the sky with a burst of infrared energy. By 1978 a similar, aircraft-mounted laser was being used to shoot down incoming missiles. Fugate's new assignment was to detect the infrared beam even when it wasn't aimed at his sensors. Little did he realize that he'd found a home in the heart of what, years later, would be called Star Wars.

Fugate's work soon evolved from beam detection and control to validating the concept of laser-beacon adaptive optics, which his five-person team successfully demonstrated in the summer and fall of 1983. A year later Fugate began lobbying for a telescope to utilize this new capability, and his 1.5-meter instrument for adaptive-optics experiments became operational in the spring of 1987.

"In the movie *Jaws* there's a scene with two guys in a boat; the shark comes up out of the water, and he's wider than their boat," Fugate recalls. "One man turns to the other and says, 'We're going to need a bigger boat.' And that's how I felt in 1987 when I went into director Pete Avizonis's office and said, 'Sir, we're going to need a bigger telescope.' And he threw me out on my ear, but I just kept going back." Persistence, hard work, and the 1.5-meter's results paid off for Fugate, as the Air Force eventually approved the 3.5-meter project.

Today, with the big scope almost complete, Fugate dreams of "power beaming" energy to drive the ion engines of orbiting satellites. Or someday he'll use lasers to communicate with far-flung planetary probes, eliminating the need for them to carry large antennas like the one that recently failed aboard the Jupiter-bound Galileo. "We're about to prove that concept," he says, "by creating a laser link between our 1.5- and 3.5-meter telescopes using the retroreflectors left on the Moon by the Apollo astronauts. And so it continues for this hard-driving blend of optician, politician, and high-tech magician.

Contributing photographer Roger Ressmeyer visited Starfire in 1992 and 1993 while on assignment for the National Geographic Society.

Big Crow Capabilities

WHITE SANDS MISSILE RANGE
NUCLEAR EFFECTS DIRECTORATE
WSMR
NEW MEXICO

Outline

Big Crow Program Office

- Mission
- Applications
- Platforms
- Active and Passive EW
- Data Collection
- Design & Development
- Experience

Organization

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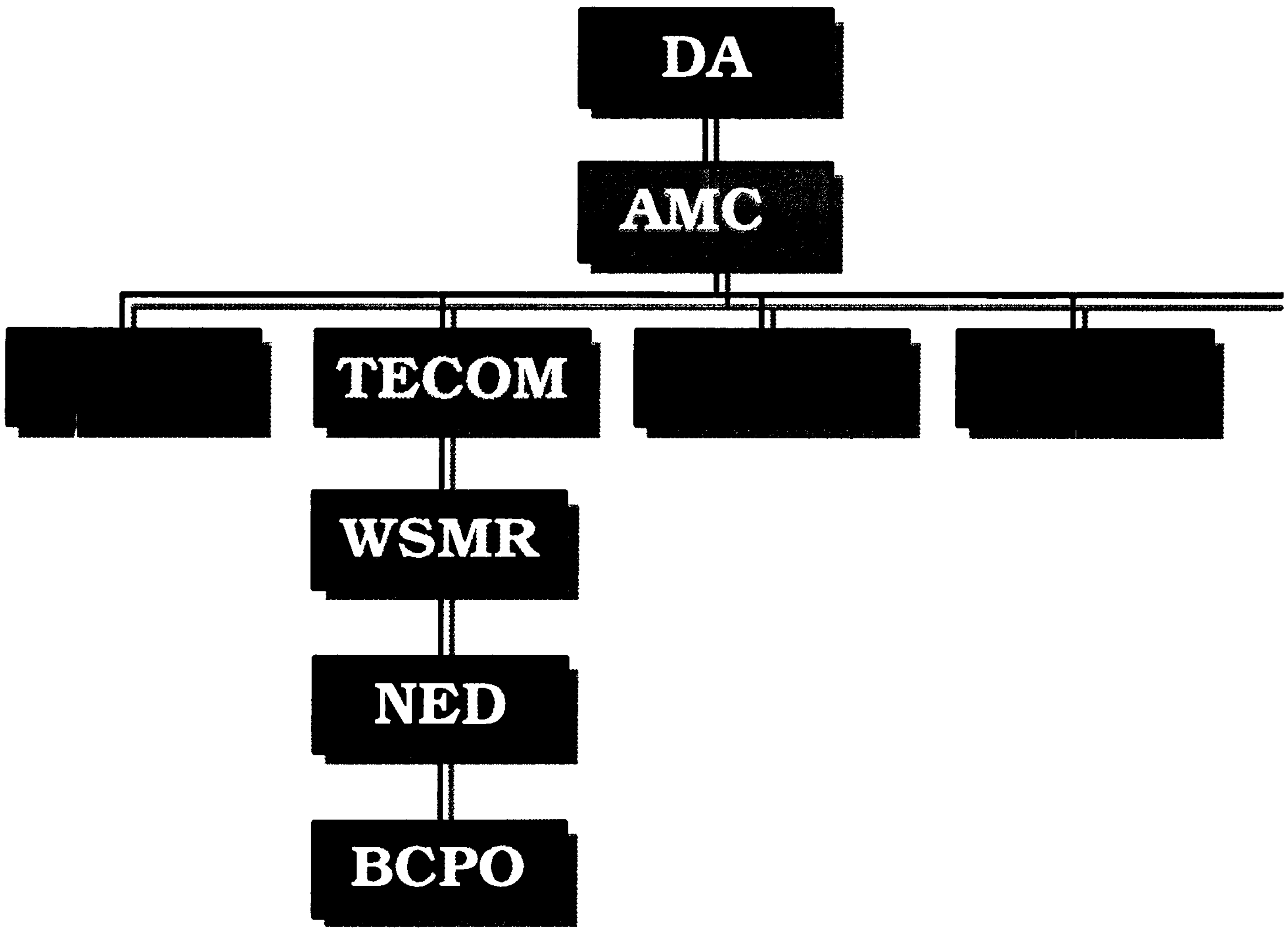

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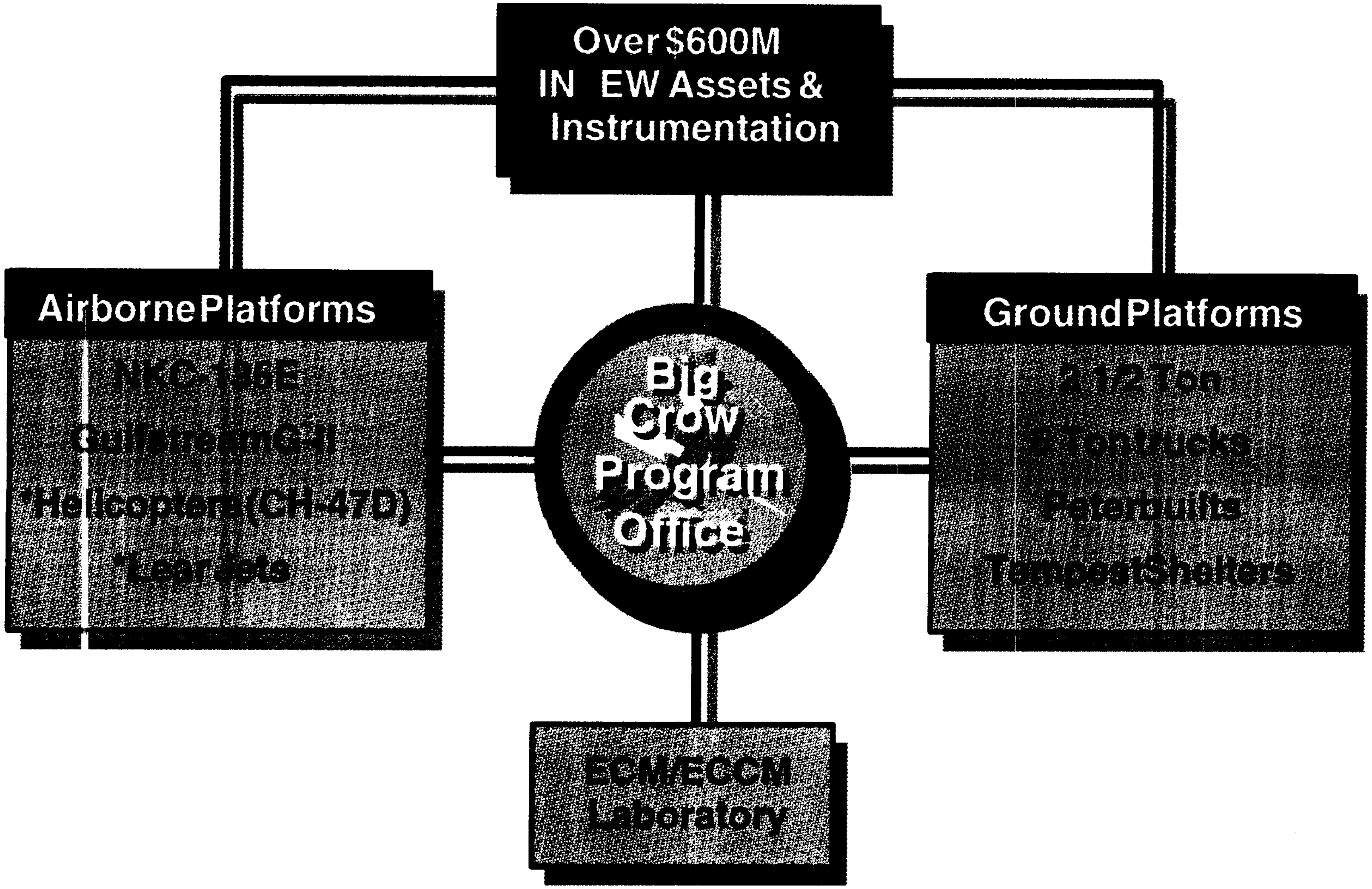

Mission

- Provide Projected EW Environments for EW Vulnerability Assessments
- Provide and Operate Airborne and Ground-Based Platforms for EW Experiments, Tests, Trials and Training

Applications

- EW Vulnerability Assessments (EWVA)
- In the Loop Bench Testing
- Radar Jamming
- Data Link Jamming
- Communications Jamming
- IR Counter Measures
- Laser Illumination
- Atmospheric Characterization
- Electronic Support Measures (ESM)
- SOJ/SSJ/ESJ
- Training Exercises
- Instrumentation Prototypes
- Black Box Prototypes

US Systems Operational Frequencies

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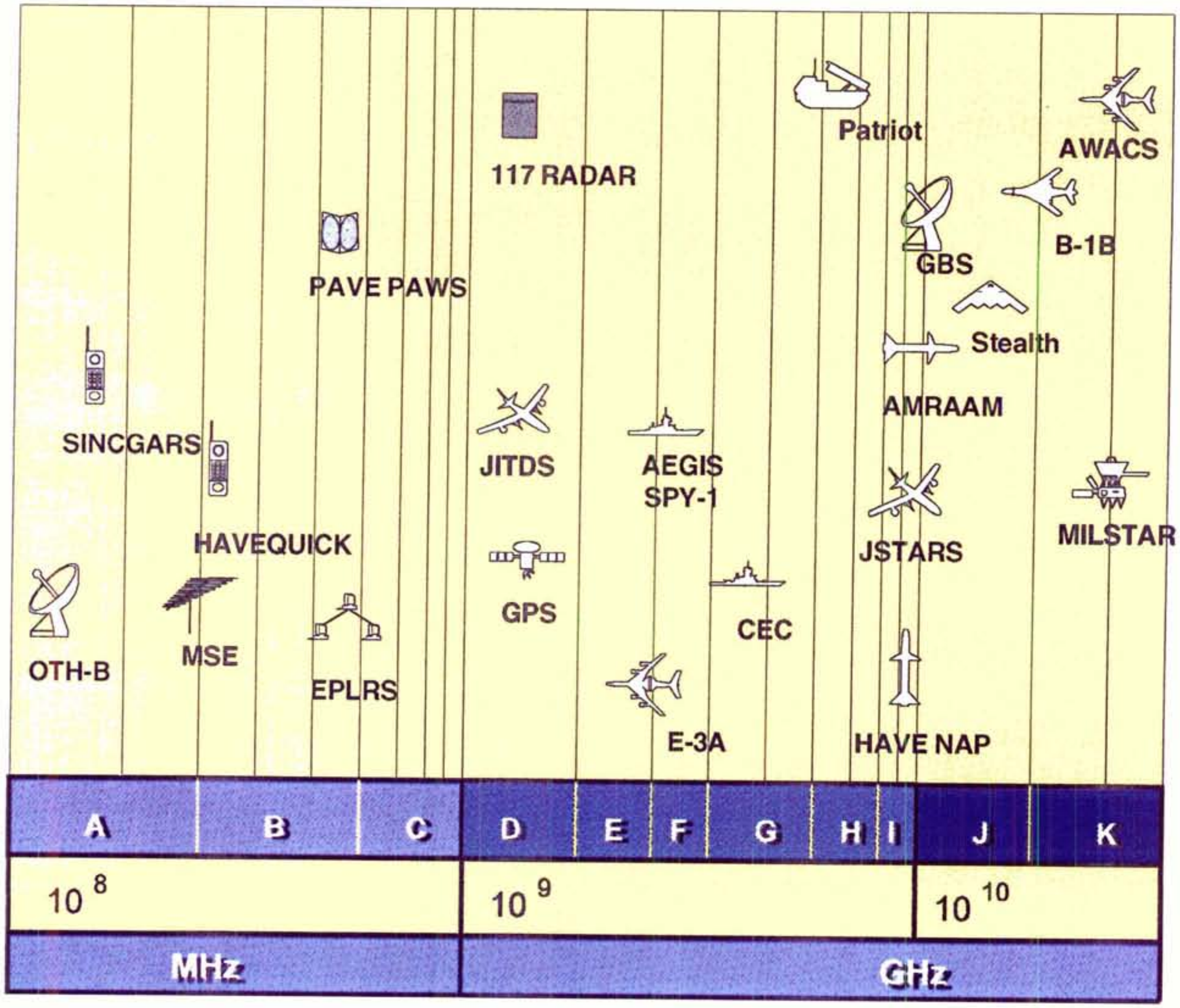

Frequency Coverage

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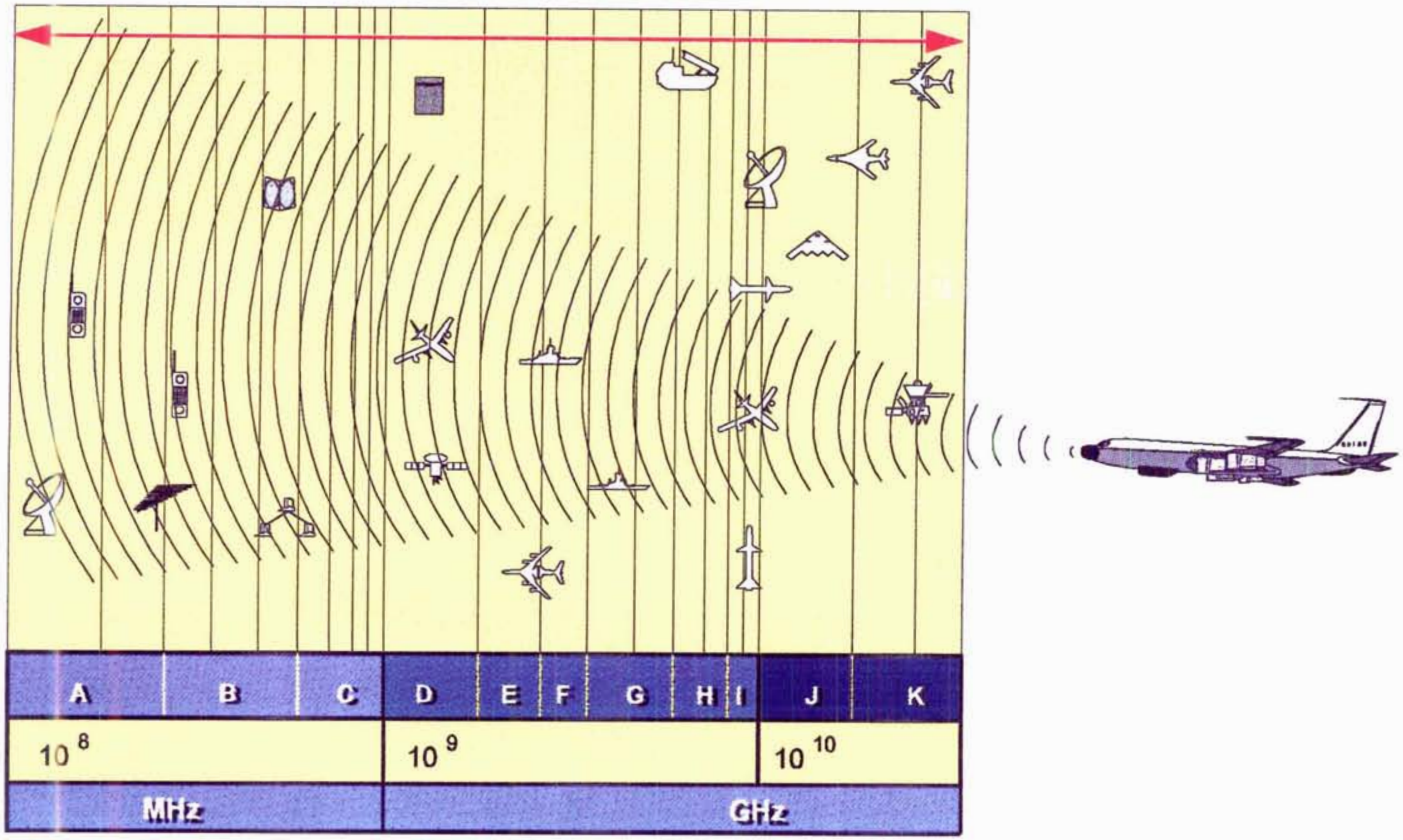

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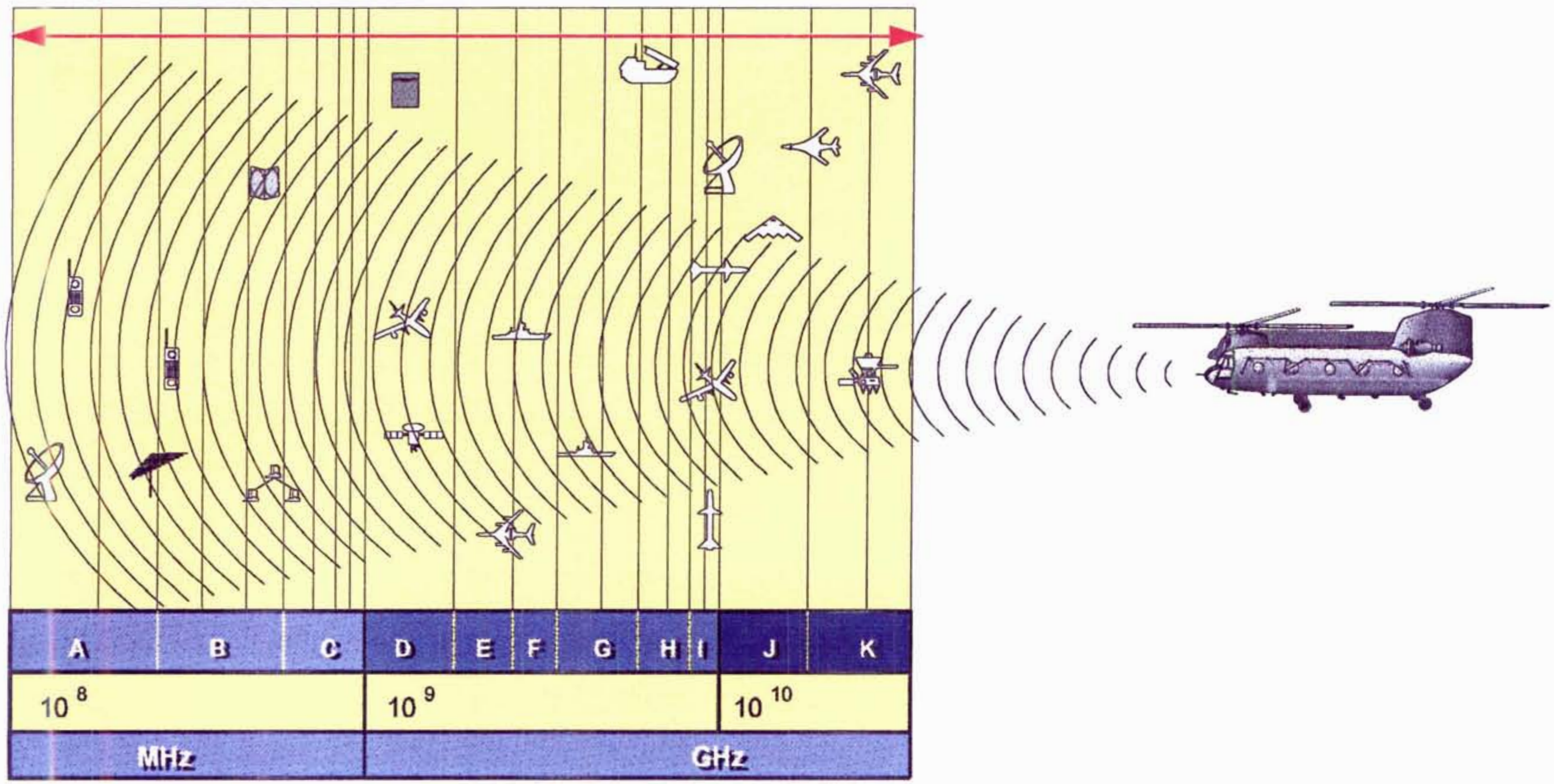

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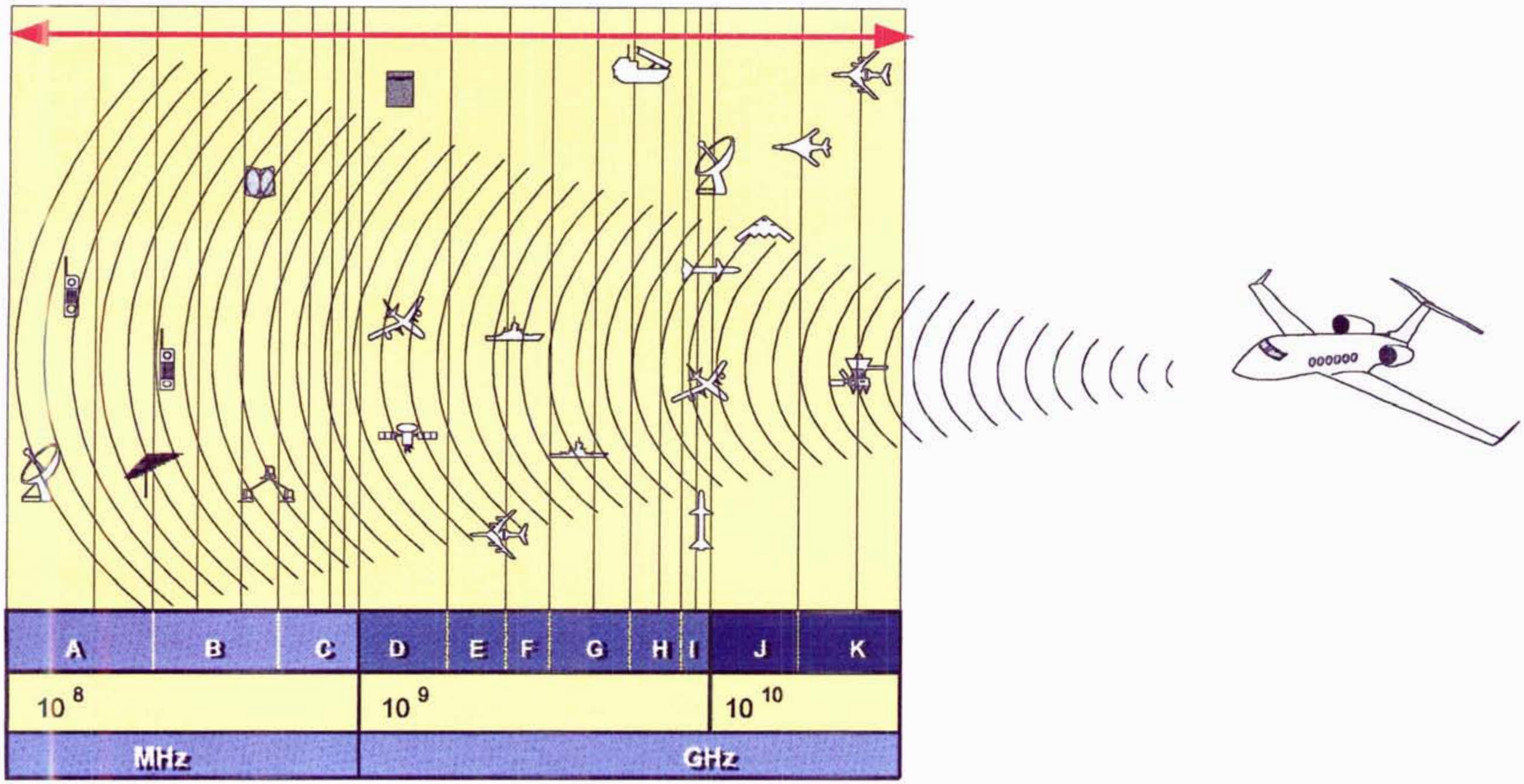

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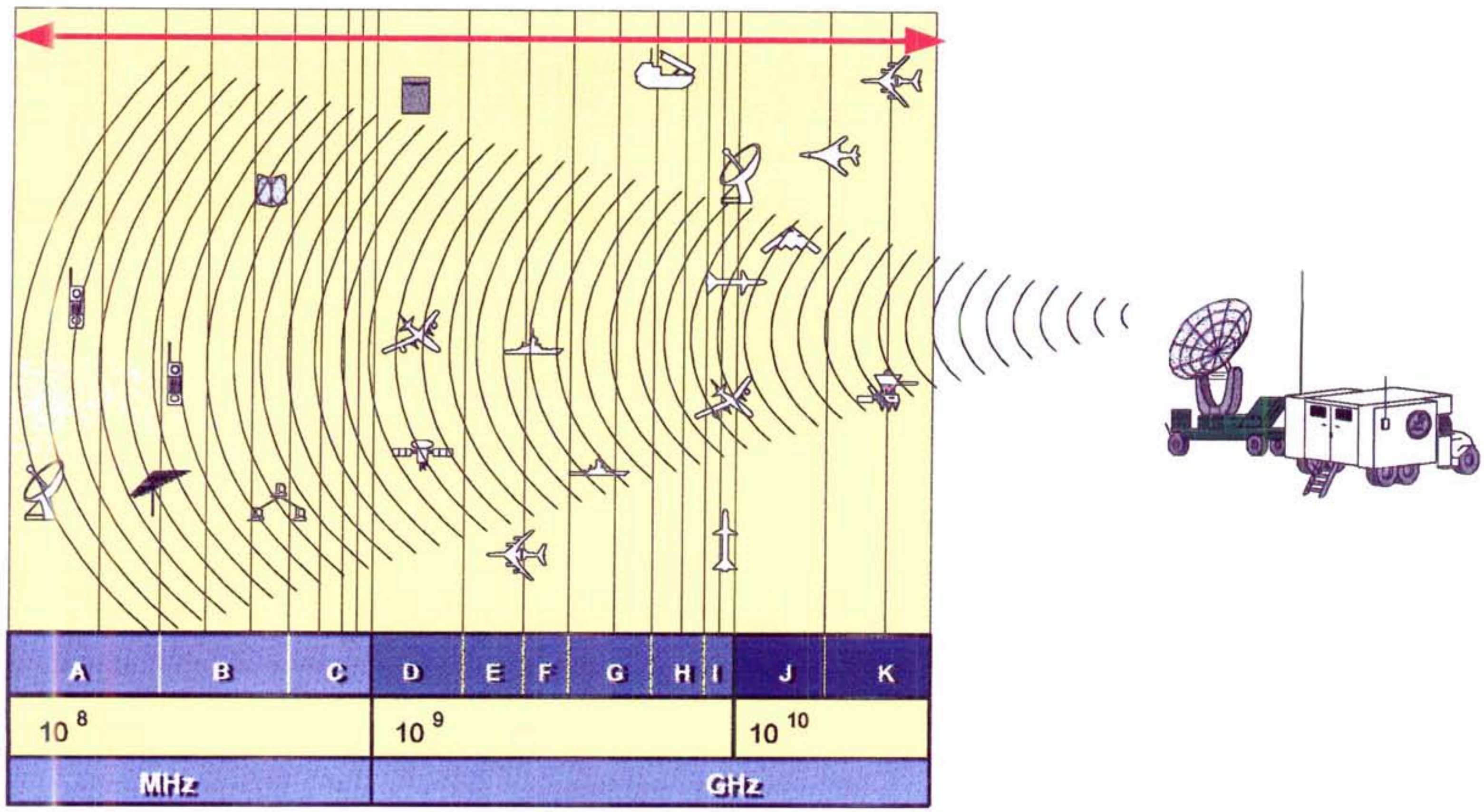


Platforms/Capabilities

Big Crow Program Office

- Mobile Test Beds/Laboratories
  - NKC-135E; TN 55-3132
    - Worldwide Deployment
    - Sustained Missions (16+ Hours)
    - Large Upper, Lower, and Nose Radomes
    - Pylons (5000lb Capacity)
  - Gulfstream G-II; TN N65ST
    - RF, MMW, EO Test Bed
    - State-of-the-Art Avionics
    - Optical Ports (Apertures up to 18"x11")
  - 10 Vans/Trucks
- Palletized Electronic Packages Usable in All Test Beds Listed and Others (e.g., CH47D)
- Electronic Pods

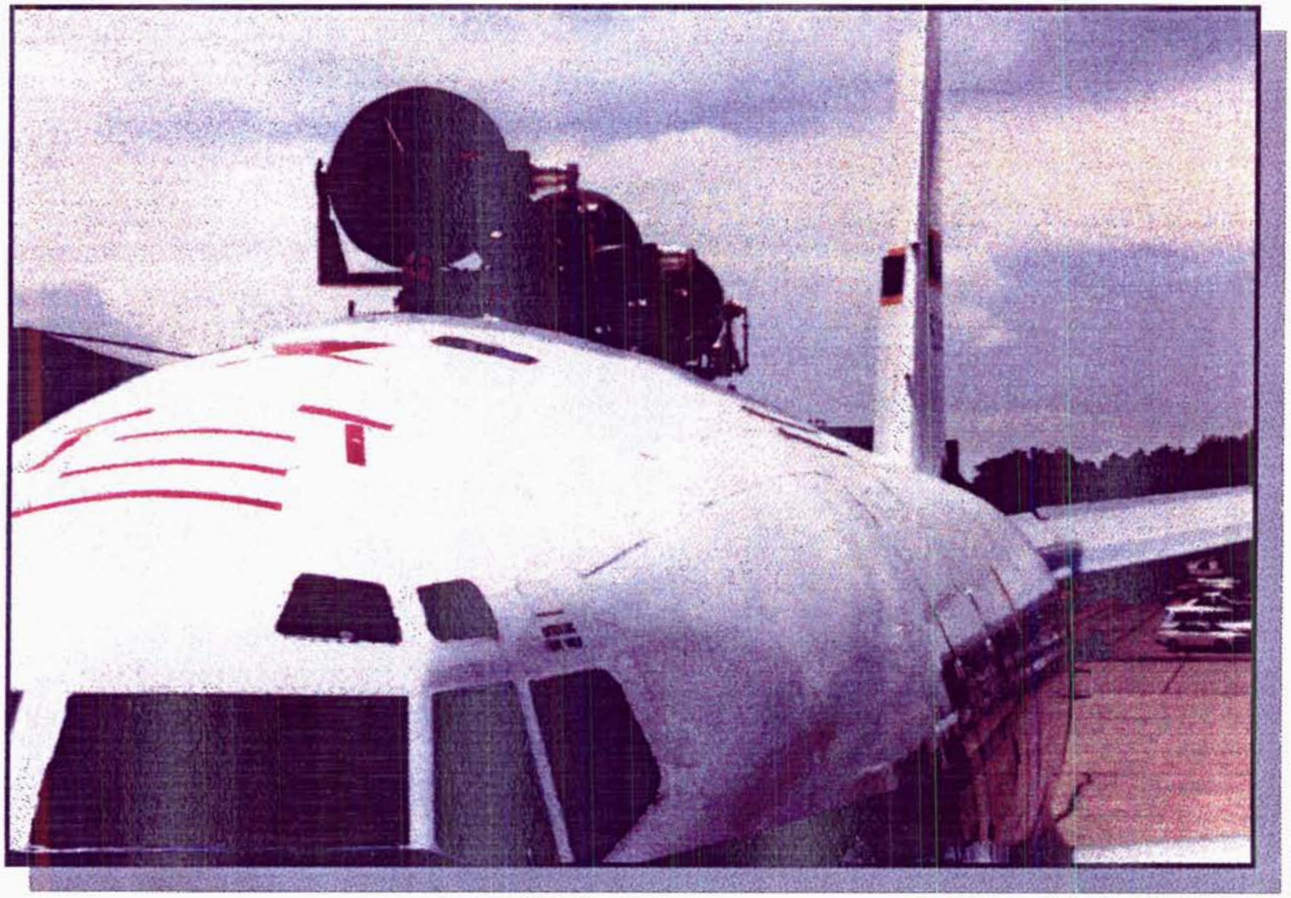
- Chaff	- ESM
- ECM	- EO

NKC-135E

Big Crow Program Office

Antenna/Pedestal Configuration

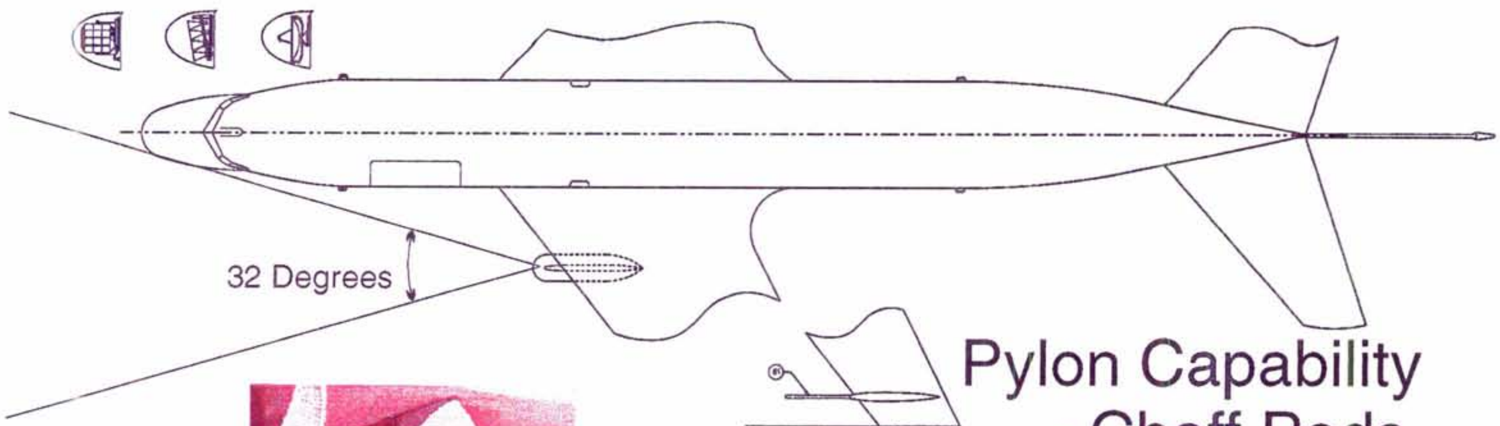
Big Crow Program Office



NKC-135E EW Features

Big Crow Program Office

Custom Antennas Designed for the NKC-135E Modified Nose



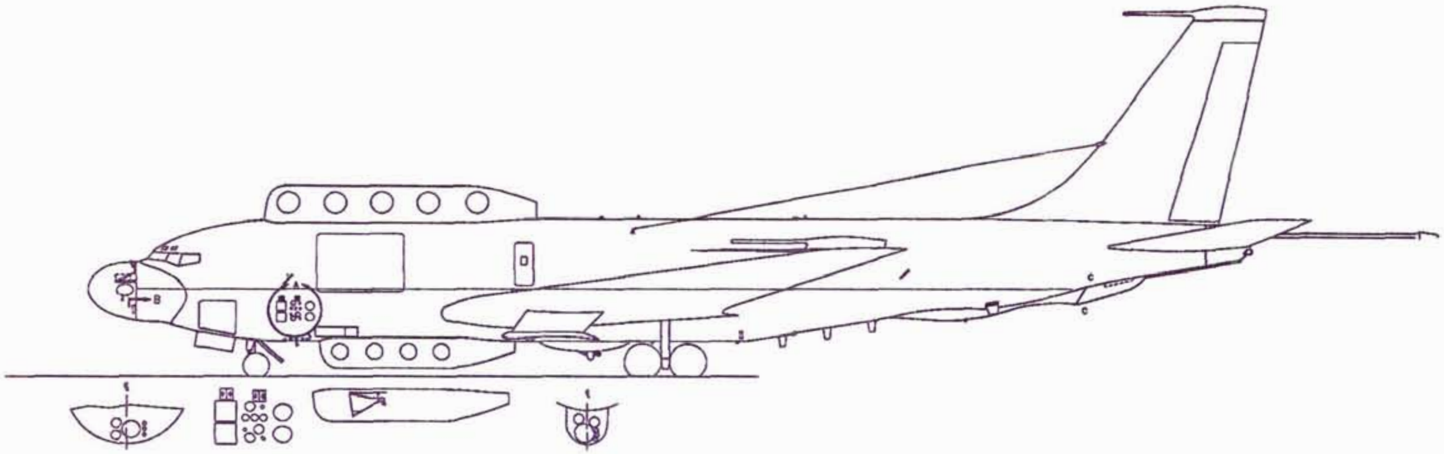
Pylon Capability
- Chaff Pods
- ECM Pods
- Customer Pods
  ≤5000#
  -3dB BW ≤32°

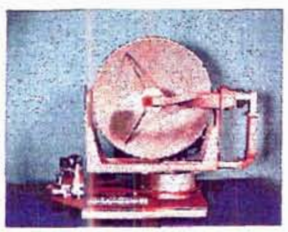
NKC-135E EW Features

Big Crow Program Office

Available Upper & Lower Radomes

- Antennas Pedestal Accuracy 1°
- Antenna Pedestals Installable in Top and Bottom
- Installation Rails in Place for Customer Instrumentation

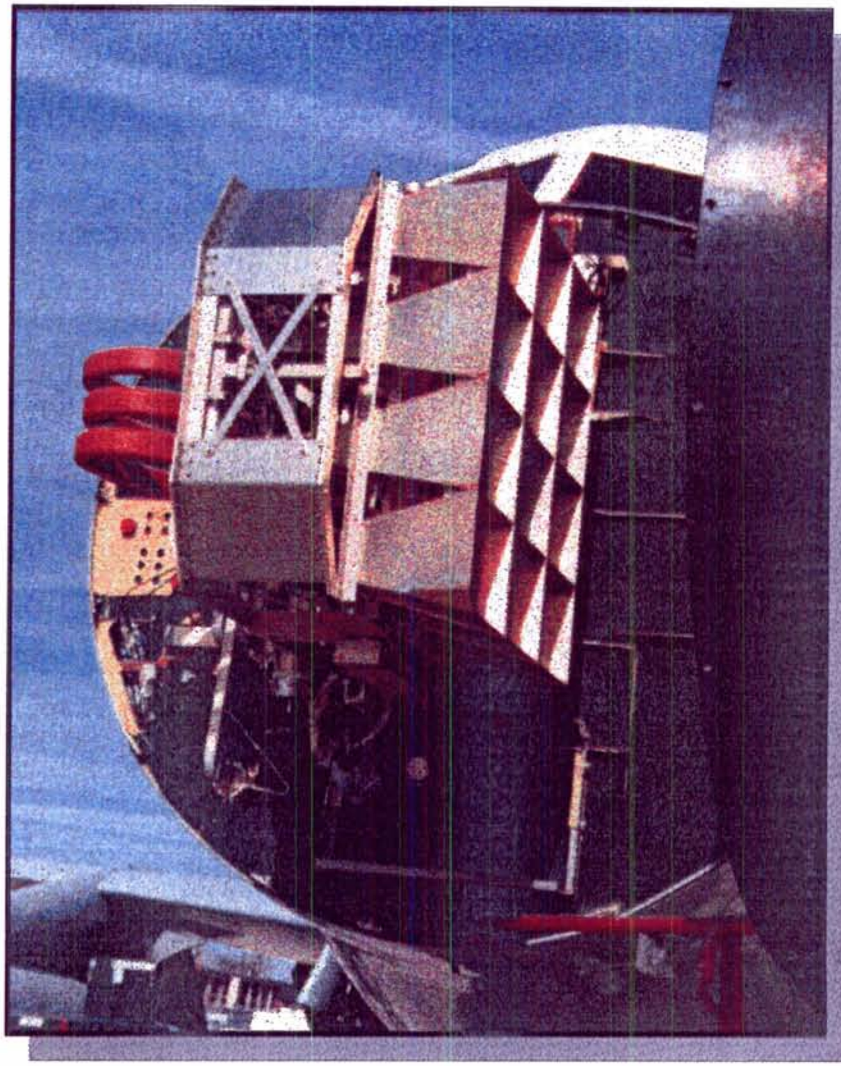




Big Crow Program Office

Horn Array

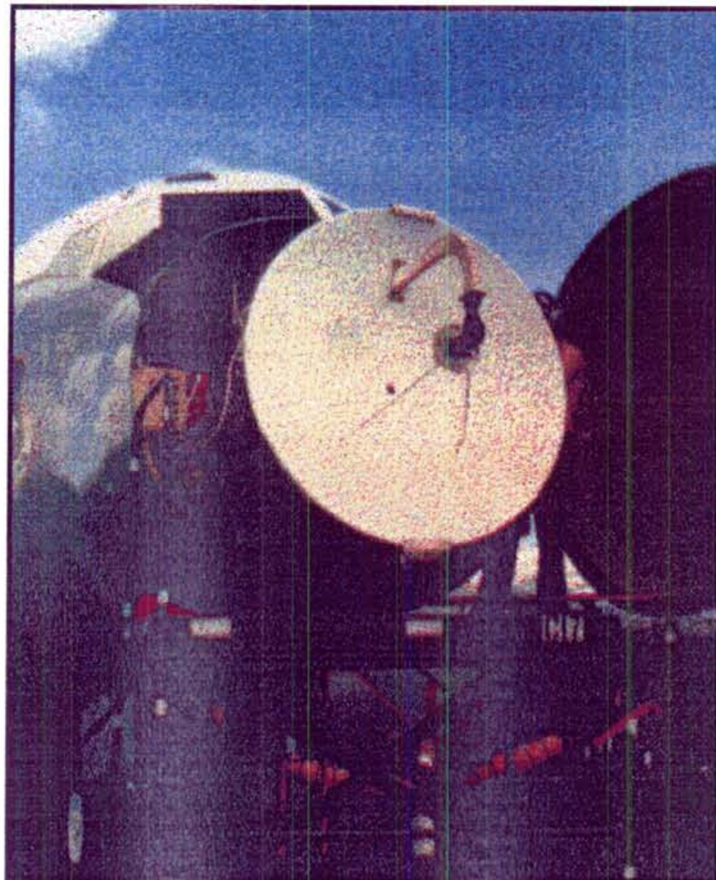
- Beamwidth
  - AZ 14°
  - EL 3.5°
- Steerible
  - AZ ±10°
  - EL ±10°
- Pointing Accuracy <1°
- G-Band
- Power Level (ERP) >1.4M Watts CW



5' Dish Antenna

Big Crow Program Office

- Beamwidth
  - AZ 3.5°
  - EL 3.5°
- Steerible
  - AZ ±15°
  - EL +5°, -15°
- Pointing Accuracy <1°
- F-Band Octave
- Power
  - Current >0.9M Watt
  - Planned >4.0M Watt



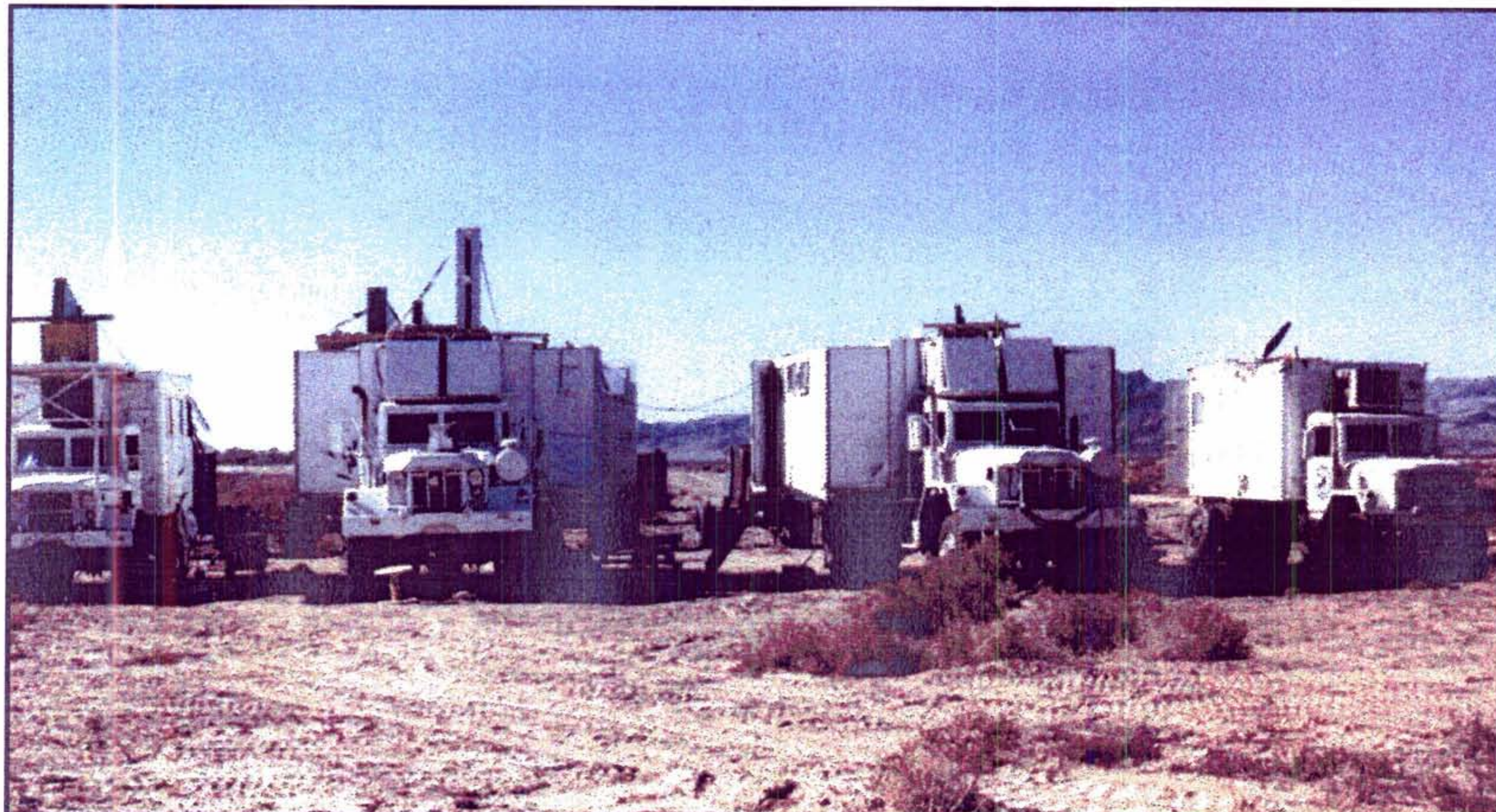
Gulfstream G-II

VHF Heliborne Jammer

Big Crow Program Office

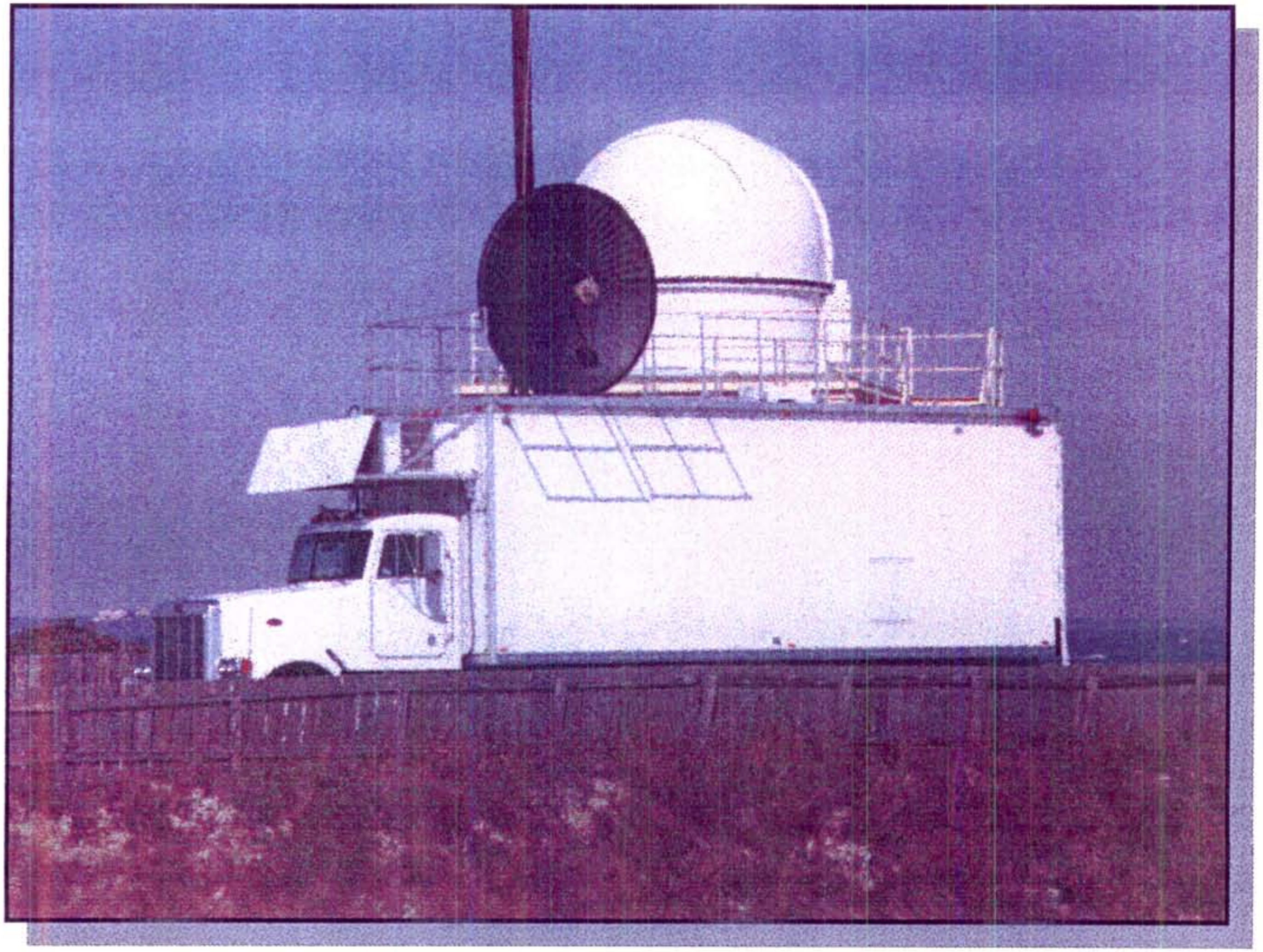
D-Band Heliborne Jammer

Tactical Ground Platforms



Mobile Ground EW Laboratory

Big Crow Program Office



Active EW Capabilities

- Frequency Coverage
  - 5 MHz to 26.5 GHz
  - MMW (26.5 GHz to 95 GHz)
  - EO (Far IR to UV)
- Amplifier Output Power
  - 2 MHz to 18 GHz 1 KW
  - 18 GHz to 26.5 GHz 20 Watts
- Modulation
  - FM, AM, FM/AM
  - Repeater
  - DRFM
- ERP up to 1 Megawatt
- Multiband Simultaneously

System Emulation

- SPS(1)
- SPS-N(1)
- SPS-5
- SPS-N(2)
- SPS-6
- SPS-N(3)
- SPS-RN(1)
- SPS-RN(2)
- SPS-RN(3a)
- SPS-RW
- SPS-5N
- SPS-WB
- SPS-P(7)

- R-325U
- R-378A
- R-378B
- R-330A
- R-330B
- R-330P
- R-330U
- R-934
- R-325U5
- R-102-M2
- ROW-RN(1)
- ROW-RN(2)

Passive EW Capabilities

- RF Receivers
  - Superheterodyne (100 MHz to 50 GHz)
  - Spectrum Analyzers (5 MHz to 26.5 GHz)
- EO Sensors
  - UV (Solar Blind); Imaging radiometers
  - Visible: Silicon Vidicon and CCD Cameras
  - IR: Radiometers, Imaging Radiometers, Spectrometers, Hyperspectral Imaging Spectrometers
- Chaff
  - ALE-32
  - ALE-38
  - ALE-43

Available Antennas

Big Crow Program Office

Frequency	Beamwidth	Gain (dB)
2-30 MHz	Omni Directional	0
30-90 MHz	60°x60°	9
90-150 MHz	Omni Directional	-3
150-500 MHz	Omni Directional	-3
500-750 MHz	50°x45°	9
750-1000 Mhz	50°x10°	15.5
1-2 GHz	24°x28°	14.8
2-4 GHz	8.5°x10°	23.9
	3.5°x3.5°	31.5
4-8 GHz	5°x6.2°	28
8-18 GHz	2.4°x2.5°	35.4

Pylon Capability

Big Crow Program Office

- Location Inboard
- MAU-12 Bomb Rack
- Weight Handling 5000 lb.
- Available Power
  - 60 Hz
  - 3ϕ 400 Hz
  - 28 VDC
- Application
  - Captive Carry
  - ECM Pods
  - Chaff Dispensers

Data Collection Capabilities

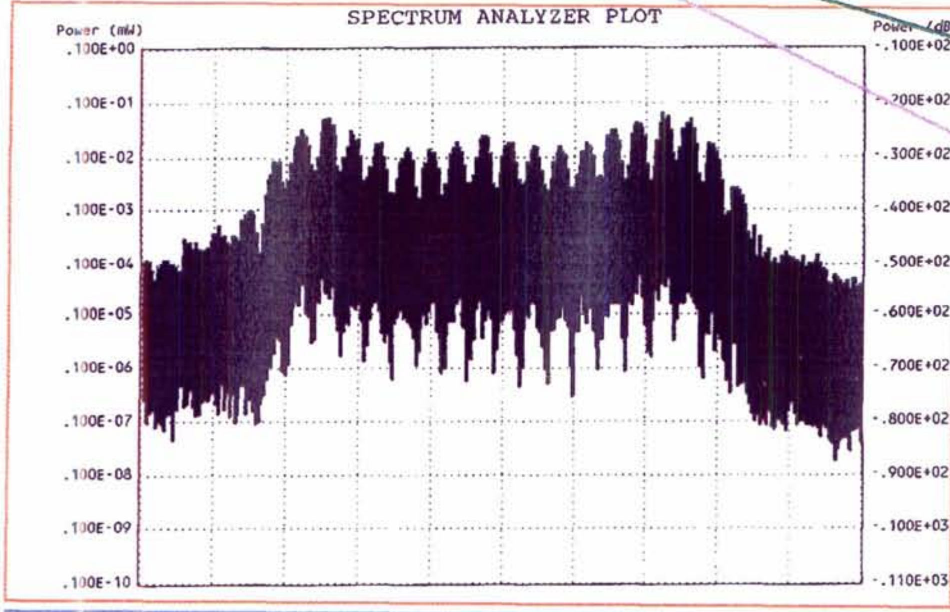
- Digital and Video Recording
- Near-Real-Time High-Resolution Image Processing and Data Compression
- Hard Copy of Digital Data
- Data Elements
  - Time (WWVB, GOES, Range, or GPS)
  - Inertial Navigation System (INS)
  - Frequency vs. Amplitude and Time
  - Power (ERP) vs. Time
  - Antenna Parametrics
  - Antenna Pedestal Parametrics
  - Operating EW Mode(s)
- Time Tagged Data Available Upon Landing

Sample Data Collection

Big Crow Program Office

```
Pedestal Parameters
    Azimuth (DDD:MM.M)......  268:46.1
    Elevation (DDD:MM.M)....  359:44.1
Antenna Parameters
    Gain (dB)...............        26
    Beamwidth (AZ) (DEG)....        14
    Beamwidth (EL) (DEG)....         3
Aiming Criteria
    Aiming mode............. Target
    Platform Position Source INS
    Target Position Source.. Keyboard   36:25.0   73:30.0   0
```

```
Positional/Attitude Data
    Altitude(FT)..................      19736
    Latitude (DDD:MM.M) (+N,-S)..     35:43.2
    Longitude (DDD:MM.M) (+W,-E).     75:09.9
    True Heading (DDD:MM.M)......    153:35.0
    Magnetic Heading (DDD:MM.M)..    163:11.8
    Roll (DDD:MM.M)..............      0:18.7
    Pitch (DDD:MM.M).............      2:47.7
    Ground Speed (Knots).........         360
```




```
Res BW      3.000 MHz        Cpld      Trace Display    C/W A;Blk B
Vid BW      3.000 MHz        Cpld      Display modes    Write A
Swp Tim    25.000 msec       Cpld      Trigger mode     Free run
Atten      10     dB         Cpld
Ref lev   -10.000 dBm
Log        10     dB/div
Center      4.802 GHz
Span        1.000 GHz
Ref off      .000 dB
CF step   100.000 MHz        Cpld
Marker            Off
Freq off     .000 Hz
Swp mode          Cont
Inp mix   -10     dBm
Trace detection   Normal(KSa)
```

Total ERP = 562.34 KiloWatts

Inertial Navigation Data

Antenna Parametrics

Targeting Parametrics

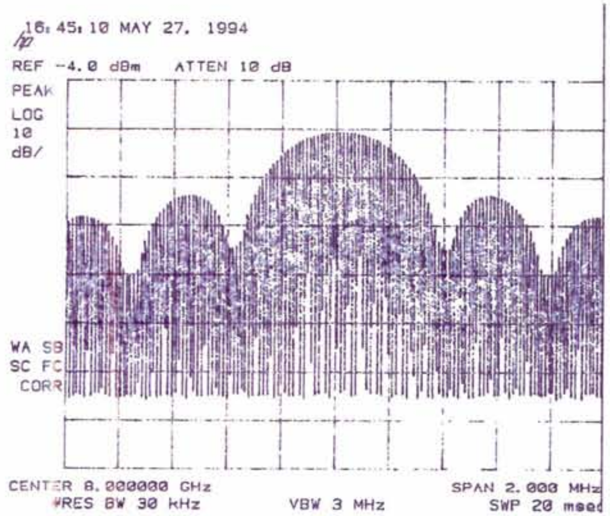
Frequency Spectrum

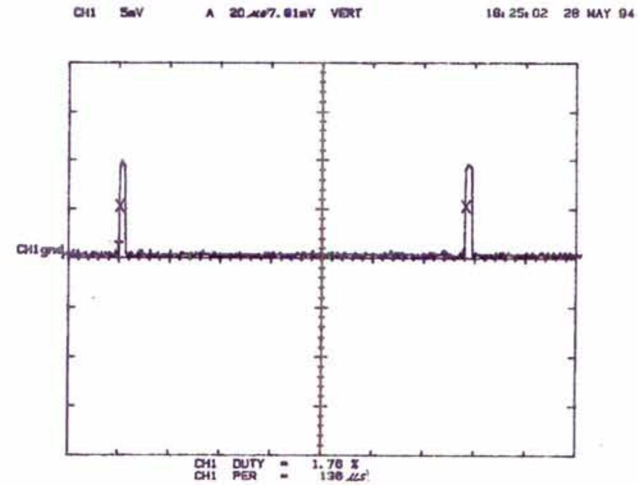
Spectrum Analyzer Setup Parameters

Transmitted Power

Sample Pulse Analysis

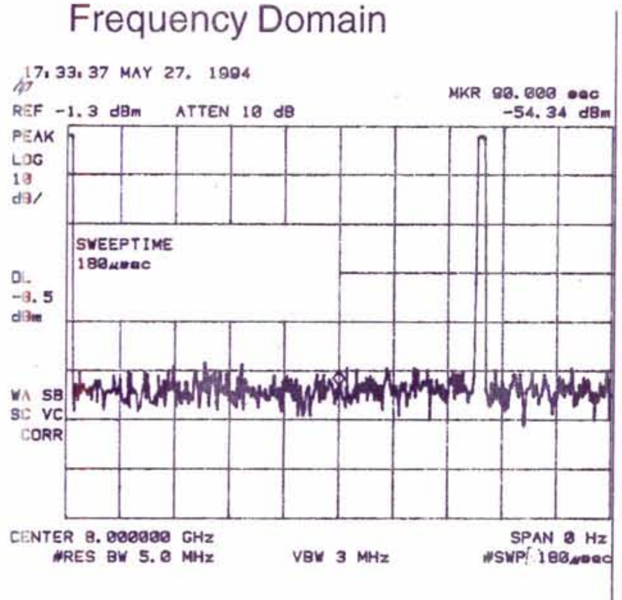
Big Crow Program Office

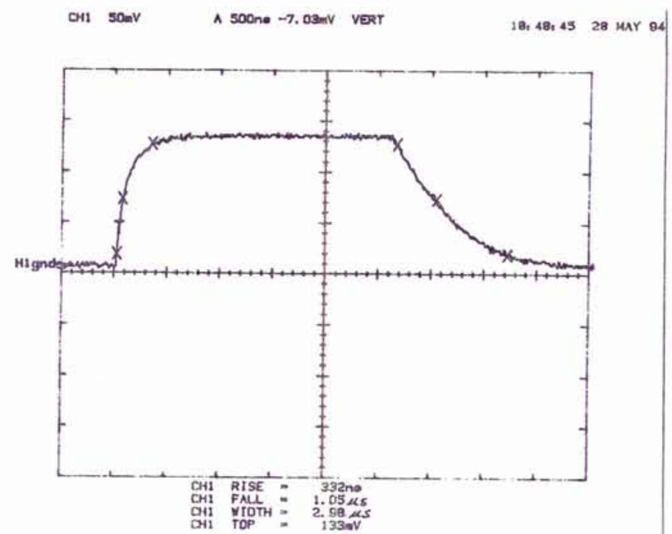




Frequency Domain

Time Domain





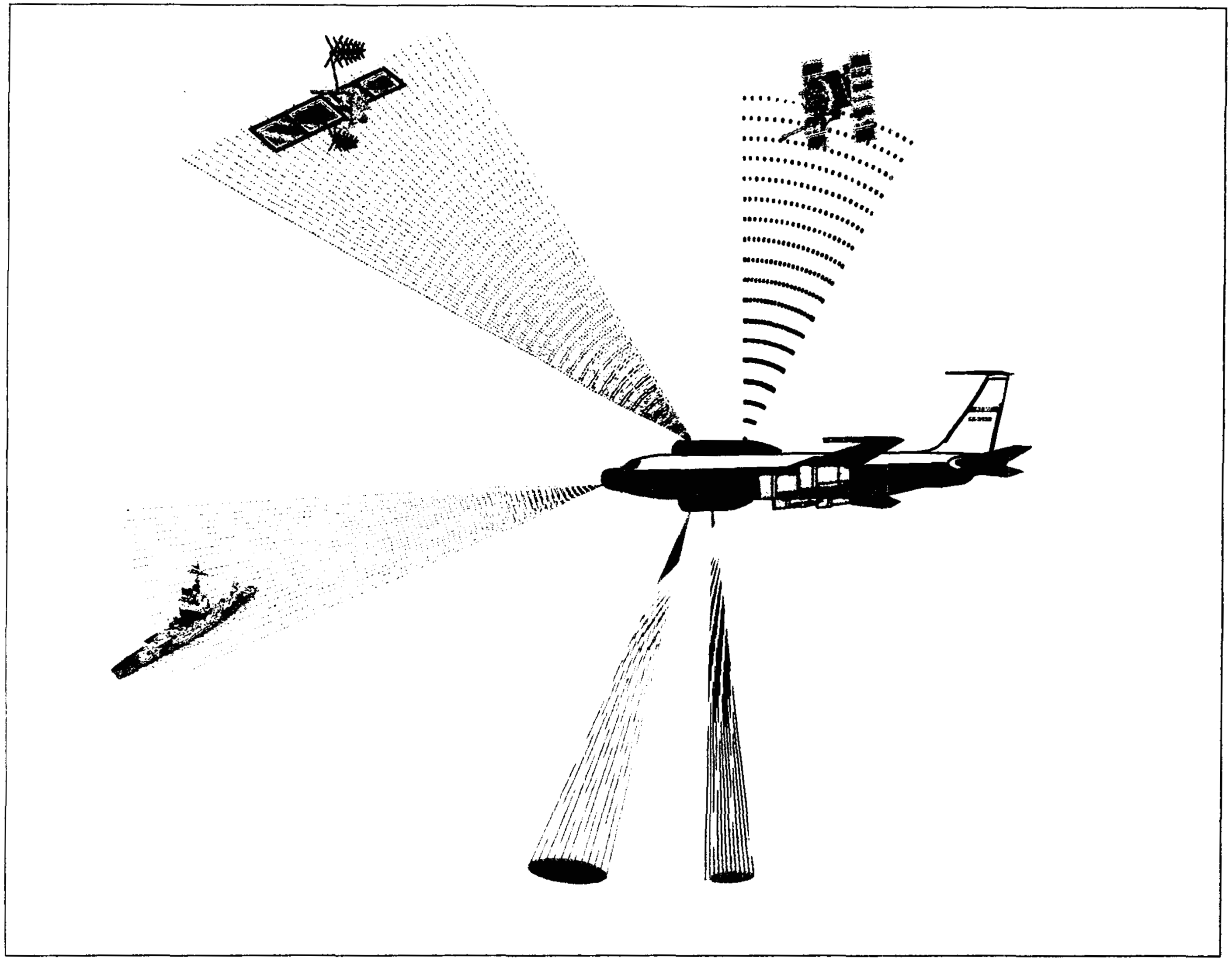
Pulse Analysis Parameters

Big Crow Program Office

- **Pulse Frequency**
- **Pulse Width (PW) (at mesial)**
- **Rise Time (proximal - distal)**
- **Fall Time (proximal - distal)**
- **Pulse Repetition Frequency (PRF)**
- **Pulse Repetition Interval (PRI)**
- **Duty Cycle**
- **Proximal Amplitude**
- **Mesial Amplitude**
- **Distal Amplitude**
- **Pulse Positive Peak Amplitude**
- **Pulse Negative Amplitude**
- **Top Amplitude**
- **Base Amplitude**
- **Overshoot**
- **Undershoot**
- **Peak-to-Peak**
- **Root-Mean-Square (RMS)**
- **Pulse Area**
- **Pulse Jitter**
- **Pulse Stagger**
- **Pulse Phase Coding**
- **Totalizer**
- **Chirp Characteristics**
- **Pulse Statistics**
  - **Mean**
  - **Std Deviation**
  - **Min**
  - **Max**
  - **Variance**
  - **Allan Var**
  - **RMS**
  - **Root AVAR**

Surgical EW Capabilities

Big Crow Program Office



Design & Development Capabilities

- Amplifiers
- Antennas
- Modulators
- Instrumentation Systems
- Aircraft Modifications (Internal & External)
- Steerable Antenna Pedestals & Controllers

Test Experience

Program Experience

- Pioneer in EWVA Methodology
- Unique U.S. National EW/EM Asset (No Known Counterpart)
- Key Element in U.S./Allied EW Infrastructure
- Extensive Blue/Gray/Red EW Database Management Expertise
- Laboratory, Systems Integration, Production Facilities
- More than $600 Million Capital Investment (excluding airborne platforms)
- Extensive Support to Over 100 Tri-Service and NATO Programs

Programs Supported

Big Crow Program Office

FY93	NKC-135E	G-II	Heliborne	Ground
AEGIS	√			
Amalgam Warrior	√			
Special Project (Black)				√
MSE/ATCCS			√	√
JTIDS	√			
FY94				
AEGIS	√			
FMS AEGIS (Japanese)	√			
CEC AEGIS	√			
ABLE-ACE		√		
AIRMS		√		
MSE/ATCCS			√	√
FAAD C3I			√	√
NORAD	√			
E-3A	√			√
JSTARS	√			
AMALGAM WARRIOR	√			
JTIDS			√	
Combat ID				√

Programs Supported

Big Crow Program Office

FY91	NKC-135E	Heliborne	Ground
Re-Engining	√		
Flight Test (lower radome)	√		
Periodic depot maintenance	√		
Power Distribution Modification on A/C	√		
Iceland Radar	√		
AEGIS (CG-64 & DDG-51)	√		
MSE		√	√
Sensor Fuzed Weapons			√
TAFIS (Demonstration)			√
OTH-B	√		
FY92			
AEGIS	√		
JTIDS	√		
MSE		√	√
Amalgam Chief	√		
Friendly Fire			√
IDL			√
JSTARS			√
Patriot	√		

Programs Supported

Big Crow Program Office

FY89	NKC-135E	Heliborne	Ground
Global Positioning System	√	√	√
Navy AEGIS	√		
Patriot Radar	√		
NORAD	√		
Patriot Communications		√	
Forward Area Air Defense System		√	
Have Nap			√
High Risk Reduction	√		
OTH-B	√		
Advanced Tactical Missle System	√		
FY90			
Global Positioning System		√	
Navy AEGIS	√		
Patriot Radar	√		
Sensor Fuze Weapon System			√
High Power Technical Risk Reduction	√		
NORAD	√		
Fire Finder			√
OTH-B	√		
E-3A			
Patriot Communications			√
Joint Tactical Information Distribution System	√		
TPS-73	√		
SINCGARS		√	

Point of Contact

Big Crow Program Office

Milton D. Boutte
Program Manager

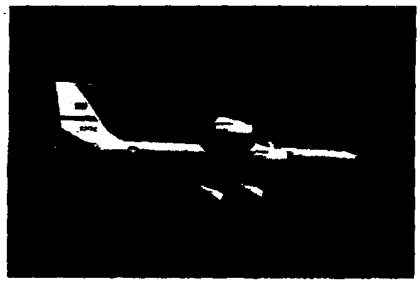
Big Crow Program Office
3710 Trestle Rd
Kirtland AFB, NM 87117-5000

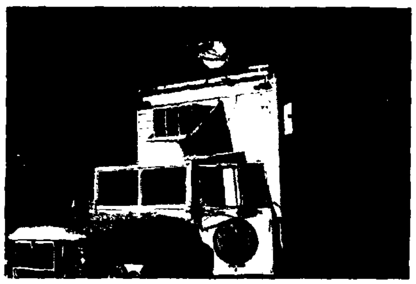
Phone: (505) 846-8498
DSN: 246-8498

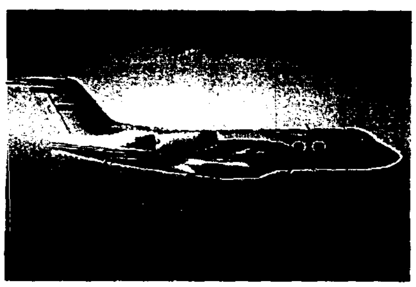
FAX: (505) 846-0345
DSN: 246-0345

Document Separator

Big Crow Program Office







The Big Crow program, which possesses the world's premier electronic warfare assessment assets, is now available to users for EW training. Big Crow, based at Kirtland Air Force Base, New Mexico, has a projection capability to any operational theater. Big Crow represents a unique collection of EW capabilities, the cornerstone of which is the program's highly modified NKC-135E aircraft. The program also features platforms such as ground-based vans, CH-47D EW helicopters, and a Gulfstream G-II. Each platform has extensive electronic mission equipment, including both comprehensive internal ESM/ECM systems and external pylon-mounted pods (ALQ-167).

The Big Crow Program Office has applied its 25 years of EW assessment expertise to developing an intensive EW training program that offers users the opportunity to strengthen the effectiveness of their existing EW resources. Big Crow personnel have the knowledge, skills, and abilities to aid customers in planning and executing comprehensive, multi-disciplined, and results-oriented EW training unavailable from any other source. The program is designed to accommodate all levels of EW proficiency from an orientation in basic fundamentals of EW to advanced ECCM techniques training.

The EW suites maintained by Big Crow enable the user to emulate every known EW threat environment with a degree of sophistication unmatched by any other training resource. By use of proven research techniques, applied to a training environment, Big Crow provides autonomous calibrated instrumentation and real-time analytical capabilities to customers. Big Crow provides users with a time and event correlated report (hard copy of magnetic media) at the completion of the mission.

The flexibility of Big Crow is enhanced through an innovative engineering approach to the mission equipment suites. All equipment suites are rapidly reconfigurable from one platform to another. Big Crow can simultaneously deploy sufficient electronic capabilities to provide EW training to large, widely dispersed formations (e.g., naval task forces, EW training ranges, and associated supporting aircraft). In exercises where EW is to be selectively applied, Big Crow can provide secure communications, and command and control to ensure the integrity of the friendly exercise forces while meeting original training objectives. Big Crow is experienced in successfully coordinating ECM frequency clearances in dense signal environments through specially developed techniques embedded within its software.

Big Crow generates various modulation schemes, including barrage noise, spot noise, continuous-wave and deception signals. It can attack all modern modulated radar with essentially any electronic warfare technique requested by the user (e.g., communications jamming, stand-off/escort self-screening/ chaff clouds/radar/data link jamming, and a full range of electronic support measures). Also it can carry aloft entire missile systems or subsystems.

The normal 8-hour mission duration for the NKC-135E aircraft is extendible to 14 hours on station through an in-flight refueling capability. For cost and availability information, U.S. users should contact the Big Crow Program Manager directly.

For additional information, contact:

Big Crow Program Office
attention: Mr. Milton D. Boutte
3710 Trestle Rd., Bldg 20797
Kirtland AFB, NM 87117-5000
DSN: 246-8494 COM: (505) 846-8494 Fax: (505) 846-0345

Big Crow Program Office

Overview

The Big Crow Program Office, based at Kirtland Air Force Base, New Mexico, possesses a unique collection of EW capabilities, the cornerstone of which is the programs highly modified NKC-135E aircraft. The program also features platforms such as ground-based vans/trucks, CH-47D Electronic Warfare (EW) helicopters and a Gulfstream G-II.

The Big Crow Program Office has applied its 25 years of EW assessment expertise to developing an intensive EW training program that offers users the opportunity to strengthen the effectiveness of their existing EW resources. Big Crow personnel have the knowledge, skills and abilities to aid customers in planning and executing comprehensive, multi-disciplined and results-oriented EW training unavailable from any other source. The program is designed to accommodate all levels of EW proficiency from an orientation in basic fundamentals of EW to advanced electronic-counter-counter-measures (ECCM) techniques training.

The EW suites maintained by Big Crow enable the user to emulate every known EW threat environment with a degree of sophistication unmatched by any other test or training resource. By use of proven research techniques, applied to a test and training environment, Big Crow provides autonomous calibrated instrumentation and real-time analytical capabilities to customers. Big Crow provides users with a time and event correlated data collection and reporting at the completion of the mission.

The flexibility of Big Crow is enhanced though an innovative engineering approach to the mission equipment suites. All equipment suites are rapidly reconfigureable from one platform to another. Big Crow can simultaneously deploy sufficient electronic assets/capabilities to provide EW test and training to large, widely dispersed formations (e.g., naval task forces, EW training ranges and associated supporting aircraft). Big Crow is experienced is successfully coordinating ECM frequency clearances in dense signal environments, utilizing specially developed filtering techniques embedded within Big Crows systems.

Big Crow generates various modulation schemes, including barrage noise, spot noise, continuous-wave and deception signals. Big Crow can attack all modern modulated radars, communication links and data links with essentially any EW technique requested by the customer as well as provide comprehensive data collection.

Big Crow is fully mission-capable to support EA/ES C2W and EO missions for all Services, the CINC's, Joint Services, DOD agencies, NORAD and NATO countries.

For Additional Information contact Big Crow Program Office, Mr. Milton D. Boutte at: Com (505) 846-8498, DSN 246-8498.

The Big Crow Program Office assets can be divided into the following categories:

1) NKC-135E Airborne Electronic Laboratory
2) Gulfstream II Airborne Electro-Optical Laboratory
3) Helicopters (CH-47D/Ft Rucker/Ft Hood/National Guard Units)
4) Mobile Electronic Ground Platforms
5) Instrumentation
6) Scientific and Technology Development Capabilities
7) Antennas
8) Receivers
9) Transmitters

The following sections discuss the salient aspects for each of the asset categories. These discussions are followed by a concluding section that provides additional information regarding the BCPO.

1) NKC-135E:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/ELINT/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides a realistic red and blue threat environment (single, multiple or simultaneous) anywhere in the world. Big Crow can cut and dispense all bands of chaff and accept specialized pods on its wing mounts.

Functional Description:

NKC-135E: The Big Crow NKC-135E is a tri-Service airborne research and development laboratory most noted for EW design and development, testing, evaluation and training. Onboard instrumentation suites consist of rack-mountable systems that are generic to all of the Big Crow platforms. These systems are palletized to enable quick reconfiguration of the platform when required. The modified NKC-135E aircraft, equipped with in-flight refueling, is capable of autonomous E^3 experimentation that with the characteristics of a flying "experimental" laboratory; flight durations are up to 15 hours. Also, complete data packages are available upon landing for analysis and verification of test parameters and procedures.

Characteristics:	Emulator/Trainer
Max Altitude:	42,000 ft
Min Altitude:	500 ft
Range:	15 hrs/12,000 miles (in-fight refueling) 6 hrs/2,500 miles (w/o refueling)
Max Speed:	.85 mach
Min Speed:	300 kts
Max Conserve:	350 kts
Runway length:	8,000 ft
ECCM Features:	DRFM

The following table is a partial list of threats which are capable of being emulated or simulated by the Big Crow aircraft.

ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEMS*	*ELNOT*	*FREQUENCY*
SPS(1)	--	--	None	30-500 Mhz
SPS-N(1)	--	--	None	30-500 MHz
SPS-5	FENCER	--	None	30-500 MHz
SPS-N(2)	FIGHTER (URS)	--	None	30-500 MHz
SPS-6	--	--	None	30-500 MHz
SPS-N(3)	FIGHTER (URS)	--	None	30-500 MHz
RJS-3140	FIGHTER (URS)	--	None	30-300 MHz
SPS-5N	--	--	None	100-500 MHz
	BASILISK (MIRAGE)	--	None	1-12 GHz
	CAIMAN (MIRAGE)	--	None	1-4 GHz
ELT-458	--	--	None	1-4 GHz
RJS-3100	--	--	None	8-12 GHz
SPS-141	FIGHTER (URS)	--	None	1-4 GHz
SPS-142	FOXBAT/FENCER	--	None	1-4 GHz
SPS-143	FOXBAT/FENCER	--	None	1-4 GHz
SPS-161	FOXBAT/FENCER	--	None	1-4 GHz
SPS-162	FOXBAT/FENCER	--	None	1-4 GHz
SPS-H(7/7x)	FOXBAT	--	None	8-12 GHz
SPS-SN	FENCER	--	None	1-4 GHz
SPS-WB(2-7)	FIGHTER (URS)	--	None	1-4 GHz

2) Gulfstream II:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/EO-IR/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides a realistic red and blue threat
environment (single, multiple or simultaneous) anywhere in the world. The G-II is capable of transporting the same EA/ES instrumentation that is used on NKC-135E and can accept specialized pods on its wing mounts. The Gulfstream II also provides an excellent platform for EO experimentation.

Functional Description:

Gulfstream II: Big Crow's Gulfstream II is also a tri-Service airborne research and development electronic laboratory. This platform also performs E^3 experimentation and is particularly suitable for EO experimentation and detection.

Characteristics:	Emulator/Trainer
Max Altitude:	50,000 ft
Min Altitude:	200 ft
Range:	6 hrs/2,500 miles
Max Speed:	.85 Mach
Stall Speed:	108 kts
Max Conserve:	.75 Mach
ECCM Features:	DRFM

The following table provides a partial list of threats which can be emulated or intercepted by the Big Crow G-II aircraft.

ELINT NOTATION	NATO PLATFORM	WEAPON SYSTEMS	ELNOT	FREQUENCY
SPS(1)	--	--	None	30-500 Mhz
SPS-N(1)	--	--	None	30-500 MHz
SPS-5	FENCER	--	None	30-500 MHz
SPS-N(2)	FIGHTER (URS)	--	None	30-500 MHz
SPS-6	--	--	None	30-500 MHz
SPS-N(3)	FIGHTER (URS)	--	None	30-500 MHz
RJS-3140	FIGHTER (URS)	--	None	30-300 MHz
SPS-5N	--	--	None	100-500 MHz
	BASILISK (MIRAGE)	--	None	1-12 GHz
	CAIMAN (MIRAGE)	--	None	1-4 GHz
ELT-458	--	--	None	1-4 GHz
RJS-3100	--	--	None	8-12 GHz
SPS-141	FIGHTER (URS)	--	None	1-4 GHz
SPS-142	FOXBAT/FENCER	--	None	1-4 GHz
SPS-143	FOXBAT/FENCER	--	None	1-4 GHz
SPS-161	FOXBAT/FENCER	--	None	1-4 GHz
SPS-162	FOXBAT/FENCER	--	None	1-4 GHz
SPS-H(7/7x)	FOXBAT	--	None	8-12 GHz
SPS-SN	FENCER	--	None	1-4 GHz
SPS-WB(2-7)	FIGHTER (URS)	--	None	1-4 GHz

3) CH-47D Helicopter:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides realistic red and blue threat environment (single, multiple or simultaneous) anywhere in the world. The CH-47D with palletized EW suite can simulate any Soviet or third world country heliborne EW threat and is fully capable of carrying any of Big Crow EA or ES capabilities.

Functional Description:

Helicopters: CH-47D helicopters are available upon demand and are obtained from either the WagonMasters at Ft Hood or "F" Company at Ft Rucker or National Guard Units. Big Crow Program Office can configure these platforms with most of the same EW equipment that the other airborne platforms accommodate.

Characteristics:	Simulator/Trainer
Max Altitude:	20,000 ft
Min Altitude:	50 ft
Range:	3 hrs/300 miles
Max Speed:	170 kts
Min Speed:	70 kts
Max Conserve:	130 kts
ECCM Features:	N/A

The following table provides a partial list of threats which are capable of being emulated or intercepted by the Big Crow helicopter platforms.

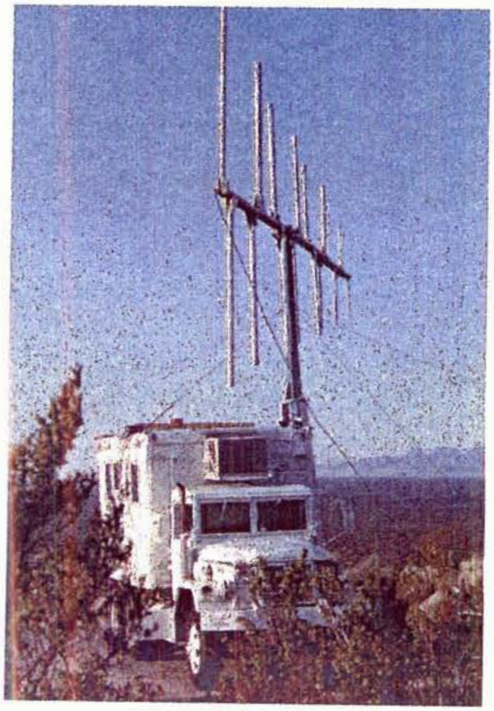
ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEMS*	*ELNOT*	*FREQUENCY*
SPS-RN(1)	HIP	None	None	30-300 MHz
SPS-RN(2)	HIP			8-12 GHz
SPS-RN(3a)	HIP			8-12 GHz
SPS-RN(3b)	HIP			8-12 GHz
SPS-RN(5)				
SPS-RN(6)				
SPS-RW	HIP J/K	None	None	1-4 Ghz
SPS-WB	HIP			8-12 GHz
SPS-P(7)	HIP J			8-12 GHz
ROW-RN(1)	HIP			30-300 MHz
ROW-RN(2)	HIP			100-500 MHz
ROW-RN(3)	HIP			8-12 Ghz
SPS-N(2)				8-12 GHz
SPS-N(3)				8-12 GHz
SPS-P(7)	HIP J	None	None	8-12 GHz

4) Ground Platforms:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides a realistic ground-level red and blue threat environment (single, multiple or simultaneous)

Functional Description:

Ground Vans: The Big Crow ground vans are configured to accept all of the same palletized systems that the airborne laboratories utilize to provide stationary EA emulators. Each van contains its own power generation capability which enables them to operate in remote areas.

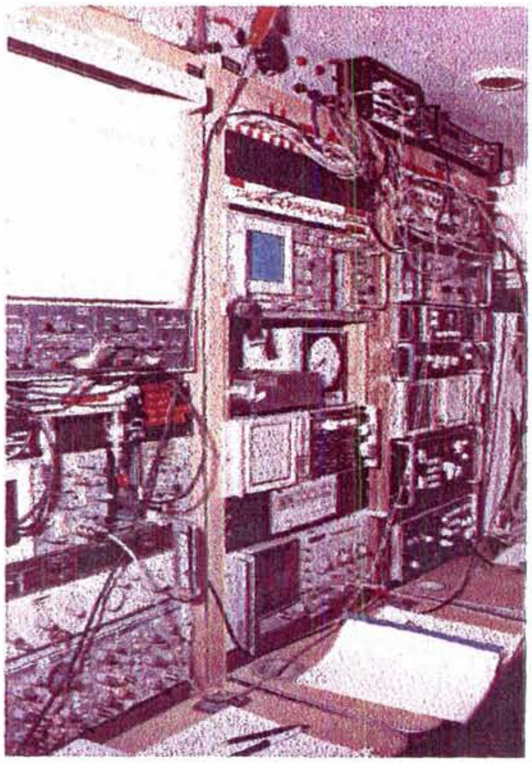


Characteristics:	Emulator/Trainer
Power Requirements:	400 Hz 3 Phase 60 Hz single Phase
Power Source:	Self-contained generators or shore power
Communication:	HF/VHF/UHF or cellular phone
Fuel requirements:	Diesel or Mo-Gas
ECCM Features:	N/A

The following table is a partial list of threats that can be emulated or intercepted by the Big Crow ground-based platforms.

ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEM*	*ELNOT*	*FREQUENCY*
R-325U		None	None	30-300 MHz
R-378A				30-300 MHz
R-378B				30-300 MHz
R-330A	SILVER TRAY			30-300 MHz
R-330B				30-300 MHz
R-330P	PIRAMIDA			30-300 MHz
R-330U	COPPER WHEEL			100-500 MHz
R-934				100-500 MHz
R-325U5				3-100 MHz
R-102-M2				8-12 GHz
	CHEESE BRICK			8-12 Ghz
	HEART ACHE (A/B)			8-12 GHz
	JACK KNIFE			8-12 GHz
	KING PIN			8-12 GHz
	KING PIN (B)			8-12 GHz
	PAINT BOX			8-12 Ghz
R-118-8M3				8-12 GHz
RP-379(D)				
C343A	SIDE GLOBE			1-2 GHz
	HUNGARIAN VHF			30-300 MHz
	HUNGARIAN UHF			100-500 MHz
EUK-7010				
TACJS				30-300 MHz
TRC-285				100-500 MHz

5) Instrumentation



The Big Crow Program Office has designed its assets in a fashion that provides its customers with timely R&D and operational support in a cost-effective manner. Thru generacism in design, Big Crow EW suites are easily accreditable on a test-by-test basis. Generacism in design also allows efficient modification to Big Crow EW suites to meet both current and future EW threat requirements. The instrumentation is rack-mounted and the platforms utilize track mounting to provide rapid equipment/system configuration/de-configuration. Also, custom-tailored data collection is available post-mission for immediate verification of test parameters and procedures. Both airborne assets contain inertial navigation systems (INS) and all Big Crow platforms contain global positioning systems (GPS).

In addition to the NKC-135E dynamic flight profile characteristics and capabilities, its instrumentation, data recording and analysis capabilities provide for a wide range of field experiments that have led to many upgrades to major systems which has enhance their battlefield survivability. This unique capability can be transferred from the NKC-135 to the G-II, CH-47D or any of a wide array of instrumentation vans.

The Big Crow Program Office employs a number of Data General, Sun Sparc stations, Hewlett-Packard and customized PC-based computer systems for controller/data collection depending on the platform used and mission requirements. Test data can be stored in a variety of formats such as 9-track tape or Bernoulli disk. Examples of the instrumentation data that can be recorded digitally are listed below:

Transmitter and Receive Waveform Characteristics:

- Power Level
- Power Spectral Density
- Center Frequency
- Bandwidth
- Sidelobe Levels
- Blink Rates

Temporal Waveforms Characteristics:

- Pulse Widths
- Rise/Fall Times
- PRI

Receivers:

- Center Frequency

Timing:

- WWVB
- GPS
- Range Control
- GOES

Antennas Characteristics:

- Pedestal Pointing Angles (antenna orientation)
- Gain
- Beamwidth (azimuth & elevation)

Aircraft Parameters:

- Latitude
- Longitude
- Altitude
- Roll
- Pitch
- Yaw

Each set of data is time tagged using GPS and/or WWVB time standard as it is collected to allow easy correlation of data during quick-look or post-test analyses.

In addition to the real-time displays, associated with the various test equipment (e.g. spectrum analyzers, oscilloscopes etc.) a real-time onboard display system (RODS) provides a current situation map indicating the aircraft position, the position of fixed ground based elements and the orientation of the various airborne antenna beams. All the test data can be plotted or printed to meet most customer requirements. The Big Crow Program Office has existing software capable of printing or plotting data from all transmitting, receiving and data collection equipment in the inventory. Special software can be generated if the customer requires special data reduction.

6) Scientific and Technology Development:

The Big Crow Program Office has designed its civilian and military assets along with its contractor base in a fashion that provides its customers with timely R&D, experimentation and operational support in a cost-effective manner. The technical and professional relationship between these various branches are extremely versatile and flexible in their knowledge of engineering and test operations. The Big Crow Program Office utilizes generic off-the-shelf equipment to provide specialized support. All of Big Crow Program Office equipment has been designed to be transferable between the various platforms that are carried in the Big Crow Program Office inventory, making this a very flexible operation.

One of the biggest assets of the BCPO is the ability to rapidly design and develop one-of-a-kind systems as required. Specifically, the Big Crow organization has an "in-house" capability to design and manufacture special purpose modulators, signal generators and antennas.

7) Antennas:

The Big Crow Program Office has a large number of antennas available, for fixed and steerable antenna pedestal mounting, providing a complete 360 degree field of view (FOV) frequency coverage (2 MHz to 50 GHz) for a variety of polarization and gain specifications. Antennas can be mounted in the nose, top and belly radomes as well as an aft- looking radome. Antennas can also be mounted on the wingtips and tailboom.

Antenna Configuration: Multiple
Antenna Type: Dish, Parabolic,HF Long Wire, Horn, Blades Helix, Log Periodic, Trailing
Wires, Spirals, Aperture Arrays

Antenna Size: Up to 58" in diameter for airborne antennas; various horns and horn array sizes available. No antenna size limitation for use in ground platforms.

The following is a partial list of antenna capability for the current inventory of antennas.

Frequency	*Antenna Beamwidth*	*Gain (db)*
2-30 MHz	Omni Directional	0
30-90 MHz	60° X 60°	9
90-150 MHz	Omni Directional	0
150-500 MHz	Omni Directional	0
500-750 MHz	50° X 45°	9
750-1000 MHz	50° X 10°	15.5
1-2 GHz	24° X 28°	14.8
2-4 GHz	8.5° X 10°	23.9
	3.5° X 3.5°	31.5
4-8 GHz	5° X 6.2°	28
8-18 GHz	2.4° X 2.5°	35.4
18-26.5 GHz	34° X 23°	16
26.5 GHz-50 GHz	Various	Various
All Frequencies	Custom	Custom

Note: The Big Crow Program Office has an enormous inventory of antennas along with the capability to design and manufacture custom antennas. In addition, the Big Crow Program Office has access to additional resources for frequency bands lying outside this range.

Gain Mainlobe:	Available upon request
Gain Sidelobe:	Available upon request
Beamwidth:	Available upon request
Polarization:	Vertical & Horizontal Linear, Left & Right Circular
Scan Type:	None
Scan Rate:	N/A

8) Receivers:

The receiving capabilities of the Big Crow Program Office are extensive, comprising state-of-art equipment in swept and non-swept receiver techniques. Currently, the Big Crow Program Office inventory contains a variety of receiving equipment that can operate over the frequency range of 2 MHz to 50 GHz. Attainable IF bandwidths are selectable, depending upon the particular receiver and specific center frequency. Please contact the Big Crow Program Office listed at the end of this document for further information.

The WJ 1740, commonly used by the Big Crow Team is an example of intercept/analysis equipment. It is a parallel-scanned, digital controlled superheterodyne receiving system which includes two tuners covering the frequency band 0.1 - 18 GHz. Expansion to 50 GHz is possible with additional tuners This equipment provides the capability of rapid signal detection and isolation into an analysis channel. The receiver then continues to perform its spectrum surveillance capability simultaneously with the analysis function of the isolated signal.

9) Transmitter Capabilities:

The transmitter/modulation capabilities of the Big Crow Program Office are extensive comprising state-of-art capability. This is a highly flexible system that can simulate both denial and deceptive EA environments over the frequencies from 2 MHz to 26.5 GHz.

The Big Crow organization has a wide variety of modulators, waveform generators and power amplifiers is its inventory. Various combinations of this equipment enables the emulation of an extremely broad number of EW threat waveforms. In addition to the emulation of well-defined threat waveforms, Big Crow is frequently involved in the generation of more specialized waveforms for use in EW testing and development.

Big Crow has a host of commercial waveform generators and synthesizers available covering the frequency range from .2 MHz to 26.5 GHz. In addition, Big Crow has developed several unique waveform generators. To provide a better understanding of these Big Crow capabilities, two examples will not be briefly described.

Generic Threat Simulator: Big Crow utilizes a generic threat emulator system. The generic threat emulator is a highly flexible and powerful system which can simulate, deny and deploy a deceptive EA environments. The system produces radio frequency (RF) signals in the frequency range and power levels needed to simulate threats and domestic EA systems. Signal sources are selected from within the 2 MHz to 26.5 GHz range to cover the frequency of interest. Techniques such as spot noise, swept spot, barrage noise and click repeater (DRFM) are but a few of the modulation techniques available as listed below. All parameters and functions are digitally controlled (with a manual override) for rapid generation of threat sets. A partial list of the available modulation types are listed:

Type	*Description*
FM	CLICK
FM	Wideband sinewave
FM	Wideband sawtooth
FM	Wideband triangle
FM/FM	Wideband sinewave/sinewave/sawtooth or triangle
FM/FM	Wideband sawtooth/sawtooth, sinewave or triangle
FM/FM	Wideband triangle/triangle, sinewave or sawtooth
FM	Gaussian Noise
FM	Swept CW
AM	Square wave
AM	Sine wave
AM	Gaussian AM Noise
AM/FM	Sinewave wobulation of a sinewave or squarewave or asymmetry pulse
AM/FM	Sawtooth wobulation of a sinewave or squarewave or asymmetry pulse wobulation of a sinewave or squarewave or asymmetry pulse.
AM/FM	Triangle wobulation of a sinewave or squarewave or symmetry pulse
AM	Blinking Generator

Special One-of-a-Kind: A special (one-of-a-kind) EA environmental test transmitter (ECMETT) designed for assessment of the U.S. Army Patriot missile system is available for expanded usage. Three classes of jamming signals are generated: Barrage noise jamming, transponder and straight through coherent repeater. Depending upon the operator-selected mode of operation, the receiver section affects the system operation in three different ways. In the transponder modes, the output of the receiver triggers the EA signal transmissions for which internal RF carrier sources are utilized; in the repeater modes, the receiver performs as the front end of the repeater-modulation configuration; finally, in the manually actuated modes the receiver is a passive indicator of the signals which represent in the band of interest. A multi-frequency determining unit (FDU) and an automatic signal recognition unit (ASRU) are included as part of the receiver section. These signal-sorting units identify the class of signal being received, display the information on the control panel and program EA response in transponder modes of operation. The modulation source section contains several sawtooth generators, a sinewave generator, Gaussian noise generator and a pseudo-random noise generator. In the repeater modes of operation there is a linear phase shifter, a frequency shifter and an inverse gain function. The resulting waveforms are combined in various configurations to yield a total of 33 modes of operation.

The below listed power amplifier are in Big Crow Program Office current inventory and have been used as threat representative against U.S. systems.

- ALT-28's: ALT-28 power amplifiers are available to meet customer barrage requirements in the frequency bands C,D,E,F,H & I.
- ALT-40's: ALT-40 power amplifiers are available to meet customer barrage requirements in the frequency bands C,D,E & F.
- Commercial power amplifiers: All the low-level modulators can be combined with power amplifiers to provide a high power EW environment. A list of power amplifiers is shown as follows:

Frequency	*100 Watts*	*250 Watts*	*1 KW*	*2 KW*	*3 KW*
1 to 220 MHz					X
2 to 32 MHz				X	
30 to 150 MHz				X	
0.1 to 0.5 GHz			X		
0.7 to 1 GHz				X	
0.8 to 2.2 GHz			X		
1.0 to 2.0 GHz					X
2.0 to 4.0 GHz		X			
4.0 to 8.0 GHz		X			
8.0 to 10 GHz	X				
10 to 18 GHz	X				

Note: These power amplifiers are capable of being deployed in either the NKC-135E, G-II, CH-47 or any of the ground test vehicles and have successfully tested against the following US systems:

- JTIDS Data Link
- AEGIS Radar/Data Link
- SINCGARS Communication System
- NORAD Ground and Air Search Radars
- MSE Communication Network
- HAWK Self-Defense Missile System
- Patriot Radar

REMARKS: The Big Crow is a versatile EW research and development airborne platform in the Department of Defense inventory. Big Crow is capable of autonomous EW experimentation that gives it the characteristics of a flying experimental EW laboratory capable of responding in a timely and cost efficient manner. It has the flexibility to accommodate a wide range of standard and developmental hardware and systems with short lead times at any customer location. Big Crows electronic suites were designed to be interchangeable between the aircraft, helicopter-based and ground-based platforms, with prime consideration for commonality of software, computer interfaces equipment racks, power and transmission lines. Thus, Big Crow Program Office can provide any EW environment with intercept, data recording/reduction and training.

10) Additional Information:

MOBILITY: Big Crow can stage from facilities capable of accommodating NKC-135 aircraft. With inflight refueling tanker support Big Crow can provide extended flight support throughout the world.

LOCATION/QUANTITY

LOCATION:	Kirtland AFB, USA TECOM
QUANTITY:	1 NKC-135E
	1 Gulfstream II
	10 Test/Instrumentation Vans
	6 CH-47D Helicopter
OFFICE:	U.S. Army Big Crow Program Office
CITY:	Kirtland AFB, NM
POC ROLE:	Program Manager (PM)
POC NAME:	Mr. Milton Boutte
COMMERCIAL PHONE:	(505)846-8494/8498
DSN PHONE:	246-8494/8498
ALTERNATE PHONE:	505 846-8498
FAX PHONE NUMBER:	505 846-0345
OFFICE:	U.S. Army Big Crow Program Office
CITY:	Kirtland AFB, NM 87117-5000

COMMENTS: The Big Crow Program Office, often referred to as a "National Asset" consists of dedicated, highly experienced engineers and is supported by a superior technical staff with a 20-year track record of success in EW test, experimentation and training in all of DOD. The Big Crow program has pioneered the model for today's military testing organization -- capable and experienced in serving in a variety of testing and training roles, producing technically excellent results, on ***time*** and within ***budget***.

Document Separator

KIRTLAND AFB UPDATE--8 MAY 1995
Thoughts From the Kirtland AFB Steering Committee

SITUATION:
The original USAF proposal to realign KAFB was to send most tenant organizations to other installations, and to canton at KAFB the Phillips Lab, the Kirtland Underground Munitions Storage and the 150th Fighter Group. To execute this proposal, the USAF estimated a one-time cost of $277 million with recurring savings of $62 million. At the 20 April Regional Hearing, the Steering Committee demonstrated the USAF plan has a one-time cost of $525 million with a recurring cost to the taxpayer of $12.7 million, and presented operational impacts not considered by the USAF.

On 3 May, the USAF released new cost estimates that show their proposed realignment has a one-time cost of $608 million with at recurring annual savings of $2 million when Department of Energy costs are considered. Operational impacts presented on 20 April were not addressed by the USAF.

Recognizing their original plan was ill conceived, the USAF began evaluating a new plan on 3 May that relocates fewer units from Kirtland, and retains a significant, consolidated support organization for both the DOD and DOE organizations remaining at KAFB, as well as retaining some support for active duty members such as the commissary. The new USAF plan begins to address operational impacts on the nuclear infrastructure, but not the other organizations.

OPERATIONAL IMPACTS:
The new USAF plan reduces impacts on the nuclear infrastructure, to some degree, by keeping the Defense Nuclear Agency at KAFB, and by retaining military security for the underground storage mission. Unfortunately, the AF Safety Center, AF Inspection Center and AF Security Police Agency are still being relocated away from the nuclear support core to undetermined locations. Given that many military will remain at KAFB which will retain a large support infrastructure, these moves appear to lack any rationale.

The USAF has directed site surveys of Hill AFB and Beale AFB for the 58th Special Operations Wing. Holloman AFB has been determined to be too expensive. In terms of flying weather, varied terrain, training areas, density altitude and existing facilities, KAFB is unquestionably better than any of the three alternatives. Any relocation will result in a perpetually inferior training environment, with little, if any, recurring cost savings justification. Finally, the GAO report explicitly states the inability of Beale AFB to accept new aircraft due to air quality.

The movement of the 58th SOW will cause disruption in overseas/CONUS personnel replacement, which will degrade special operations capabilities during the multi-year duration of the relocation. This disruption unfortunately comes at a time of increasing force structure growth. Further, the flight simulators of the 58th SOW will be unavailable for real-world mission planning and rehearsal, and will result in increased training flying hour demands on SOF aircraft. SOF aircraft are currently undergoing extensive modification, making fewer available for training. Both initial and concurrency training will suffer needless degradation.

COST:
When the DOE costs are considered within the USAF cost estimates from their 3 May, there is reasonable agreement with the cost data provided by the Steering Committee on 20 April. While the Steering Committee still has issues with the USAF estimate, both the USAF estimate and the Steering Committee estimate confirm the original USAF proposal is fiscally unsound.

No cost data has yet been generated for the 3 May USAF option, nor do we expect the USAF to provide that data in a timely manner. However, the USAF strategy appears to be to create recurring annual savings by having the USAF provide support services to DOE organizations more cheaply than the DOE organizations can provide it to themselves. This would simultaneously eliminate most of the DOE recurring cost of $30.6 million, and remove DOE from the cost discussion process. To avoid one-time costs for military construction, USAF guidance is to find existing facilities, at any location, for units departing Kirtland. Operational concerns resulting from a relocation based upon availability of facilities, are secondary. The USAF is searching for any scheme for KAFB that will provide a return-on-investment of ten years or less.

CONFORMITY OF OBJECTIVES:
The Steering Committee believes that any proposal or recommendations they submit to the Commission must be consistent with the goals of reducing infrastructure and saving taxpayer dollars while maintaining, or if possible, improving military effectiveness and efficiency. The Steering Committee would like to see improved military effectiveness and efficiency at KAFB by enhancing the capability of organizations like Phillips Labs, and by improved inter-agency synergy through the co-location of organizations with related missions. But, there is absolute recognition that these desires must be complementary, not merely feasible, with the Commission's objectives. None of the USAF proposals satisfy the Commission's goals.

OPPORTUNITIES FOR THE AIR FORCE:
Numerous options involving KAFB are available that will improve military effectiveness and efficiency, reduce unneeded infrastructure, yield significant savings to the taxpayer, and provide economic community reuse potential. Few of these options are original; most have been created, studied and recommended by the USAF. The immediate action suggested to the Commission is to add Los Angeles AFB, Beale AFB and Hanscom AFB to the closure/realignment list on 10 May. Closure of LAAFB allows consolidation of the space product center with the space lab (Phillips) at KAFB, consistent with recommendations in USAF analyses, and LAAFB's prime location near the Los Angeles airport has superb economic value for community reuse. BAFB is poorly suited to special operations training, cannot accept additional aircraft types because of air quality restrictions, and multiple relocation sites for the U-2/TR-1 aircraft currently at BAFB are available in California. Closing LAAFB and BAFB will save the taxpayer $103 million annually after a one time cost of $649 million (cost from Feb 95 USAF BRAC Submission). Placing HAFB on the list for realignment permits the complete integration of the Phillips Lab's Geophysics Directorate, currently located at HAFB, with the parent lab at KAFB.

KIRTLAND AFB COSTS UPDATE

- MAY 3RD USAF ESTIMATE
  - ONE TIME COST: $538M
  - ANNUAL SAVINGS: $32.8M
- ONE TIME DOES NOT INCLUDE DOE COSTS: $64M
- ANNUAL DOES NOT INCLUDE:
  - DOE ANNUAL IMPACT $ 30.6M
  - CHAMPUS FOR RETIREES: 20.3M
  - VA HOSPITAL; 5.1M
  - 58TH SOW ADDED FLIGHT TIME 2.0M

KIRTLAND OPERATIONAL UPDATE

- AF CONSIDERING MOVING 58TH TO BEALE OR HILL, MAYBE OTHERS
- NEGATIVE IMPACTS
  - WEATHER
  - TRAINING AREAS/ROUTES
  - DENSITY ALTITUDE (IMPORTANT FOR HELO TNG)
  - INFRASTRUCTURE
  - ENVIRONMENTAL IMPACTS
  - COMMUNITY SUPPORT IS UNKNOWN
- **NO OPERATIONAL ADVANTAGE TO MOVING FROM KIRTLAND**

KIRTLAND SUMMARY

- NO OPERATIONAL BENEFITS TO AF PROPOSED REALIGNMENT
  - NUCLEAR INFRASTRUCTURE IMPAIRED
  - 58TH SOW MISSION DISRUPTED; NO COST OR OPERATIONAL BENEFIT
- RESULT IS RECURRING COSTS TO TAXPAYER - NO SAVINGS
- REMOVING KIRTLAND FROM REALIGNMENT MAKES IT AVAILABLE TO BRAC COMMISSION FOR OTHER DOD CONSOLIDATION INITIATIVES

ONGOING KIRTLAND RELOCATIONS

- SPACE AND MISSILE SYSTEMS CENTER FOR TEST AND EVALUATION (SMC/TE)
  - RELOCATING FROM ONIZUKA TO KIRTLAND AT REDUCED LEVEL
  - SHOULD NOW CONTINUE AS ORIGINALLY PLANNED
- PHILLIPS LABORATORY CONSOLIDATION
  - DIRECTORATES GEOGRAPHICALLY SEPARATED
  - SECAF DIRECTED CONSOLIDATION
  - CONTINUE AS ORIGINALLY PLANNED

CLOSE LOS ANGELES AFB

- CLOSING LOS ANGELES AFB (CO-LOCATES SMC WITH PL)
  - SAVES $64M ANNUALLY; ROI = 10 YEARS
  - ENVIRONMENTAL REVIEW THROUGH PUBLIC HEARINGS; CAN CLOSE 18 MONTHS EARLIER THAN OTHER INITIATIVES FROM BRAC 95

KIRTLAND PRODUCT CENTER / LABORATORY CONSOLIDATION

- AF INITIATIVE : CO-LOCATE CENTERS WITH LABS; EXAMPLES INCLUDE:
  - AIRCRAFT AT WRIGHT-PATTERSON
  - ELECTRONICS AT HANSCOM
- PRIOR TO 1994, AF PLANNED TO CO-LOCATE SPACE AND MISSILE SYSTEMS CENTER (SMC) WITH PHILLIPS LAB
- AF CHANGED PLAN AND CITED
  - AIR QUALITY IN ALBUQUERQUE
  - NEW MEXICO GROSS RECEIPTS TAX

Document Separator

SHIPYARD / SUBMARINE ISSUES

SSN 688 Class Submarines

DON Recommendation

- Close Long Beach NSYD and SRF Guam
- Analyzed but did not recommend closure of Portsmouth NSYD because of uncertainty of future SSN requirements
  - SSN modernization
  - Possible increase in force structure of SSNs
  - Potential requirement for SSN refuelings instead of programmed inactivations

Question #1

What are the facility, equipment and training requirements and costs necessary to enable a Navy nuclear shipyard to refuel SSN 688 class submarines?

Facility Requirements / Costs

- Shipboard & shore fuel handling enclosures
- Adequate crane capacity and reach
- Reactor component handling equipment
- Reactor component storage enclosures
- Training facilities
- Cost: $20-50M

Equipment Requirements / Cost

- Fuel and irradiated reactor component handling containers
- Cutting machines
- Reactor training mockup
- Approximately 200 pieces of equipment provided-additional 100 locally manufactured or bought
- Cost: $25M

Training Requirements / Cost

- Training required for:
  - Mechanics
  - Radiological personnel
  - Inspectors
  - Refueling engineers
- Cost: $5M

Question #2

What is the date when each shipyard will be ready to perform refuelings?

SSN 688 Refueling Capable NSYDs

- Norfolk: essentiallly
- Pearl Harbor: in 18 months
  - Training
  - Crane
  - Approximately 50% implementation costs spent
  - Equipment & facility ready in approximately 6 months
- Portsmouth: now
- Puget Sound:essentially

Question #3

What is the schedule and location for each planned SSN 688 class refueling?

SSN 688 Refueling Schedule

SECNAV Approved Schedule

- FY 1995: none
- FY 1996: 1 at Portsmouth
- FY 1997: none

Strategic Planning Schedule

- FY 1998: none
- FY 1999: 1 at Portsmouth
- FY 2000: 1 each, Portsmouth and Norfolk
- FY 2001: 1 each, Portsmouth and Pearl Harbor
- FY 2002-2005: 2 per year

Question #4

What are the cost estimates for facilitizing a private construction yard to do SSN 688 class refuelings?

Private Yard Facilitization

- Electric Boat: $50-100M
  - Dockside refueling enclosures
  - Radiological facilities
  - Extend railroad tracks
  - Training
  - Refueling equipment
- Newport News: $45-55M
  - Refueling facility conversion
  - Training
  - Refueling equipment

Question #5

What are the spent fuel storage issues?

Spent Fuel Storage Issues

- Historically not stored at shipyards
- 1993 court order: temporary storage
- Storage issue does not affect refueling location decision

Question #6

What is the impact of the recent increase in the SSN 688 class operating cycle and what is its effect on shipyard workload?

Increased Operating Cycles

- DMP workload bow waves into busy refueling/inactivation period
- FY 1996/1997: 5 DMPs and 8 DSRAs deferred to later years
- Simultaneous refueling / DMP / inactivation workload requires 4 nuclear yards over the period FY 2000-2005
- DMP / DSRA packages not reduced

Impact of Portsmouth Closure

- Current schedule marginally achievable (high risk)
  - Drydock / facility / equipment limitations
  - Drydocks scheduled "heel to toe"
    - no required maintenance availabilities
    - assumes that 15 month in dock **never** exceeded
  - Requires considerable schedule adjustment for non-SSN ships
- Cannot accommodate even 1 additional refueling, in lieu of inactivation

SSN 688 Refueling

- Notional duration:
  20-24 months total, with 15 months in drydock
- Completed 2: USS Philadelphia and USS Los Angeles
  - completed: 27 months and 29 months
  - dockings: 15 months and 19 months
- USS Memphis: currently in ERO
  - 23 months duration
  - 16.5 months in drydock

Pearl Harbor NSYD

- Drydock configuration

  #1: SSN 688 ERO / defueling (under construction)

  #2: Nuclear capable
  (not facilitized for refueling/defueling)

  #3: Not usable

  #4: CV / CVNs

Norfolk NSYD

- Drydock Configuration

  #1,#6,#7: Barge/service craft (shallow draft)

  #2: Being configured for SSN 688 / CGN defueling

  #3: Nuclear capable being used for CGN and surface ship availabilities

  #4: SSN 688 / CGN fueling/defueling

  #8: CV / CVN dock

Portsmouth NSYD

- Drydock configuration
  - #1: DMP / SRA dock - not configured for SSN 688 ERO or defueling
  - #2: SSN 688 ERO and defueling
  - #3: SSN 688 defueling

Puget Sound NSYD

(continued)

- Drydock configuration

  #1: SSN 637 / SSBN defueling

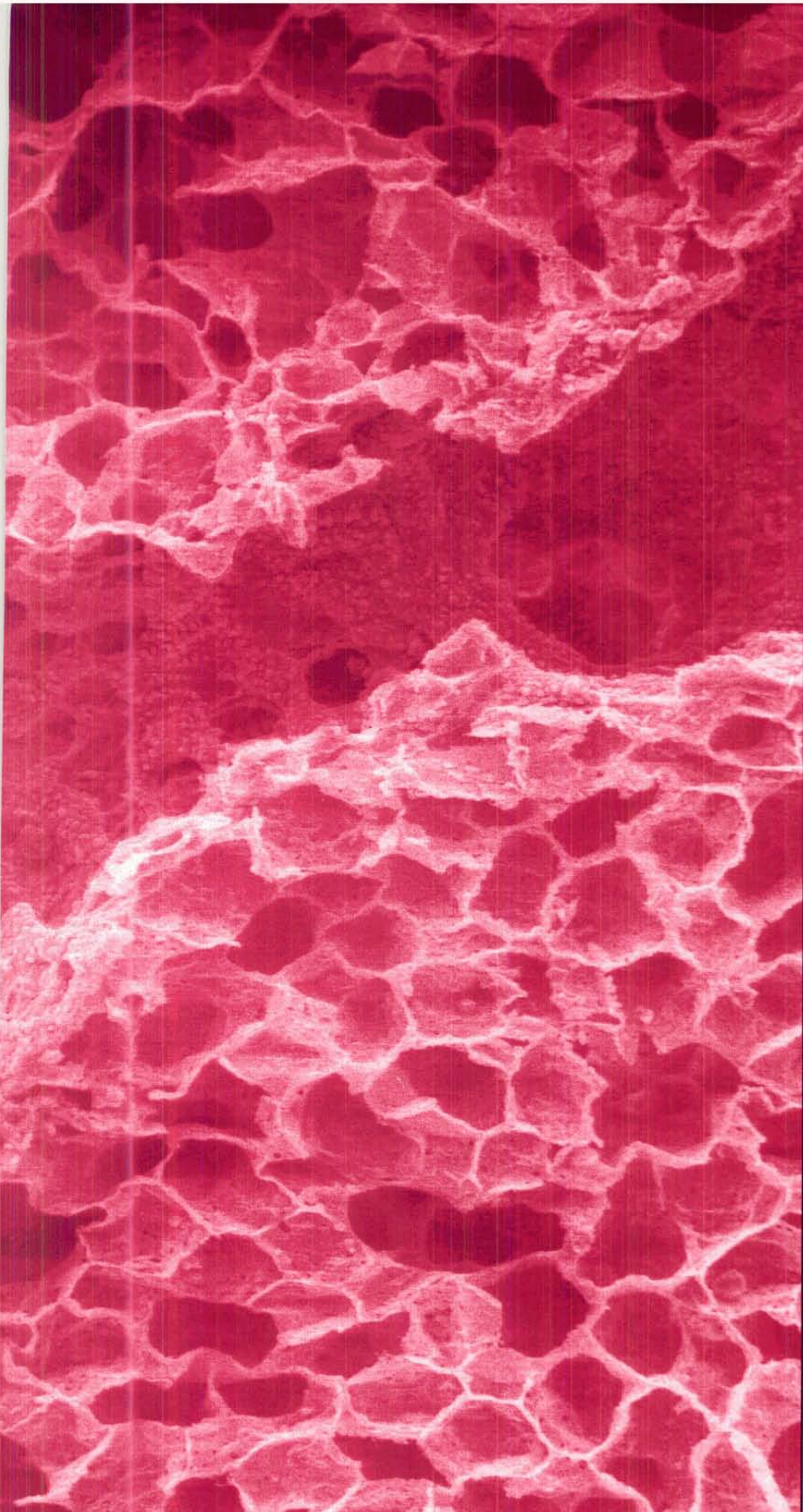
  #2: Nuclear capable (not facilitized)

  #3: Non-nuclear, used for submarine disposal, currently in 1 year dock maintenance period

  #4: SSN 637 defueling

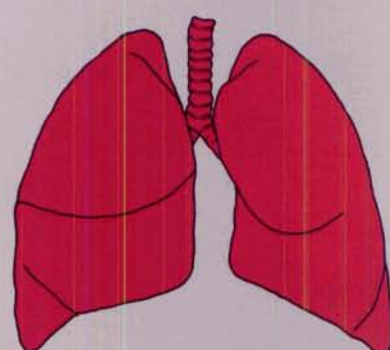
  #5: CGN / SSN 688 defueling

  #6: CVN / fleet support dock

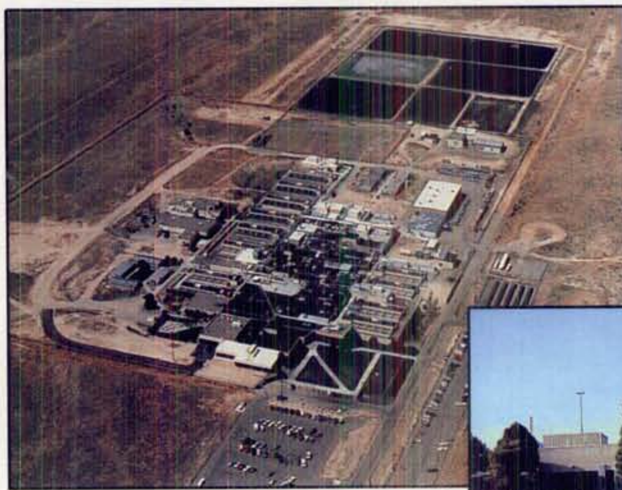


ITRI

INHALATION
TOXICOLOGY
RESEARCH
INSTITUTE

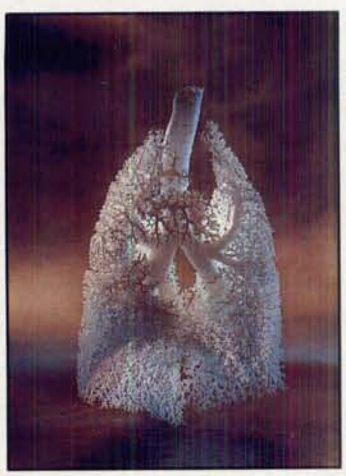


The Inhalation Toxicology Research Institute (ITRI, pronounced "I-try") is a Federally Funded Research and Development Center that serves as an international research resource for government and industry. The facilities are owned by the Department of Energy (DOE) and staffed and operated by the private, non-profit Lovelace Biomedical and Environmental Research Institute, Inc., a subsidiary of Albuquerque's Lovelace Medical Foundation.

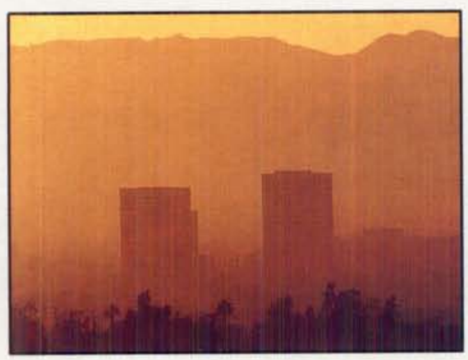


The Institute began in the early 1960s as a joint effort between the Lovelace organization and the Atomic Energy Commission to assemble a research team for determining the long-term health impact of inhaling radioactive particles. This team and the facilities it occupies have evolved to become a premier center for inhalation toxicology and associated fields. Today, ITRI is broadly recognized for its expertise in aerosol science, toxicology, radiobiology, respiratory tract structure and function, dosimetry and metabolism of inhaled agents, and the pathogenesis of cancerous and non-cancerous respiratory disease.

Mission



ITRI is dedicated to protecting human health by conducting basic and applied research to improve our understanding of the respiratory tract and the health effects that might occur in humans from inhaling airborne toxicants in the home, workplace, or environment. The Institute's tripartite mission includes research, education, and technology transfer. Its primary goals are to conduct high quality, unbiased research and to link laboratory results with epidemiological findings in order to identify, define, and reduce human health risks. The Institute is oriented toward collaborating with other scientists, developing research partnerships with industry for problem solving and technology transfer, and serving the scientific community through advisory roles, leadership in professional societies, and research training.



ITRI fills a unique scientific niche that complements resources in universities, industry, and testing laboratories. The uniqueness of the Institute stems from its combination of diverse and highly qualified staff and its specialized facilities. A hallmark of ITRI is its ability to readily assemble multidisciplinary teams of internationally recognized investigators in order to develop research strategies and address sponsor needs. The ITRI staff serves freely as a resource of information and advice. ITRI is oriented toward building bridges between the biological and physical sciences, basic and applied research, animal and human research, and hazard identification and risk assessment. ITRI

management and staff place high value on communicating, collaborating, and integrating study results into the broader context of solving problems and minimizing health risks.

No classified research is conducted at the Institute, and the staff is oriented toward rapid publication of research results; however, confidentiality is maintained to suit sponsor needs.

Unique Scientific Strengths

The breadth of ITRI's capability for integrative research is unmatched in the field of inhalation toxicology and pulmonary disease research. At ITRI, a broad spectrum of clinical and bioassay capabilities coexists with capabilities for working with innocuous and hazardous materials of all types, expertise in evaluating airborne materials, dosimetry and toxicokinetics, health effects from the molecular level to the intact individual, and risk assessment.

Some of ITRI's most broadly recognized scientific strengths include:

Basic aerosol science, air sampling technology and monitoring strategies, evaluation of the generation of airborne materials from environmental sources, industrial processes, and waste handling.

Generation and delivery of aerosols, gases, and vapors for experimental and medical applications, and for testing and demonstration of instrumentation.

Novel and conventional methods for acute to chronic inhalation exposures of all laboratory animals to all physical forms of hazardous and nonhazardous chemicals and radionuclides, including the use of chemical and radioactive tracers.

Routine and novel clinical evaluation and treatment of laboratory animals by procedures applied in human clinical medicine, including clinical

pathology, cardiorespiratory physiology, immunology, x-ray and gamma imaging, bronchopulmonary lavage and endoscopy, and cellular and molecular assays.

A genetically defined dog colony with an ongoing breeding program, multigeneration capability, and broad age availability.

Dosimetry and toxicokinetics of chemical and radioactive agents using tissue and fluid sampling, metabolic collections, radiotracer

ITRI

studies, extensive analytical and radioanalytical capability, and computer modeling and simulation.

Cellular and molecular biology of cancerous and noncancerous responses, including access to animal and human tissues, tissue culture and banking capability, cytotoxicity and transformation assays, transplant and repopulation studies, and routine and novel molecular biology approaches for relating gene alterations to disease development.

Experimental pathology, including necropsy, microdissection and cell isolation, routine and special fixation techniques, qualitative and morphometric light and electron microscopy, slide preparation with routine and special stains, histochemistry, immunohistochemistry, autoradiography, and in situ hybridization.

Commitment to quality assurance and quality control with incorporation of Good Laboratory Practices (GLP) principles in all studies and the capability for full GLP compliance as required.

Staff

The approximately 180 full-time employees of ITRI include a research staff of about 30 principal investigators and 60 technicians who encompass a broad range of disciplines and experience including aerosol science, chemistry, toxicology, cellular and molecular biology, radiobiology, pathology, veterinary medicine, biomathematics, and risk assessment. The research is supported by an animal care staff of approximately 20 and the full range of administrative support staff. The hallmarks of the staff are its diversity, qualifications, motivation and productivity, orientation toward excellence, readiness to communicate and collaborate, and culture of teamwork that not only crosses disciplinary lines, but also bridges between the research and support staff.

The combined professional expertise and outstanding individual qualifications of the ITRI staff constitute a remarkable resource. ITRI scientists are highly visible in the scientific mainstream and have a strong reputation for scientific credibility. They hold over 50 positions on national and international advisory boards, review panels, and study sections, 15 positions as scientific editors or on editorial boards of scientific journals, and numerous offices in leading professional scientific societies.

Professional certifications include the American Board of Toxicology (6), American Board of Veterinary Toxicology, American College of Pathologists, American College of Veterinary Pathologists (3), American Board of Health Physics (2), American Board of Industrial Hygiene, American Academy of Microbiology, and American College of Laboratory Animal Medicine. Most ITRI researchers have at least one academic appointment and are active lecturers and graduate and postdoctoral mentors.

Facilities

ITRI encompasses 290,000 square feet of laboratory, office, animal housing, clinical, and research support space with a replacement value of over \$62M and containing capital equipment valued at over \$14M. The Institute is located on a 40-acre site near Albuquerque, NM. These resources include:

State-of-the-art facilities for the housing, care, and breeding of over 1000 dogs, 10,000 rodents, and other species of all sizes.

Inhalation exposure facilities for acute to life-span exposures of all species by whole-body, nose-only, or intra-airway routes to innocuous, hazardous, and radioactive airborne materials in all physical forms, including single agents and mixtures such as tobacco smoke and engine exhaust.

Specialized aerosol laboratories supporting inhalation studies, basic and applied laboratory research, and field studies, including environmental chambers, wind tunnels, exhaust dilution tunnels, and respiratory tract casts and models.

A well-equipped veterinary clinic for examination and treatment of animals, including clinical chemistry and microbiology laboratories, x-ray and gamma imaging, surgery, respiratory physiology, electrocardiology, electroencephalography, and bronchoscopy.

High-capacity necropsy and histopathology laboratories, light and electron microscope suites, and facilities for video imaging and image analysis.

Cellular and molecular biology laboratories with capability for tissue and cell collection and banking, flow cytometry, cell and tissue culture, and tumor transplantation. DNA, RNA, and protein

evaluations, including gel and capillary electrophoresis, PCR, DNA adduct analysis, fluorescent microscopy, and immunocytochemistry.

Analytical organic and inorganic chemistry and radiochemistry laboratories.

Facilities and procedures for the safe collection, segregation, packaging, and temporary storage of all research-generated chemical and radioactive wastes in compliance with DOE, EPA, and state regulations, and for onsite disposal of uncontaminated biological wastes.

Quality assurance facilities including data and experimental sample archives and instrumentation calibration laboratories with traceable standards.

An extensive research library containing 280 journal subscriptions, 10,500 bound journals, 10,000 books, and 20,000 documents, with full on-line search capability.

ITRI

Animal Care and Use

ITRI management and staff are deeply committed to the humane care and proper use of laboratory animals. All protocols involving animals are reviewed and approved by the Institute's Animal Research Committee, composed of staff at all levels and a non-employee community member.

The Institute has maintained full accreditation by the American Association for the Accreditation of Laboratory Animal Care since 1971, is registered under the Animal Welfare Act (Reg. No. 85-R-003), and is in full compliance with the Act's provisions. All animals are maintained and used according to the recommendations in NIH Publication 85-23, "Guide for the Care and Use of Laboratory Animals." ITRI has an approved Public Health Service Animal Welfare Assurance (NIH Assurance No. 3083-01).

Quality Assurance

ITRI holds an excellent reputation for scientific integrity and for the quality of its research and the resulting publications, and presentations. The Quality Assurance (QA) Unit, reporting to the Director, administers a comprehensive site-wide QA program, integrating a culture of quality into research and support operations alike. All studies are conducted in the spirit of Good Laboratory Practices (GLP) and in strict accordance with FDA or EPA GLP regulations as required. All research is conducted under approved, rigorously reviewed protocols. Standard operating procedures and calibration logs are in place. Research and results are recorded using standardized notebooks, forms, and electronic media, and both data and experimental samples are archived as needed. The QA Unit conducts critical phase inspections, data audits, and report audits according to a QA plan developed for each study.

Stewardship of the Environment and Human Safety

Safeguarding the safety and health of staff and avoiding adverse impacts on the environment are top priorities at ITRI. The Health Protection Operations (HPO) Unit, reporting to the Director, provides direction and oversight to ensure that research and support activities are in compliance with applicable regulations and good practices. The HPO Unit maintains progressive programs in health physics, industrial hygiene, environmental compliance, laboratory safety, and emergency preparedness to meet requirements of DOE, OSHA, state, and local regulations. Located 10 miles from the nearest residential area, and isolated from other nonresidential facilities, ITRI presents no offsite contamination hazards. Hazardous and radioactive wastes are managed according to RCRA and DOE regulations. All hazardous wastes are shipped offsite to EPA-permitted disposal facilities. ITRI participates actively in the DOE Environmental Restoration and Waste Management Five-Year Plan, ensuring identification and remediation of contaminated sites and safe management of current waste streams.

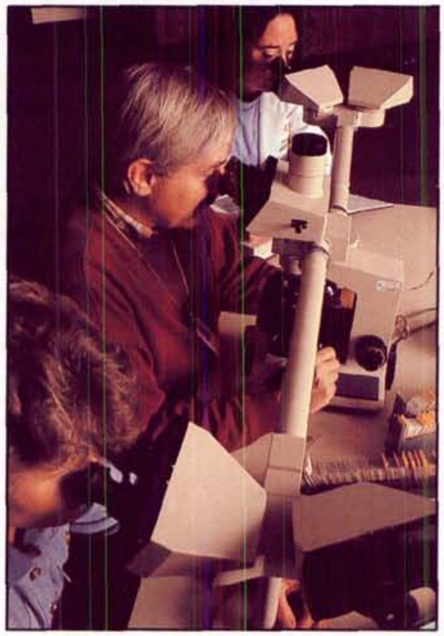
Educational Programs

ITRI takes pride in its broad involvement in education and serves as a key national research training resource. Long a Lovelace tradition, education is now also a DOE mission, lending a strong element of academia to the ITRI culture. Educational programs are aimed at all levels, from elementary school to senior scientists. Individuals and organizations interested in ITRI educational programs are encouraged to contact the Institute.

ITRI has a long reputation for the high quality of its summer research internship programs which engage participants as true co-investigators in studies from experimental design to reporting of results. Over 570 individuals have participated in summer programs aimed at minority high school students, undergraduate university students, and secondary school science and math teachers.

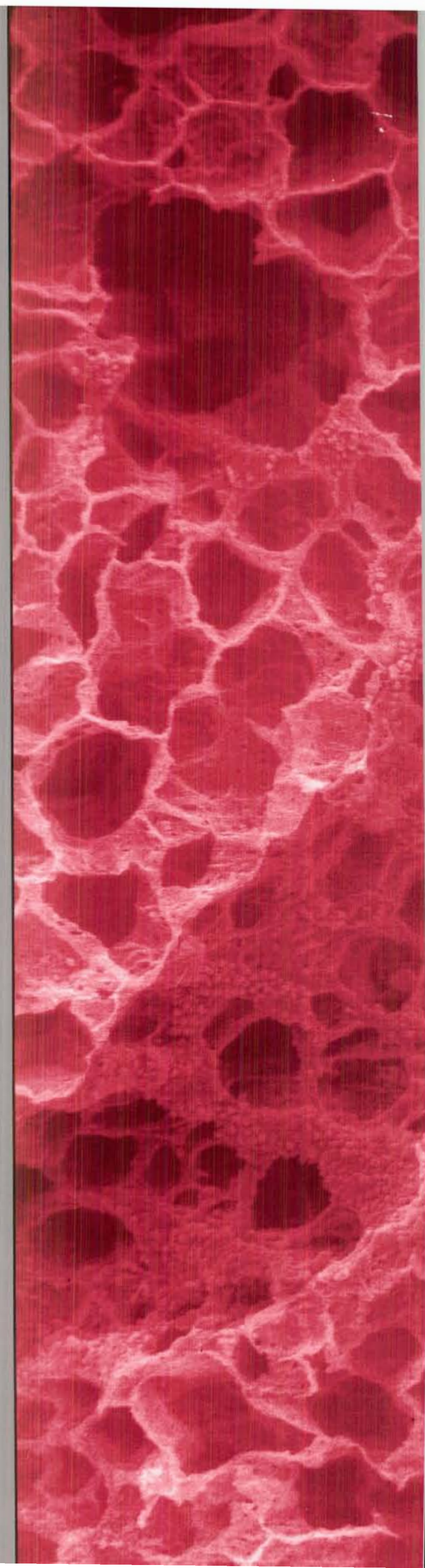
With the University of New Mexico (UNM) College of Pharmacy, ITRI conducts a doctoral-granting graduate program in inhalation toxicology that is funded by the Lovelace-Anderson Endowment Foundation, the DOE, and industry sponsors. The combined ITRI-UNM toxicology programs constitute one of the larger toxicology graduate training centers in the US. Students entering with bachelors, masters, and professional degrees conduct research at ITRI in selected areas of focus and complete coursework at UNM.

ITRI is also active in postgraduate training. Postdoctoral fellowships are offered in all of the Institute's scientific disciplines. The Institute also hosts pulmonary fellows for research training and visiting scientists on sabbatical leave or other temporary collaborative or training assignments.



Opportunities for Research Sponsorship

As a Federally Funded Research and Development Center (FFRDC), ITRI is available to conduct research for all government and industry sponsors. Although the largest single sponsor is DOE, ITRI research is funded by other agencies, private industry, and industry and government-industry consortia. Non-DOE government sponsors fund ITRI research through interagency agreements and grants, while non-government sponsors fund research through contracts and Cooperative Research and Development Agreements (CRADAs). FFRDCs are not allowed to submit bids or respond competitively to Requests for Proposals (RFPs), but may respond to Requests for Applications (RFAs) or to sole-source inquiries. ITRI collaborates in research under grants and contracts with other institutions through subcontracts. We invite inquiries about research needs.



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Adaptive Optics: Straightening Starlight

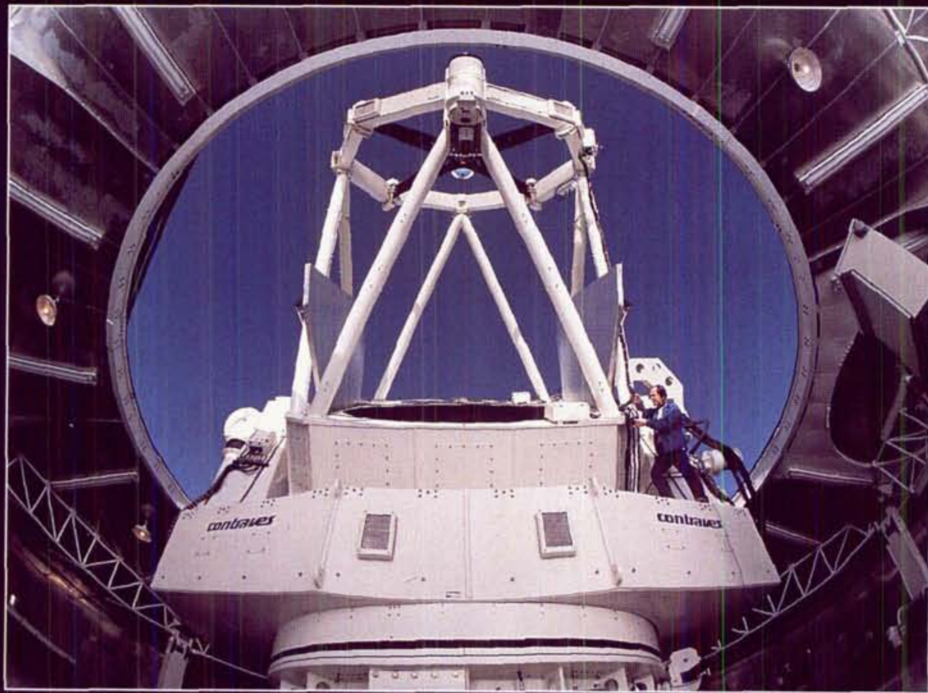
Adaptive-Optics Guru Robert Fugate

Recently declassified experiments in adaptive optics offer astronomers new weapons against an old bugaboo: bad seeing.

Untwinkling the Stars-

By Robert Q. Fugate and Walter J. Wild

Photograph by Roger H. Ressmeyer



Twinkle, twinkle, little star,
How I wonder what you are!
Up above the world so high,
Like a diamond in the sky. . . .

WE ALL KNOW this little children's rhyme, which recalls how a twinkling star can be pretty, even romantic to behold. When it comes to serious work, however, astronomers are not inclined to be romantic. The twinkling is caused by the Earth's atmosphere, which, even on the clearest and most transparent of nights, is constantly in a state of turmoil.

Throughout the centuries, telescopes have had to cope with the atmosphere — so necessary for life but a hindrance for astronomers. In fact, while the largest telescopes in the world collect a lot of light, they typically cannot resolve double stars or the divisions in the rings of Saturn any better than a humble 6-inch reflector. For cosmological studies a mere hundred miles of atmosphere ruins untold light-years of flawless wave propagation through intergalactic space!

The culprit is the presence of random temperature variations in the air, causing slight local changes in its refractive index. Turbulent pockets of air act like little transient lenses, redirecting portions of the incoming plane wavefronts from a star. When focused by a telescope the star's image becomes a spread-out blob that churns and boils, frequently flaring out and perhaps occasionally settling down.

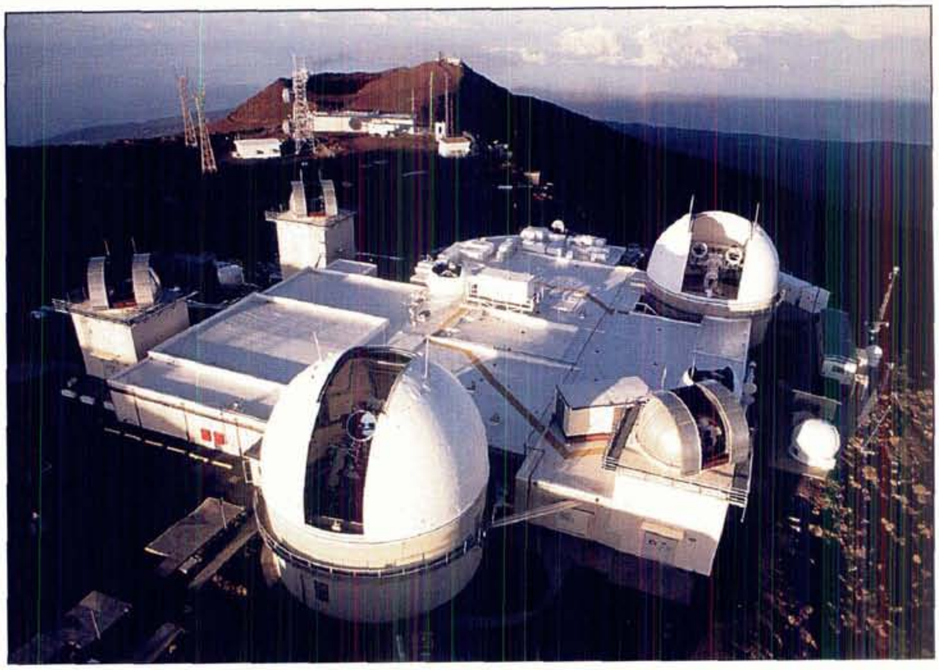
Each distorted wavefront consists of many contiguous segments whose sizes are governed by those of the cells of turbulence. A crinkled piece of chicken wire offers a good analogy. The whole thing is certainly distorted, yet the individual openings remain flat — they are merely tilted in a random fashion relative to their neighbors.

An emerging technology called adaptive optics will soon revolutionize ground-

—Part I

Facing page: **High over the Starfire Optical Range in New Mexico, beams from powerful copper-vapor and sodium lasers converge at a point in Draco where the 1.5-meter telescope (large dome) is aimed. During much of the last decade the technique remained a military secret of the U. S. Strategic Defense Initiative, but soon it will help astronomers gain views of the universe with a clarity hitherto impossible with ground-based telescopes. In February, this photograph won first-place awards from both the World Press Photo Foundation and the University of Missouri/NPPA Pictures of the Year competition. All photographs on pages 24–26 are ©1994 Roger H. Ressmeyer–Starlight/MP©A.**

Above: **Starfire's new 3.5-meter reflector, which saw "first light" on February 10th of this year, may soon offer celestial views that are sharp right down to the instrument's 0.04-arc-second diffraction limit. Next to the primary mirror cell and surrounded by the open-air, retractable dome is range director and coauthor Robert Q. Fugate.**



Above: **Photographer Roger Ressmeyer recorded a nightful of laser-beam experiments at Hawaii's Haleakala Crater in this time exposure from an adjacent air-traffic-control tower.**

Left: **Long cloaked in secrecy, the domes at Science City on Haleakala greet the sunrise in this Ressmeyer photograph.**

based astronomy. It will enable astronomers to attain full diffraction-limited performance — almost as if corrective eyeglasses were placed upon their telescopes. Features 10 to 100 times smaller than are currently observed from Earth will be clarified, whether the target is a comet's nucleus, a chunky asteroid, distant interacting galaxies, or the heart of the Milky Way.

Adaptive optics work by what is popularly termed a "rubber mirror" — a reflector inserted in the telescope's light path that can rapidly alter its shape to counteract the distortions of the atmosphere. The most common design employs a thin faceplate mounted on an array of pistons. In effect, this deformable mirror flattens the chicken wire out again.

But how can a high-speed computer controlling a deformable mirror get the information it needs to undo the distortions? That central question has occupied many teams of researchers for more than two decades. A bright star readily furnishes its own beacon, or reference wavefront, but an extended object like a planet or nebula generally will not suffice. Unfortunately, most natural point sources (stars) are much too faint to provide sufficient signal levels for an adaptive-optics system to drive a deformable mirror effectively.

Furthermore, the angle over which light from astronomical bodies encounters essentially the same atmospheric turbulence is only about 2 arc seconds at visible wavelengths. This small cone of sky is called the *isoplanatic patch,* a fundamental limit on how big an image area the adaptive optics can fully correct at any one time. The size of the patch increases with wavelength, so a larger area of sky can be corrected in infrared than in visible light.

Two arc seconds is an incredibly small angle — equal to the separation of a car's headlights seen 100 kilometers away — giving some idea of what we are up against when dealing with the atmosphere. Not only does an astronomical image change randomly on a time scale of milliseconds, but in a very short exposure that freezes the turbulence even stars 10 arc seconds apart will look totally different!

Despite these seemingly overwhelming difficulties, scientists were making steady progress in their quest for suitable wavefront correctors when a bit of serendipity in Hawaii profoundly enhanced the prospects for a workable adaptive-optics system.

THE LASER BEACON

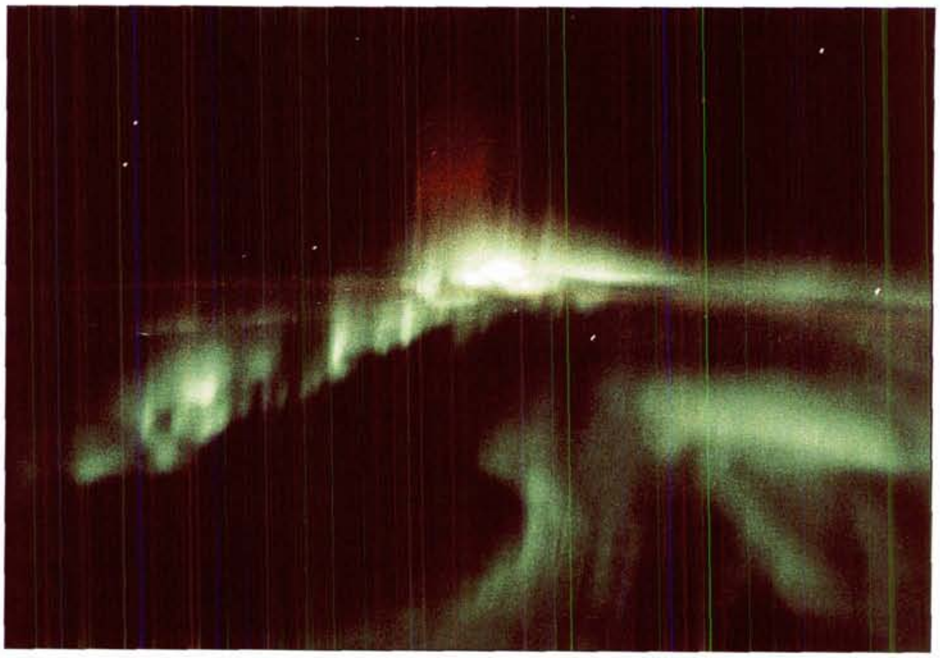
Back in the summer of 1981 Julius Feinleib, president of Adaptive Optics Associates in Cambridge, Massachusetts, happened to visit the U. S. Air Force's Maui Optical Station at Haleakala Crater in Hawaii. He observed some lidar (light detection and ranging) experiments that used a laser beam transmitted by one of the telescopes there. He also knew that the Defense Advanced Research Projects Agency (DARPA) of the Department of Defense was interested in the use of adaptive optics for viewing faint military targets, and that Richard Hutchin (Itek) and Donald Hanson (Air Force Rome Development Center) were already at work on this problem. Indeed, the Rome-Itek team had built the Compensated Imaging System in use on the Maui 1.6-meter telescope.

As Feinleib watched the pulsed laser beam shooting into the night sky, a concept jelled. Why not use this beam as a kind of probe by which an adaptive-optics system could measure the atmospheric distortions independently of the object being viewed?

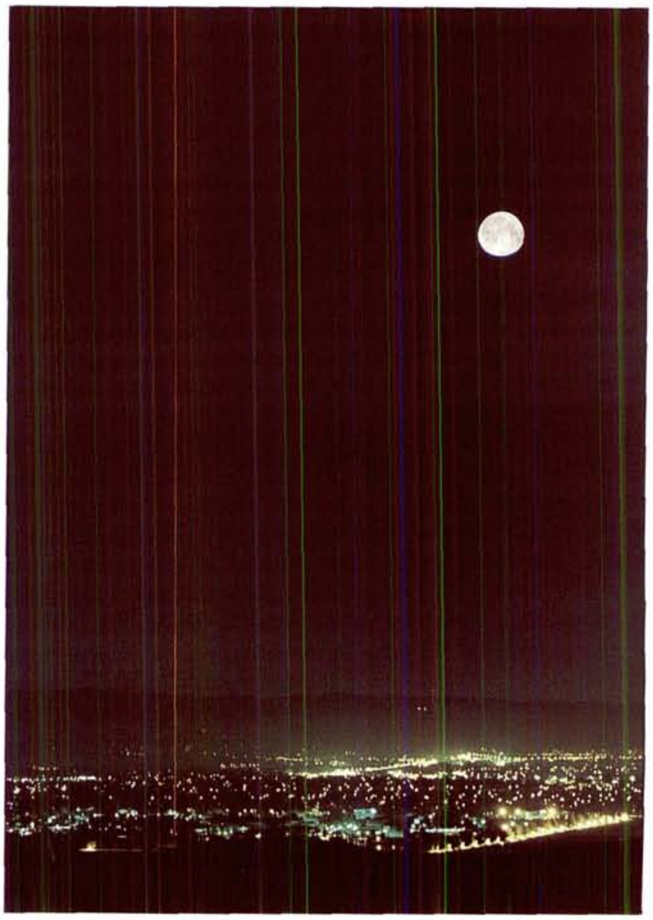
In October, after refining his concept, Feinleib prepared a proposal for further development. Rett Benedict at DARPA was interested in the idea and called a meeting of researchers to discuss it. Among those attending was David L. Fried, a major contributor to our understanding of atmospheric turbulence and astronomical seeing.

Fried was initially skeptical of the concept, which involved focusing a laser to create a point source in the lower atmosphere that would be visible by the mechanism of Rayleigh backscatter from air molecules. While this artificial source could be positioned almost exactly in any desired line of sight (that is, on virtually any celestial target), it would not sample the air turbulence *beyond* the beacon and would therefore lead to incomplete compensation at best. Nevertheless, the very night after that pivotal meeting, Fried burned the midnight oil and derived the equations needed to predict how well such an artificial beacon would work.

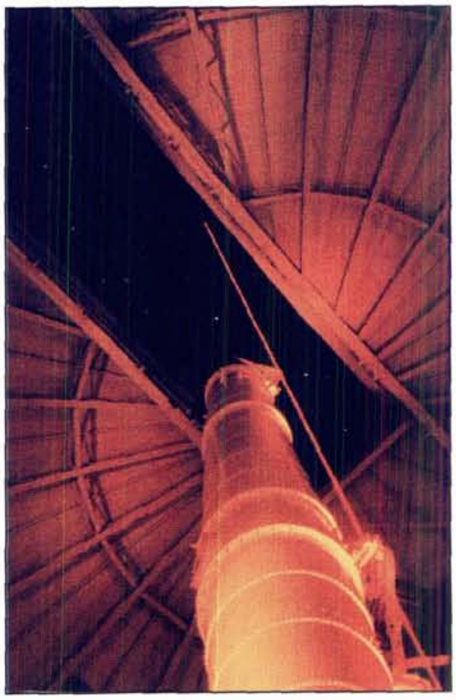
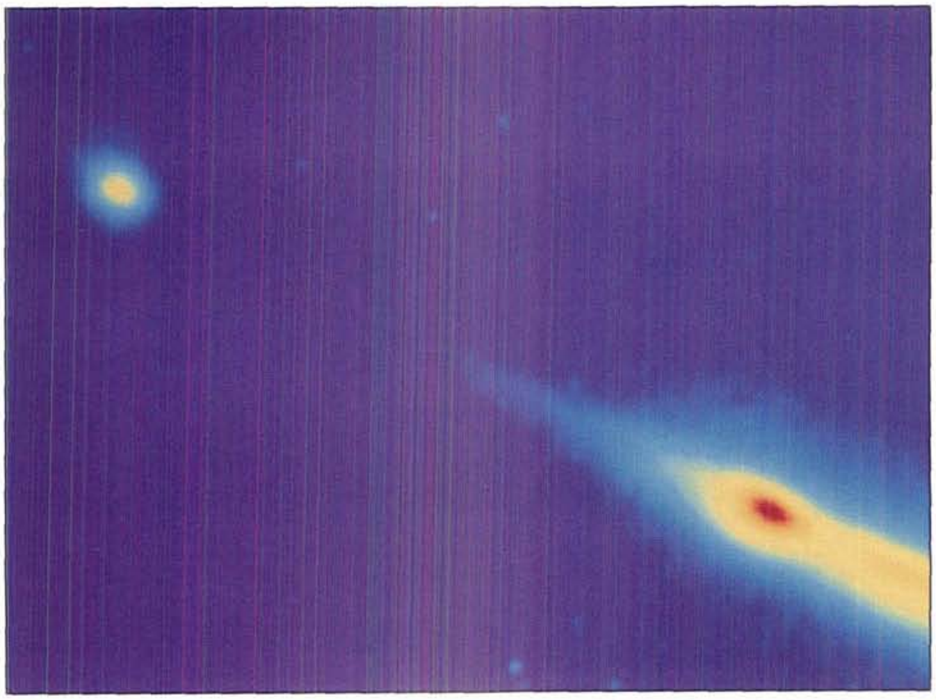
Over the next several months Fried set about evaluating the complicated mathematical integrals in the theory. When he and colleague John Belsher completed this work they found that the wavefront-sensing error, due mainly to the finite range of the laser beacon, should increase with the aperture of the viewing telescope. Even so, their results predicted the beacon *should* be useful for adaptive optics. The engineers and scientists at Adaptive Optics Associates began to de-



During the September 1992 flight of Space Shuttle *Endeavour*, astronaut Jay Apt captured this view of the aurora australis with its green curtains and reddish fringe. The faintly visible yellow arc curving along the Earth's limb is the thin layer of sodium atoms roughly 90 kilometers up that offers astronomers such promise for laser-controlled adaptive optics. Photograph courtesy NASA/Starlight.



A beam rises skyward over California from one of the world's most powerful dye lasers. Each such test, conducted by the Lawrence Livermore National Laboratory to produce a sodium "guide star," attracts wide notice in the local press. To make this photograph Joe Galkowski opened his camera for 10 minutes and captured the laser beam and lights of Livermore Valley, then added the Moon in a separate brief exposure.

Left: **In their experiments with a half-watt dye laser in 1992, University of Chicago astronomers used the Yerkes 40-inch refractor to view the return when the laser beam was sent skyward through the piggyback 5-inch guidescope. Photograph by Walter Wild.** ***Right:*** **In this highly foreshortened side view of the return, the streak at lower right is produced by low-altitude Rayleigh backscatter and becomes most intense (red spot in this false-color image) when at 23 kilometers the beam encounters volcanic dust that was lofted by Mount Pinatubo in 1991. Farther up the backscatter fades in the rarefied air. Finally, at upper left the expected 12th-magnitude guide star appears as the laser beam excites free sodium atoms in the mesosphere.**

velop the hardware required to test this prediction.

By the summer of 1982 there was considerable excitement in the defense community about the laser-beacon concept. When a special advisory group held its annual meeting in La Jolla, California, Fried and other atmospheric scientists were invited to discuss the subject. Princeton University's Will Happer, a member of the group that reviewed the theory, expanded the concept by suggesting an entirely new source for the artificial beacon: the free sodium atoms located some 90 km (60 miles) high in the layer of the upper atmosphere called the mesosphere. Situated outside nearly all the Earth's air, such a beacon would offer much better wavefront sensing than a low-altitude Rayleigh beacon.

If a laser could be built to resonate at the wavelength of one or both of the yellow sodium D lines in the visible spectrum, Happer realized, it would excite those atoms. The light they then emitted would become an ideal beacon for adaptive optics.

THE FIRST BEACON TRIALS

With the stage thus set, DARPA's Benedict immediately sponsored two experiments — one to test the Rayleigh concept and the other to try out the sodium layer. The first was carried out by the Air Force Phillips Laboratory at the Starfire Optical Range near Albuquerque, New Mexico. The sodium experiment was designed at the Massachusetts Institute of Technology's Lincoln Laboratory and conducted at White Sands Missile Range, also in New Mexico.

The purpose of the Rayleigh experiment was to find out whether the laser-beacon concept would work at all, and then to verify Fried's theoretical predictions. Researchers pointed a laser at a bright star and fitted a 40-centimeter viewing telescope with a mask having 18 small openings. The real star and the artificial "guide star" permitted simultaneous measurement of the two wavefronts. Even without bringing adaptive optics into play, we would learn whether the wavefront distortions from the two very different point sources were similar enough for the technique to work. Performed in the summer and fall of 1983, this experiment definitively confirmed Fried's theory. The results were reported to an audience of nearly 200 people at a classified conference held in February of 1984.

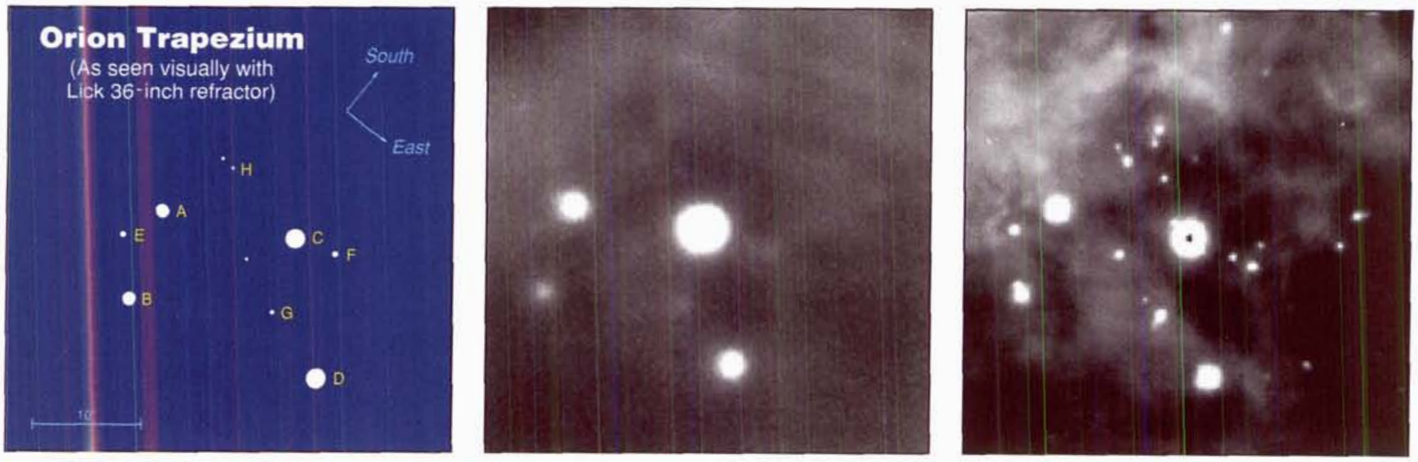
The Lincoln Lab sodium experiment used just two subapertures separated by 76 cm and compared the tilt differences between them when focusing on a sodium laser beacon and a bright star. Completed in early 1985, this test confirmed that the error incurred by using such an artificial beacon decreases as its altitude gets higher, just as Fried's theory said it should.

These two pioneering experiments validated our understanding of the physics and established the limitations of using a single, focused laser beam as an artificial beacon for adaptive optics.

ASTRONOMERS DISCOVER THE LASER-BEACON CONCEPT

Independently of the work being done by the U. S. Department of Defense, two French astronomers, Renaud Foy and Antoine Labeyrie, introduced the laser-beacon concept in a letter published in *Astronomy & Astrophysics* in the summer of 1985. They discussed the use of both Rayleigh and sodium beacons for astronomical seeing correction. Since that time a number of civilian groups in both the United States and Europe have gotten into the act. They include astronomers in France, at the European Southern Observatory in Germany, and at the Universities of Illinois, Chicago, and Arizona, as well as the Lawrence Livermore National Laboratory in California.

While the experimental results of these groups have lagged considerably behind those of the defense community, the latter began making information and hardware available to assist astronomers in their particular applications. Laird Thompson and Chester Gardner (Uni-



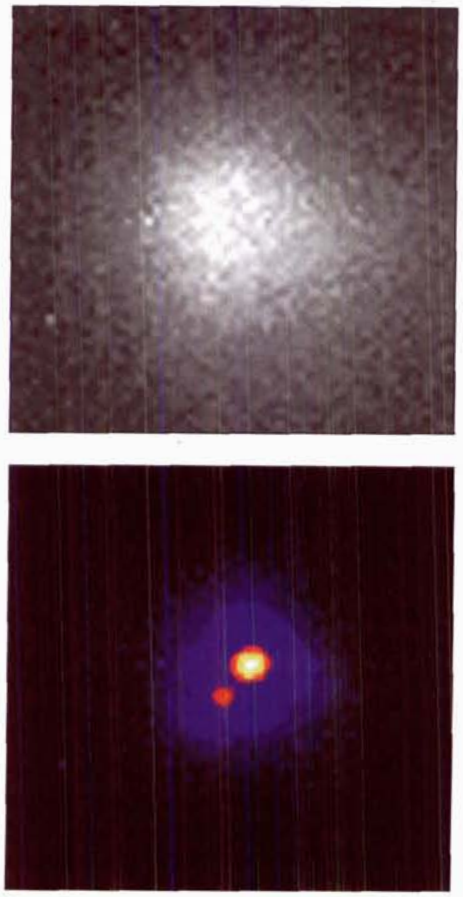
Left: Deep in the heart of the Orion Nebula, the famous Trapezium is a tight clump of four stars visible in modest telescopes and commonly denoted A, B, C, and D. In 1889 S. W. Burnham identified the six additional companions marked here, a few of which taxed even the most skilled observers using the 36-inch Lick refractor. *Center:* Because of glare from the brighter stars and unsteady air, conventional photographic or electronic techniques seldom do much better on this difficult object, as illustrated by this image taken with the Starfire 1.5-meter reflector in 3-arc-second seeing. *Right:* This laser-compensated Starfire view is a spectacular improvement. In a 4-minute exposure made in red hydrogen-alpha light, the adaptive-optics system has sharpened the entire 40-arc-second field, but the correction is best near the C component at which the laser was aimed. This luminous star is believed responsible for the faint "comet tails" — ionized gaseous envelopes — that project away from a few of the surrounding stars. Peter McCullough (University of Illinois) suggested the observation, which is discussed in a paper submitted to the *Astrophysical Journal.*

versity of Illinois) generated a sodium laser beacon at Mauna Kea, Hawaii, in 1987 and photographed it in an 8-minute exposure with the 2.2-meter University of Hawaii telescope. While their beacon was too weak and too unfocused to be useful for adaptive optics, it did verify the concept and the expected strength of the return signal.

Thompson also succeeded in generating high-quality Rayleigh laser beacons more than 15 km above the 1-meter Mount Laguna telescope in California, using an excimer laser operating at the ultraviolet wavelength of 3510 angstroms. A team of French workers has done similar Rayleigh-beacon experiments with the 1.52-meter telescope at the Observatoire de la Côte d'Azur in southern France.

A significant adaptive-optics program dubbed CHAOS, for *Ch*icago *A*daptive *O*ptics *S*ystem, is being led by Edward Kibblewhite (University of Chicago) to produce a sodium-beacon system for infrared work with the 3.5-meter Astrophysical Research Consortium telescope at Apache Point, New Mexico. In its preliminary trials, as pictured on the facing page, this group beamed a low-power laser through a small telescope and successfully observed the beacons with the Yerkes 40-inch refractor.

Several California amateurs have noticed, and even photographed, a sodium-layer beacon that is occasionally visible to the naked eye in the sky over San Francisco Bay. It is part of an experiment by researchers at Lawrence Livermore with a powerful dye laser (about 1,000



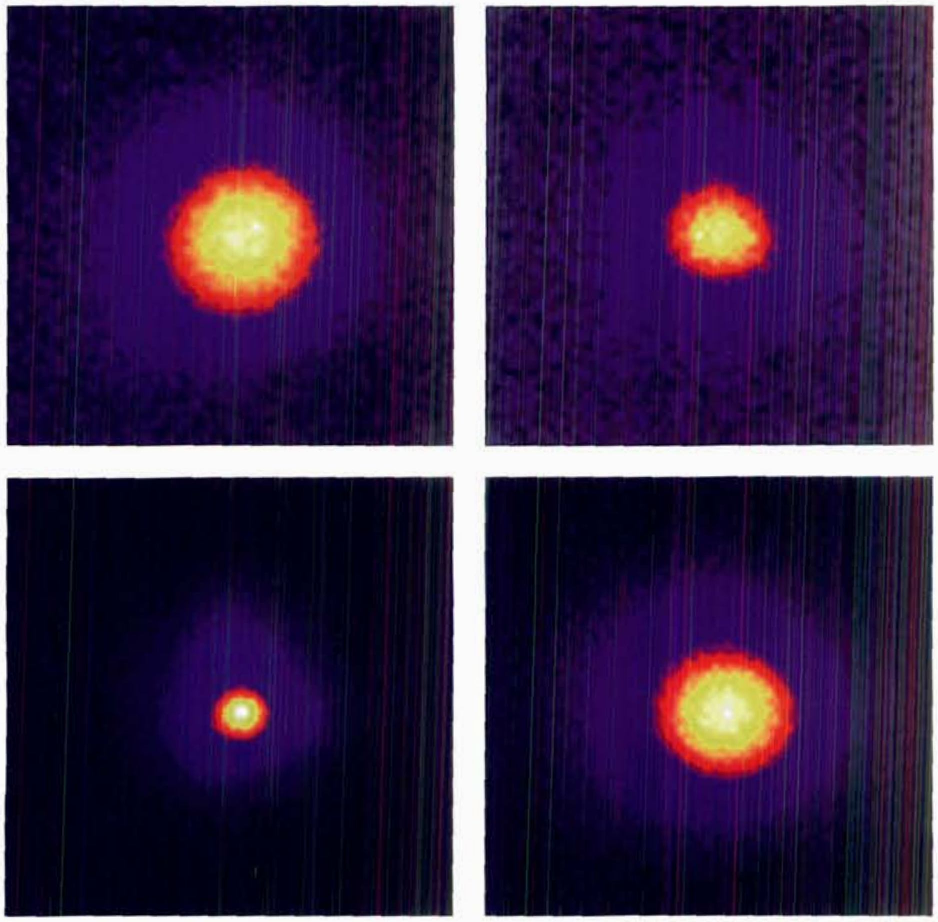
Beta Delphini is a huge blob in the uncompensated image (*top*) obtained with the Starfire 1.5-meter telescope. Switching on the laser beacon and adaptive optics brings out the star's binary nature, with components just 0.20 arc second apart (*bottom*). Furthermore, the intensity at the image core is enhanced 8 times. These are 1-minute exposures in the near infrared (8500 angstroms), and the frames are 1.7 arc seconds across.

watts) tuned to the sodium resonance frequency. They hope to achieve full wavefront compensation in the visible part of the spectrum.

During 1993 researchers at the Multiple Mirror Telescope (MMT) in Arizona made significant advances in work with sodium-layer beacons, testing concepts to be used for full adaptive correction of the 6.5-meter mirror to be installed in the MMT in 1996. Working first with Kibblewhite's team and James Beletic (Georgia Tech), and later with Steve Benda (Coherent Inc.), Roger Angel and Michael Lloyd-Hart (University of Arizona) projected the light from a commercial continuous-wave dye laser through a small telescope on the central axis of the MMT array. This created an 11th-magnitude sodium guide star as sharp as 1.3 arc seconds. The team found very close agreement between the wavefront distortions of this guide star and a natural star over the full 6.9-meter aperture of the MMT's present six mirrors. These are the first such measurements with a very large astronomical telescope. Furthermore, adaptive corrections made 20 times a second produced a clear reduction in the atmospheric jitter of natural star images.

REAL-TIME CORRECTION

Creating bright beacons at a suitable altitude is just the first step — making them work for adaptive optics is quite another matter. To date, the most impressive demonstrations of real-time compensation with lasers have come from two research teams working for the



Three asteroids show their true disks in these near-infrared images made with the Starfire 1.5-meter reflector and a laser beacon. The false-color frames are 1.7 arc seconds across and show (*clockwise from upper left*) Ceres, Pallas, Vesta, and the 7th-magnitude star SAO 110603 for comparison. The exposure times ranged from 20 to 60 seconds. Note that Pallas appears slightly elongated, confirming a finding from ground-based occultation observations in 1983.

U. S. Department of Defense.

In mid-1988 Lincoln Lab became the first group to succeed. Their deformable mirror with 241 actuators was mounted on a 60-cm telescope at Haleakala and teamed with a dye laser emitting blue-green pulses 2.5 times a second. But since any correction is only valid for a few milliseconds at visible wavelengths, the slow pulse rate meant that the aperture was effectively compensated less than one percent of the time — an obvious limitation if faint astronomical objects are to be studied.

The Lincoln Lab experimenters obtained star images whose peak intensities were 40 percent of their theoretical value — a sign they were well on their way to diffraction-limited performance. (Ground-based telescopes normally achieve a ratio of only 1 to 5 percent; the repaired Hubble Space Telescope gets 60 to 85 percent.) They also demonstrated how data could be combined from more than one artificial beacon, a technique that will ultimately be required if telescopes of very large aperture are to be successfully compensated.

Then in February 1989 the Phillips Lab team struck pay dirt with its 1.5-meter telescope and a copper-vapor laser emitting 5,000 pulses per second. The high repetition rate meant the atmosphere could be sampled often enough, and the deformable mirror's shape adjusted in step, to operate in a continuous, real-time mode. Working at 8800 angstroms in the infrared, this system intensified the cores of star images more than 10-fold and reduced their seeing disks from 2 arc seconds to only 0.18 arc second.

The Phillips Lab team has since acquired a new deformable mirror and wavefront sensor. Stellar images are now as small as 0.13 arc second across, measured to where the intensity has fallen to half its central value. Distortion has been reduced to $\frac{1}{10}$ wave, averaged over the aperture, making possible extremely sharp images of such complex regions as the Orion Trapezium (see the pictures at the top of page 29).

BEACON REQUIREMENTS

A laser beacon should have, as nearly as possible, the characteristics of a real star — a bright point source well outside the atmosphere. It must also be bright enough for the wavefront sensor to operate in the required sample time.

A beacon at 20 km is already above, and thus useful for correcting, 95 percent of the atmospheric turbulence. But an even higher beacon is desirable for a more important reason. Because the beacon is formed a finite distance away, its light rays arriving at the center and edge of the telescope aperture must diverge by a very small angle. When this angle reaches about twice the size of the isoplanatic patch mentioned earlier, wavefront correction deteriorates.

For example, in visible light the deviation should not exceed about 3 arc seconds, corresponding to 2.5 meters for a beacon as high as 90 km. Thus, such a beacon could not help a telescope any larger than the Palomar 5-meter reflector. Current theories predict that a 10-km beacon allows the same level of correction in a 0.6-meter telescope as a 90-km beacon with a 2.4-meter instrument. The useful aperture is also proportional to the observing wavelength raised to the $\frac{6}{5}$ power. The bottom line: If we want to correct an 8-meter telescope, we will probably need more than one beacon positioned over the aperture.

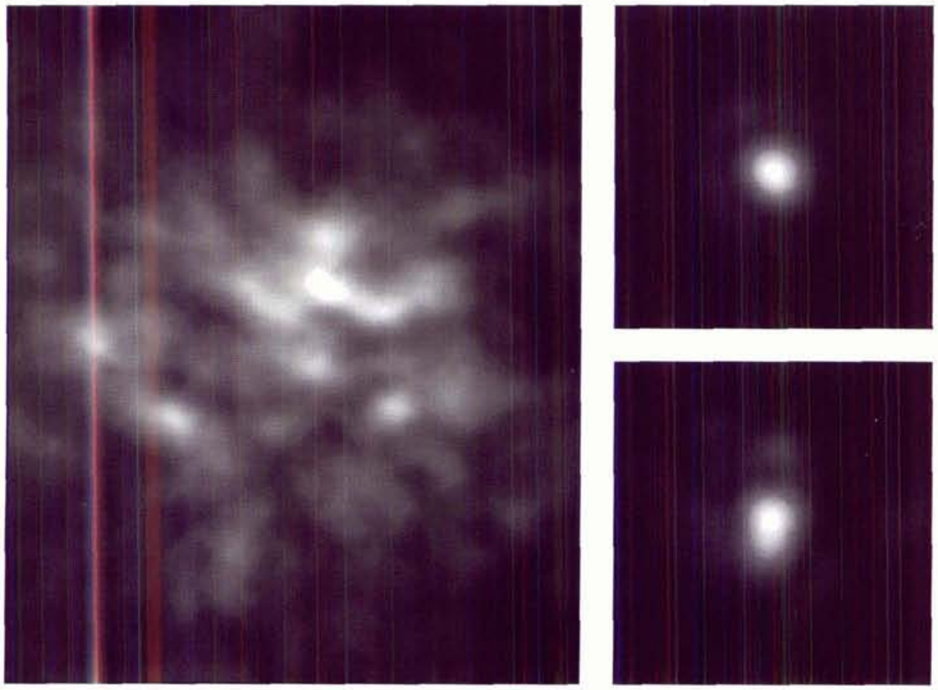
Extremely small angular size is another beacon requirement. If the laser's natural beam divergence is too great, the beacon can be sharpened by expanding the beam and feeding it through a large-aperture telescope. Typically we want the beam divergence to be less than that caused by atmospheric turbulence.

A very desirable location for the transmitting aperture is just beyond the imaging telescope's secondary mirror, where the outgoing beam is perfectly coaxial with the telescope but blocked from view. In this case the beacon is brightest and smallest because it is viewed end on, rather than from slightly to one side.

The laser beacon must also be fairly intense to be at all effective, at least as bright as 6th magnitude at visual wavelengths and 12th magnitude for infrared operation.

UNWANTED LASER LIGHT

Furthermore, how can we keep the laser's light from blinding the scientific camera? We want it to go only where it belongs: into the wavefront sensor. A straightforward approach is to use a pulsed laser and turn the sensor on just long enough to receive the backscattered



Left: The light of Betelgeuse spreads completely across the 3.1-arc-second width of this frame, which shows an uncompensated ⅟₅₀-second exposure obtained with the Starfire 1.5-meter telescope. Reproduced at the same scale, but cropped in, are two images showing the great improvement when this 1st-magnitude star serves as its own beacon (*upper right*), or when a laser beacon 10 kilometers away is used (*lower right*). The star-compensated image is best, having a peak intensity 12 times that of the raw image, but the laser-beacon image is still an exceptional improvement.

light from each pulse. An electro-optical switch or mechanical chopper can be used to block out the offending laser light from the camera during the time it is most intense.

If the scientific camera operates in a different spectral region than the laser, special filters may create enough isolation. For example, the infrared camera at Starfire contains a polarizing beamsplitter and filter. It shares the 1.5-meter telescope 100 percent of the time with a pulsed copper-vapor laser emitting blue-green and yellow light, yet exposures lasting tens of seconds show no detectable light from the laser.

Most observatories have several telescopes in use simultaneously. If one of these instruments is emitting laser light, another telescope could pick up side scatter if it tries to look through that beam. In the future, observing plans may need coordination to minimize such interference.

TILT CORRECTION

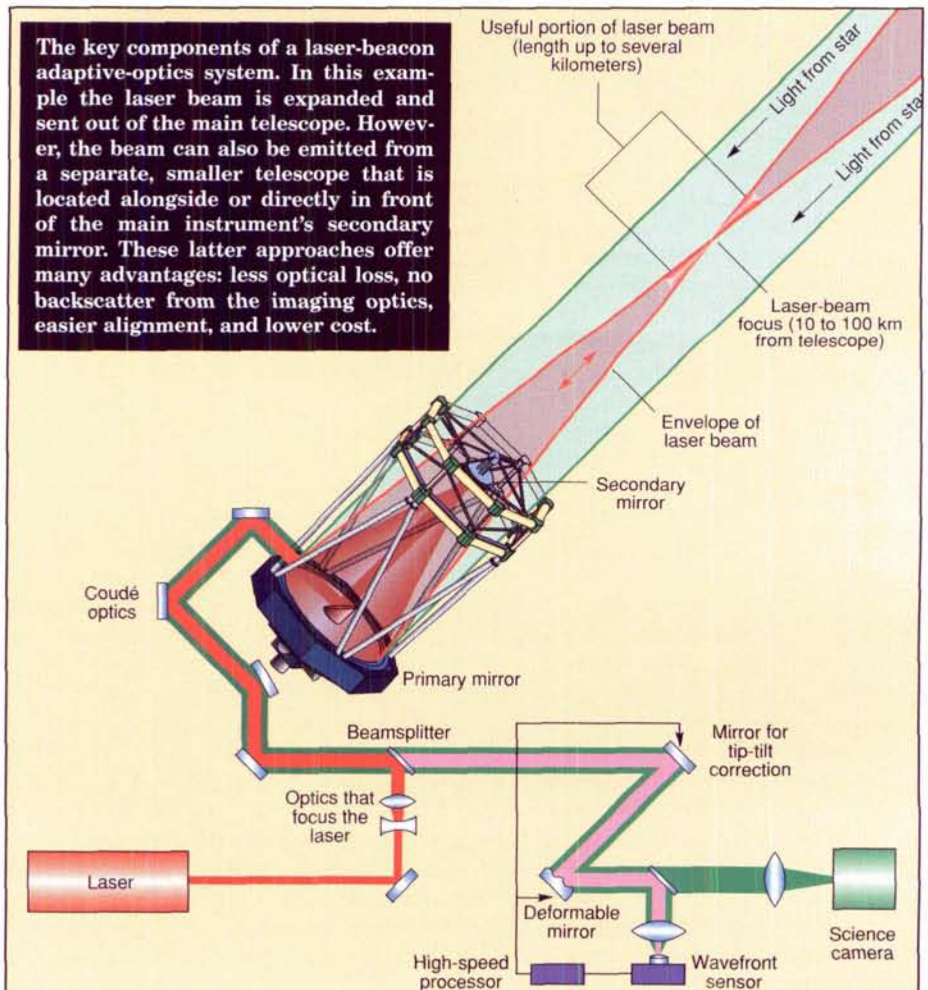
Despite the early successes with laser beacons there remains a final, serious limitation to their effectiveness for adaptive optics. Although these beacons reveal much about the higher-order details of atmospheric turbulence, they can't provide any information about what is called *full-aperture tilt.* On its upward propagation through the atmosphere the beam wanders randomly, and the unknown final offset from the aim point at the beacon's altitude leads to an unknown overall tilt to the returned wavefront.

As a result, while the beacon may indeed help correct a natural star for wavefront error, there is nothing to prevent the newly sharpened image from jittering around so badly as to ruin a long exposure. The final image would be hardly any better than without the adaptive optics! All this means a laser beacon cannot be the ultimate cure-all; the Starfire system uses a natural star *in addition to* a laser beacon to correct for both wavefront distortion and aperture tilt.

Meanwhile, other groups of astronomers are continuing to pursue seeing-compensation techniques that use no lasers at all. One even provides close-up views of fine structure on the surface of the Sun. We'll explore these alternate approaches in a future issue of *Sky & Telescope.*

After several years at the Starfire Optical Range Walter Wild is now part of the Kibblewhite adaptive-optics group at the University of Chicago. A glimpse at Robert Fugate's pioneering role in the field begins on page 20.

The key components of a laser-beacon adaptive-optics system. In this example the laser beam is expanded and sent out of the main telescope. However, the beam can also be emitted from a separate, smaller telescope that is located alongside or directly in front of the main instrument's secondary mirror. These latter approaches offer many advantages: less optical loss, no backscatter from the imaging optics, easier alignment, and lower cost.



JOSÉ R. DÍAZ

Meet the man in charge of the most revolutionary telescope in the world.

Robert Q. Fugate: Starfire's Magician Optician

Text and Photographs by Roger H. Ressmeyer

AS TECHNICAL DIRECTOR of the Starfire Optical Range (SOR) in New Mexico, physicist Robert Q. Fugate commands the most advanced adaptive-optics facility in the world. The man is consumed by his mission, one so secret that for 20 years he couldn't even mention it to his wife, Marilyn. "I couldn't tell her what I was doing or who I was meeting or why I had to go back to work at night." Things got so bad that one day their two children, Jeffrey and Elizabeth, declared, "We should buy a cardboard daddy and put him in the living room."

The Starfire project was finally declassified in May 1991, a day Fugate remembers vividly. "It was amazing, just incredible. Previously we had been talking to such a small audience, and suddenly I was sharing our work with a group of 600 at an open meeting of the American Astronomical Society in Seattle."

And the family? "Declassification has made our life together much better," he admits. "I was working no less than 80 hours a week. I'd get home after sunrise, sleep for four or five hours until noon, and go right back out to prepare for the coming night. I still do that now, sometimes."

Working at SOR takes a lot of energy, stamina, and dedication, and Fugate is the embodiment of these qualities. As team leader in the early 1980s his experiment proved the concept of laser-beacon adaptive optics. Today, he presides over a huge, state-of-the-art telescope dedicated to refining the technique. It's perched on the windward edge of a 1,950-meter rise deep within Kirtland Air Force Base, only 30 kilometers from downtown Albuquerque. The instrument received its 3.5-meter f/1.5 primary mirror (spin-cast by Roger Angel) just last August — yet made its first-light images in February!

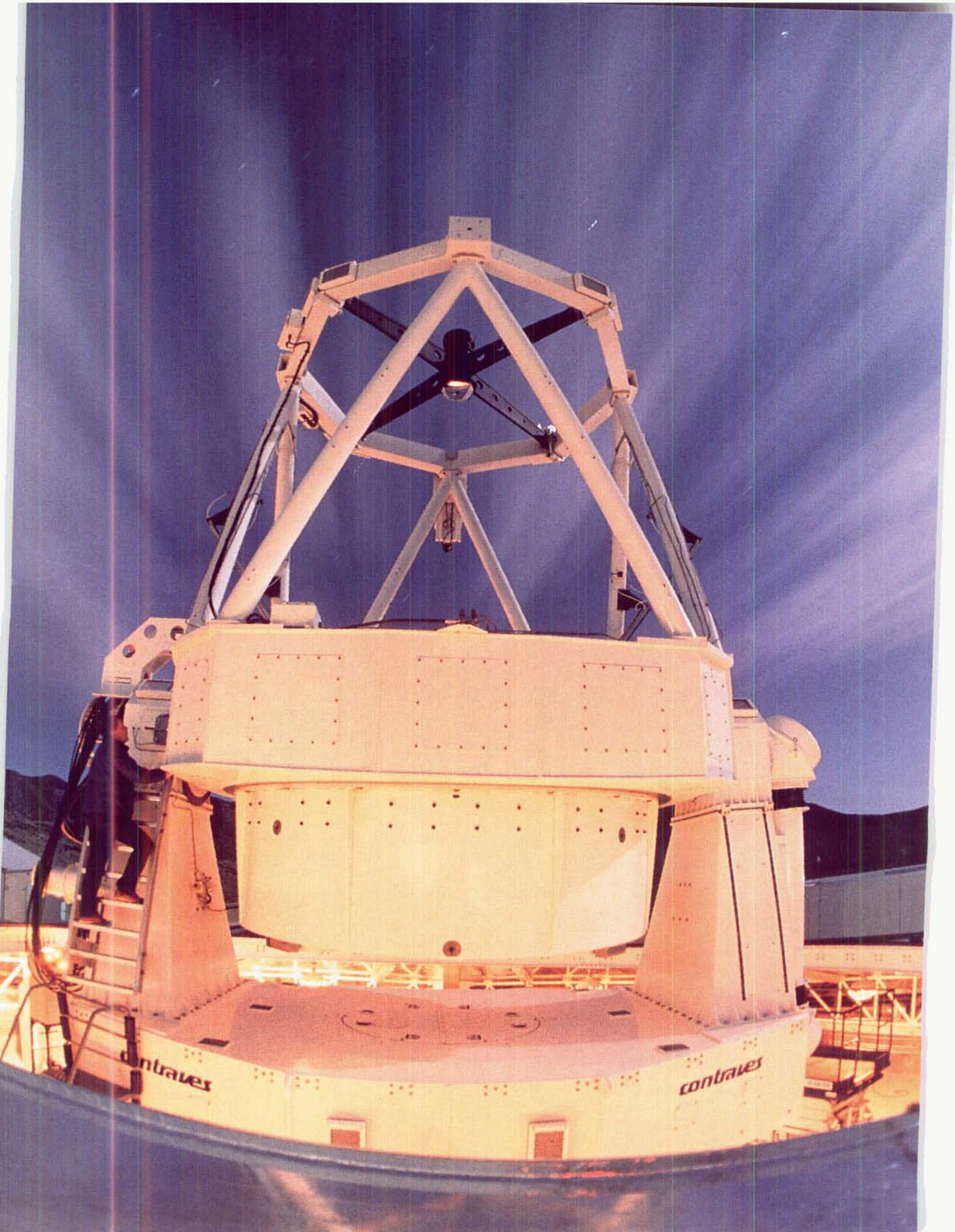
Surveying the scene at night, I am surprised to find "spotter" platforms next to Starfire's main and smaller (1.5-meter) telescopes. These, I learn, are used by sentries watching for incoming aircraft — so that Starfire's brilliant laser beacons can be shut down if a plane accidentally strays toward the blinding light.

Fugate describes the 3.5-meter's revolutionary enclosure as a "Boy Scout cup" whose three concentric cylinders collapse around the telescope, leaving the instrument completely exposed to the night air. "This has two advantages," he explains. "It provides complete ambient-air ventilation all around the telescope, and you don't have to turn a heavy dome when you move the telescope at 12° per second. This is the largest telescope around that slews at high speed with extremely low jitter." That also makes it the largest spyglass on Earth for tracking and imaging low-orbit satellites.

The SOR staff of 40 or 50 is a mix of Air Force personnel attired in military garb and civilians, like Fugate, in jeans and sweaters. During my tour of the facility I ask to see some of the pictures of orbiting spacecraft taken here. "Sorry," Fugate re-

Facing page: **The Starfire Optical Range's 3.5-meter telescope, the brainchild of SOR director Robert Q. Fugate, has a spin-cast f/1.5 primary mirror and uses adaptive-optics technology to counter atmospheric turbulence. Moonlight, dusk, and dawn aid in the scene's illumination. All photographs with this article are ©1994 Roger H. Ressmeyer–Starlight/MP©A.**

Above: **No one can accuse Fugate, now 49, of lacking vision. For observations at visible and near-infrared wavelengths, he asserts, "our goal is diffraction-limited imaging at the sky background — around 20th or 21st magnitude."**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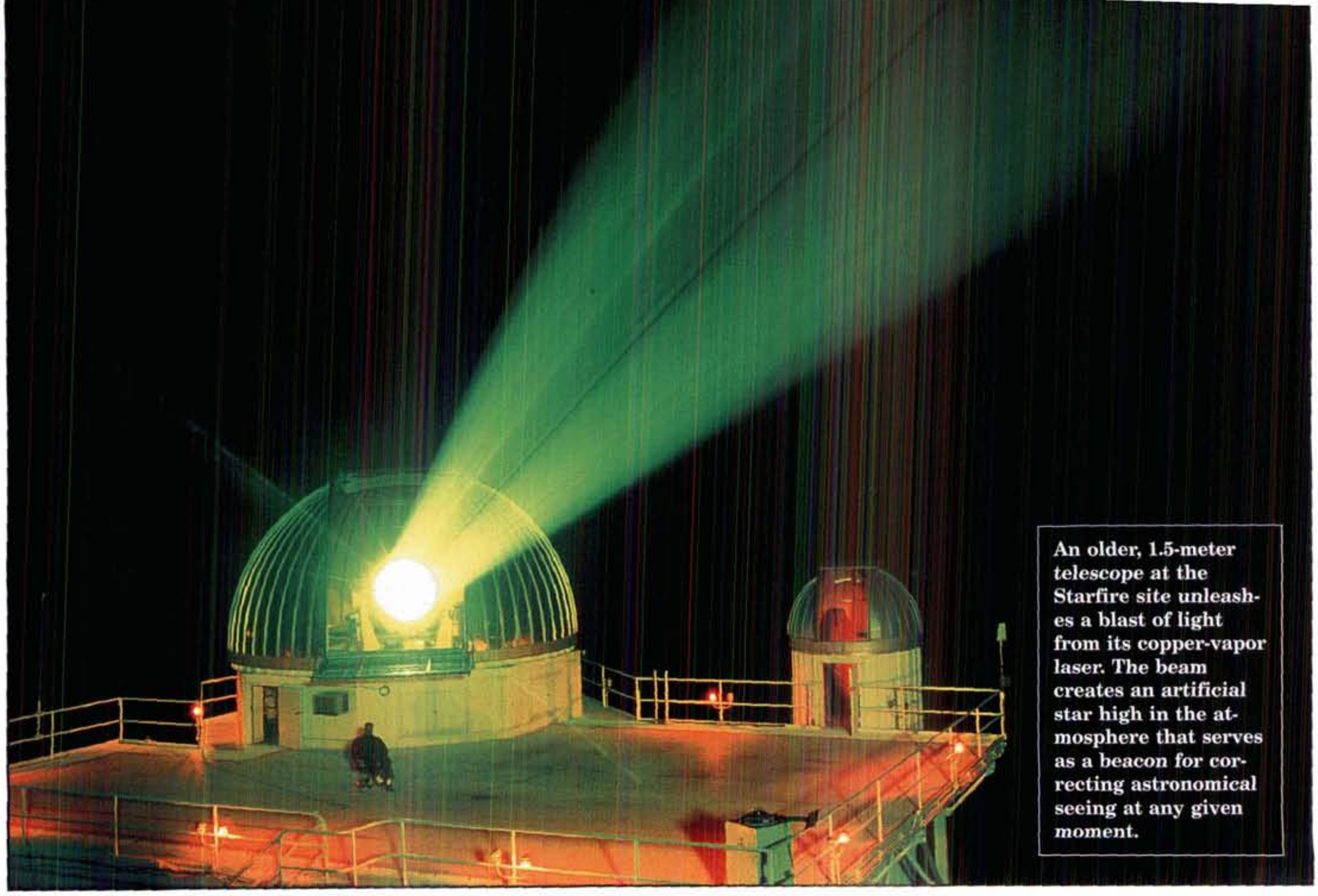


An older, 1.5-meter telescope at the Starfire site unleashes a blast of light from its copper-vapor laser. The beam creates an artificial star high in the atmosphere that serves as a beacon for correcting astronomical seeing at any given moment.

sponds. "All the astronomy stuff is unclassified, but they're real persnickety about satellite imagery." Sensing my disappointment, he adds, "Today 5 percent of our work is in astronomy, but we want it to grow. We want to share this technology fully with the astronomy community, and we're doing everything we can in the world to do that."

I ask him about the strange, dark blockhouse a few hundred yards downhill from the telescope and connected to the observatory with large pipes. He explains that it's a high-tech icehouse. "During the daytime we manufacture and store up to 4½ million pounds of ice in that reservoir. At night we circulate water through it, chilling the water. Then we pump the water up here to remove heat from the building. A fan pulls air through the telescope structure and primary mirror, and we exhaust the warm air alongside the icehouse."

Despite Fugate's quiet, calm humility, his story could have come straight from the pages of a Tom Clancy novel. In 1970, with his newly minted Ph.D. from Iowa State University in hand, Fugate joined a glut of physics graduates who were having a difficult time finding work. Then his mother-in-law, a hairdresser, learned over soapsuds from one of her customers that a scientist at Wright-Patterson Air Force Base in Ohio was looking to hire a brilliant young physicist. Fugate called for an interview, and the rest is history.

He went right to work in lasers and electro-optics, his assignment being to detect "hostile" aircraft-threatening lasers. By 1978 he'd become an acknowledged expert in laser detection, and one day he was asked to visit a top-secret project at Kirtland in New Mexico known as the Sandia Optical Range. (Eventually he would personally rename it the Starfire Optical Range.) Fugate's clandestine trip to the air base came about because five years earlier scientists at SOR had used a potent, carbon dioxide laser to blast an airplane out of the sky with a burst of infrared energy. By 1978 a similar, aircraft-mounted laser was being used to shoot down incoming missiles. Fugate's new assignment was to detect the infrared beam even when it wasn't aimed at his sensors. Little did he realize that he'd found a home in the heart of what, years later, would be called Star Wars.

Fugate's work soon evolved from beam detection and control to validating the concept of laser-beacon adaptive optics, which his five-person team successfully demonstrated in the summer and fall of 1983. A year later Fugate began lobbying for a telescope to utilize this new capability, and his 1.5-meter instrument for adaptive-optics experiments became operational in the spring of 1987.

"In the movie *Jaws* there's a scene with two guys in a boat; the shark comes up out of the water, and he's wider than their boat," Fugate recalls. "One man turns to the other and says, 'We're going to need a bigger boat.' And that's how I felt in 1987 when I went into director Pete Avizonis's office and said, 'Sir, we're going to need a bigger telescope.' And he threw me out on my ear, but I just kept going back." Persistence, hard work, and the 1.5-meter's results paid off for Fugate, as the Air Force eventually approved the 3.5-meter project.

Today, with the big scope almost complete, Fugate dreams of "power beaming" energy to drive the ion engines of orbiting satellites. Or someday he'll use lasers to communicate with far-flung planetary probes, eliminating the need for them to carry large antennas like the one that recently failed aboard the Jupiter-bound Galileo. "We're about to prove that concept," he says, "by creating a laser link between our 1.5- and 3.5-meter telescopes using the retroreflectors left on the Moon by the Apollo astronauts. And so it continues for this hard-driving blend of optician, politician, and high-tech magician.

Contributing photographer Roger Ressmeyer visited Starfire in 1992 and 1993 while on assignment for the National Geographic Society.

Big Crow Capabilities

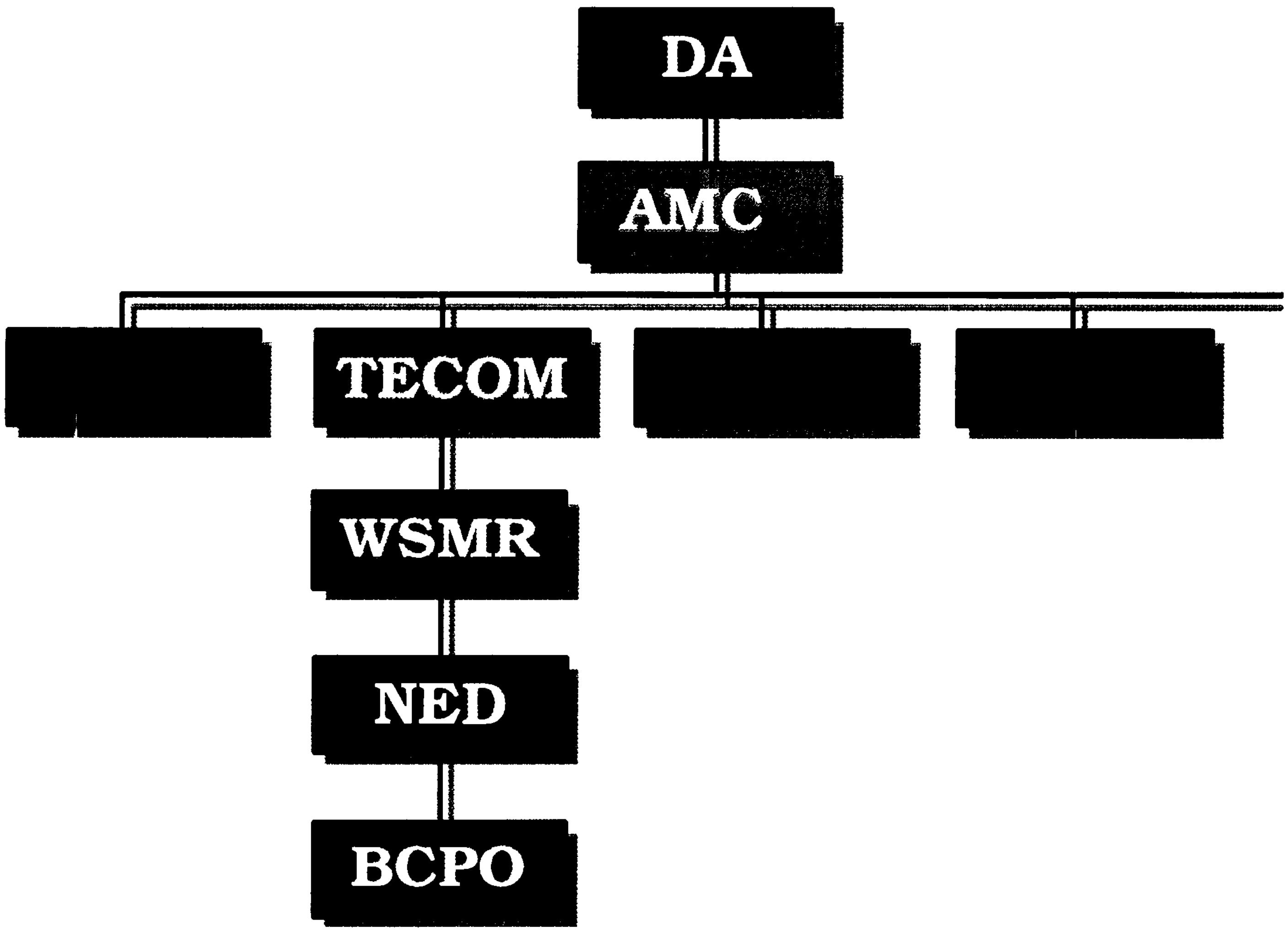
WHITE SANDS MISSILE RANGE
NUCLEAR EFFECTS DIRECTORATE
WSMR
NEW MEXICO

Outline

Big Crow Program Office

- Mission
- Applications
- Platforms
- Active and Passive EW
- Data Collection
- Design & Development
- Experience

Organization



Big Crow Program Office

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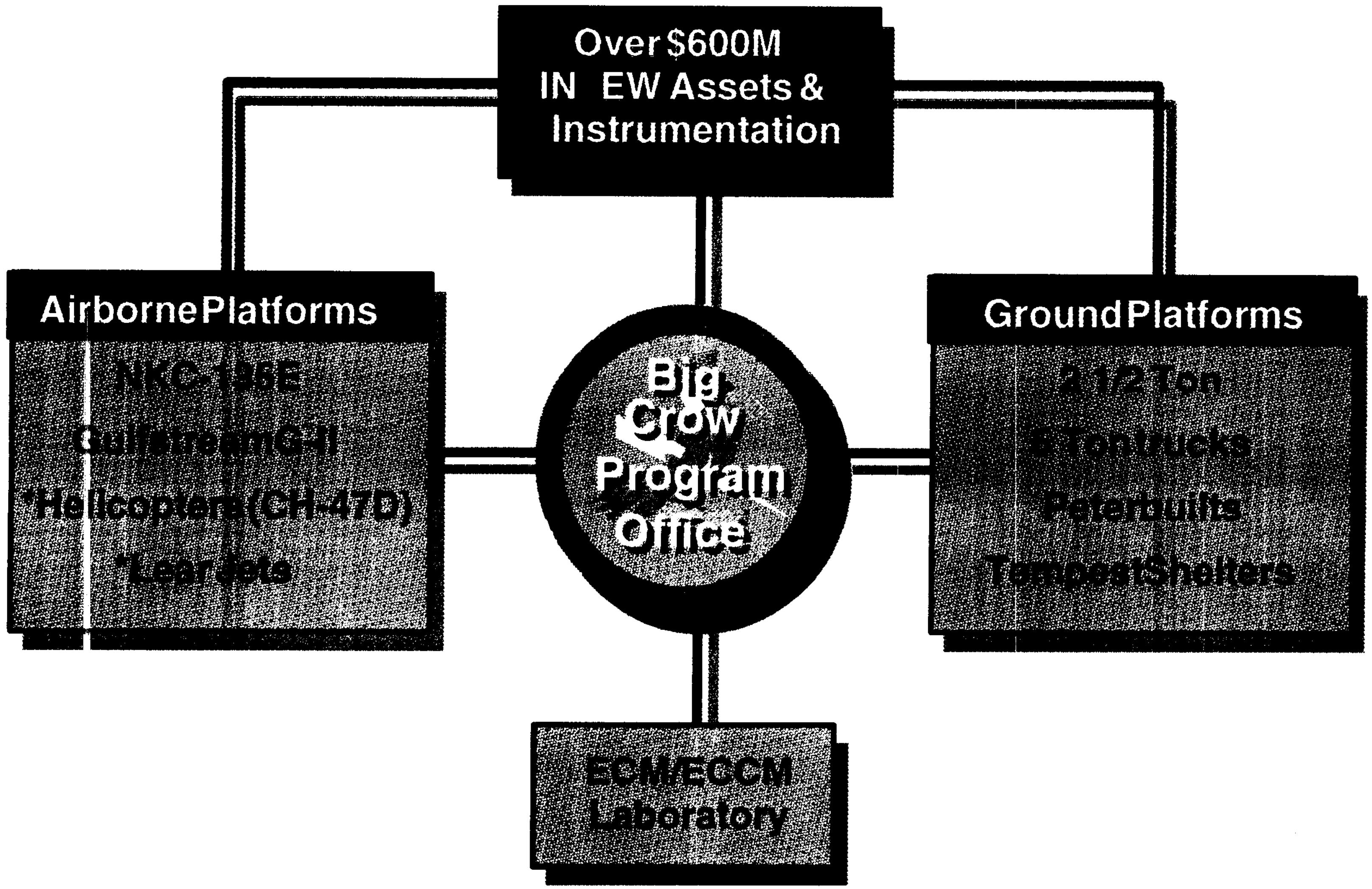

Mission

- Provide Projected EW Environments for EW Vulnerability Assessments
- Provide and Operate Airborne and Ground-Based Platforms for EW Experiments, Tests, Trials and Training

Applications

- EW Vulnerability Assessments (EWVA)
- In the Loop Bench Testing
- Radar Jamming
- Data Link Jamming
- Communications Jamming
- IR Counter Measures
- Laser Illumination
- Atmospheric Characterization
- Electronic Support Measures (ESM)
- SOJ/SSJ/ESJ
- Training Exercises
- Instrumentation Prototypes
- Black Box Prototypes

US Systems Operational Frequencies

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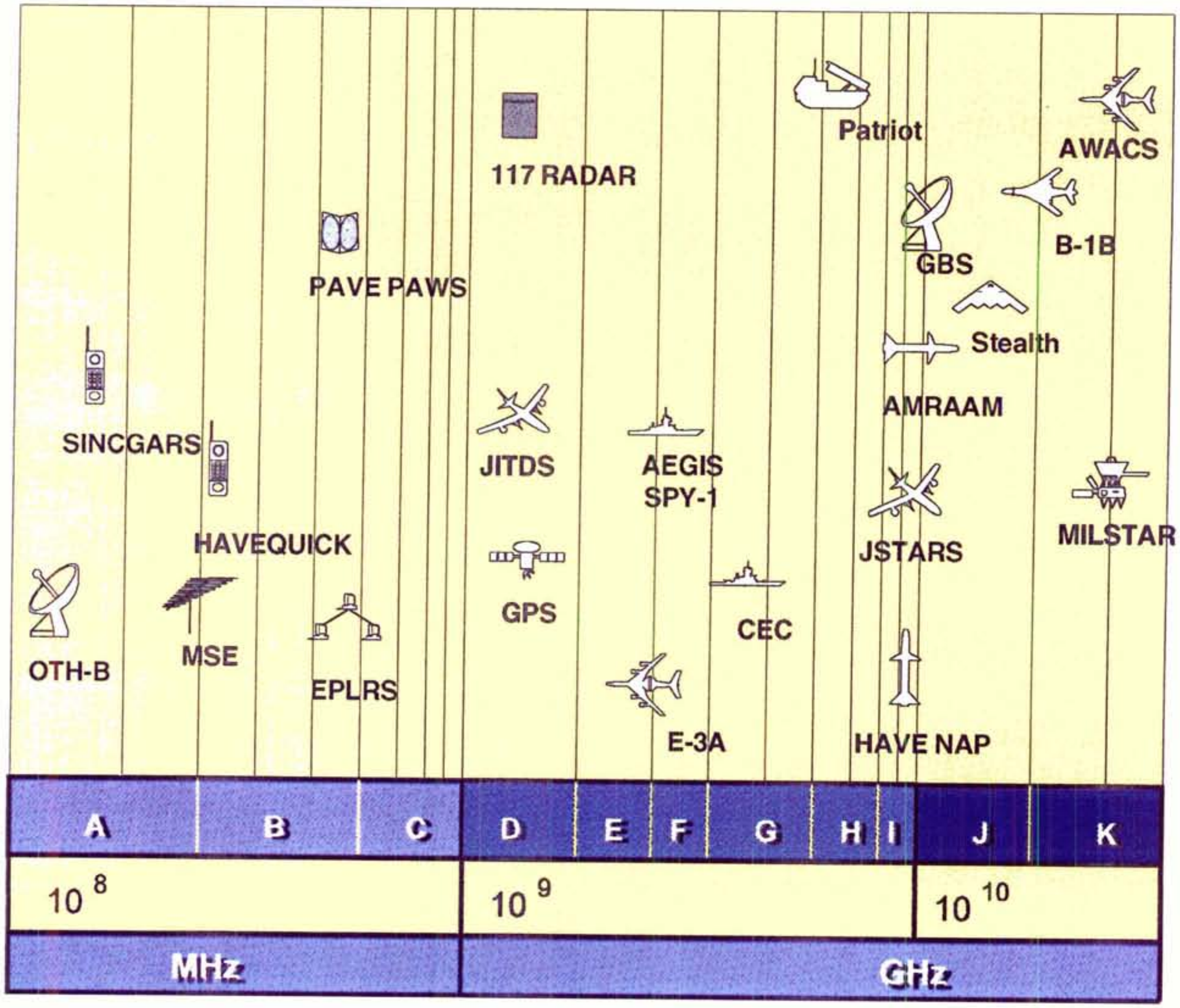

Frequency Coverage

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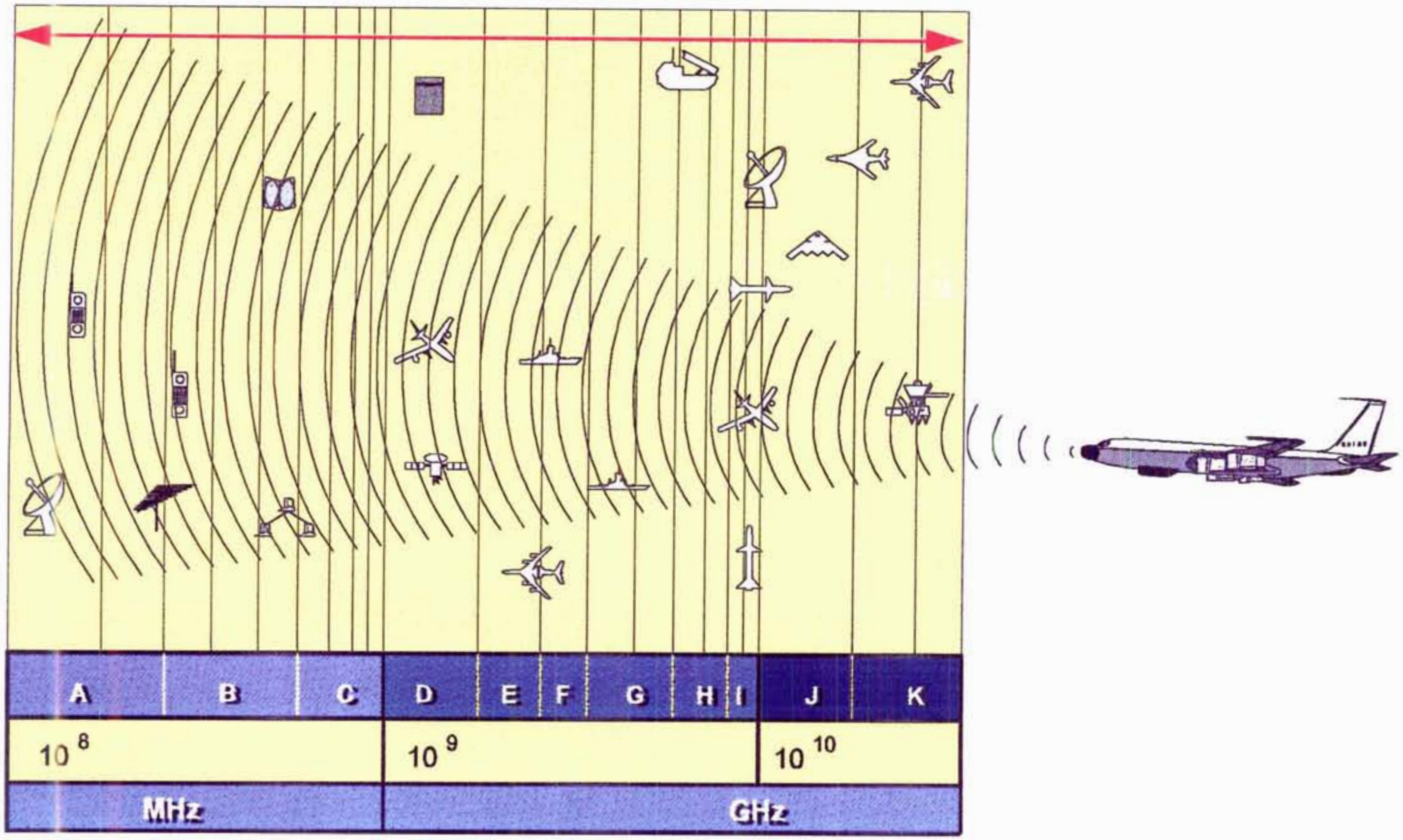

Frequency Coverage

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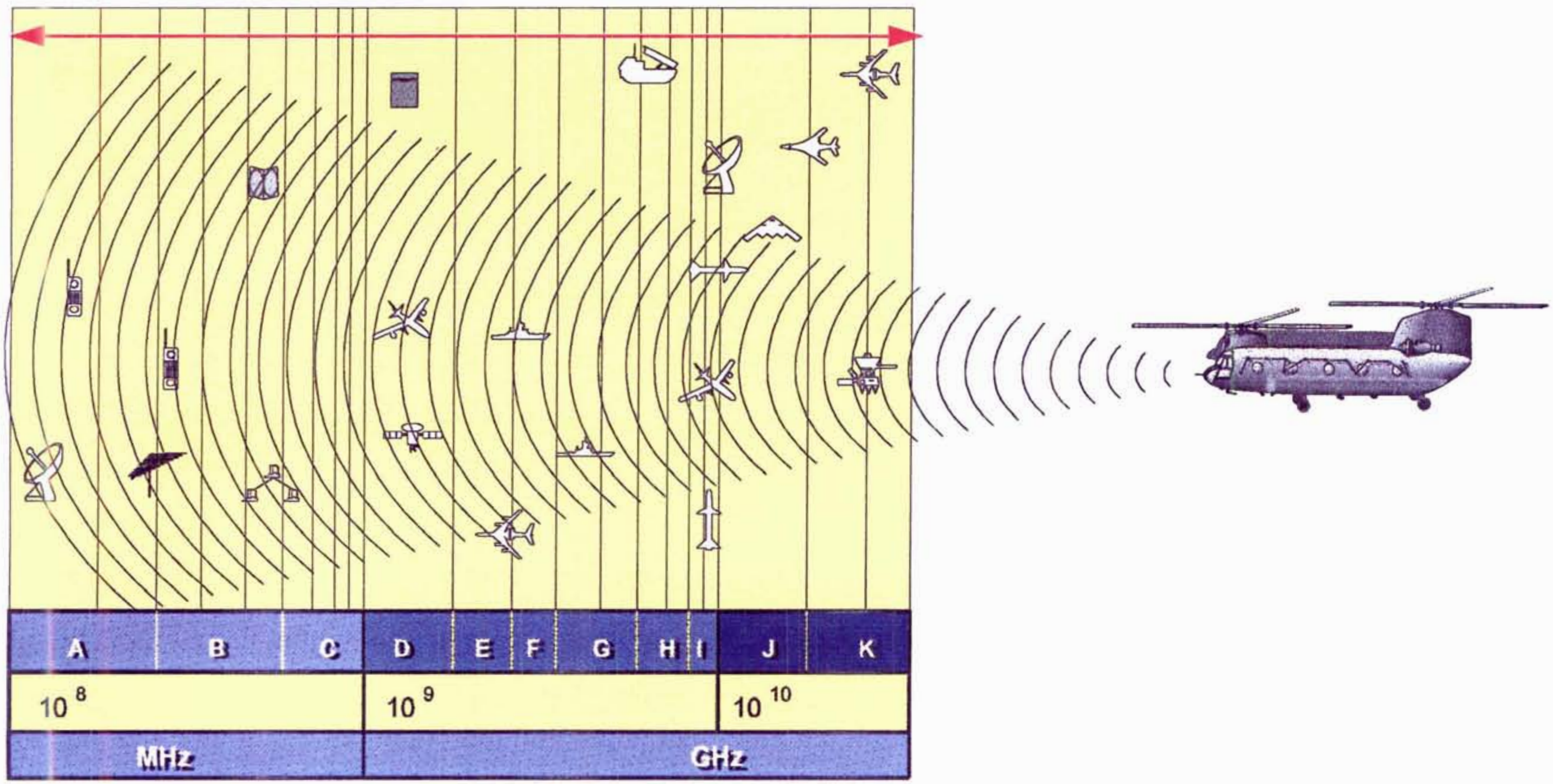

Frequency Coverage

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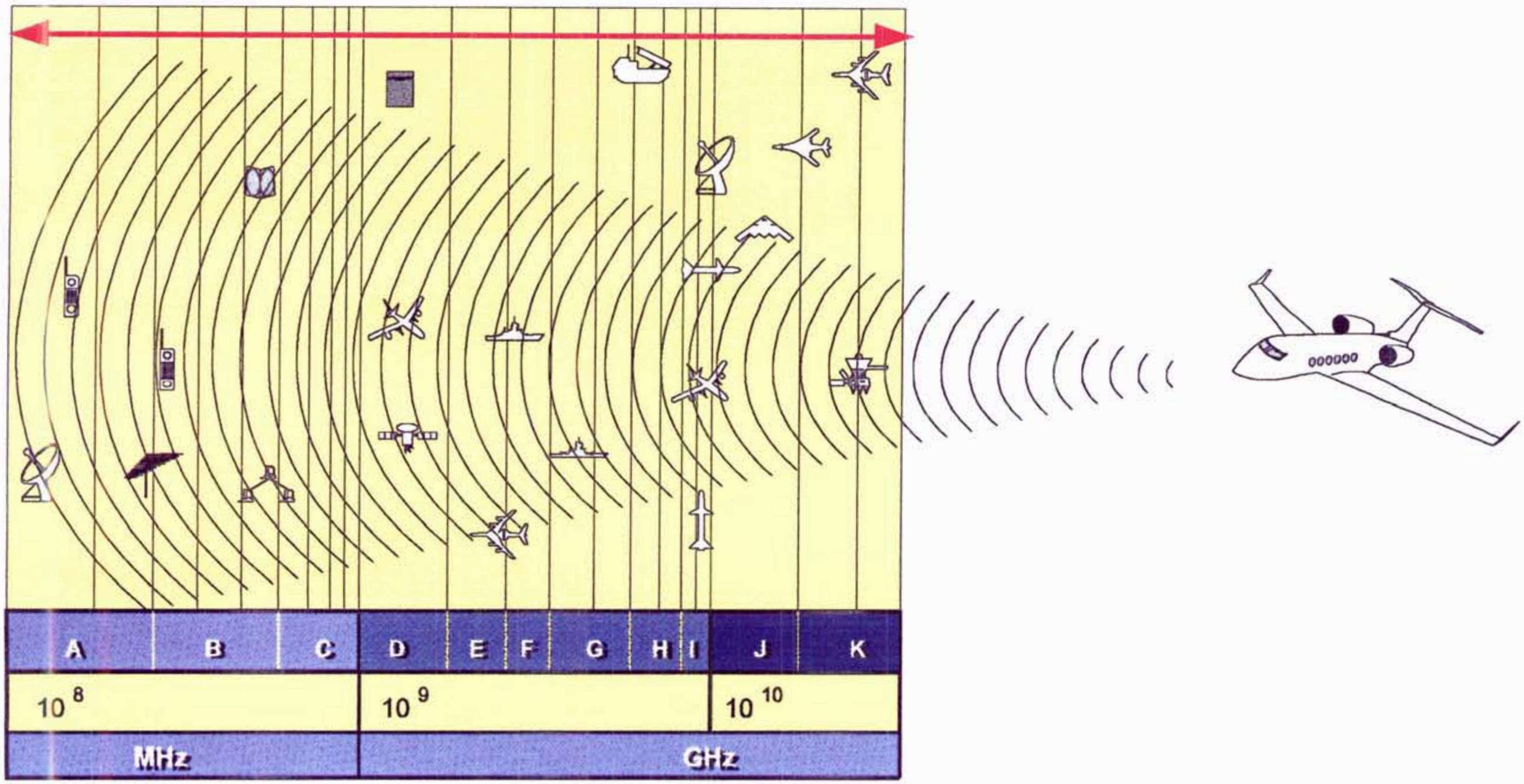

Frequency Coverage

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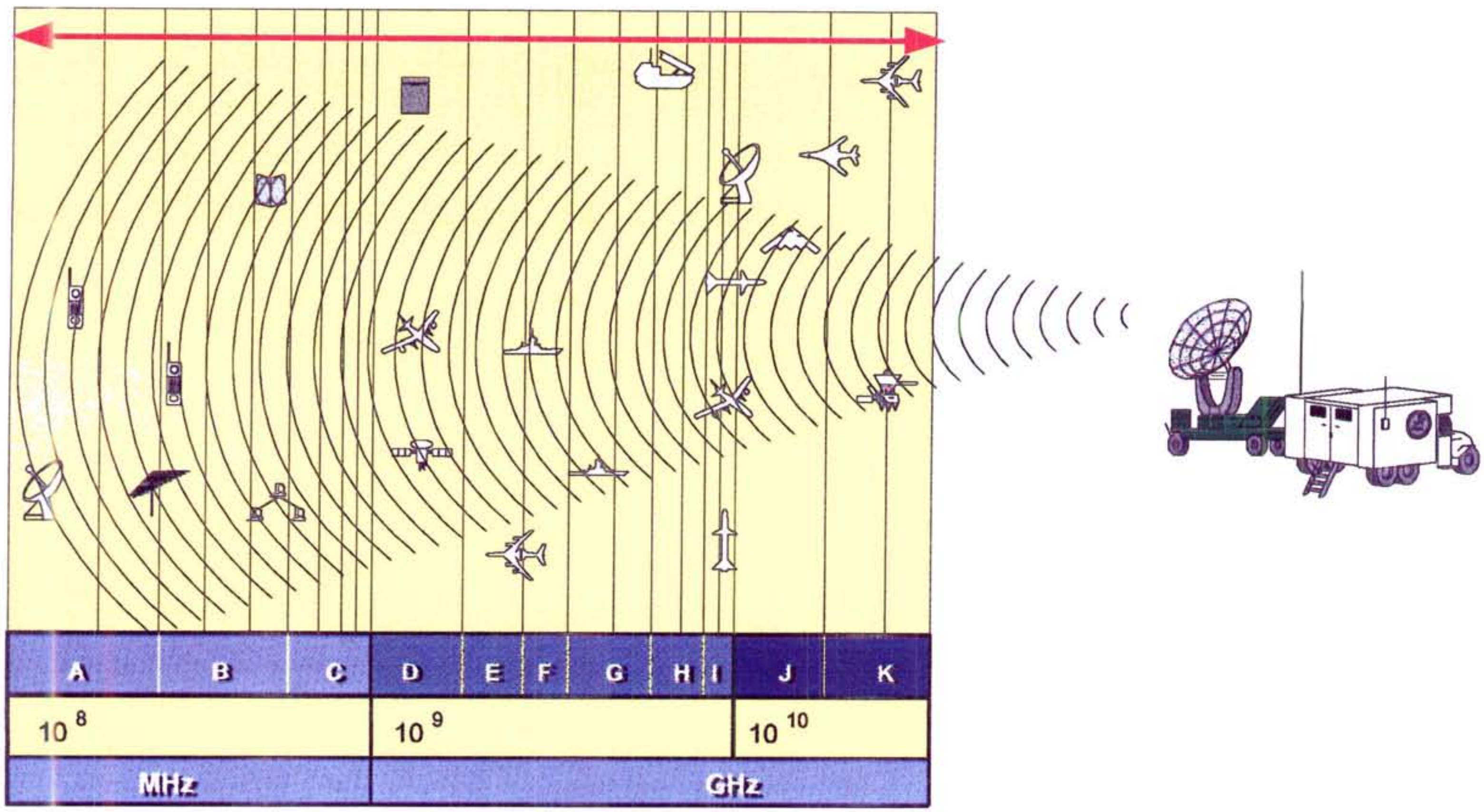

Platforms/Capabilities

- Mobile Test Beds/Laboratories
  - NKC-135E; TN 55-3132
    - Worldwide Deployment
    - Sustained Missions (16+ Hours)
    - Large Upper, Lower, and Nose Radomes
    - Pylons (5000lb Capacity)
  - Gulfstream G-II; TN N65ST
    - RF, MMW, EO Test Bed
    - State-of-the-Art Avionics
    - Optical Ports (Apertures up to 18"x11")
  - 10 Vans/Trucks
- Palletized Electronic Packages Usable in All Test Beds Listed and Others (e.g., CH47D)
- Electronic Pods
  - Chaff
  - ESM
  - ECM
  - EO

NKC-135E

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Antenna/Pedestal Configuration

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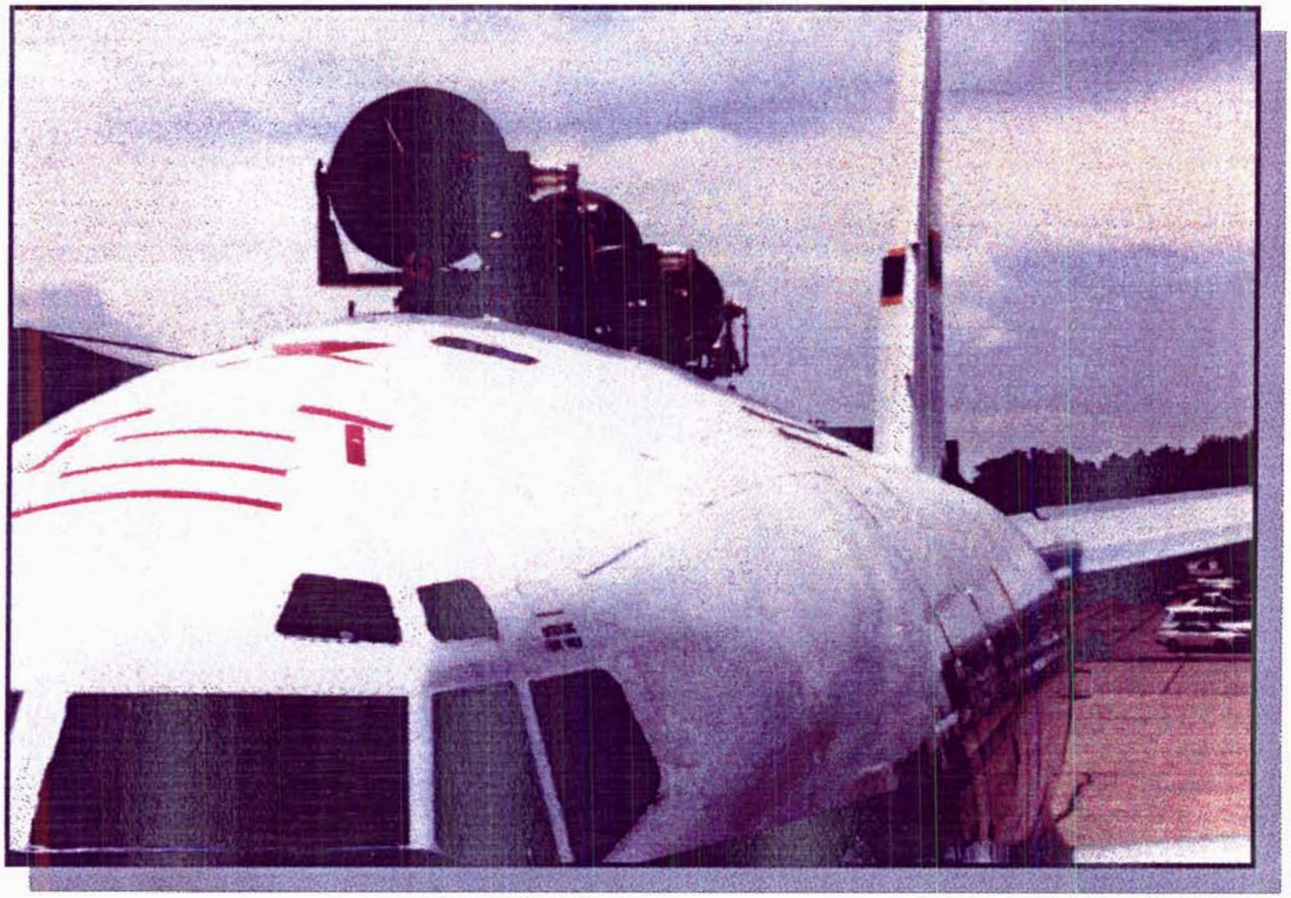
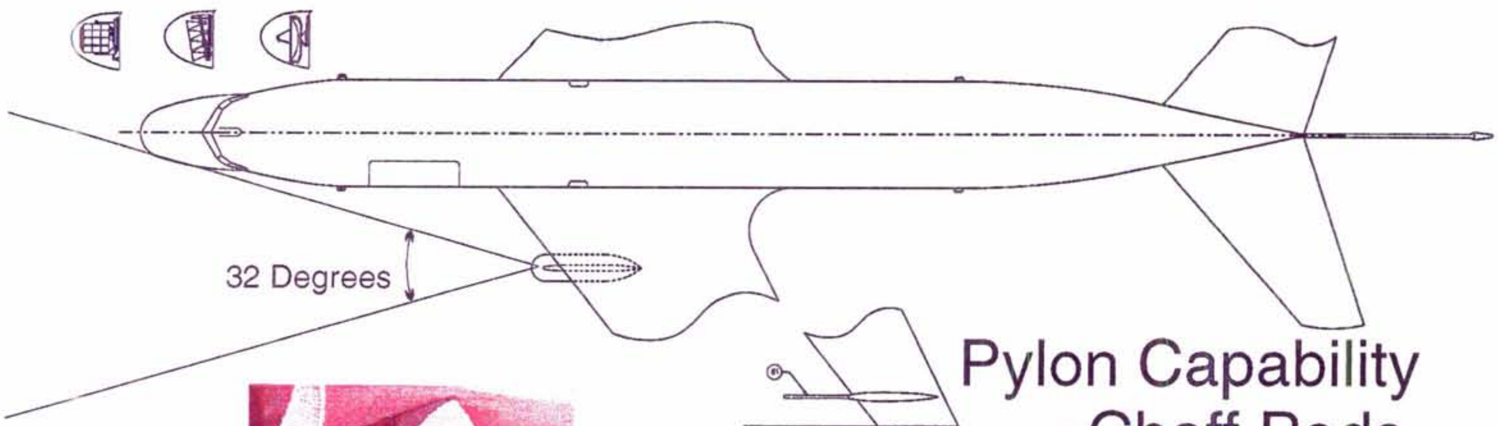


NKC-135E EW Features

Big Crow Program Office

Custom Antennas Designed for the NKC-135E Modified Nose



Pylon Capability
- Chaff Pods
- ECM Pods
- Customer Pods

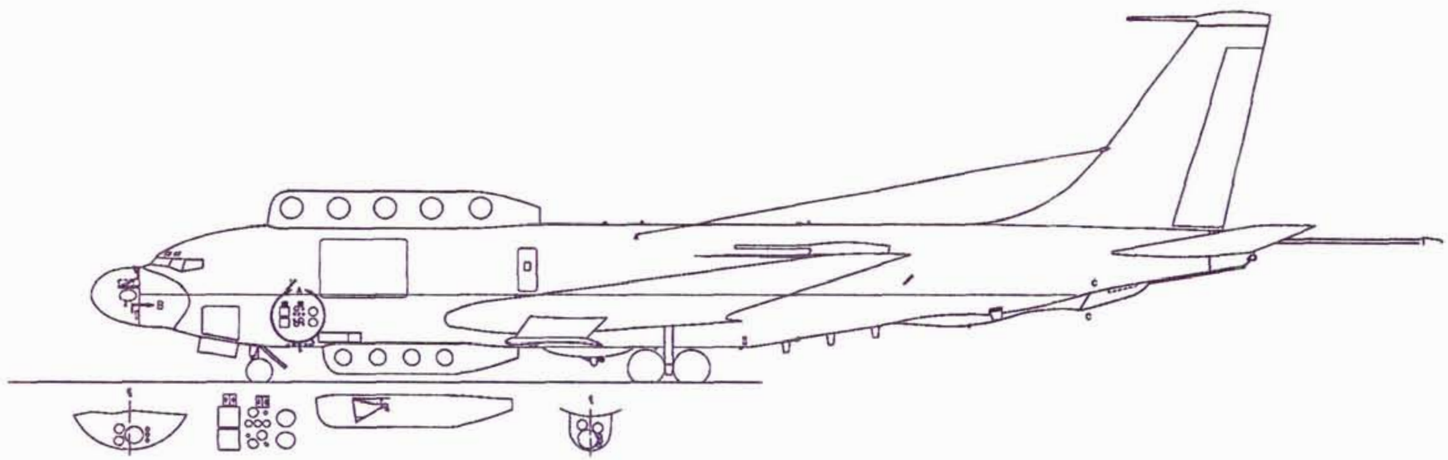
  ≤5000#

  -3dB BW ≤32°

NKC-135E EW Features

Available Upper & Lower Radomes

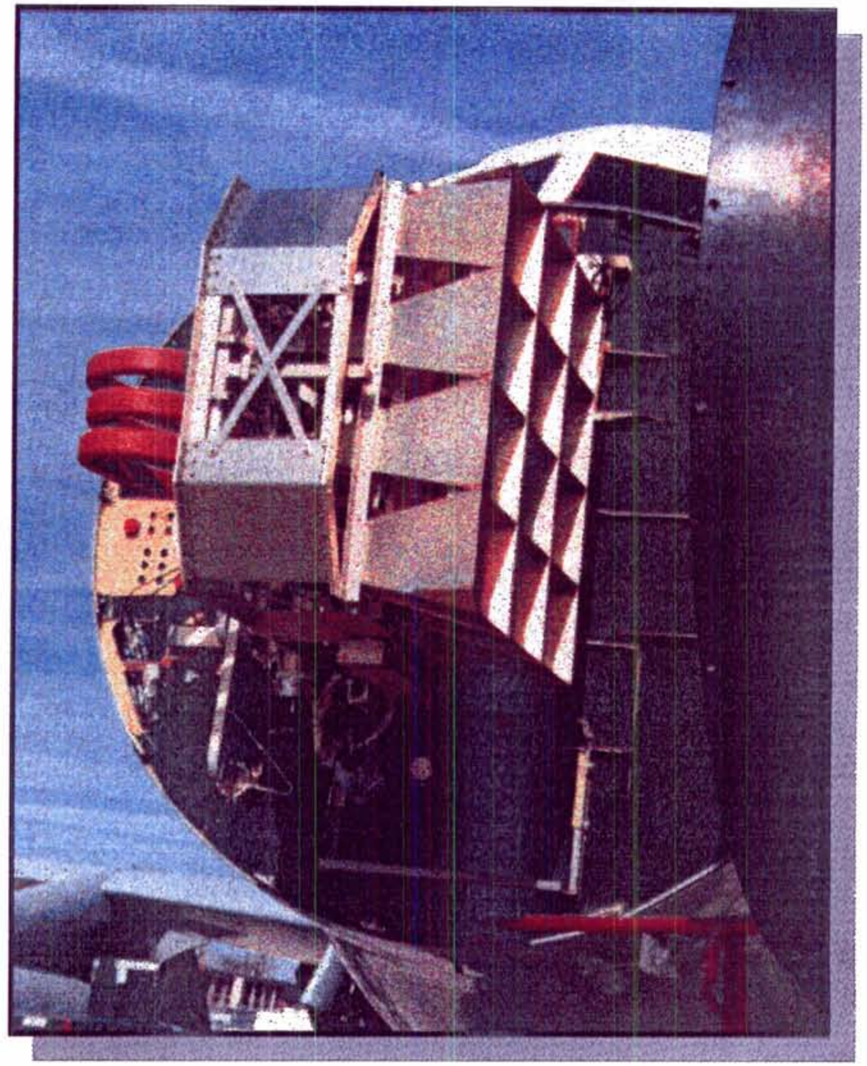
- Antennas Pedestal Accuracy 1°
- Antenna Pedestals Installable in Top and Bottom
- Installation Rails in Place for Customer Instrumentation



Horn Array

Big Crow Program Office

- Beamwidth
  - AZ 14°
  - EL 3.5°
- Steerible
  - AZ ±10°
  - EL ±10°
- Pointing Accuracy <1°
- G-Band
- Power Level (ERP) >1.4M Watts CW



5' Dish Antenna

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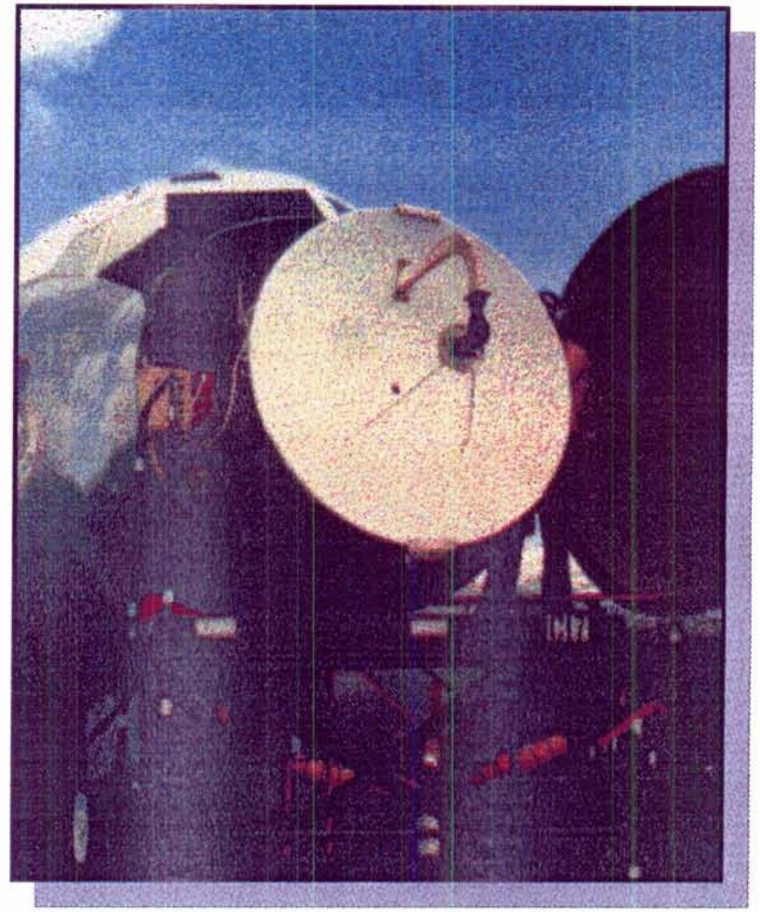
- Beamwidth
  - AZ 3.5°
  - EL 3.5°
- Steerible
  - AZ ±15°
  - EL +5°, -15°
- Pointing Accuracy <1°
- F-Band Octave
- Power
  - Current >0.9M Watt
  - Planned >4.0M Watt



Gulfstream G-II

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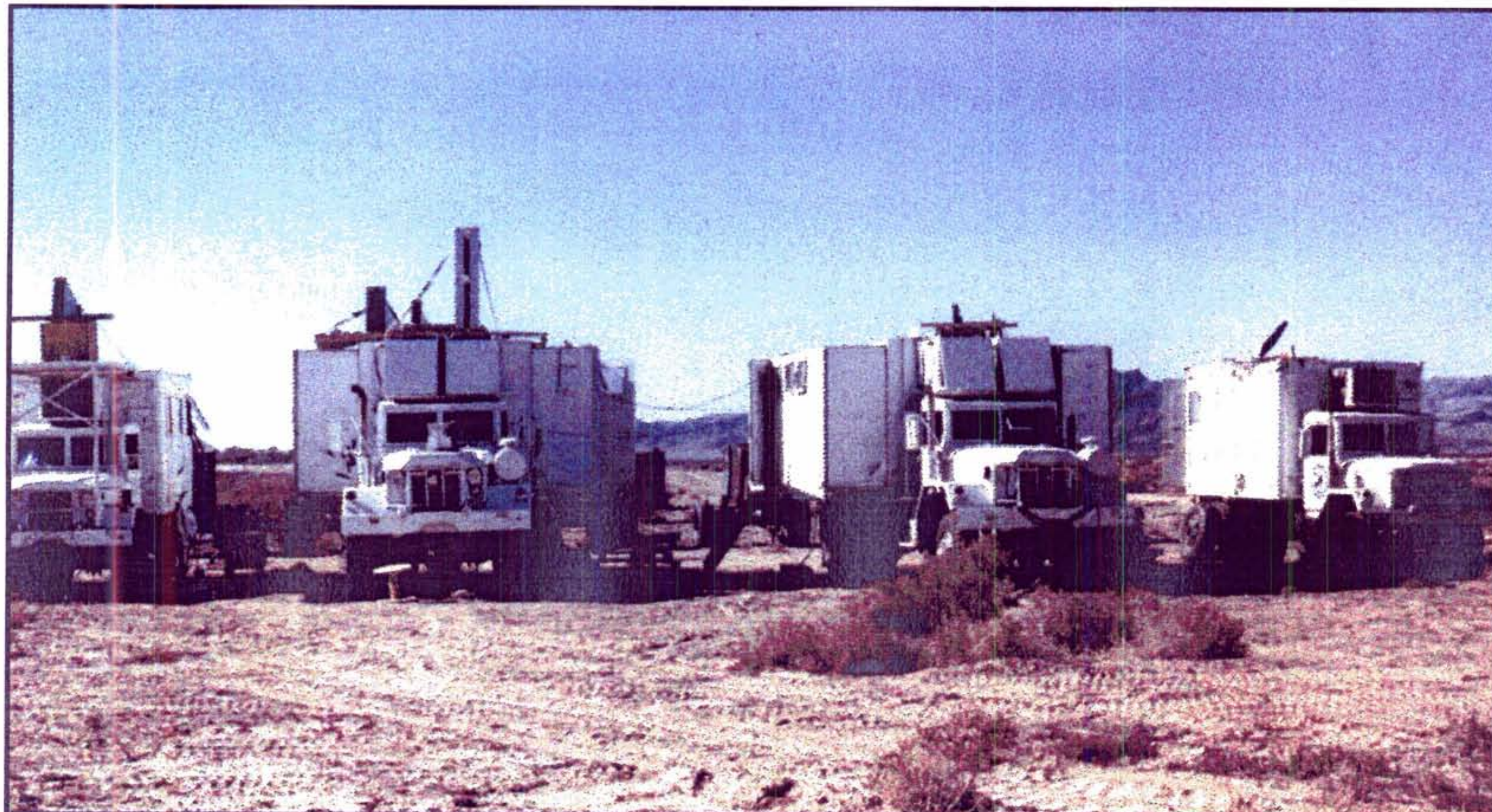
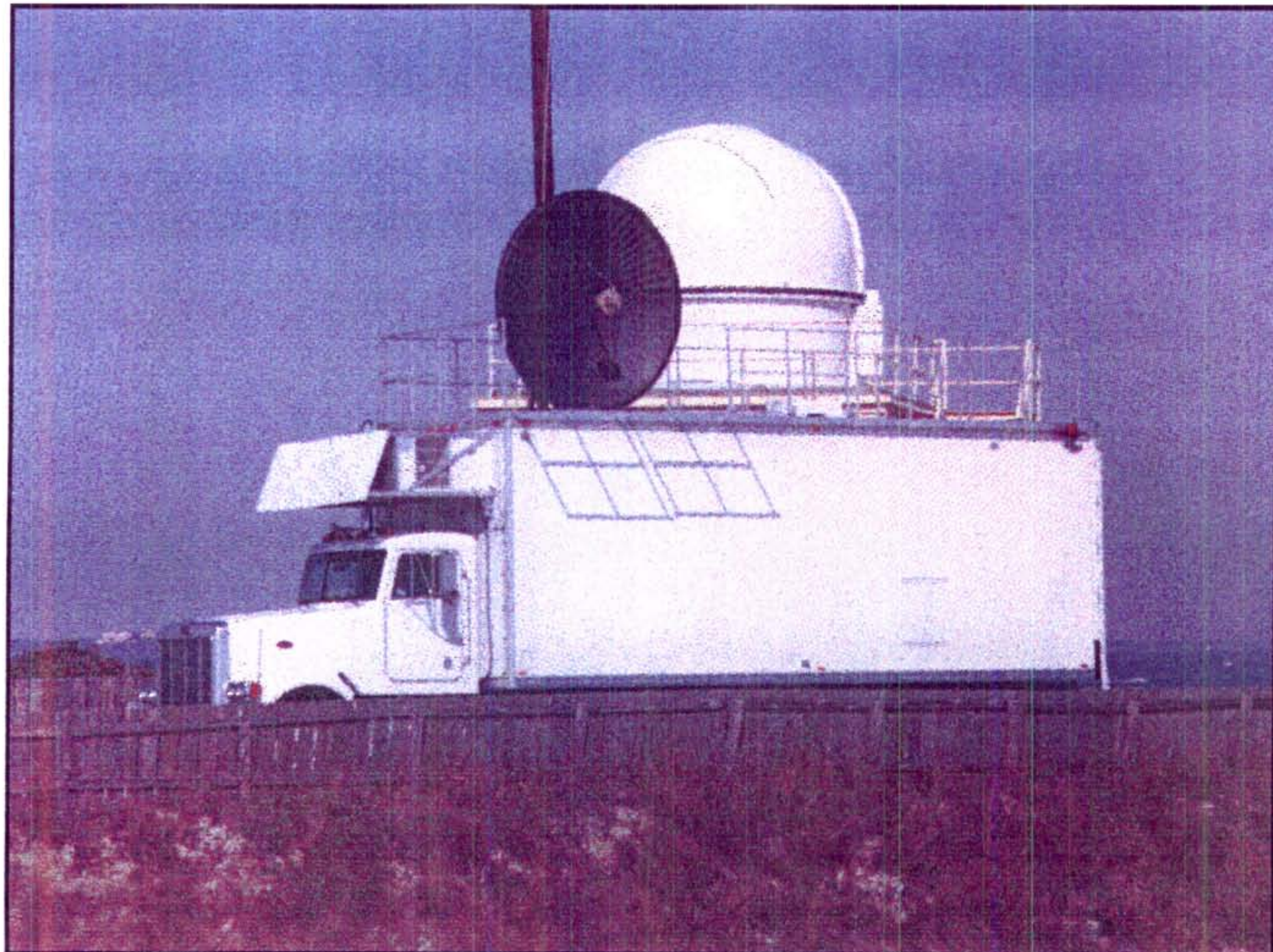
VHF Heliborne Jammer

D-Band Heliborne Jammer

Tactical Ground Platforms



Mobile Ground EW Laboratory



Active EW Capabilities

Big Crow Program Office

- Frequency Coverage
  - 5 MHz to 26.5 GHz
  - MMW (26.5 GHz to 95 GHz)
  - EO (Far IR to UV)
- Amplifier Output Power
  - 2 MHz to 18 GHz 1 KW
  - 18 GHz to 26.5 GHz 20 Watts
- Modulation
  - FM, AM, FM/AM
  - Repeater
  - DRFM
- ERP up to 1 Megawatt
- Multiband Simultaneously

System Emulation

- SPS(1)
- SPS-N(1)
- SPS-5
- SPS-N(2)
- SPS-6
- SPS-N(3)
- SPS-RN(1)
- SPS-RN(2)
- SPS-RN(3a)
- SPS-RW
- SPS-5N
- SPS-WB
- SPS-P(7)
- R-325U
- R-378A
- R-378B
- R-330A
- R-330B
- R-330P
- R-330U
- R-934
- R-325U5
- R-102-M2
- ROW-RN(1)
- ROW-RN(2)

Passive EW Capabilities

- RF Receivers
  - Superheterodyne (100 MHz to 50 GHz)
  - Spectrum Analyzers (5 MHz to 26.5 GHz)
- EO Sensors
  - UV (Solar Blind); Imaging radiometers
  - Visible: Silicon Vidicon and CCD Cameras
  - IR: Radiometers, Imaging Radiometers, Spectrometers, Hyperspectral Imaging Spectrometers
- Chaff
  - ALE-32
  - ALE-38
  - ALE-43

Available Antennas

Big Crow Program Office

Frequency	Beamwidth	Gain (dB)
2-30 MHz	Omni Directional	0
30-90 MHz	60°x60°	9
90-150 MHz	Omni Directional	-3
150-500 MHz	Omni Directional	-3
500-750 MHz	50°x45°	9
750-1000 Mhz	50°x10°	15.5
1-2 GHz	24°x28°	14.8
2-4 GHz	8.5°x10°	23.9
	3.5°x3.5°	31.5
4-8 GHz	5°x6.2°	28
8-18 GHz	2.4°x2.5°	35.4

Pylon Capability

- Location Inboard
- MAU-12 Bomb Rack
- Weight Handling 5000 lb.
- Available Power
  - 60 Hz
  - 3ϕ 400 Hz
  - 28 VDC
- Application
  - Captive Carry
  - ECM Pods
  - Chaff Dispensers

Data Collection Capabilities

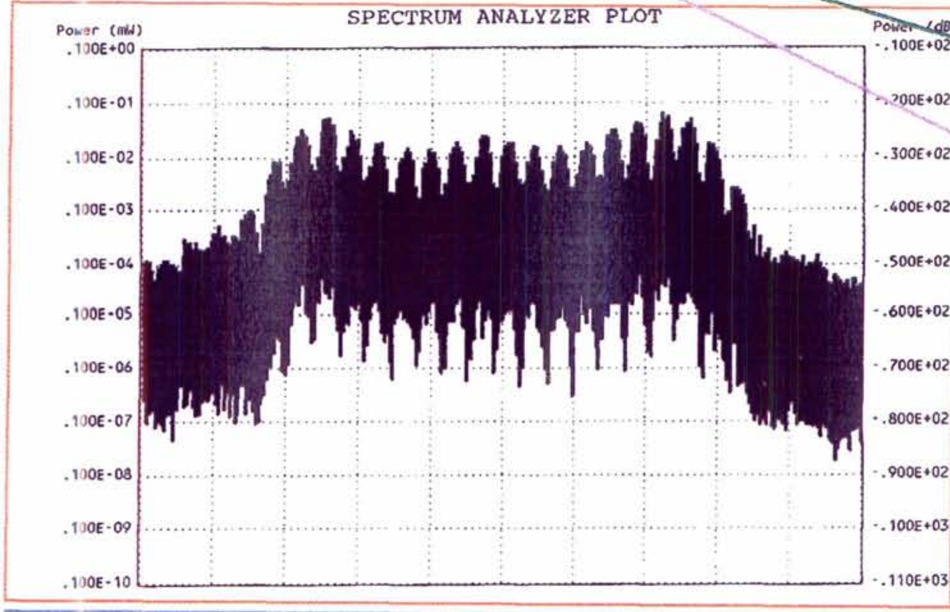
- Digital and Video Recording
- Near-Real-Time High-Resolution Image Processing and Data Compression
- Hard Copy of Digital Data
- Data Elements
  - Time (WWVB, GOES, Range, or GPS)
  - Inertial Navigation System (INS)
  - Frequency vs. Amplitude and Time
  - Power (ERP) vs. Time
  - Antenna Parametrics
  - Antenna Pedestal Parametrics
  - Operating EW Mode(s)
- Time Tagged Data Available Upon Landing

Sample Data Collection

Big Crow Program Office

Pedestal Parameters	
Azimuth (DDD:MM.M)......	268:46.1
Elevation (DDD:MM.M)....	359:44.1
Antenna Parameters	
Gain (dB)...............	26
Beamwidth (AZ) (DEG)....	14
Beamwidth (EL) (DEG)....	3
Aiming Criteria	
Aiming mode............	Target
Platform Position Source	INS
Target Position Source..	Keyboard 36:25.0 73:30.0 0

Positional/Attitude Data	
Altitude(FT).................	19736
Latitude (DDD:MM.M) (+N,-S)..	35:43.2
Longitude (DDD:MM.M) (+W,-E).	75:09.9
True Heading (DDD:MM.M)......	153:35.0
Magnetic Heading (DDD:MM.M)..	163:11.8
Roll (DDD:MM.M)..............	0:18.7
Pitch (DDD:MM.M).............	2:47.7
Ground Speed (Knots).........	360



Res BW	3.000	MHz	Cpld		Trace Display	C/W A;Blk B
Vid BW	3.000	MHz	Cpld		Display modes	Write A
Swp Tim	25.000	msec	Cpld		Trigger mode	Free run
Atten	10	dB	Cpld			
Ref lev	-10.000	dBm				
Log	10	dB/div				
Center	4.802	GHz				
Span	1.000	GHz				
Ref off	.000	dB				
CF step	100.000	MHz	Cpld			
Marker		Off				
Freq off	.000	Hz				
Swp mode		Cont				
Inp mix	-10	dBm				
Trace detection		Normal(KSa)				

Total ERP = 562.34 KiloWatts

Inertial Navigation Data

Antenna Parametrics

Targeting Parametrics

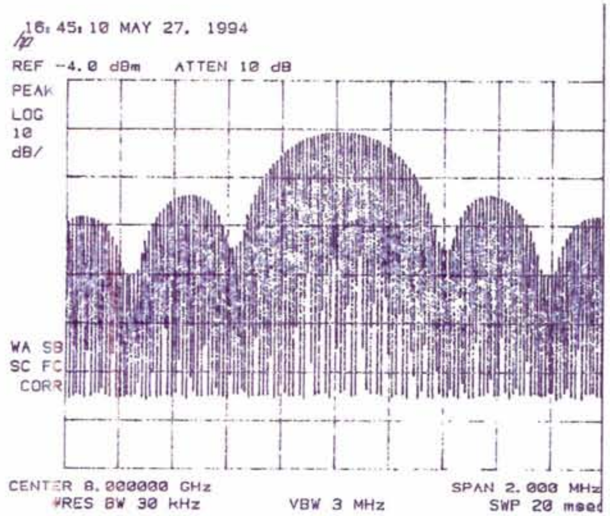
Frequency Spectrum

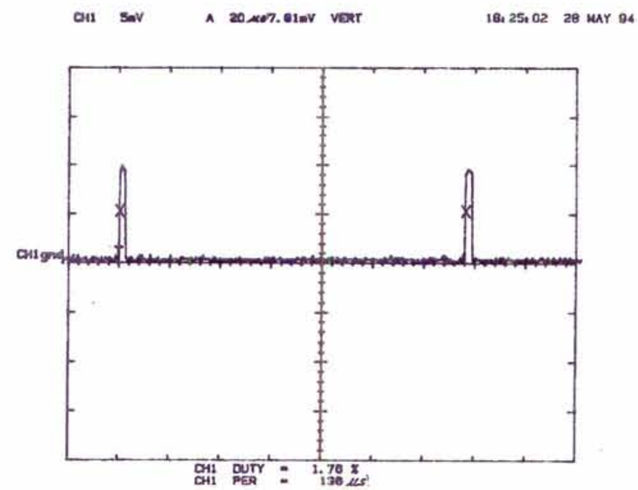
Spectrum Analyzer Setup Parameters

Transmitted Power

Sample Pulse Analysis

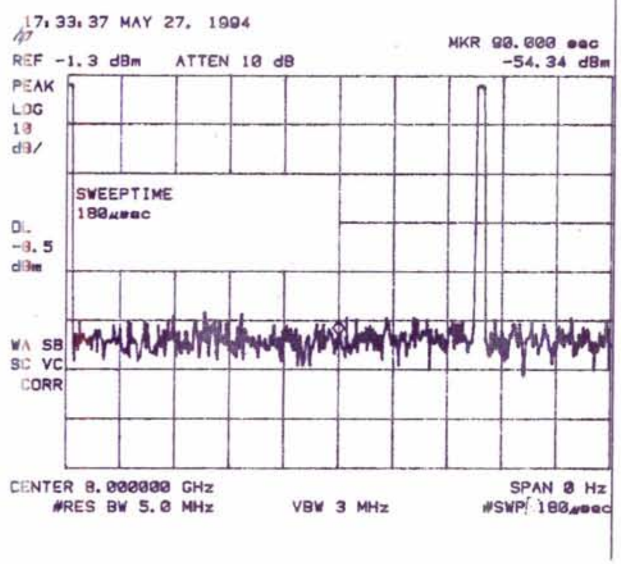
Big Crow Program Office

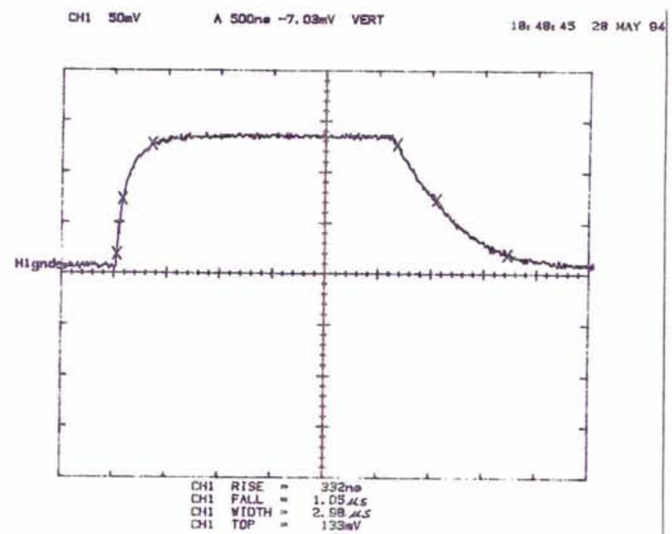




Frequency Domain

Time Domain



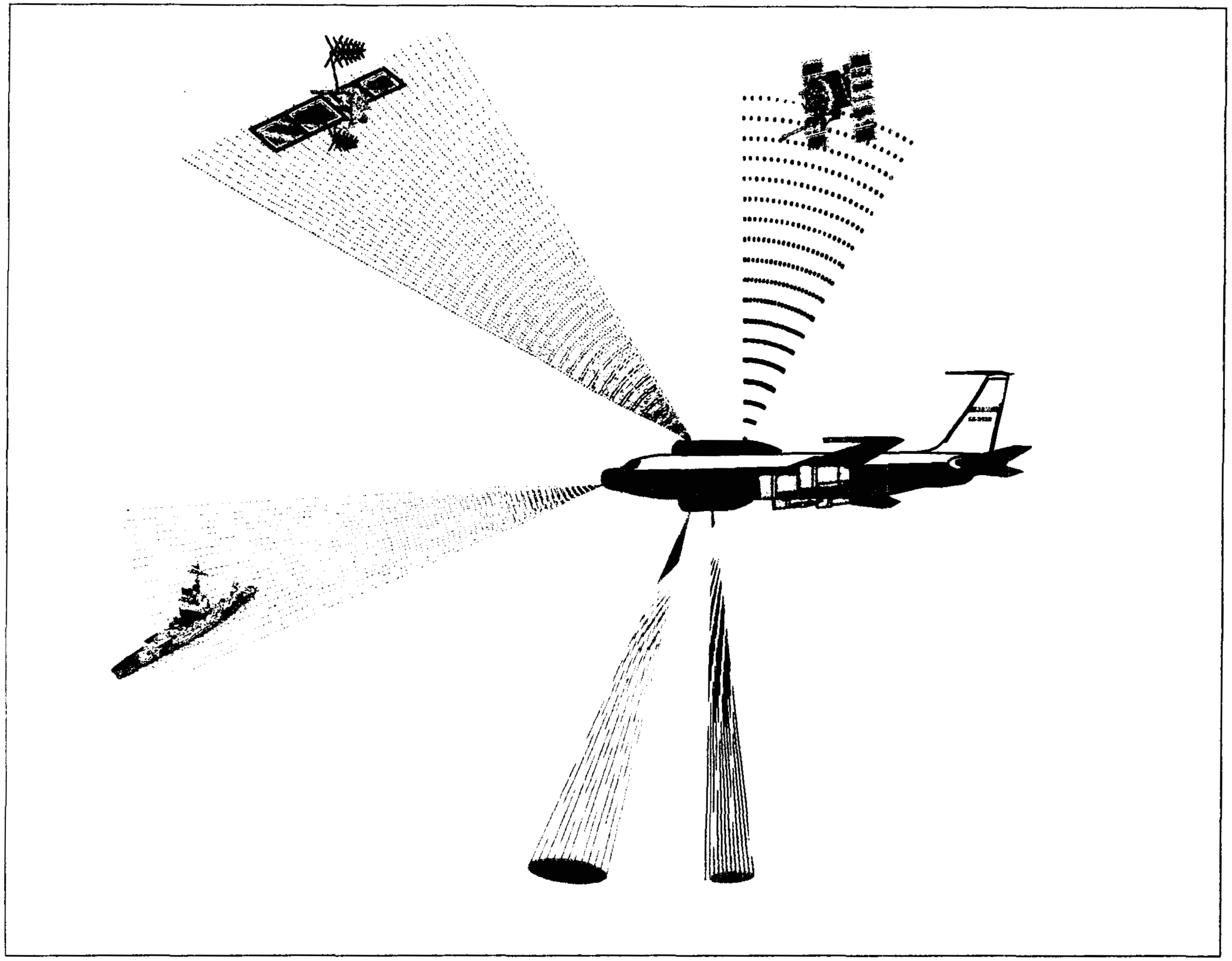


Pulse Analysis Parameters

Big Crow Program Office

- **Pulse Frequency**
- **Pulse Width (PW) (at mesial)**
- **Rise Time (proximal - distal)**
- **Fall Time (proximal - distal)**
- **Pulse Repetition Frequency (PRF)**
- **Pulse Repetition Interval (PRI)**
- **Duty Cycle**
- **Proximal Amplitude**
- **Mesial Amplitude**
- **Distal Amplitude**
- **Pulse Positive Peak Amplitude**
- **Pulse Negative Amplitude**
- **Top Amplitude**
- **Base Amplitude**
- **Overshoot**
- **Undershoot**
- **Peak-to-Peak**
- **Root-Mean-Square (RMS)**
- **Pulse Area**
- **Pulse Jitter**
- **Pulse Stagger**
- **Pulse Phase Coding**
- **Totalizer**
- **Chirp Characteristics**
- **Pulse Statistics**
  - **Mean**
  - **Std Deviation**
  - **Min**
  - **Max**
  - **Variance**
  - **Allan Var**
  - **RMS**
  - **Root AVAR**

Surgical EW Capabilities



Design & Development Capabilities

- Amplifiers
- Antennas
- Modulators
- Instrumentation Systems
- Aircraft Modifications (Internal & External)
- Steerable Antenna Pedestals & Controllers

Test Experience

Big Crow Program Office

Program Experience

Big Crow Program Office

- Pioneer in EWVA Methodology
- Unique U.S. National EW/EM Asset (No Known Counterpart)
- Key Element in U.S./Allied EW Infrastructure
- Extensive Blue/Gray/Red EW Database Management Expertise
- Laboratory, Systems Integration, Production Facilities
- More than $600 Million Capital Investment (excluding airborne platforms)
- Extensive Support to Over 100 Tri-Service and NATO Programs

Programs Supported

Big Crow Program Office

FY93	NKC-135E	G-II	Heliborne	Ground
AEGIS	√			
Amalgam Warrior	√			
Special Project (Black)				√
MSE/ATCCS			√	√
JTIDS	√			
FY94				
AEGIS	√			
FMS AEGIS (Japanese)	√			
CEC AEGIS	√			
ABLE-ACE		√		
AIRMS		√		
MSE/ATCCS			√	√
FAAD C3I			√	√
NORAD	√			
E-3A	√			√
JSTARS	√			
AMALGAM WARRIOR	√			
JTIDS			√	
Combat ID				√

Programs Supported

Big Crow Program Office

FY91	NKC-135E	Heliborne	Ground
Re-Engining	√		
Flight Test (lower radome)	√		
Periodic depot maintenance	√		
Power Distribution Modification on A/C	√		
Iceland Radar	√		
AEGIS (CG-64 & DDG-51)	√		
MSE		√	√
Sensor Fuzed Weapons			√
TAFIS (Demonstration)			√
OTH-B	√		
FY92			
AEGIS	√		
JTIDS	√		
MSE		√	√
Amalgam Chief	√		
Friendly Fire			√
IDL			√
JSTARS			√
Patriot	√		

Programs Supported

FY89	NKC-135E	Heliborne	Ground
Global Positioning System	√	√	√
Navy AEGIS	√		
Patriot Radar	√		
NORAD	√		
Patriot Communications		√	
Forward Area Air Defense System		√	
Have Nap			√
High Risk Reduction	√		
OTH-B	√		
Advanced Tactical Missle System	√		
FY90			
Global Positioning System		√	
Navy AEGIS	√		
Patriot Radar	√		
Sensor Fuze Weapon System			√
High Power Technical Risk Reduction	√		
NORAD	√		
Fire Finder			√
OTH-B	√		
E-3A			
Patriot Communications			√
Joint Tactical Information Distribution System	√		
TPS-73	√		
SINCGARS		√	

Point of Contact

Big Crow Program Office

Milton D. Boutte
Program Manager

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3710 Trestle Rd
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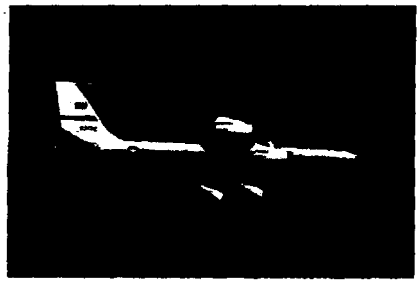
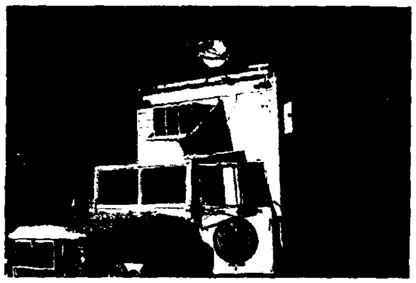
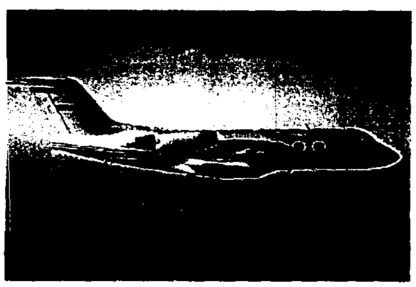
Document Separator

Big Crow Program Office







The Big Crow program, which possesses the world's premier electronic warfare assessment assets, is now available to users for EW training. Big Crow, based at Kirtland Air Force Base, New Mexico, has a projection capability to any operational theater. Big Crow represents a unique collection of EW capabilities, the cornerstone of which is the program's highly modified NKC-135E aircraft. The program also features platforms such as ground-based vans, CH-47D EW helicopters, and a Gulfstream G-II. Each platform has extensive electronic mission equipment, including both comprehensive internal ESM/ECM systems and external pylon-mounted pods (ALQ-167).

The Big Crow Program Office has applied its 25 years of EW assessment expertise to developing an intensive EW training program that offers users the opportunity to strengthen the effectiveness of their existing EW resources. Big Crow personnel have the knowledge, skills, and abilities to aid customers in planning and executing comprehensive, multi-disciplined, and results-oriented EW training unavailable from any other source. The program is designed to accommodate all levels of EW proficiency from an orientation in basic fundamentals of EW to advanced ECCM techniques training.

The EW suites maintained by Big Crow enable the user to emulate every known EW threat environment with a degree of sophistication unmatched by any other training resource. By use of proven research techniques, applied to a training environment, Big Crow provides autonomous calibrated instrumentation and real-time analytical capabilities to customers. Big Crow provides users with a time and event correlated report (hard copy of magnetic media) at the completion of the mission.

The flexibility of Big Crow is enhanced through an innovative engineering approach to the mission equipment suites. All equipment suites are rapidly reconfigurable from one platform to another. Big Crow can simultaneously deploy sufficient electronic capabilities to provide EW training to large, widely dispersed formations (e.g., naval task forces, EW training ranges, and associated supporting aircraft). In exercises where EW is to be selectively applied, Big Crow can provide secure communications, and command and control to ensure the integrity of the friendly exercise forces while meeting original training objectives. Big Crow is experienced in successfully coordinating ECM frequency clearances in dense signal environments through specially developed techniques embedded within its software.

Big Crow generates various modulation schemes, including barrage noise, spot noise, continuous-wave and deception signals. It can attack all modern modulated radar with essentially any electronic warfare technique requested by the user (e.g., communications jamming, stand-off/escort self-screening/ chaff clouds/radar/data link jamming, and a full range of electronic support measures). Also it can carry aloft entire missile systems or subsystems.

The normal 8-hour mission duration for the NKC-135E aircraft is extendible to 14 hours on station through an in-flight refueling capability. For cost and availability information, U.S. users should contact the Big Crow Program Manager directly.

For additional information, contact:
Big Crow Program Office
attention: Mr. Milton D. Boutte
3710 Trestle Rd., Bldg 20797
Kirtland AFB, NM 87117-5000
DSN: 246-8494 COM: (505) 846-8494 Fax: (505) 846-0345

Big Crow Program Office

Overview

The Big Crow Program Office, based at Kirtland Air Force Base, New Mexico, possesses a unique collection of EW capabilities, the cornerstone of which is the programs highly modified NKC-135E aircraft. The program also features platforms such as ground-based vans/trucks, CH-47D Electronic Warfare (EW) helicopters and a Gulfstream G-II.

The Big Crow Program Office has applied its 25 years of EW assessment expertise to developing an intensive EW training program that offers users the opportunity to strengthen the effectiveness of their existing EW resources. Big Crow personnel have the knowledge, skills and abilities to aid customers in planning and executing comprehensive, multi-disciplined and results-oriented EW training unavailable from any other source. The program is designed to accommodate all levels of EW proficiency from an orientation in basic fundamentals of EW to advanced electronic-counter-counter-measures (ECCM) techniques training.

The EW suites maintained by Big Crow enable the user to emulate every known EW threat environment with a degree of sophistication unmatched by any other test or training resource. By use of proven research techniques, applied to a test and training environment, Big Crow provides autonomous calibrated instrumentation and real-time analytical capabilities to customers. Big Crow provides users with a time and event correlated data collection and reporting at the completion of the mission.

The flexibility of Big Crow is enhanced though an innovative engineering approach to the mission equipment suites. All equipment suites are rapidly reconfigureable from one platform to another. Big Crow can simultaneously deploy sufficient electronic assets/capabilities to provide EW test and training to large, widely dispersed formations (e.g., naval task forces, EW training ranges and associated supporting aircraft). Big Crow is experienced is successfully coordinating ECM frequency clearances in dense signal environments, utilizing specially developed filtering techniques embedded within Big Crows systems.

Big Crow generates various modulation schemes, including barrage noise, spot noise, continuous-wave and deception signals. Big Crow can attack all modern modulated radars, communication links and data links with essentially any EW technique requested by the customer as well as provide comprehensive data collection.

Big Crow is fully mission-capable to support EA/ES C2W and EO missions for all Services, the CINC's, Joint Services, DOD agencies, NORAD and NATO countries.

For Additional Information contact Big Crow Program Office, Mr. Milton D. Boutte at: Com (505) 846-8498, DSN 246-8498.

The Big Crow Program Office assets can be divided into the following categories:

1) NKC-135E Airborne Electronic Laboratory
2) Gulfstream II Airborne Electro-Optical Laboratory
3) Helicopters (CH-47D/Ft Rucker/Ft Hood/National Guard Units)
4) Mobile Electronic Ground Platforms
5) Instrumentation
6) Scientific and Technology Development Capabilities
7) Antennas
8) Receivers
9) Transmitters

The following sections discuss the salient aspects for each of the asset categories. These discussions are followed by a concluding section that provides additional information regarding the BCPO.

1) NKC-135E:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/ELINT/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides a realistic red and blue threat environment (single, multiple or simultaneous) anywhere in the world. Big Crow can cut and dispense all bands of chaff and accept specialized pods on its wing mounts.

Functional Description:

NKC-135E: The Big Crow NKC-135E is a tri-Service airborne research and development laboratory most noted for EW design and development, testing, evaluation and training. Onboard instrumentation suites consist of rack-mountable systems that are generic to all of the Big Crow platforms. These systems are palletized to enable quick reconfiguration of the platform when required. The modified NKC-135E aircraft, equipped with in-flight refueling, is capable of autonomous E^3 experimentation that with the characteristics of a flying "experimental" laboratory; flight durations are up to 15 hours. Also, complete data packages are available upon landing for analysis and verification of test parameters and procedures.

Characteristics:	Emulator/Trainer
Max Altitude:	42,000 ft
Min Altitude:	500 ft
Range:	15 hrs/12,000 miles (in-fight refueling) 6 hrs/2,500 miles (w/o refueling)
Max Speed:	.85 mach
Min Speed:	300 kts
Max Conserve:	350 kts
Runway length:	8,000 ft
ECCM Features:	DRFM

The following table is a partial list of threats which are capable of being emulated or simulated by the Big Crow aircraft.

ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEMS*	*ELNOT*	*FREQUENCY*
SPS(1)	--	--	None	30-500 Mhz
SPS-N(1)	--	--	None	30-500 MHz
SPS-5	FENCER	--	None	30-500 MHz
SPS-N(2)	FIGHTER (URS)	--	None	30-500 MHz
SPS-6	--	--	None	30-500 MHz
SPS-N(3)	FIGHTER (URS)	--	None	30-500 MHz
RJS-3140	FIGHTER (URS)	--	None	30-300 MHz
SPS-5N	--	--	None	100-500 MHz
	BASILISK (MIRAGE)	--	None	1-12 GHz
	CAIMAN (MIRAGE)	--	None	1-4 GHz
ELT-458	--	--	None	1-4 GHz
RJS-3100	--	--	None	8-12 GHz
SPS-141	FIGHTER (URS)	--	None	1-4 GHz
SPS-142	FOXBAT/FENCER	--	None	1-4 GHz
SPS-143	FOXBAT/FENCER	--	None	1-4 GHz
SPS-161	FOXBAT/FENCER	--	None	1-4 GHz
SPS-162	FOXBAT/FENCER	--	None	1-4 GHz
SPS-H(7/7x)	FOXBAT	--	None	8-12 GHz
SPS-SN	FENCER	--	None	1-4 GHz
SPS-WB(2-7)	FIGHTER (URS)	--	None	1-4 GHz

2) Gulfstream II:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/EO-IR/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides a realistic red and blue threat
environment (single, multiple or simultaneous) anywhere in the world. The G-II is capable of transporting the same EA/ES instrumentation that is used on NKC-135E and can accept specialized pods on its wing mounts. The Gulfstream II also provides an excellent platform for EO experimentation.

Functional Description:

Gulfstream II: Big Crow's Gulfstream II is also a tri-Service airborne research and development electronic laboratory. This platform also performs E^3 experimentation and is particularly suitable for EO experimentation and detection.

Characteristics:	Emulator/Trainer
Max Altitude:	50,000 ft
Min Altitude:	200 ft
Range:	6 hrs/2,500 miles
Max Speed:	.85 Mach
Stall Speed:	108 kts
Max Conserve:	.75 Mach
ECCM Features:	DRFM

The following table provides a partial list of threats which can be emulated or intercepted by the Big Crow G-II aircraft.

ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEMS*	*ELNOT*	*FREQUENCY*
SPS(1)	--	--	None	30-500 Mhz
SPS-N(1)	--	--	None	30-500 MHz
SPS-5	FENCER	--	None	30-500 MHz
SPS-N(2)	FIGHTER (URS)	--	None	30-500 MHz
SPS-6	--	--	None	30-500 MHz
SPS-N(3)	FIGHTER (URS)	--	None	30-500 MHz
RJS-3140	FIGHTER (URS)	--	None	30-300 MHz
SPS-5N	--	--	None	100-500 MHz
	BASILISK (MIRAGE)	--	None	1-12 GHz
	CAIMAN (MIRAGE)	--	None	1-4 GHz
ELT-458	--	--	None	1-4 GHz
RJS-3100	--	--	None	8-12 GHz
SPS-141	FIGHTER (URS)	--	None	1-4 GHz
SPS-142	FOXBAT/FENCER	--	None	1-4 GHz
SPS-143	FOXBAT/FENCER	--	None	1-4 GHz
SPS-161	FOXBAT/FENCER	--	None	1-4 GHz
SPS-162	FOXBAT/FENCER	--	None	1-4 GHz
SPS-H(7/7x)	FOXBAT	--	None	8-12 GHz
SPS-SN	FENCER	--	None	1-4 GHz
SPS-WB(2-7)	FIGHTER (URS)	--	None	1-4 GHz

3) CH-47D Helicopter:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides realistic red and blue threat environment (single, multiple or simultaneous) anywhere in the world. The CH-47D with palletized EW suite can simulate any Soviet or third world country heliborne EW threat and is fully capable of carrying any of Big Crow EA or ES capabilities.

Functional Description:

Helicopters: CH-47D helicopters are available upon demand and are obtained from either the WagonMasters at Ft Hood or "F" Company at Ft Rucker or National Guard Units. Big Crow Program Office can configure these platforms with most of the same EW equipment that the other airborne platforms accommodate.

Characteristics:	Simulator/Trainer
Max Altitude:	20,000 ft
Min Altitude:	50 ft
Range:	3 hrs/300 miles
Max Speed:	170 kts
Min Speed:	70 kts
Max Conserve:	130 kts
ECCM Features:	N/A

The following table provides a partial list of threats which are capable of being emulated or intercepted by the Big Crow helicopter platforms.

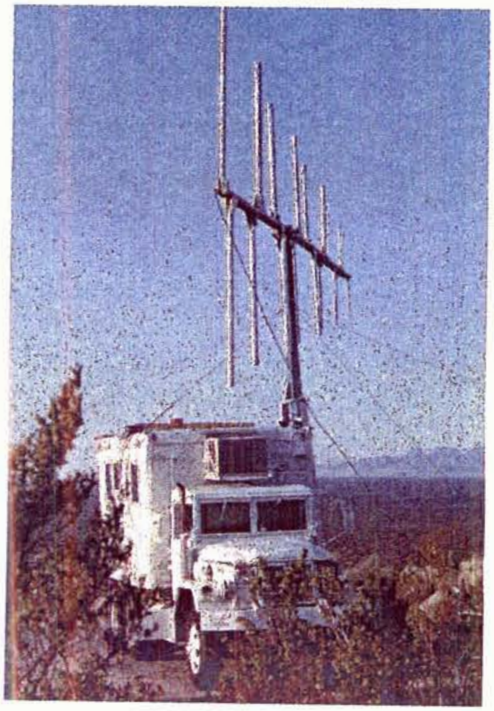
ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEMS*	*ELNOT*	*FREQUENCY*
SPS-RN(1)	HIP	None	None	30-300 MHz
SPS-RN(2)	HIP			8-12 GHz
SPS-RN(3a)	HIP			8-12 GHz
SPS-RN(3b)	HIP			8-12 GHz
SPS-RN(5)				
SPS-RN(6)				
SPS-RW	HIP J/K	None	None	1-4 Ghz
SPS-WB	HIP			8-12 GHz
SPS-P(7)	HIP J			8-12 GHz
ROW-RN(1)	HIP			30-300 MHz
ROW-RN(2)	HIP			100-500 MHz
ROW-RN(3)	HIP			8-12 Ghz
SPS-N(2)				8-12 GHz
SPS-N(3)				8-12 GHz
SPS-P(7)	HIP J	None	None	8-12 GHz

4) Ground Platforms:

Agency: Army/TECOM/BCPO
Category: Emulator/SIGNET/Trainer
Classification: Unclassified, Classified upon request
Type: Emitter/Receiver/Processor
Mobility: Mobile
Date as of: 6/94
Current Validation: Accreditation accomplished on a per mission basis
IOC Date: N/A
Operational Status: Fully Operational
Threats Simulated: Provides a realistic ground-level red and blue threat environment (single, multiple or simultaneous)

Functional Description:

Ground Vans: The Big Crow ground vans are configured to accept all of the same palletized systems that the airborne laboratories utilize to provide stationary EA emulators. Each van contains its own power generation capability which enables them to operate in remote areas.

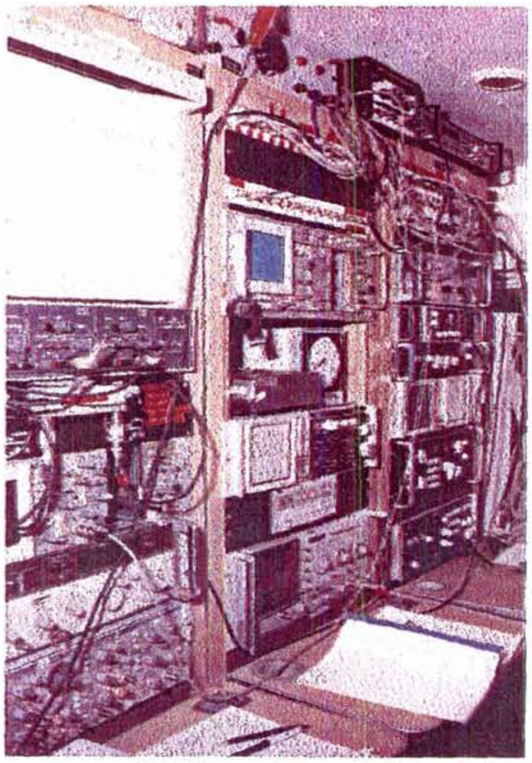


Characteristics:	Emulator/Trainer
Power Requirements:	400 Hz 3 Phase 60 Hz single Phase
Power Source:	Self-contained generators or shore power
Communication:	HF/VHF/UHF or cellular phone
Fuel requirements:	Diesel or Mo-Gas
ECCM Features:	N/A

The following table is a partial list of threats that can be emulated or intercepted by the Big Crow ground-based platforms.

ELINT NOTATION	*NATO PLATFORM*	*WEAPON SYSTEM*	*ELNOT*	*FREQUENCY*
R-325U		None	None	30-300 MHz
R-378A				30-300 MHz
R-378B				30-300 MHz
R-330A	SILVER TRAY			30-300 MHz
R-330B				30-300 MHz
R-330P	PIRAMIDA			30-300 MHz
R-330U	COPPER WHEEL			100-500 MHz
R-934				100-500 MHz
R-325U5				3-100 MHz
R-102-M2				8-12 GHz
	CHEESE BRICK			8-12 Ghz
	HEART ACHE (A/B)			8-12 GHz
	JACK KNIFE			8-12 GHz
	KING PIN			8-12 GHz
	KING PIN (B)			8-12 GHz
	PAINT BOX			8-12 Ghz
R-118-8M3				8-12 GHz
RP-379(D)				
C343A	SIDE GLOBE			1-2 GHz
	HUNGARIAN VHF			30-300 MHz
	HUNGARIAN UHF			100-500 MHz
EUK-7010				
TACJS				30-300 MHz
TRC-285				100-500 MHz

5) Instrumentation



The Big Crow Program Office has designed its assets in a fashion that provides its customers with timely R&D and operational support in a cost-effective manner. Thru generacism in design, Big Crow EW suites are easily accreditable on a test-by-test basis. Generacism in design also allows efficient modification to Big Crow EW suites to meet both current and future EW threat requirements. The instrumentation is rack-mounted and the platforms utilize track mounting to provide rapid equipment/system configuration/de-configuration. Also, custom-tailored data collection is available post-mission for immediate verification of test parameters and procedures. Both airborne assets contain inertial navigation systems (INS) and all Big Crow platforms contain global positioning systems (GPS).

In addition to the NKC-135E dynamic flight profile characteristics and capabilities, its instrumentation, data recording and analysis capabilities provide for a wide range of field experiments that have led to many upgrades to major systems which has enhance their battlefield survivability. This unique capability can be transferred from the NKC-135 to the G-II, CH-47D or any of a wide array of instrumentation vans.

The Big Crow Program Office employs a number of Data General, Sun Sparc stations, Hewlett-Packard and customized PC-based computer systems for controller/data collection depending on the platform used and mission requirements. Test data can be stored in a variety of formats such as 9-track tape or Bernoulli disk. Examples of the instrumentation data that can be recorded digitally are listed below:

Transmitter and Receive Waveform Characteristics:

- Power Level
- Power Spectral Density
- Center Frequency
- Bandwidth
- Sidelobe Levels
- Blink Rates

Temporal Waveforms Characteristics:

- Pulse Widths
- Rise/Fall Times
- PRI

Receivers:

- Center Frequency

Timing:

- WWVB
- GPS
- Range Control
- GOES

Antennas Characteristics:

- Pedestal Pointing Angles (antenna orientation)
- Gain
- Beamwidth (azimuth & elevation)

Aircraft Parameters:

- Latitude
- Longitude
- Altitude
- Roll
- Pitch
- Yaw

Each set of data is time tagged using GPS and/or WWVB time standard as it is collected to allow easy correlation of data during quick-look or post-test analyses.

In addition to the real-time displays, associated with the various test equipment (e.g. spectrum analyzers, oscilloscopes etc.) a real-time onboard display system (RODS) provides a current situation map indicating the aircraft position, the position of fixed ground based elements and the orientation of the various airborne antenna beams. All the test data can be plotted or printed to meet most customer requirements. The Big Crow Program Office has existing software capable of printing or plotting data from all transmitting, receiving and data collection equipment in the inventory. Special software can be generated if the customer requires special data reduction.

6) Scientific and Technology Development:

The Big Crow Program Office has designed its civilian and military assets along with its contractor base in a fashion that provides its customers with timely R&D, experimentation and operational support in a cost-effective manner. The technical and professional relationship between these various branches are extremely versatile and flexible in their knowledge of engineering and test operations. The Big Crow Program Office utilizes generic off-the-shelf equipment to provide specialized support. All of Big Crow Program Office equipment has been designed to be transferable between the various platforms that are carried in the Big Crow Program Office inventory, making this a very flexible operation.

One of the biggest assets of the BCPO is the ability to rapidly design and develop one-of-a-kind systems as required. Specifically, the Big Crow organization has an "in-house" capability to design and manufacture special purpose modulators, signal generators and antennas.

7) Antennas:

The Big Crow Program Office has a large number of antennas available, for fixed and steerable antenna pedestal mounting, providing a complete 360 degree field of view (FOV) frequency coverage (2 MHz to 50 GHz) for a variety of polarization and gain specifications. Antennas can be mounted in the nose, top and belly radomes as well as an aft- looking radome. Antennas can also be mounted on the wingtips and tailboom.

Antenna Configuration: Multiple
Antenna Type: Dish, Parabolic,HF Long Wire, Horn, Blades Helix, Log Periodic, Trailing
Wires, Spirals, Aperture Arrays

Antenna Size: Up to 58" in diameter for airborne antennas; various horns and horn array sizes available. No antenna size limitation for use in ground platforms.

The following is a partial list of antenna capability for the current inventory of antennas.

Frequency	*Antenna Beamwidth*	*Gain (db)*
2-30 MHz	Omni Directional	0
30-90 MHz	60° X 60°	9
90-150 MHz	Omni Directional	0
150-500 MHz	Omni Directional	0
500-750 MHz	50° X 45°	9
750-1000 MHz	50° X 10°	15.5
1-2 GHz	24° X 28°	14.8
2-4 GHz	8.5° X 10°	23.9
	3.5° X 3.5°	31.5
4-8 GHz	5° X 6.2°	28
8-18 GHz	2.4° X 2.5°	35.4
18-26.5 GHz	34° X 23°	16
26.5 GHz-50 GHz	Various	Various
All Frequencies	Custom	Custom

Note: The Big Crow Program Office has an enormous inventory of antennas along with the capability to design and manufacture custom antennas. In addition, the Big Crow Program Office has access to additional resources for frequency bands lying outside this range.

Gain Mainlobe:	Available upon request
Gain Sidelobe:	Available upon request
Beamwidth:	Available upon request
Polarization:	Vertical & Horizontal Linear, Left & Right Circular
Scan Type:	None
Scan Rate:	N/A

8) Receivers:

The receiving capabilities of the Big Crow Program Office are extensive, comprising state-of-art equipment in swept and non-swept receiver techniques. Currently, the Big Crow Program Office inventory contains a variety of receiving equipment that can operate over the frequency range of 2 MHz to 50 GHz. Attainable IF bandwidths are selectable, depending upon the particular receiver and specific center frequency. Please contact the Big Crow Program Office listed at the end of this document for further information.

The WJ 1740, commonly used by the Big Crow Team is an example of intercept/analysis equipment. It is a parallel-scanned, digital controlled superheterodyne receiving system which includes two tuners covering the frequency band 0.1 - 18 GHz. Expansion to 50 GHz is possible with additional tuners This equipment provides the capability of rapid signal detection and isolation into an analysis channel. The receiver then continues to perform its spectrum surveillance capability simultaneously with the analysis function of the isolated signal.

9) Transmitter Capabilities:

The transmitter/modulation capabilities of the Big Crow Program Office are extensive comprising state-of-art capability. This is a highly flexible system that can simulate both denial and deceptive EA environments over the frequencies from 2 MHz to 26.5 GHz.

The Big Crow organization has a wide variety of modulators, waveform generators and power amplifiers is its inventory. Various combinations of this equipment enables the emulation of an extremely broad number of EW threat waveforms. In addition to the emulation of well-defined threat waveforms, Big Crow is frequently involved in the generation of more specialized waveforms for use in EW testing and development.

Big Crow has a host of commercial waveform generators and synthesizers available covering the frequency range from .2 MHz to 26.5 GHz. In addition, Big Crow has developed several unique waveform generators. To provide a better understanding of these Big Crow capabilities, two examples will not be briefly described.

Generic Threat Simulator: Big Crow utilizes a generic threat emulator system. The generic threat emulator is a highly flexible and powerful system which can simulate, deny and deploy a deceptive EA environments. The system produces radio frequency (RF) signals in the frequency range and power levels needed to simulate threats and domestic EA systems. Signal sources are selected from within the 2 MHz to 26.5 GHz range to cover the frequency of interest. Techniques such as spot noise, swept spot, barrage noise and click repeater (DRFM) are but a few of the modulation techniques available as listed below. All parameters and functions are digitally controlled (with a manual override) for rapid generation of threat sets. A partial list of the available modulation types are listed:

Type	*Description*
FM	CLICK
FM	Wideband sinewave
FM	Wideband sawtooth
FM	Wideband triangle
FM/FM	Wideband sinewave/sinewave/sawtooth or triangle
FM/FM	Wideband sawtooth/sawtooth, sinewave or triangle
FM/FM	Wideband triangle/triangle, sinewave or sawtooth
FM	Gaussian Noise
FM	Swept CW
AM	Square wave
AM	Sine wave
AM	Gaussian AM Noise
AM/FM	Sinewave wobulation of a sinewave or squarewave or asymmetry pulse
AM/FM	Sawtooth wobulation of a sinewave or squarewave or asymmetry pulse wobulation of a sinewave or squarewave or asymmetry pulse.
AM/FM	Triangle wobulation of a sinewave or squarewave or symmetry pulse
AM	Blinking Generator

Special One-of-a-Kind: A special (one-of-a-kind) EA environmental test transmitter (ECMETT) designed for assessment of the U.S. Army Patriot missile system is available for expanded usage. Three classes of jamming signals are generated: Barrage noise jamming, transponder and straight through coherent repeater. Depending upon the operator-selected mode of operation, the receiver section affects the system operation in three different ways. In the transponder modes, the output of the receiver triggers the EA signal transmissions for which internal RF carrier sources are utilized; in the repeater modes, the receiver performs as the front end of the repeater-modulation configuration; finally, in the manually actuated modes the receiver is a passive indicator of the signals which represent in the band of interest. A multi-frequency determining unit (FDU) and an automatic signal recognition unit (ASRU) are included as part of the receiver section. These signal-sorting units identify the class of signal being received, display the information on the control panel and program EA response in transponder modes of operation. The modulation source section contains several sawtooth generators, a sinewave generator, Gaussian noise generator and a pseudo-random noise generator. In the repeater modes of operation there is a linear phase shifter, a frequency shifter and an inverse gain function. The resulting waveforms are combined in various configurations to yield a total of 33 modes of operation.

The below listed power amplifier are in Big Crow Program Office current inventory and have been used as threat representative against U.S. systems.

- ALT-28's: ALT-28 power amplifiers are available to meet customer barrage requirements in the frequency bands C,D,E,F,H & I.
- ALT-40's: ALT-40 power amplifiers are available to meet customer barrage requirements in the frequency bands C,D,E & F.
- Commercial power amplifiers: All the low-level modulators can be combined with power amplifiers to provide a high power EW environment. A list of power amplifiers is shown as follows:

Frequency	*100 Watts*	*250 Watts*	*1 KW*	*2 KW*	*3 KW*
1 to 220 MHz					X
2 to 32 MHz				X	
30 to 150 MHz				X	
0.1 to 0.5 GHz			X		
0.7 to 1 GHz				X	
0.8 to 2.2 GHz			X		
1.0 to 2.0 GHz					X
2.0 to 4.0 GHz		X			
4.0 to 8.0 GHz		X			
8.0 to 10 GHz	X				
10 to 18 GHz	X				

Note: These power amplifiers are capable of being deployed in either the NKC-135E, G-II, CH-47 or any of the ground test vehicles and have successfully tested against the following US systems:

- JTIDS Data Link
- AEGIS Radar/Data Link
- SINCGARS Communication System
- NORAD Ground and Air Search Radars
- MSE Communication Network
- HAWK Self-Defense Missile System
- Patriot Radar

REMARKS: The Big Crow is a versatile EW research and development airborne platform in the Department of Defense inventory. Big Crow is capable of autonomous EW experimentation that gives it the characteristics of a flying experimental EW laboratory capable of responding in a timely and cost efficient manner. It has the flexibility to accommodate a wide range of standard and developmental hardware and systems with short lead times at any customer location. Big Crows electronic suites were designed to be interchangeable between the aircraft, helicopter-based and ground-based platforms, with prime consideration for commonality of software, computer interfaces equipment racks, power and transmission lines. Thus, Big Crow Program Office can provide any EW environment with intercept, data recording/reduction and training.

10) Additional Information:

MOBILITY: Big Crow can stage from facilities capable of accommodating NKC-135 aircraft. With inflight refueling tanker support Big Crow can provide extended flight support throughout the world.

LOCATION/QUANTITY

LOCATION:	Kirtland AFB, USA TECOM
QUANTITY:	1 NKC-135E
	1 Gulfstream II
	10 Test/Instrumentation Vans
	6 CH-47D Helicopter
OFFICE:	U.S. Army Big Crow Program Office
CITY:	Kirtland AFB, NM
POC ROLE:	Program Manager (PM)
POC NAME:	Mr. Milton Boutte
COMMERCIAL PHONE:	(505)846-8494/8498
DSN PHONE:	246-8494/8498
ALTERNATE PHONE:	505 846-8498
FAX PHONE NUMBER:	505 846-0345
OFFICE:	U.S. Army Big Crow Program Office
CITY:	Kirtland AFB, NM 87117-5000

COMMENTS: The Big Crow Program Office, often referred to as a "National Asset" consists of dedicated, highly experienced engineers and is supported by a superior technical staff with a 20-year track record of success in EW test, experimentation and training in all of DOD. The Big Crow program has pioneered the model for today's military testing organization -- capable and experienced in serving in a variety of testing and training roles, producing technically excellent results, on ***time*** and within ***budget***.

Document Separator

KIRTLAND AFB UPDATE--8 MAY 1995
Thoughts From the Kirtland AFB Steering Committee

SITUATION:
The original USAF proposal to realign KAFB was to send most tenant organizations to other installations, and to canton at KAFB the Phillips Lab, the Kirtland Underground Munitions Storage and the 150th Fighter Group. To execute this proposal, the USAF estimated a one-time cost of $277 million with recurring savings of $62 million. At the 20 April Regional Hearing, the Steering Committee demonstrated the USAF plan has a one-time cost of $525 million with a recurring cost to the taxpayer of $12.7 million, and presented operational impacts not considered by the USAF.

On 3 May, the USAF released new cost estimates that show their proposed realignment has a one-time cost of $608 million with at recurring annual savings of $2 million when Department of Energy costs are considered. Operational impacts presented on 20 April were not addressed by the USAF.

Recognizing their original plan was ill conceived, the USAF began evaluating a new plan on 3 May that relocates fewer units from Kirtland, and retains a significant, consolidated support organization for both the DOD and DOE organizations remaining at KAFB, as well as retaining some support for active duty members such as the commissary. The new USAF plan begins to address operational impacts on the nuclear infrastructure, but not the other organizations.

OPERATIONAL IMPACTS:
The new USAF plan reduces impacts on the nuclear infrastructure, to some degree, by keeping the Defense Nuclear Agency at KAFB, and by retaining military security for the underground storage mission. Unfortunately, the AF Safety Center, AF Inspection Center and AF Security Police Agency are still being relocated away from the nuclear support core to undetermined locations. Given that many military will remain at KAFB which will retain a large support infrastructure, these moves appear to lack any rationale.

The USAF has directed site surveys of Hill AFB and Beale AFB for the 58th Special Operations Wing. Holloman AFB has been determined to be too expensive. In terms of flying weather, varied terrain, training areas, density altitude and existing facilities, KAFB is unquestionably better than any of the three alternatives. Any relocation will result in a perpetually inferior training environment, with little, if any, recurring cost savings justification. Finally, the GAO report explicitly states the inability of Beale AFB to accept new aircraft due to air quality.

The movement of the 58th SOW will cause disruption in overseas/CONUS personnel replacement, which will degrade special operations capabilities during the multi-year duration of the relocation. This disruption unfortunately comes at a time of increasing force structure growth. Further, the flight simulators of the 58th SOW will be unavailable for real-world mission planning and rehearsal, and will result in increased training flying hour demands on SOF aircraft. SOF aircraft are currently undergoing extensive modification, making fewer available for training. Both initial and concurrency training will suffer needless degradation.

COST:

When the DOE costs are considered within the USAF cost estimates from their 3 May, there is reasonable agreement with the cost data provided by the Steering Committee on 20 April. While the Steering Committee still has issues with the USAF estimate, both the USAF estimate and the Steering Committee estimate confirm the original USAF proposal is fiscally unsound.

No cost data has yet been generated for the 3 May USAF option, nor do we expect the USAF to provide that data in a timely manner. However, the USAF strategy appears to be to create recurring annual savings by having the USAF provide support services to DOE organizations more cheaply than the DOE organizations can provide it to themselves. This would simultaneously eliminate most of the DOE recurring cost of $30.6 million, and remove DOE from the cost discussion process. To avoid one-time costs for military construction, USAF guidance is to find existing facilities, at any location, for units departing Kirtland. Operational concerns resulting from a relocation based upon availability of facilities, are secondary. The USAF is searching for any scheme for KAFB that will provide a return-on-investment of ten years or less.

CONFORMITY OF OBJECTIVES:

The Steering Committee believes that any proposal or recommendations they submit to the Commission must be consistent with the goals of reducing infrastructure and saving taxpayer dollars while maintaining, or if possible, improving military effectiveness and efficiency. The Steering Committee would like to see improved military effectiveness and efficiency at KAFB by enhancing the capability of organizations like Phillips Labs, and by improved inter-agency synergy through the co-location of organizations with related missions. But, there is absolute recognition that these desires must be complementary, not merely feasible, with the Commission's objectives. None of the USAF proposals satisfy the Commission's goals.

OPPORTUNITIES FOR THE AIR FORCE:

Numerous options involving KAFB are available that will improve military effectiveness and efficiency, reduce unneeded infrastructure, yield significant savings to the taxpayer, and provide economic community reuse potential. Few of these options are original; most have been created, studied and recommended by the USAF. The immediate action suggested to the Commission is to add Los Angeles AFB, Beale AFB and Hanscom AFB to the closure/realignment list on 10 May. Closure of LAAFB allows consolidation of the space product center with the space lab (Phillips) at KAFB, consistent with recommendations in USAF analyses, and LAAFB's prime location near the Los Angeles airport has superb economic value for community reuse. BAFB is poorly suited to special operations training, cannot accept additional aircraft types because of air quality restrictions, and multiple relocation sites for the U-2/TR-1 aircraft currently at BAFB are available in California. Closing LAAFB and BAFB will save the taxpayer $103 million annually after a one time cost of $649 million (cost from Feb 95 USAF BRAC Submission). Placing HAFB on the list for realignment permits the complete integration of the Phillips Lab's Geophysics Directorate, currently located at HAFB, with the parent lab at KAFB.

KIRTLAND AFB COSTS UPDATE

- MAY 3RD USAF ESTIMATE
  - ONE TIME COST: $538M
  - ANNUAL SAVINGS: $32.8M
- ONE TIME DOES NOT INCLUDE DOE COSTS: $64M
- ANNUAL DOES NOT INCLUDE:

– DOE ANNUAL IMPACT	$ 30.6M
– CHAMPUS FOR RETIREES:	20.3M
– VA HOSPITAL;	5.1M
– 58TH SOW ADDED FLIGHT TIME	2.0M

KIRTLAND OPERATIONAL UPDATE

- AF CONSIDERING MOVING 58TH TO BEALE OR HILL, MAYBE OTHERS
- NEGATIVE IMPACTS
  - WEATHER
  - TRAINING AREAS/ROUTES
  - DENSITY ALTITUDE (IMPORTANT FOR HELO TNG)
  - INFRASTRUCTURE
  - ENVIRONMENTAL IMPACTS
  - COMMUNITY SUPPORT IS UNKNOWN
- **NO OPERATIONAL ADVANTAGE TO MOVING FROM KIRTLAND**

KIRTLAND SUMMARY

- NO OPERATIONAL BENEFITS TO AF PROPOSED REALIGNMENT
  - NUCLEAR INFRASTRUCTURE IMPAIRED
  - 58TH SOW MISSION DISRUPTED; NO COST OR OPERATIONAL BENEFIT
- RESULT IS RECURRING COSTS TO TAXPAYER - NO SAVINGS
- REMOVING KIRTLAND FROM REALIGNMENT MAKES IT AVAILABLE TO BRAC COMMISSION FOR OTHER DOD CONSOLIDATION INITIATIVES

ONGOING KIRTLAND RELOCATIONS

- SPACE AND MISSILE SYSTEMS CENTER FOR TEST AND EVALUATION (SMC/TE)
  - RELOCATING FROM ONIZUKA TO KIRTLAND AT REDUCED LEVEL
  - SHOULD NOW CONTINUE AS ORIGINALLY PLANNED
- PHILLIPS LABORATORY CONSOLIDATION
  - DIRECTORATES GEOGRAPHICALLY SEPARATED
  - SECAF DIRECTED CONSOLIDATION
  - CONTINUE AS ORIGINALLY PLANNED

CLOSE LOS ANGELES AFB

- CLOSING LOS ANGELES AFB (CO-LOCATES SMC WITH PL)
  - SAVES $64M ANNUALLY; ROI = 10 YEARS
  - ENVIRONMENTAL REVIEW THROUGH PUBLIC HEARINGS; CAN CLOSE 18 MONTHS EARLIER THAN OTHER INITIATIVES FROM BRAC 95

KIRTLAND PRODUCT CENTER / LABORATORY CONSOLIDATION

- AF INITIATIVE : CO-LOCATE CENTERS WITH LABS; EXAMPLES INCLUDE:
  - AIRCRAFT AT WRIGHT-PATTERSON
  - ELECTRONICS AT HANSCOM
- PRIOR TO 1994, AF PLANNED TO CO-LOCATE SPACE AND MISSILE SYSTEMS CENTER (SMC) WITH PHILLIPS LAB
- AF CHANGED PLAN AND CITED
  - AIR QUALITY IN ALBUQUERQUE
  - NEW MEXICO GROSS RECEIPTS TAX

Document Separator

SHIPYARD / SUBMARINE ISSUES

SSN 688 Class Submarines

DON Recommendation

- Close Long Beach NSYD and SRF Guam
- Analyzed but did not recommend closure of Portsmouth NSYD because of uncertainty of future SSN requirements
  - SSN modernization
  - Possible increase in force structure of SSNs
  - Potential requirement for SSN refuelings instead of programmed inactivations

Question #1

What are the facility, equipment and training requirements and costs necessary to enable a Navy nuclear shipyard to refuel SSN 688 class submarines?

Facility Requirements / Costs

- Shipboard & shore fuel handling enclosures
- Adequate crane capacity and reach
- Reactor component handling equipment
- Reactor component storage enclosures
- Training facilities
- Cost: $20-50M

Equipment Requirements / Cost

- Fuel and irradiated reactor component handling containers
- Cutting machines
- Reactor training mockup
- Approximately 200 pieces of equipment provided-additional 100 locally manufactured or bought
- Cost: $25M

Training Requirements / Cost

- Training required for:
  - Mechanics
  - Radiological personnel
  - Inspectors
  - Refueling engineers
- Cost: $5M

Question #2

What is the date when each shipyard will be ready to perform refuelings?

SSN 688 Refueling Capable NSYDs

- Norfolk: essentiallly
- Pearl Harbor: in 18 months
  - Training
  - Crane
  - Approximately 50% implementation costs spent
  - Equipment & facility ready in approximately 6 months
- Portsmouth: now
- Puget Sound:essentially

Question #3

What is the schedule and location for each planned SSN 688 class refueling?

SSN 688 Refueling Schedule

SECNAV Approved Schedule

- FY 1995: none
- FY 1996: 1 at Portsmouth
- FY 1997: none

Strategic Planning Schedule

- FY 1998: none
- FY 1999: 1 at Portsmouth
- FY 2000: 1 each, Portsmouth and Norfolk
- FY 2001: 1 each, Portsmouth and Pearl Harbor
- FY 2002-2005: 2 per year

Question #4

What are the cost estimates for facilitizing a private construction yard to do SSN 688 class refuelings?

Private Yard Facilitization

- Electric Boat: $50-100M
  - Dockside refueling enclosures
  - Radiological facilities
  - Extend railroad tracks
  - Training
  - Refueling equipment
- Newport News: $45-55M
  - Refueling facility conversion
  - Training
  - Refueling equipment

Question #5

What are the spent fuel storage issues?

Spent Fuel Storage Issues

- Historically not stored at shipyards
- 1993 court order: temporary storage
- Storage issue does not affect refueling location decision

Question #6

What is the impact of the recent increase in the SSN 688 class operating cycle and what is its effect on shipyard workload?

Increased Operating Cycles

- DMP workload bow waves into busy refueling/inactivation period
- FY 1996/1997: 5 DMPs and 8 DSRAs deferred to later years
- Simultaneous refueling / DMP / inactivation workload requires 4 nuclear yards over the period FY 2000-2005
- DMP / DSRA packages not reduced

Impact of Portsmouth Closure

- Current schedule marginally achievable (high risk)
  - Drydock / facility / equipment limitations
  - Drydocks scheduled "heel to toe"
    - no required maintenance availabilities
    - assumes that 15 month in dock **never** exceeded
  - Requires considerable schedule adjustment for non-SSN ships
- Cannot accommodate even 1 additional refueling, in lieu of inactivation

SSN 688 Refueling

- Notional duration:
  20-24 months total, with 15 months in drydock
- Completed 2: USS Philadelphia and USS Los Angeles
  - completed: 27 months and 29 months
  - dockings: 15 months and 19 months
- USS Memphis: currently in ERO
  - 23 months duration
  - 16.5 months in drydock

Pearl Harbor NSYD

- Drydock configuration

  #1: SSN 688 ERO / defueling (under construction)

  #2: Nuclear capable
  (not facilitized for refueling/defueling)

  #3: Not usable

  #4: CV / CVNs

Norfolk NSYD

- Drydock Configuration

  #1,#6,#7: Barge/service craft (shallow draft)

  #2: Being configured for SSN 688 / CGN defueling

  #3: Nuclear capable being used for CGN and surface ship availabilities

  #4: SSN 688 / CGN fueling/defueling

  #8: CV / CVN dock

Portsmouth NSYD

- Drydock configuration
  - #1: DMP / SRA dock - not configured for SSN 688 ERO or defueling
  - #2: SSN 688 ERO and defueling
  - #3: SSN 688 defueling

Puget Sound NSYD

(continued)

- Drydock configuration

  #1: SSN 637 / SSBN defueling

  #2: Nuclear capable (not facilitized)

  #3: Non-nuclear, used for submarine disposal, currently in 1 year dock maintenance period

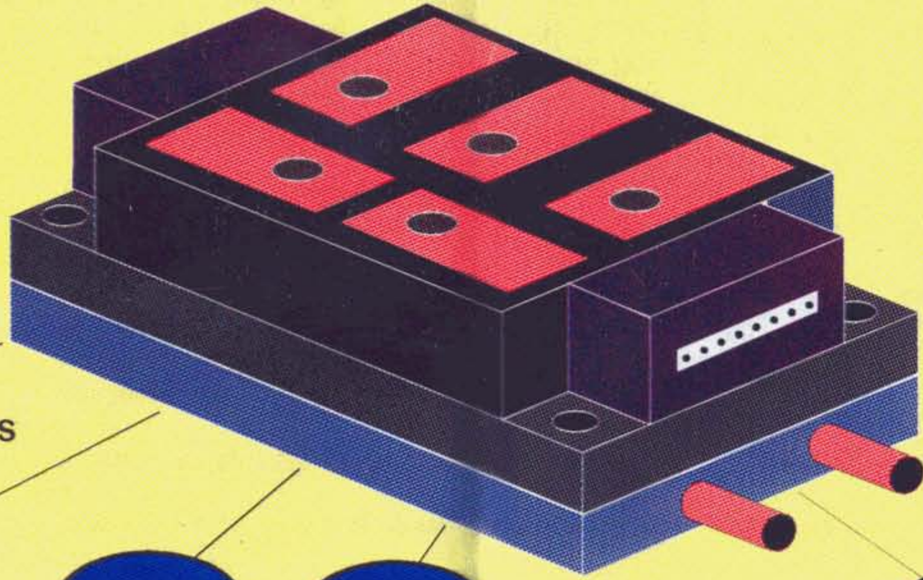
  #4: SSN 637 defueling

  #5: CGN / SSN 688 defueling

  #6: CVN / fleet support dock

PEBBs ARE A NEW UNIT OF MANUFACTURE

3-PHASE 120 HP MOTOR DRIVE PEBB



TRANSPORTATION
AEROSPACE
UTILITIES
MILITARYC
OMMUNICATIONS
PULSE
POWERIN
DUSTRIAL

HARRIS MCT CUSTOMERS

NASA LERC
NASA SUPPLIERS
NASA LABS

AIRFORCE AFWAL
AIRFORCE LABS
A.F. SUPPLIERS

ARMY ARL,EPSD
ARMY LABS
ARMY SUPPLIERS

EPRI
SUPPLIERS
MEMBER UTILITIES

UNIVERSITIES

>99.5% EFFICIENCY
>150 kW/in2

NAVY CDNSWC
NAVY LABS
NAVY SUPPLIERS

TECHNOLOGY INSERTION

DEVICES, DRIVERS AND PEBB'S FOR TEST AND FOR CONCURRENT BETA SITE ACCELERATED TECHNOLOGY INSERTION PROGRAM

Material, Device, and Equipment are Merged into a New System Level Component