Ophir Corporation

"Airborne, Optical Remote Sensing of Methane and Ethane for Natural Gas Pipeline Leak Detection"

Mr. Jerry Myers
Program Manager


DILBERT
BY
SCOTT
ADAMS
THE ORIGINAL SCHEDULE LOOKED LIKE THIS...
ONE MONTH FOR A MANAGEMENT DECISION AND ONE YEAR TO DO THE PROJECT.
DECIDE
DO
THE REVISED SCHEDULE IS THIS...
ONE YEAR OF INDECISION FOLLOWED BY INTENSE PRESSURE TO DO THE IMPOSSIBLE BEFORE THE DEADLINE.
INDECISION
NO WAY
NOW IF YOU'LL EACH TAKE A PAIR OF 3-D GLASSES...
YOU CAN SEE THE LAYERS OF MANAGEMENT INCOMPETENCE PRACTICALLY JUMP OUT AT YOU.
NOW SCRATCH ONE OF THESE SCENTED CARDS TO SNIFF THE UNMISTAKABLE ODOR OF DOOM.
I DON'T SMELL ANYTHING. IS MINE BROKEN?
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CLASSIC PEANUTS®

Overview

- Ophir Corporation Introduction
- Present Technology Status
- Research Management Plan Review

Ophir Corporation

- Colorado Small Business
  - Founded in 1980
- Successfully Completed over 80 Contracts
  - U.S. Government and Aerospace Companies
- AS9000 Compliant (~ISO-9001)

OPHIR Corporation

- Previous Commercialization Success
  - Over $35 Million in Optical Remote-Sensing Technologies
  - Commercialization “Success Story”
    - Army, Navy, NASA
- 15 Years of Experience with Airborne Optical Systems
  - Own/Maintain Test Aircraft

CORPORATION

duoThane™

- Advantages:
  - Methane + Ethane = Natural Gas
  - Technology Can be Utilized for Fence – Line, Airborne and Vehicle Mounted Leak Inspections
  - Provides Cost Effective Natural Gas Pipeline Leak Inspections

CORPORATION

duoThane™

- Features:
  - Optical Infrared Absorption Method
  - Considerably Less Expensive Than Laser Based Radar
  - Can be adapted to sense other gases

CORPORATION

duoThane™

- Features (cont.)
  - Remote-Sensing Capability
  - Fence-line
  - Monitoring Distance of 1000 Yards Demonstrated
    - Methane – 50 ppb (parts-per-BILLION)
    - Ethane – 33 ppb

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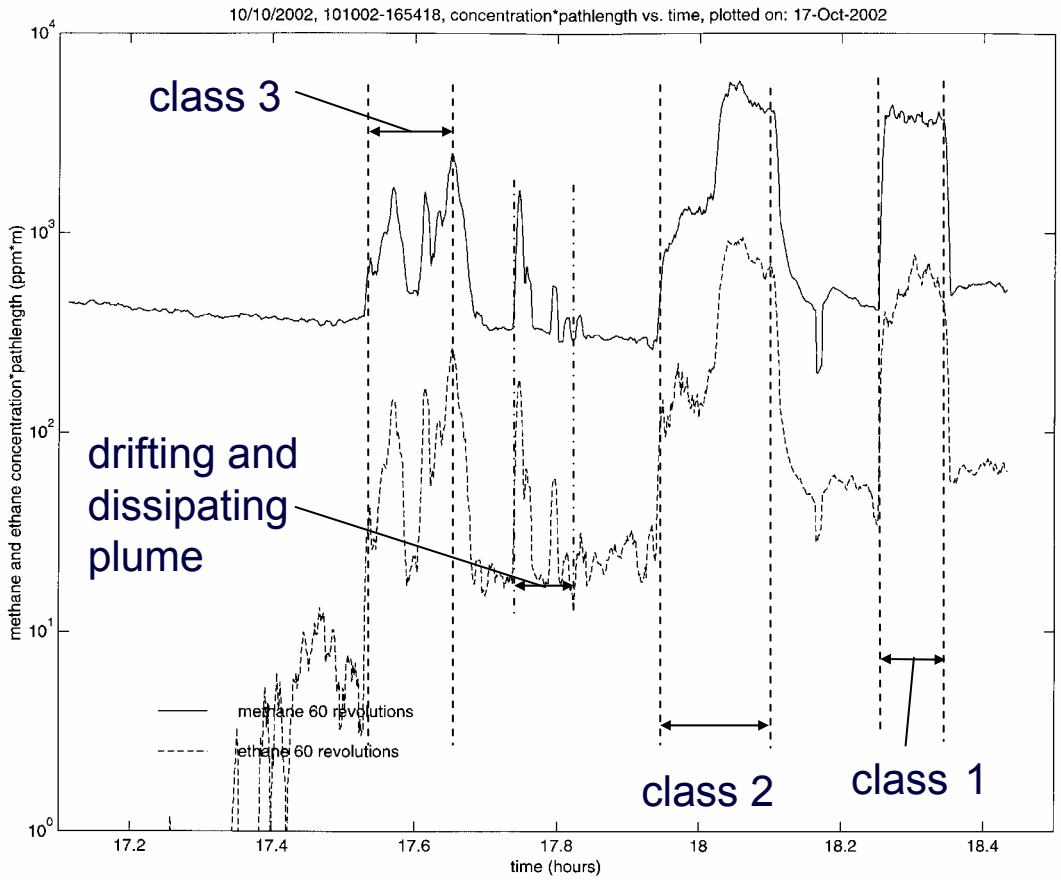
duoThane™

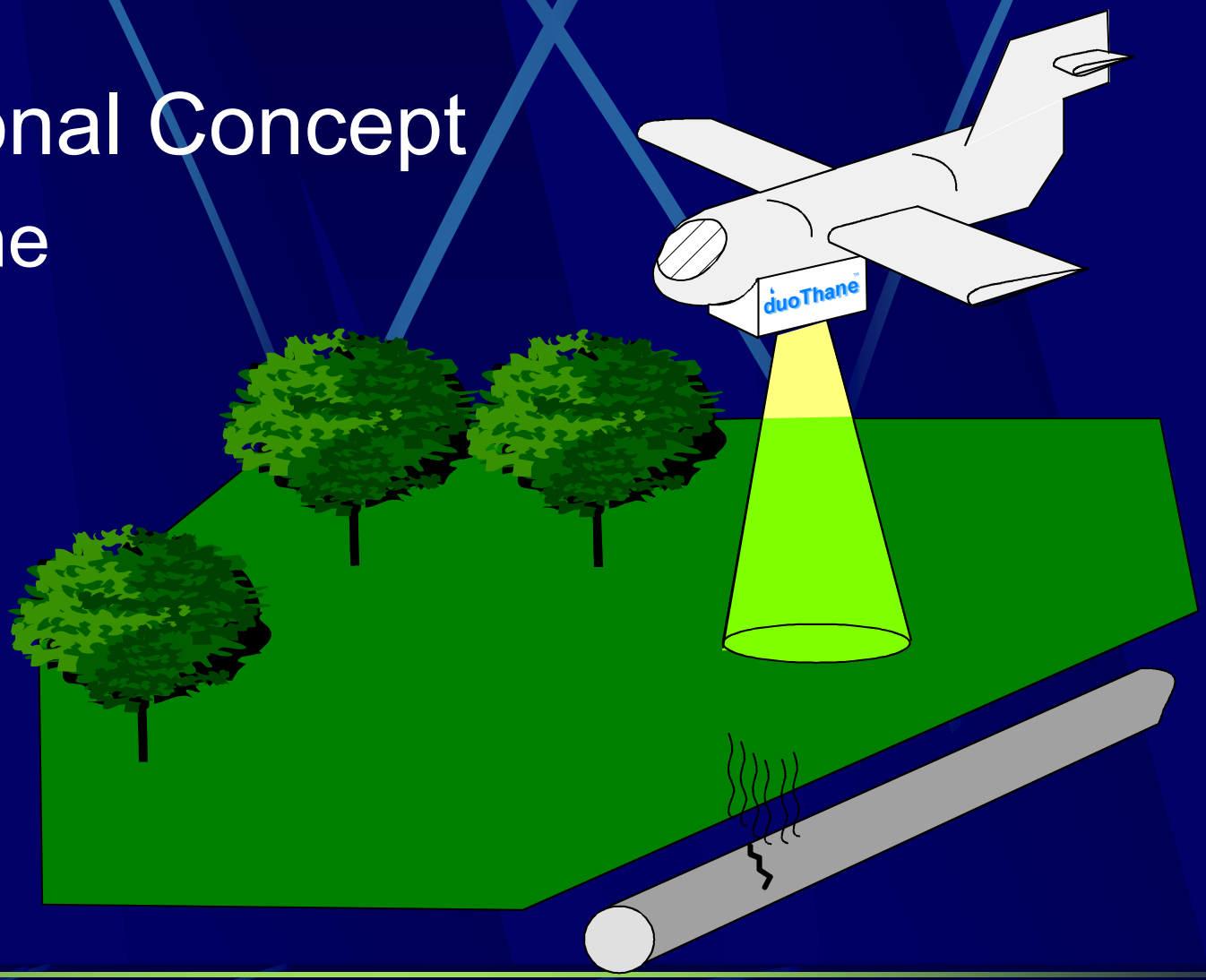
- Technology Status
  - Prototype Demonstration Completed
  - Four Field Tests Completed
    - Littleton, CO (U.S. EPA test)
    - Hobbs, NM (U.S. DOE test)
    - Texas (Private Oil & Gas Exploration Company)
    - Glendive, MT (Operational Transmission Pipeline)
  - $387,000 Already Expended in R&D
    - U.S. EPA, U.S. DOE, OPHIR Corporation

Glendive, MT Test Data



Airborne Optical Sensing

- Operational Concept
  - Airborne



Objective

- The prime objective of this research is to design, assemble and flight-test an airborne, optical remote sensing system for natural gas pipeline leak detection.

Project Summary and Snapshot

- Airborne Sensing Project is an 18 Month Co-Funded DOE / Ophir $750,000 Effort
- Research Management Plan has Been Submitted to NETL for Review on 11/12/02
- Technology Status Assessment Due by 12/13/02
- Optical Sensing System Requirements are Being Defined
- Modeling of the System Signal Response Has Been Started

Development Task Summary

- Task 1: Airborne Optical Remote-Sensing System Design Requirements
- Task 2: Sensor Performance Modeling Under Operational Conditions
- Task 3: Airborne Transceiver Design
- Task 4: Procurement and Assembly of the Airborne Prototype
- Task 5: Laboratory Testing
- Task 6: Aircraft Installation and Preliminary Testing
- Task 7: Proof-of-Capability Flight Testing

Task 1: Airborne Optical Remote Sensing Design Requirements

- Determine Issues Which Will Impact Airborne Design. Examples of Impacting Issues Are:
  - Platform Stability Requirements
  - Dynamically changing geographic location
  - Signal reflectivity changes of background
  - Need for rapid data acquisition
- Meet With WBI Holdings Inc. to Discuss Industry Desired Requirements for Airborne Sensing Systems

Task 2: Co-Located Sensor Performance Modeling

- Signal Modeling of Airborne System Co-Located Transceiver
  - Source light output available
  - Reflective surface losses
  - Measurement speed or integration time
  - Optics efficiency losses
  - Photodetector and circuit noise
  - Solar flux contributions
  - Ground-based sensor test data results

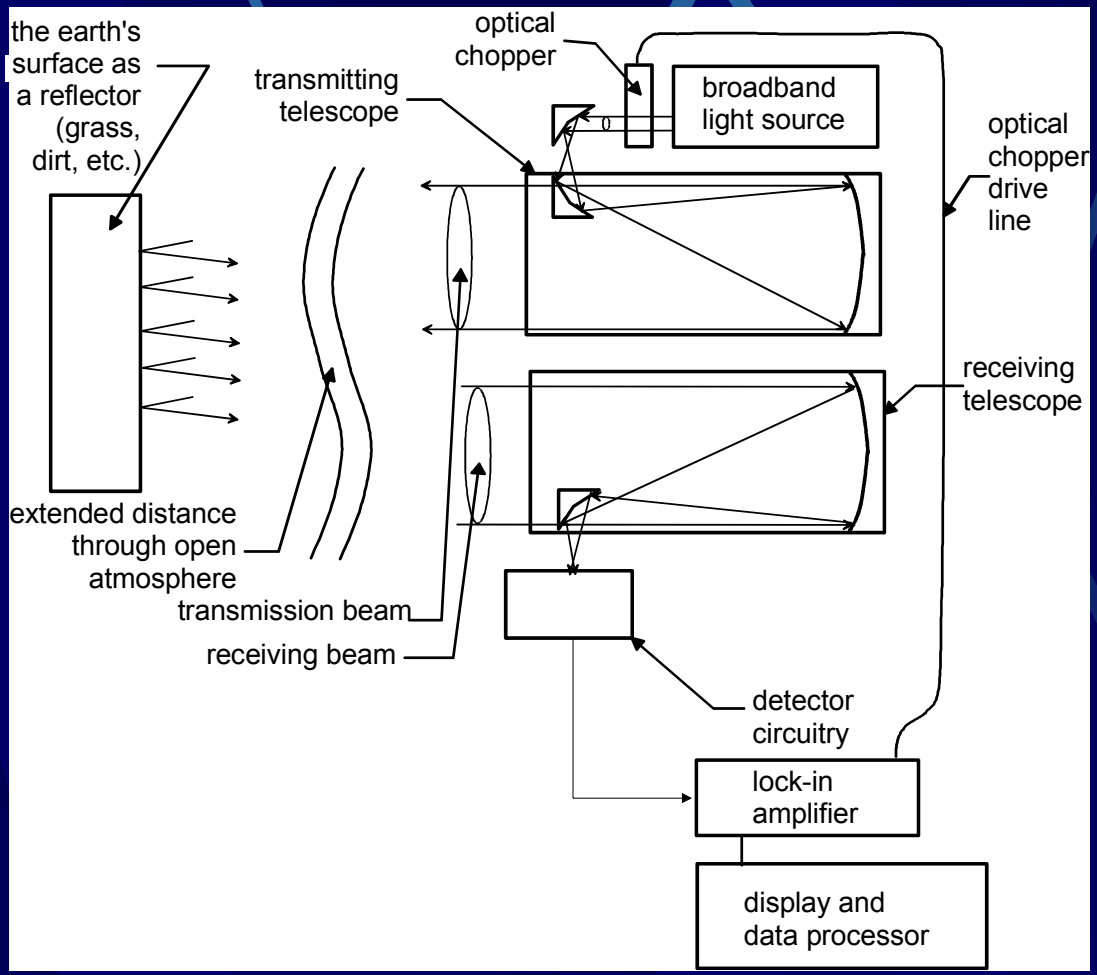
Design Decision Point

- Successful Completion of Task 1 and 2 Is Critical In Selecting the Optimal Optical Sensing Wavelength (either 1.65 um or 3.3 um), Light Source, Photodetector, and Data Acquisition Circuitry

Task 3: Airborne Transceiver Design

- Illumination Source
- Transmitter Optics
- Receiver Optics
- Gas Cell Designs
- Detector and Lock In Amplifier
- Transceiver Mechanical Chassis
- Electrical System Interface
- Aircraft Interface Fixture
- System Software Interface

Airborne System Architecture



Critical Design Topic: Illumination Source Design

- Factors That Influence Source Selection:
  - Earth's surface is a poor reflector
  - Methane and ethane absorption lines
  - System ground spatial resolution
  - Blackbody radiators vs. solid state sources
  - Unwanted absorption due to water vapor and other components
  - Required control electronics

Critical Design Topic: Signal Detection Circuitry

- Detector Selection Hinges Upon:
  - Wavelength band – HgCdTe detector for 3.3 um centered band or InGaAs detector for 1.65um band
  - Signal to Noise Ratio required – Analysis of dominant noise within selected detector
  - Responsivity and sensitivity specs
  - Detector amplifier front end circuitry

Other Hardware and Software Design Topics

- Transceiver Optical Design
- Target Gas Cell (Both Transceiver and Lab Gas Cells
- Transceiver Mechanical Chassis
- Electrical System Interface
- PC Interface Hardware
- Software Development Platform

Task 4: Procurement and Assy

- Ophir Has Extensive Experience in the Development of Airborne Systems
- Transceiver Fixture to Interface to Ophir Beechcraft A36 Test Airplane
- Ophir Will Develop Lab/Airborne Test Procedures to Prove System Performance
- Optical Sensor Assembly Scheduled for Completion on 09/01/03

Task 5: Laboratory Testing

- System Integration and Testing
  - Integration of All System Components
  - Perform System Dark Noise Analysis
  - Perform Short Path Optical Test With Turning Mirrors Using Ground Reflective Surfaces
  - Perform Outside Moderate Path Testing With Reflective Surfaces
  - Scheduled Completion Date 12/08/03

Task 6: Aircraft Installation and Preliminary Testing

- Power, Signal, and Software Interface
- Interface to Existing Aircraft Power
- Check for Proper Aiming of Transceiver
- Inspect Ruggedness of Setup

Task 7: Proof-of-Capability Flight Testing

- Flight Testing of System
  - A series of flight tests over existing WBI Holdings pipelines
  - Two one-week field tests are envisioned
  - WBI will assist Ophir with pipeline selection and location of leaks
  - Maximize the diversity of terrain
  - Rocky Mountain Oil Field Test Center Option
  - Flight Testing is Scheduled for January – February of 2004

Technical Metrics

- Minimal Detectable Concentration — W.F. 1
- Ability to Detect Both Methane and Ethane Gases — W.F. 1
- Ground Spatial Resolution for Gas Concentration — W.F. 2
- Measurement Speed — W.F. 2
- Impact of Buried Gas Pipelines on Airborne Detection — W.F. 3
- Impact of Plume Migration on Pointing — W.F. 3

Technical Metrics (continued)

Impact of Changing Reflective Surfaces on Signal Return	W.F. 3
Tracking of Physical Gas Pipeline	W.F. 4
Ease of Operator Use / User Interface	W.F. 4
Cost of Production Airborne System	W.F. 5
System Size and Weight	W.F. 6
Light Source Eye Safe Concerns	W.F. 7

Ophir Corporation DOE 1632 Technical Reporting Schedule

Report	Due Date	Delivery Method	Receiver Name	Receiver Address
Task 1--Research Management Plan	11/13/2002	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Task 1--Research Management Plan	11/13/2002	us mail	NETL AAD	Bldg. 921, US Department of Energy National Energy Technology Laboratory PO Box 10940 Pittsburgh, PA 15236-0940
Hazardous Substance Report	11/13/2002	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Hazardous Substance Report	11/13/2002	us mail	NETL AAD	Bldg. 921, US Department of Energy National Energy Technology Laboratory PO Box 10940 Pittsburgh, PA 15236-0940
Informal Status Report	11/13/2002	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Task 2--Technology Status Assessment	12/13/2002	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Task 2--Technology Status Assessment	12/13/2002	us mail	NETL AAD	See address above
Informal Status Report	12/13/2002	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	1/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	2/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	3/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	4/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	5/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Technical Progress Report	5/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Technical Progress Report	5/13/2003	us mail	NETL AAD	See address above
Informal Status Report	6/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	7/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	8/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	9/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	10/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Topical Report	10/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Topical Report	10/13/2003	us mail	NETL AAD	See address above
Informal Status Report	11/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Technical Progress Report	11/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
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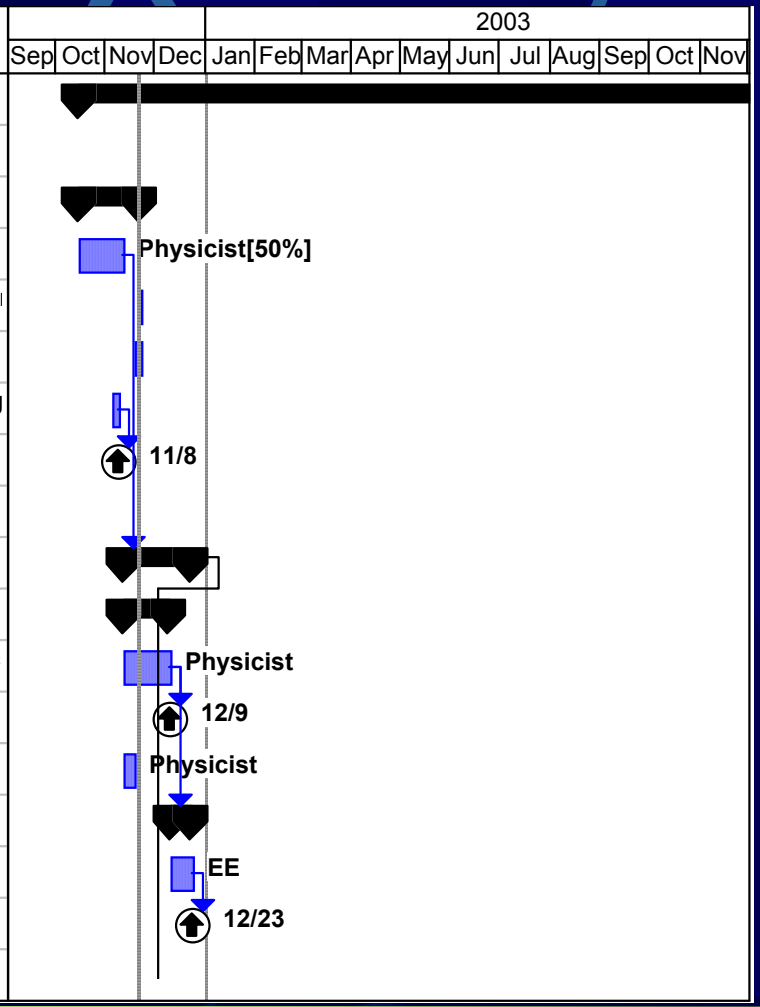
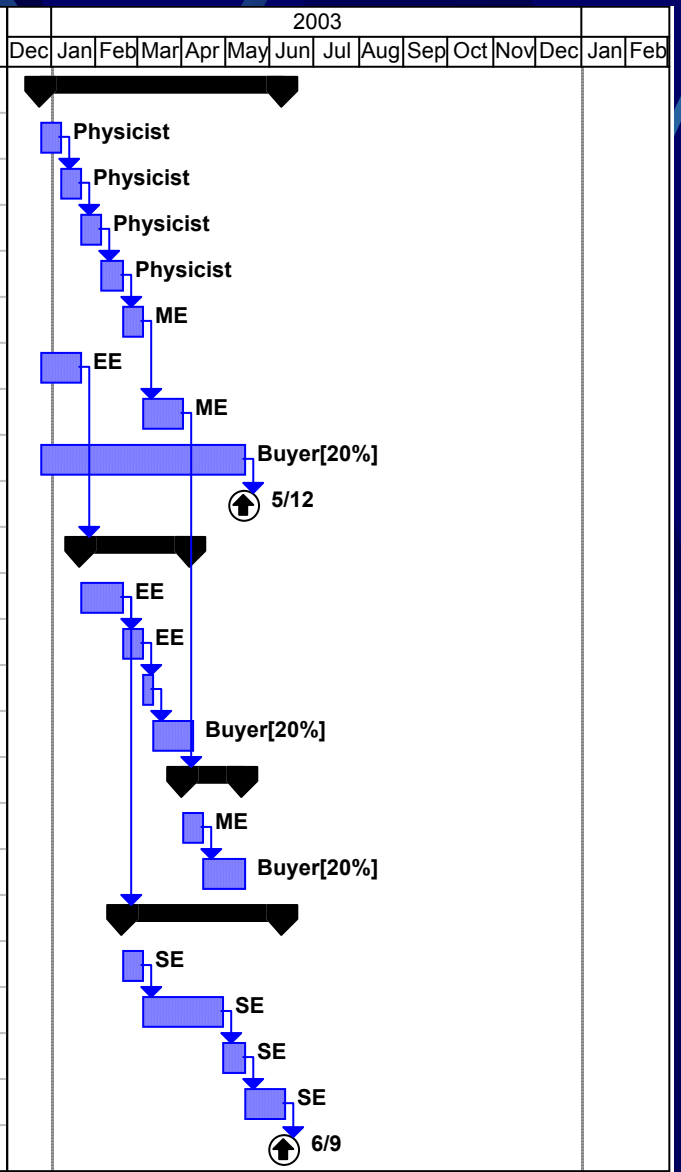
Informal Status Report	12/13/2003	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	1/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	2/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	3/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Informal Status Report	4/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Final Report	4/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Final Report	4/13/2004	us mail	NETL AAD	See address above
Report of Termination or Completion Inven	4/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Report of Termination or Completion Inven	4/13/2004	us mail	NETL AAD	See address above
Hazardous Waste Report	4/13/2004	email	Magda Rivera	Magda.Rivera@netl.doe.gov
Hazardous Waste Report	4/13/2004	us mail	NETL AAD	See address above

Work Breakdown Schedule for Airborne Sensing Project

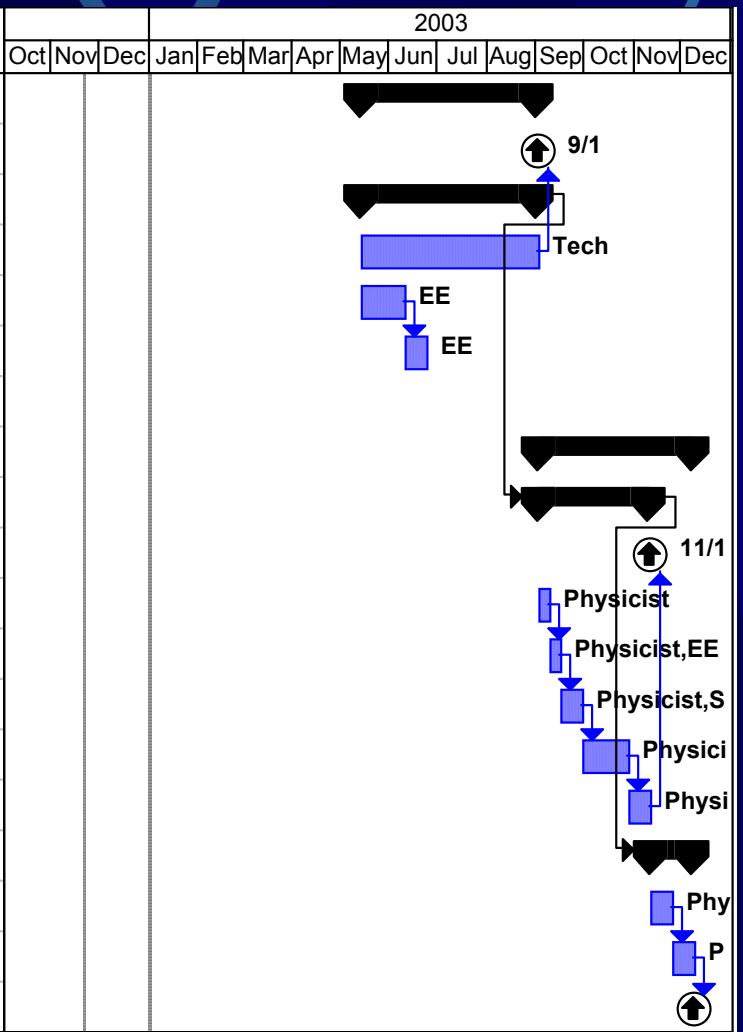
ID	Task Name
1	**Airborne Active Gas Correlation Radiometer Project**
2	
3	**Task 1.0: Airborne Optical Remote-Sensing System Design**
4	Investigation of Airborne AGCS Technical Parameters
5	Meeting With WBI Holdings to Discuss Airborne Requireme
6	Literature Search on Buried Pipe Gas Plume Disipation
7	(EPA Contract) Testing of Ground Based Transceiver Desig
8	Co-Located Transceiver Testing With Targets
9	
10	**Task 2.0: Sensor Performance Modeling Under Operational**
11	**Complete Sensor Performance Modeling**
12	Signal to Noise Modelling for 3.3 um and 1.6 um Sourc
13	SNR Modelling for 3.3 um and 1.6 um Sources
14	Modelling of Ethane and Methane Absorption Bands
15	**Creation of Subsystem Block Diagram**
16	Development of Hardware Requirements
17	Completion of Hardware Requirements
18	



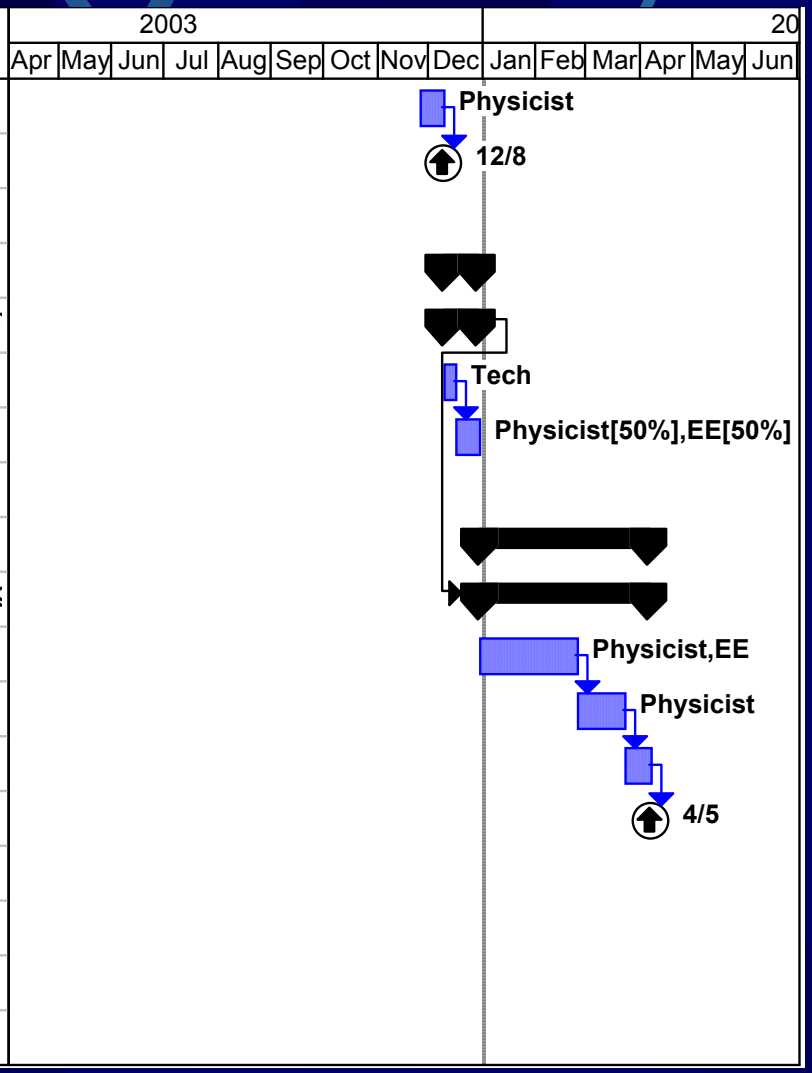
ID	Task Name
19	**Task 3.0: Airborne Transceiver Design**
20	Illumination Source Design
21	Transmitter Optics Design
22	Receiver Optics Design
23	Detector Channel Optics Design
24	Target Gas/Blank Cell Design
25	Detector and Lock In Amplifier Design
26	Transceiver Mechanical Chassis Design
27	Procure/Fabricate Transceiver Parts
28	Completion of Transceiver Hardware Design
29	**Electrical System Interface Design**
30	PC Computer Processor and Data Acquisition Design
31	Power Management Design
32	GPS Sub-System Selection
33	Procure Electrical Interface Parts
34	**AGCS Aircraft Interface Fixture Design**
35	Interface Design
36	Procure Parts
37	**System Software Design**
38	Develop Software Requirements Document
39	Software System Development Upgrade
40	Development of Software Test Procedures
41	Software Test Integration
42	System Software Design Complete



ID	Task Name
43	**Task 4.0: Procurement and Assembly of the Airborne Proto**
44	Completion of Transceiver Assembly
45	**Assembly of Transceiver and Subsystems**
46	Assemble Transceiver Subsystem
47	Assemble Electrical Interface
48	**Development of Hardware Test Procedures**
49	
50	**Task 5.0: Laboratory Testing**
51	**System Integration and Testing at the Laboratory Level**
52	Completion of Laboratory Integration and Testing
53	Design/Procure Laboratory Variable Gas Cells
54	Installation of Hardware in Lab
55	Integration of Hardware and Software
56	Optical Test with Turning Mirrors
57	Optical Test with Reflective Surfaces
58	**System Testing at Moderate Path Lengths With Various**
59	Field Testing at OPHIR Facility
60	Data Analysis
61	Conpletion of Testing at Moderate Path Lengths



ID	Task Name
60	Data Analysis
61	Conpletion of Testing at Moderate Path Lengths
62	
63	**Task 6.0: Aircraft Installation and Preliminary Testing**
64	**Installation of Airborne AGCS System on OPHIR Airplar**
65	Install Equipment on Airplane
66	Ground Test Checkout
67	
68	**Task 7.0: Proof-of-Capability Flight Testing**
69	**Flight Test Demonstration of Airborne AGCS Long Rang**
70	Field Test
71	Data Analysis
72	Technology Assessment
73	Proof-of-Capability Flight Testing



Schedule Milestones

Milestone	Completion Date
Transceiver Testing With Target	11/08/2002
Signal to Noise Modeling	12/09/2002
System Hardware Requirements	12/23/2002
Transceiver Hardware Design	05/12/2003
System Software Design	06/09/2003
Airborne AGCR Assembly	09/01/2003
System Laboratory Test	11/10/2003
System Moderate Path Length Test	12/08/2003
Proof-of-Capability Flight Testing	04/05/2004

Project Staffing Plan

Airborne AGCR Major Task	Tech.	EE	ME	SE	QA	Buyer	Phys.	PM	TOTALS
Task 1.0: Airborne Optical Remote-Sensing System Design							80	7	87
Task 2.0: Sensor Performance Modeling Under Operational Con.							160	14	174
Task 3.0: Transceiver Design	200	600	320	520	120	304	353	205	2622
Task 4.0: Procurement and Assembly of the Airborne Prototype	400	160	41		48	82	80	69	880
Task 5.0: Laboratory Testing	200	200	120	160	42	32	520	108	1382
Task 6.0: Aircraft Installation and Preliminary Testing	40	40	40			16	40	15	191
Task 7.0: Proof-of-Capability Flight Testing		185		40	40	16	360	54	695
Briefing # 1								48	48
Briefing # 2								40	40
Final Report							176	15	191
Technical Paper							56		56
TOTALS	840	1185	521	720	250	450	1825	575	6366

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Cost Element Summary

Cost Element	First Budget Period (First Year)		Second Budget Period (Last 6 Months)		Total Project
	DOE	Ophir Corporation	DOE	Ophir Corporation	($)
Direct Labor	$95,457	$31,073	$47,729	$15,537	$189,796
Fringe Benefits					
Labor Overhead	$122,641	$39,923	$61,320	$19,961	$243,845
Travel	$4,424		$12,958		$17,382
Equipment					
Supplies / Materials	$50,800				$50,800
Subcontracts					
Consultants					
Outside Services	$14,000		$16,800		$30,800
TOTAL DIRECT COSTS	$287,322	$70,996	$138,807	$35,498	$532,623
G&A / FCCM	$117,229	$29,004	$56,641	$14,503	$217,377
TOTAL COSTS		$504,551		$245,449	$750,000
AWARDEE COST SHARE		$100,000		$50,000	$150,000
DOE COST SHARE		$404,551		$195,449	$600,000
TOTAL COSTS		$504,551		$245,449	$750,000

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Supplies/Materials Costs

DESCRIPTION	COST BASIS	NO. OF UNITS	UNIT PRICE	ESTIMATED COST
First Budget Period (First Year)				
Lock In Amplifier	Historical (HC)	2	$ 4,275.00	$ 8,550.00
Telescope	HC	3	$ 800.00	$ 2,400.00
Light Chopper	HC	1	$ 2,250.00	$ 2,250.00
Filter Set	HC	4	$ 329.00	$ 1,316.00
Steering Optics	HC	2	$ 1,000.00	$ 2,000.00
Mercury Cadmium Detectors	Catalog Price(CA)	4	$ 1,100.00	$ 4,400.00
Gas Cells	Eng. Estimate(EE)	2	$ 500.00	$ 1,000.00
Collimation Optics Mirror	HC	1	$ 550.00	$ 550.00
Focuser, 2"	HC	1	$ 1,092.00	$ 1,092.00
ZnSe Dish, Sapphire Window	HC	1	$ 425.00	$ 425.00
Portable Industrial Grade Computer	CA	1	$ 5,000.00	$ 5,000.00
Batteries, Extended Output	HC	2	$ 130.00	$ 260.00
Sine Wave Inverter	HC	1	$ 800.00	$ 800.00
Data Acquisition PCB	CA	1	$ 2,000.00	$ 2,000.00
PC GPS Receiver Board With Antenna	CA	1	$ 2,280.00	$ 2,280.00
Cabling System	EE	6	$ 150.00	$ 900.00
Misc. Hardware	EE	1	$ 3,138.00	$ 3,138.00
Detector Power Supply	CA	1	$ 1,500.00	$ 1,500.00
Steering Mirror d=4" for Aircraft Install	CA	1	$ 640.00	$ 640.00
Steering Mirror d=8" for Aircraft Install	CA	2	$ 2,302.00	$ 4,604.00
Aircraft Mounting Fixture	EE	1	$ 500.00	$ 500.00
National Instruments LabView Software	CA	1	$ 1,995.00	$ 1,995.00
Matlab Analysis Software License	CA	1	$ 2,700.00	$ 2,700.00
Video Camera with C-Mount Lens	CA	1	$ 500.00	$ 500.00
Total Cost				$ 50,800.00

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Direct Costs / Outside Services

DESCRIPTION	COST BASIS	NO. OF UNITS	UNIT PRICE	ESTIMATED COST
FIRST BUDGET PERIOD (FIRST YEAR)				
Transceiver Fixture Fabrication	Eng. Estimate(EE)	1	$7,500	$7,500
Detector PCB Layout (hours)	Historical Quote(HC)	40	$50	$2,000
Detector PCB Fabrication (minimum)	HC	6	$250	$1,500
Calibrated Gas Samples	HC	1	$3,000	$3,000
SECOND BUDGET PERIOD (LAST 6 MONTHS)				
Beechcraft A36 Bonanza Flight Test (hours)	HC	56	$300	$16,800
TOTAL DIRECT COST / OUTSIDE SERVICES				$30,800

Travel Costs

DESCRIPTION	TRAVELERS	NO. OF DAYS	NO. OF TRIPS	EST. COST PER TRIP	EST. TOTAL
FIRST BUDGET PERIOD (FIRST YEAR)					
From: Littleton, CO	1	3	2	$2,212	$4,424
To: Morgantown, WV					
Purpose of Trip(s): One Briefing and One					
Technical Paper					
SECOND BUDGET PERIOD					
From: Littleton, CO	1	3	1	$2,212	$2,212
To: Morgantown, WV					
Purpose of Trip: One Briefing					
From: Littleton, CO	3	7	2	$5,373	$10,746
To: Bismark, ND					
Purpose of Trip: Pipeline Flight Test					
TOTAL COST					$17,382

NOTE: Travel amounts proposed and incurred cannot exceed rates/amounts contained in the Federal Travel Regulations.

Project Risk Analysis

- Risk 1 – Insufficient Optical Return
  - Risk mitigation early in project
  - Risk mitigation throughout the project
- Risk 2 – Inability to Test Airborne System Over Variety of Surfaces
- Risk 3 – Inability to Test Leaks Around Underground Pipelines

Contact Information

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(303) 933-2200