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DEVELOPMENT OF AN EO WAVE IMAGING SYSTEM ON PELICAN, A REMOTELY PILOTED AIRCRAFT

PHILIP A. SELWYN
LAWRENCE JENDRO
GUY FARRUGGIA

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Areté Associates

P.O. BOX 16269, ARLINGTON, VIRGINIA 22215

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Philip Selwyn, Larry Jendro, Guy Farruggia

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Arete Associates
P. O. Box 16269
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13. ABSTRACT *(Maximum 200 words)*

In this report Areté proposes the development of an electro-optical wave imaging system and its installation on the Pelican remotely piloted aircraft. This system would collect a time series of electro-optical images over a precisely fixed area of the ocean to provide wave spectra which would be analyzed to determine important coastal ocean parameters such as bathymetry, wave characteristics and surface currents. The coastal-zone of the ocean is spatially and temporally complex, exhibiting a number of physical processes occurring simultaneously. Specific items of interest include ocean swell, wind-driven waves, mean and variance in turbulent fluxes, breaking waves and currents. In the coastal zone, the situation is complicated by significant spatial gradients that cause inhomogeneities on relatively small spatial scales. Although small on geophysical scales, these coastal features are too extensive and complex to be measured well by a small number of research vessels or buoys, yet they are too small and vary too rapidly to be measured by satellite sensors. What is needed is an instrument system that can measure many of the required parameters, but is small and lightweight so that it can be mounted in an aircraft and therefore cover a wide area of interest over relatively long span of time. Areté has determined that a system can be developed which uses an electro-optical sensor (digital camera) mounted in a remotely piloted aircraft (RPA) to collect wave spectra data which can be analyzed to provide information on waves, currents and coastal-zone Bathymetry. The camera and turret system proposed will be directly transferable to small UAVs such as the Predator. Upon completion of this development project the system will be immediately available for transition to military operational capability.

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Development of an EO Wave Imaging System on PELICAN, a Remotely Piloted Aircraft (RPA) Phase II Fast Track Planning

Philip Selwyn, Larry Jendro, and Guy Farruggia

Areté Associates

Presented to Bob Bluth, March 21, 1997

Updated May 30, 1997

Outline of Briefing

- Review of Phase I Progress
- Phase II Plan
  - Preliminary System Design
  - System Hardware
  - Timeline Milestone Chart
  - Cost Breakdown
  - GFE Items
  - Phase II Testing
- Arete's Unique Strengths
- Transition Planning

RPA Optical Remote Sensor

- Objective: Provide Coastal Zone Wave Spectra Measurements
  - Promote Scientific Advances in Littoral Oceanography
  - Support Military Operations

SBIR Phase I Approach

- Define Objectives
- Develop Scientific Specifications
- Develop System Design Concept
- Specify System Hardware
- Determine Feasibility
- Produce Preliminary Design Drawings

Science Objectives:

- Coastal Wave Spectra Measurements
  - Space/time data for algorithm development
    - Littoral parameters: depth, waves, current
    - Detection of surface/submerged targets (mines+ obstacles)
  - Support experiments on shoaling waves and surf dynamics

Support for Military Ops.

- Expeditionary Forces
  - Landing zone bathymetry, wave & current determination
  - Detection of submerged objects (mines+ obstacles)
  - Responsively tasked by local commanders
- NAVOCEANO Data Collection
  - Responsive coverage.
  - Rapid, minimally intrusive, close-in surveys

Scientific System Specifications

- Determined by Real-world Experience with Related Projects
  - EO Data Collection & Analysis (Dugan, ARE)
  - Anamorphic Lens Development (Mc Lean, ART)
- Resolution of Ocean Waves Requires
  - Pixel size < 2 meters
  - Field of view > 2 km X 2 km
  - Sampling Rate > 4 images/second
  - Dwell = several 10's of seconds
  - Resolution 10-12 bits

Phase I Results

- RPA Optical Sensor is Feasible
  - Specifications developed
  - Preliminary design nearly complete
  - Integration engineering underway
  - Alternative development paths investigated
  - Optimum Plan for Phase II ready

Expected System Performance

- Nominal Geometry
  - 5.6 km orbit radius
  - 2.8 km altitude
  - 35 km circumference
  - 7.8 minute orbits
- Performance
  - Pixel size ~ 2m
  - FOV 2km X 2km
  - Sample Rate 4 - 8 Hz
  - Dwell Time 10s secs.
  - Resolution 10-12 bits

Phase II Proposal

- System Description
- Equipment Procurement
- Time Line/Milestones
- Cost Estimate

System Hardware

- Gimbaled Platform requirements
- DAQ System
- Camera Design Specifications
- Pelican Mechanical Interfaces
- Pelican Electrical Interfaces

System Hardware

- Gimbaled Platform requirements
  - Stable platform-Wescam Model 14
    - 14" dia. gimbal
    - 160 microrad RMS jitter
  - Pointing system requirements
    - Absolute - 10 pixel registration, 1.6 mrad heading, 3.2 mrad roll
    - Relative - 160 microrad heading, 320 microrad roll
    - Dwell - Several 10s of seconds

System Hardware

- DAQ System
  - Data rate:~16.8 Mbytes/sec
  - Data storage: 38 Gbytes
  - Data recording capacity, 30-60 minutes
  - Mission length 1-4 hours depending on: duty cycle, image rate

System Hardware

- Camera Design Specifications
  - Specific camera TBD
    - 12 bits
    - 4 Hz
    - 1024X1024 pixels
  - 2:1 anamorphic lens
    - 18 deg Azimuth X 9 deg Elevation FOV

System Hardware

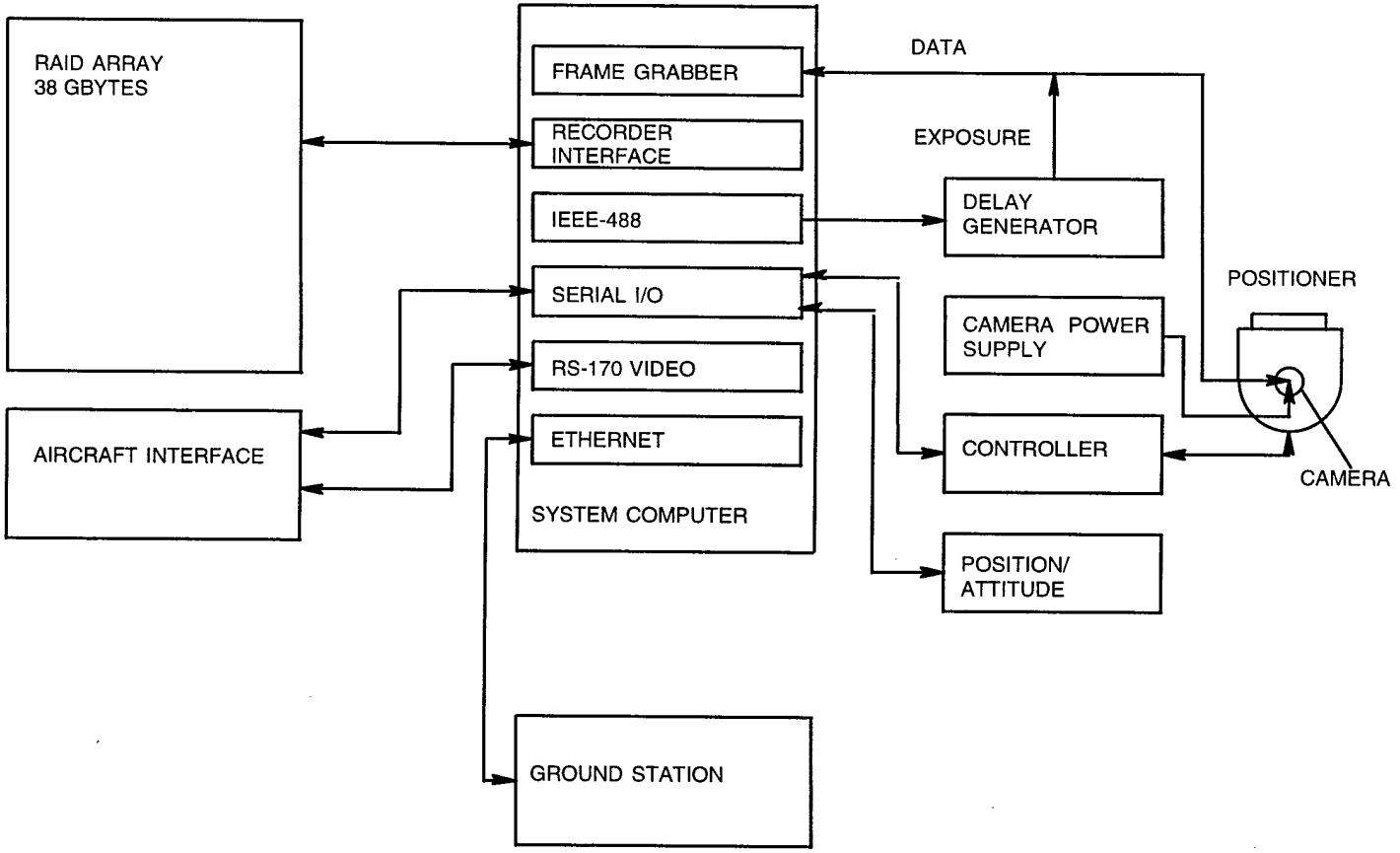
- Pelican Mechanical Interfaces
  - Hardware location specified
    - System design meets payload specifications
      - Maximum allowable ~300 lb.
    - Nose-cone GFE
    - Mounting fabrication GFE from Arete design drawings

System Hardware

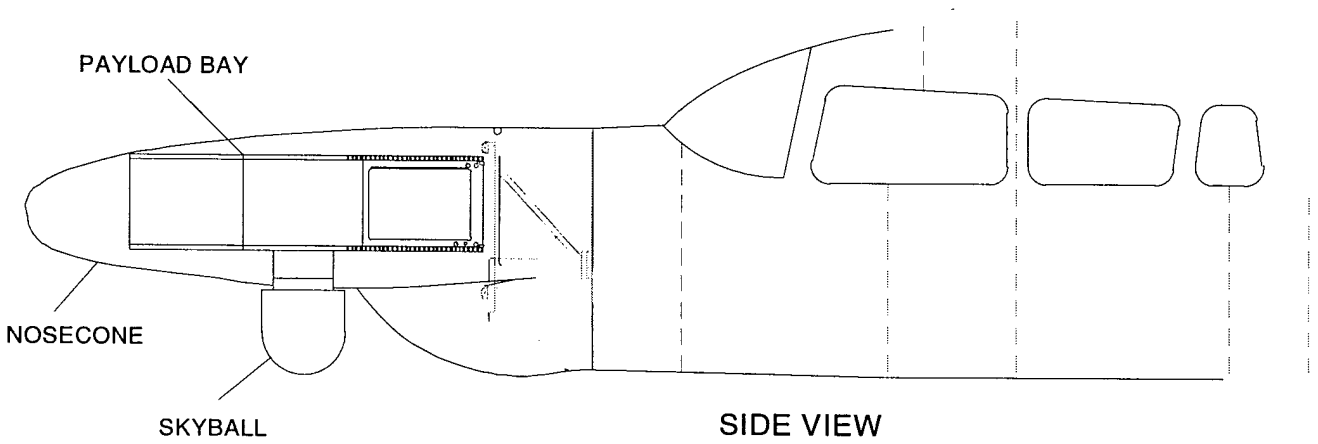
- Pelican Electrical Interfaces
  - System power provided from auto-pilot 28 vdc
  - AC power derived from 800 watt inverter (Arete supplied)
  - Serial data stream obtained from Pelican DAQ (RS-422, 1 Hz rate)
    - Lat, Long, Alt, Time, Pitch, Roll, Vel, Heading, True Airspeed

Hardware Configuration

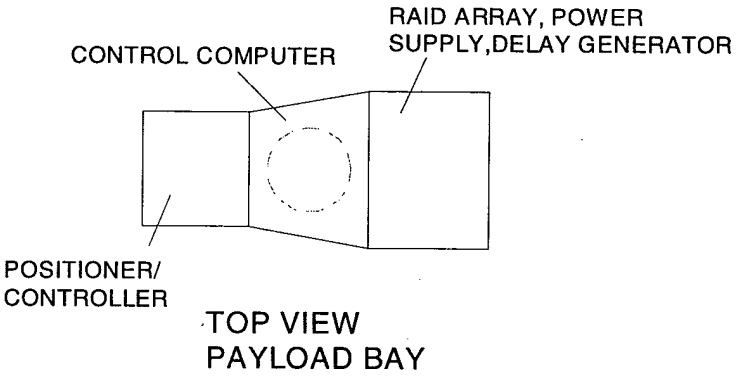
PELICAN PASSIVE OPTICAL SENSOR



Camera System Installation



SIDE VIEW



TOP VIEW
PAYLOAD BAY

TOTAL PAYLOAD INCLUDING MOUNTING FIXTURE = 268 LBS.

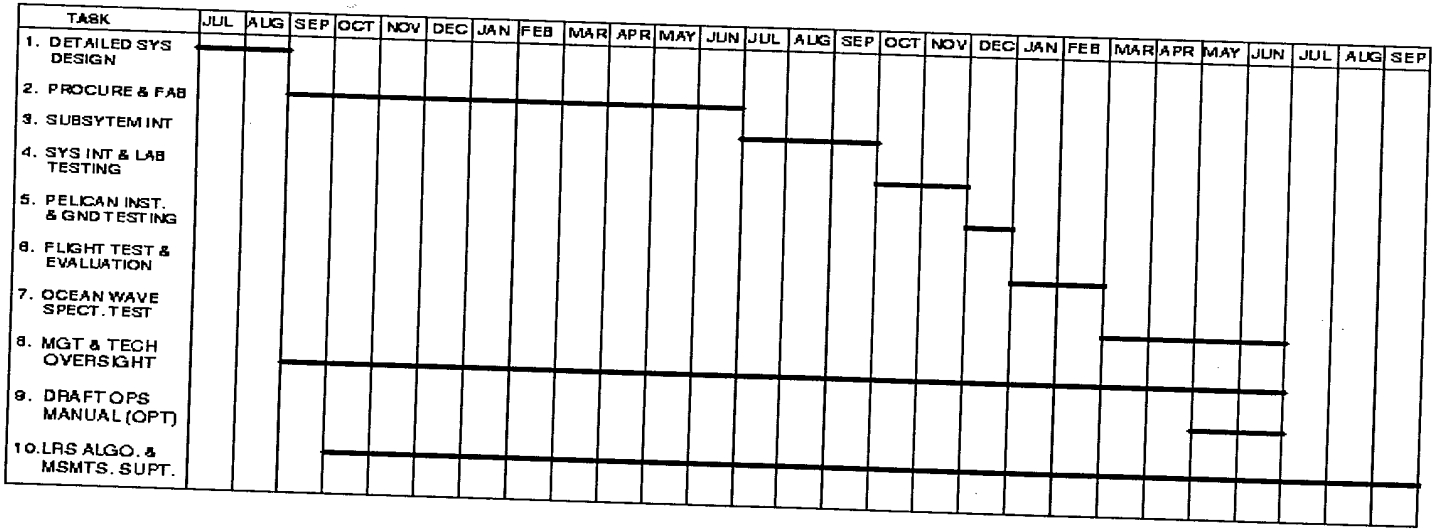
MAXIMUM ALLOWABLE LOAD AT 28.4" CG ~ 320 LBS.

Program Plan

1. Detailed Design
2. Procure & Fabricate
3. Subsystem Integration
4. System Integration & Lab Characterization
5. Pelican Integration & Ground Testing
6. Flight Test & Evaluation
7. Ocean Wave Spectrum Test
8. Management & Technical Oversight
9. Option (Create System Documentation)
10. Algorithm and data analysis software development and coastal oceanography measurements support (LRS Program Fast Track Co-Sponsor task).

Milestone Chart

PHASE II MILESTONE CHART



GFE Items

Name	Part # /Description	Estimated Cost	Required Delivery Date
PELICAN NOSE-CONE	Engineering Preparation of *Pelican*	Separately Funded	Completed by CIRPAS by 1 April, '98
IMU	30134-533-X	$25 K	1 Oct. '97
TURRET	VERSATRON MODEL 14	$ 160 K	1 Oct. '97
DIGITAL CAMERA	TBD In Detailed Design	$ 15 K	1 Nov. '97

Consultants/Subcontractors

- WESCAM/VERSATRON
  - Pointing system integration
- Mel Wieting
  - Optics Engineeer
- SA&C
  - Servo control loop for precise geodetic positioning

Detailed Task/Cost Breakdown

1. Detailed Design (Phase I Option)	113K
2. Procure & Fabricate **Camera System** **DAQ System** **Skyball** Positioner Miscellaneous Wescam Subcontract **IMU Unit**	322K
3. Subsystem Integration	51K
4. System Integration & Lab Char	34K
5. Pelican Install & Ground Testing	34K
6. Flight Test & Evaluation	53K
7. Ocean Wave Spectrum Test	98K
8. Management & Technical Oversight	45K
10. LRS Algorithm & Measurements Support (Contribution by ONR's Littoral Remote Sensing Program, SBIR Phase II Fast Track Co-sponsor)	550K
Total	1300K
9. Option: Create System Documentation	60K

Phase II Final Exam

- Locate precise points on the ground
- Image coastal ocean at instrumented buoy with specified spatial resolution and dwell
  - Analyze EO data for ocean parameters
  - Compare with buoy ground-truth
- Demonstrate capability to extract bathymetry from EO sensor data, obtained during Littoral Remote Sensing Program coastal measurements

Arete's Unique Strengths I

- Expert Key Personnel
  - John Dugan (Ocean Remote Sensing)
  - John McLean (Optics Engineering)
  - Guy Farruggia (System Engineering)
  - Larry Jendro (Management)

Arete's Unique Strengths II

- Ongoing Synergistic Research
  - EO Ocean Simulation
  - EO Data Collection & Analysis project
  - Development of Anamorphic Camera
  - Littoral Remote Sensing Research
  - STIL Design, Fabrication and Testing
  - STIL Aircraft Integration
  - Littoral Zone Ground-truth Capabilities
    - SCAMP
    - ATV

Transition Planning

- Immediate implementation into ONR's Littoral Remote Sensing (LRS) Program (SBIR Phase II Fast Track Co-sponsor)
- Military Ops. Support
  - Design facilitates transition to "Predator"
  - Expeditionary Force,
  - NAVOCEANO
  - Across the beach Logistics
- Broad-brush Rapid Hydrography
- Environmental Protection Coastal Studies