

REPORT DOCUMENTATION PAGE			<i>Form Approved</i> OMB No. 0704-0188		
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1. REPORT DATE (DD-MM-YYYY) 19-03-2017		2. REPORT TYPE Conference Technical Paper		3. DATES COVERED (From - To) 19 Mar 2009 – 26 July 2010	
4. TITLE AND SUBTITLE Binocular Multispectral Adaptive Imaging System (BMAIS)			5a. CONTRACT NUMBER FA8650-10-C-6109		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER 65502F		
6. AUTHOR(S) Wesley Sheridan			5d. PROJECT NUMBER 3005		
			5e. TASK NUMBER RC		
			5f. WORK UNIT NUMBER H02N (3005RC42)		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Sage Technologies Ltd 1 Ivybrook Blvd Ste 190 Warminster PA 18974-1779			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Materiel Command Air Force Research Laboratory 711 Human Performance Wing, Airman Systems Directorate Warfighter Interface Division, Battlespace Visualization Branch Wright-Patterson AFB OH 45433-7022			10. SPONSOR/MONITOR'S ACRONYM(S) USAF AFMC 711 HPW/RHCV		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION / AVAILABILITY STATEMENT DISTRIBUTION STATEMENT A. Approved for public release: distribution is unlimited.					
13. SUPPLEMENTARY NOTES 88ABW Cleared 7/19/2010; 88ABW-2010-3866. Report contains color. Conference proceedings of the Institute for Defense & Government Advancement (IDGA) Night Vision Summit held in Arlington VA on 26 July 2010.					
14. ABSTRACT The Binocular Multispectral Adaptive Imaging System (BMAIS) is being developed as a replacement for night vision goggles that will also facilitate the integration of other sensor and systems that are part of the pilot's situational awareness in the cockpit and overall mission operational environment. The development approach is structured to accommodate the technology advances of the sensors and displays in order to realize the performance enhancements afforded by the technology evolution in those respective areas. BMAIS is a binocular helmet mounted imaging system that features dual shortwave infrared (SWIR) cameras, embedded image processors and dual electronic displays to present the imagery to the pilot. The system is ergonomically designed to be light weight with a component distribution to minimize the moment arm on the helmet. The unit supports sophisticated image processing with adaptive fusion, and the integration of external aircraft systems to include sensor imagery, embedded symbology and other aircraft/mission data. The system is fully digital allowing image enhancement algorithms and fusion of other sensor sites such as forward looking infrared (FLIR) and other aircraft subsystems. BMAIS is attached to the helmet via the standard banana clip on the HGU-55/P helmet.					
15. SUBJECT TERMS Binocular Multispectral Adaptive Imaging System, BMAIS, Shortwave Infrared, SWIR, Alternative Night/day Imaging Technologies, ANIT, Aircraft Helmet Image System, Digital Helmet Mounted Display, DHMD					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			Darrel G. Hopper
			SAR	30	19b. TELEPHONE NUMBER (include area code)

Binocular Multispectral Adaptive Imaging System (BMAIS)

Wesley Sheridan

Sage Technologies Ltd, 1 Ivybrook Blvd Ste 190, Warminster PA 18974-1779

This is a reprint of a paper by Sage Technologies Ltd (STL) and included in the proceedings of the Institute for Defense & Government Advancement (IDGA) Night Vision Summit held in Arlington VA on 26 July 2010. This work was performed under SBIR Phase I and II contracts FA8650-09-M-6960 and FA8650-10-C-6109 awarded to STL under the “AF083-015 Binocular Multispectral Imaging System (BMAIS)” program.

Key BMAIS requirements from the topic addressed by STL in this paper include:

Binocular (VNIR) SWIR System 40° FOV

100% Overlap with 1:1 magnification

Image Resolution:

Threshold 640 x 512 px

Intermediate 1280 x 1024 px

Objective 2560 x 2048 px

Frame Rate: 30 to 60 Hz (threshold to objective)

Supports inputs from aircraft-mounted sensors & computers

Space, Weight, Ergonomics & Power (SWEP):

Consistent with combat pilot helmet-mounted system

Mounts on standard aircrew helmet (HGU-55/P)

Night Vision Technology Application

Binocular Multispectral Adaptive Imaging System (BMAIS)

26 July 2010

Wesley Sheridan, Principal Engineer

Sage Technologies



BMAIS

Sponsor: SBIR contract, (FA8650-10-C-6109)

Wright Patterson Air Force Base

TPOC: Dr. Darrel Hopper, WPAFB

Human Effectiveness Directorate
Department of the Air Force
Wright-Patterson Air Force Base

Completed Phase I SBIR – December 2009

Initiated Phase II contract – May 2010



BMAIS

Objective:

Develop a helmet-mounted display (HMD) system for pilots that adaptively integrates shortwave infrared (SWIR), visible, near-IR (NIR), off-head thermal, and computer symbology/imagery into fused visualizations.

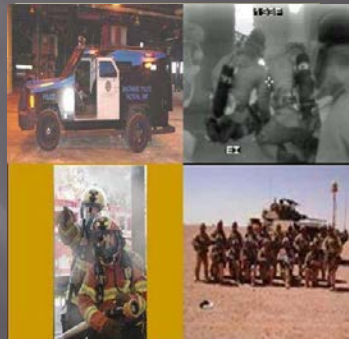
Goal:

Create and develop a revolutionary pilot HMD visualization system via a spiral development process leveraging recent advances in imaging sensors, fusion algorithms, and supercomputing processors.



Corporate Profile

- Veteran Owned small business incorporated over 25 years ago
- System Design and Integration (SDI) of infrared thermal imaging cameras, encrypted wireless digital video, and remote monitoring displays for military, night vision, security, law enforcement & surveillance applications.
- Provides System Engineering Services, Product Design, development and production
- System Engineering and Life Cycle Support for the Executive Transport Helicopter



Products that Reduce Warfighter vulnerability by improving Situational Awareness



LOW POWER ENVIRONMENTALLY HARDENED PORTABLE VISION ENHANCEMENT SYSTEMS

INTEGRATION OF VIDEO, LONG WAVE INFRARED (LWIR), AND SHORT WAVE INFRARED (SWIR) SENSOR TECHNOLOGIES

DEVELOPED SENSOR SHARING MODES THROUGH WIDE BAND DIGITAL WIRELESS COMMUNICATIONS



Presidential Helicopter

AVIONICS ENGINEERING SUPPORT



VH-3D



VH-60

VH Program (1986 - 2010)

NAVIGATION AND COMMUNICATIONS

COMPUTER SYSTEM

SYSTEM INTERFACES

SOFTWARE DESIGN

RADIO DESIGN

SIMULATORS

CONTROL PANELS



Development Partners

Goodrich Corporation
Sarnoff
Gentex

SWIR Camera
Image Processing
Mounting, Ergonomics



BMAIS

What Are We Doing?

Replace Night Vision Goggles for pilots

Why?

NVGs don't always work.

They require a compatible cockpit for use.

NVGs are not readily integrated.

Preliminary analysis shows that more favorable
size/weight/moment arm can be achieved
with new solid state technology

SWIR vs. NVG effectivity



BMAIS

Requirements

Binocular (VNIR) SWIR System

40° FOV

100% Overlap with 1:1 magnification

Resolution

Threshold 640 x 512

Intermediate 1280 x 1024

Objective 2560 x 2048

Mounts on standard aircrew helmet (HGU-55/P)

Supports computer input/other A/C systems



BMAIS – Phase II Application Development

Principle Effort:

Develop an Evaluation Tool to support the utility and effectiveness assessments of SWIR technology based imaging in the cockpit.

Support the experimentation and assessment of “SWIRology” as a means to broaden the application and effectiveness of night vision assisted systems, including the dusk/dawn transition phases of operational scenarios.

Ultimate Goal:

Replace the NVG with SWIR based imaging technology.



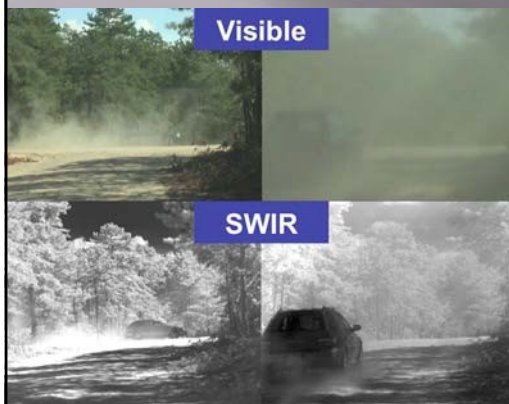
BMAIS

Why SWIR?

- Emergence of small, light weight and relatively low power sensors
- Range of response and extended response across the NIR and Vis bands of operation
- Wide dynamic range that can provide imagery from minimal night illumination to day light conditions
- Functional in situations that compromise NVGs such as: dust, fog, ambient light
- Imagery that is digitally based and can support image fusion efforts as well as inter system integration
- Potential for higher resolution, lower power, faster response without significant impact on size and weight



BMAIS - SWIR SENSOR COMPARISONS



Photos Courtesy Goodrich



Littleton, et. al.



Dynamic Range Example

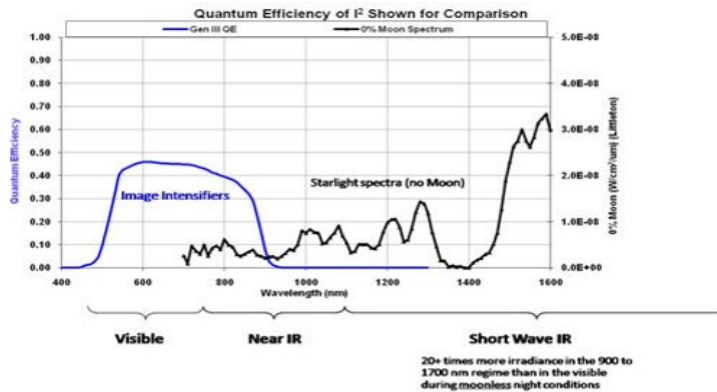
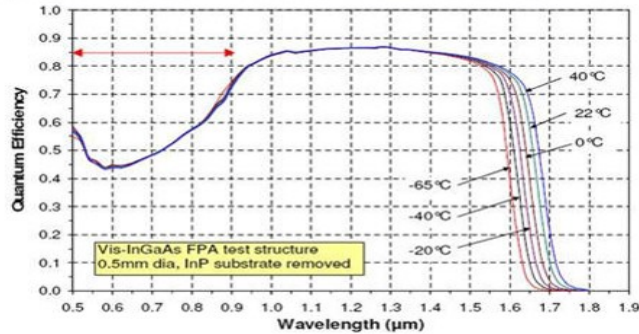


Figure 19: Night Sky Illumination Comparison of a Gen III I²QE to the measured night sky spectrum (Littleton). Visible, Near IR, and Short Wave IR spectral

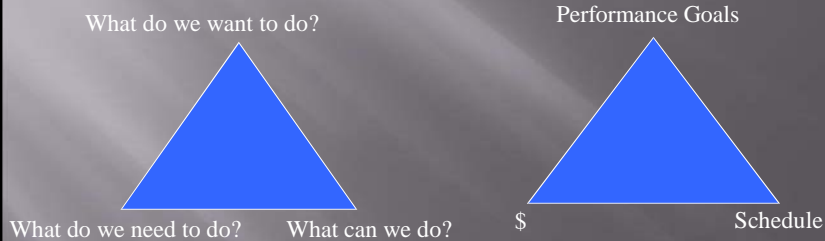


BMAIS

Why not just build a SWIR based NVG?

Application development is about 3-legged stools

Balance the goals vs. Constraints



BMAIS Functional Elements

It is not just the technology

Subsystems

- SWIR
- Processor
- Image Processing
- Display
- Controls/Updates/Expandability

SWEPI (Size/Weight/Ergonomics/Power/Integration)

- Mounting Concept
- Moment Arm
- Stowage/Deployment
- Design Concept
- User Adjustments



BMAIS

Requirements

Binocular (VNIR) SWIR System

40° FOV

100% Overlap with 1:1 magnification

Resolution

Threshold 640 x 512

Intermediate 1280 x 1024

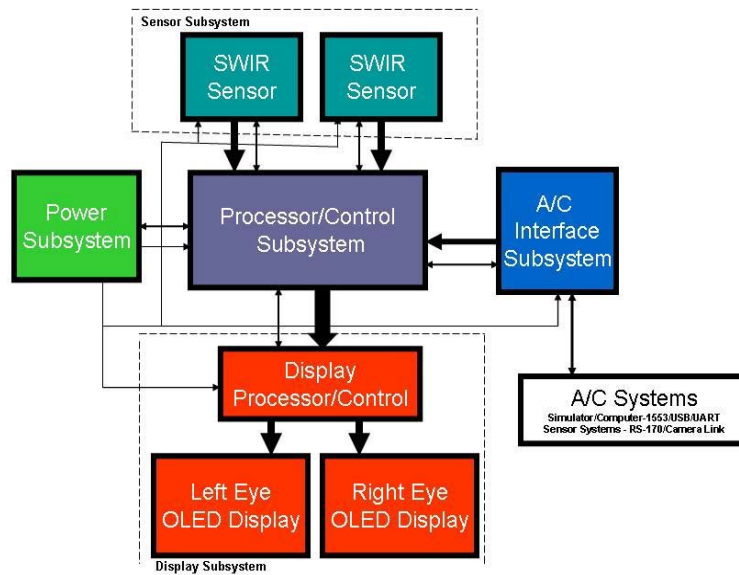
Objective 2560 x 2048

Mounts on standard aircrew helmet (HGU-55/P)

Supports computer input/other A/C systems



BMAIS SYSTEM BLOCK DIAGRAM



SWIR CAMERA

Subsystem:
SWIR
Processor
Image Processing
Display
Controls

Candidate Matrix – Substantial number of Cameras

Availability Filter

Threshold Performance (640 x 512)

SWEPI CRITERIA

- Suitable for Binocular
Helmet Mounted Application



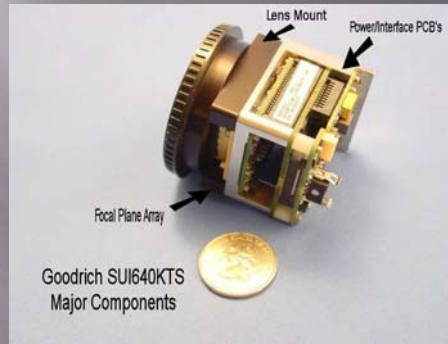
SWIR Camera

Preferred Options: (Size/Weight/Power advantages)

Resolution
Responsivity
Dynamic Range
Cockpit Compatibility
Near/Far Focus
Lighting
Colors



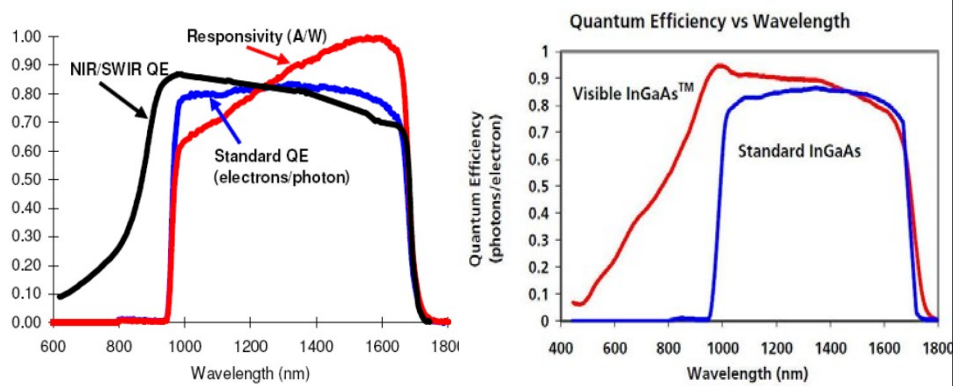
SWIR Camera Candidate



- Seeing in the light of night glow or night sky radiance
- Day-to-night imaging
- Covert illumination
- Able to see covert lasers and beacons
- 640 x 512 resolution
- Small size (2" x 2" x 1")
- Lowpower (~2W)



Vis/NIR/SWIR Spectral Response



Goodrich SWIR Camera



SWIR Candidate Performance Specifications

Goodrich – SU640KTSX-DR1-NIR-1.7R/RS170

Format	640 x 512
Pitch	25 μ m
Spectral Response	600nm – 1700nm
Mean Detectivity ($\text{cm}^*\sqrt{\text{Hz/W}}$)	$>1.5 \times 10^{13}$
Noise Equivalent Irradiance (photons/ $\text{cm}^2 \cdot \text{s}$)	$<8 \times 10^8$
Noise (rms, electrons)	<125
Full Well (electrons)	1700k
Camera Core Size (MM)	42 x 38 x 41
Weight (g)	<90
Power (W)	2.5 - 6.0



SWIR Camera – Adaptation Potential

Interfaces:

RS-170
CameraLink®

PCB Stack:

Unstack for mass redistribution

Power Management:

Restrict operating environment
Project use in TEC less configuration



SWIR Camera - Futures

Multiple 1280x1024 cameras in development

Reduced pixel size will afford similar size to 640x512

Lower power with scaled back or eliminated TEC

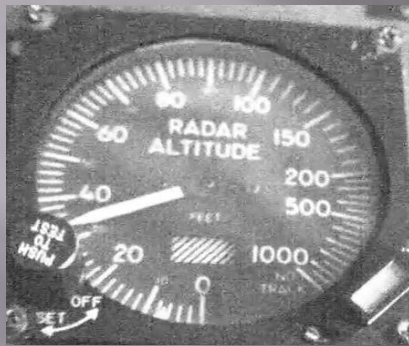
Decreased weight

Provide interface options to reduce board stack requirements

Potential to replace Electronics and Firmware with ACADIA Interface and Processing to reduce size/weight/power by eliminating redundant functions



SWIR vs. Visible Image



SWIR Camera (320x240 Res)
Minimum External Illumination



Visible Camera



BMAIS Processor

Subsystem:
SWIR
Processor
Image Processing
Display
Controls

ACADIA® II SOC is an advanced vision processing technology by Sarnoff, developed with support by DARPA under the MANTIS program.



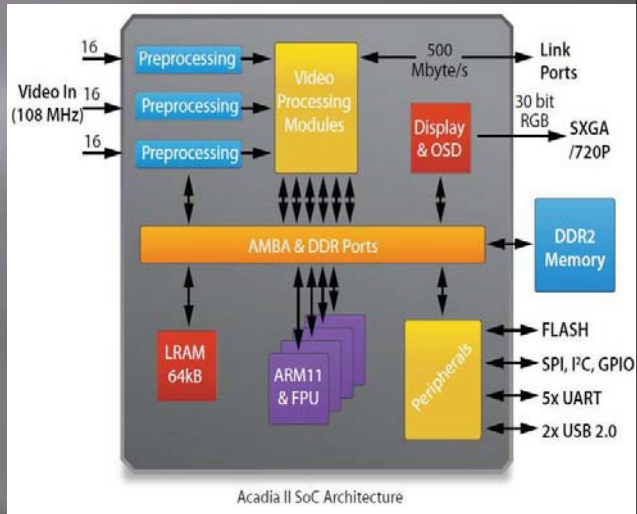
Capabilities:

- Three channel, pattern-selective adaptive fusion for night vision
- Real-time, low latency processing
- Full color, full resolution processing (up to 1280x1024 and 30/60Hz)
- Robust stabilization, multiple alignment models up to 1/10 of a pixel accuracy
- 1280x1024 RGB video output with on-screen display processor
- Four ARM®11 300MHz floating-point processors



Acadia II Mezzanine PCB

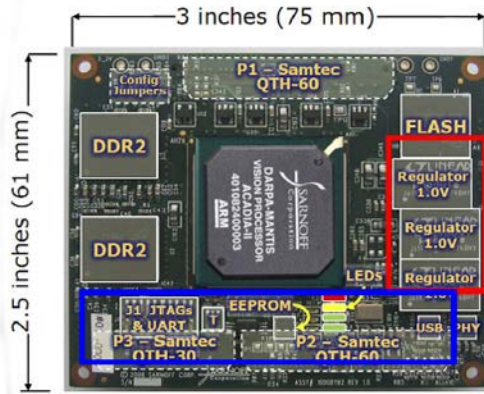
- For BMAIS:
- Low Power (<1W to 4W)
- 3 Digital Video Input Ports
- Video Output Port (30 Bit RGB)
- USB Port
- UART
- I²C



Acadia II SoC Architecture



Acadia II Vision Module (Mezzanine Card)



P1-3 (Samtec) Connectors Provide:

- Power, Ground
- Clocks, Resets
- Video Inputs and Output
- I²C, SPI, and USB buses
- Link ports

J1 (Debug) Connector Provides:

- One UART connection
- Two JTAG interfaces
 - One for the ARM11TM MPCore™ debug port
 - One for the Acadia II SOC test port

- On-board Flash, EEPROM, and DDR2
- High-speed DDR2 Signal Routes Solved
- Runs applications right "out of the box"
- Available for prototyping or production

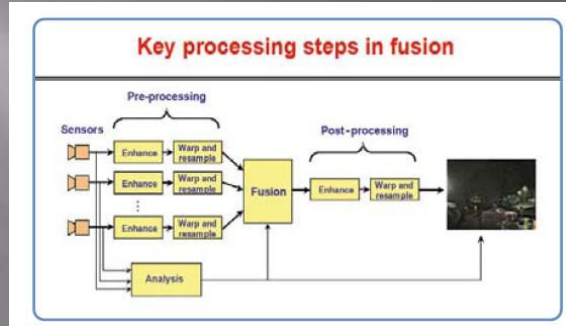


BMAIS Processor

ACADIA II Mezzanine PCB (Part of Development Board)
Sarnoff/ACADIA Software/Algorithm Support Package
VxWorks Kernel with the Software Package
VxWorks Development Station to be Acquired for BMAIS
Custom Functions
Microprocessor/Controller to Support ACADIA Control/
Monitoring, External Communications, Boot-Up
Configuration Control



Processor - Acadia II Fusion & Stabilization



Pre-processing

- Noise Reduction
- Histogram Normalization
- Geometric Correction – translation, rotation, zooming or shearing (align to 1/10 pixel)
- Stabilization – balance shaky imagery

Analysis – automatic adjustment of imagery based on real-time statistics

Fusion – Combine “best information” from all sources

Post-processing – Optimize contrast to match image display

Speed – full frame rate 30 to 60 frames per second (~ 2 frames latency)



BMAIS Processor Futures

Readily Supports the Intermediate Level Performance Requirements:

1280 x 1024 Imagers

1280 x 1024 Displays

Excess processing capacity (4 ARMs)

Ongoing Image Processing Development

Objective Level :

2048 x 2048 at reduced frame rate



ACADIA Processing Functions

Subsystem:
SWIR
Processor
Image Processing
Display
Controls

- Optimized Processing Functions*
- Contrast Normalization (CN)*
 - Flat Field Correction*
 - Noise Reduction*
 - Warping*
 - Histograms*
 - Bayer Conversion*
 - Output Color Correction*



Acadia II Automatic Detection & Tracking



- Accuracy** – down to 20 pixel targets
- Filtered Imagery** – resilient to sensor and environmental clutter and captures imagery at multiple scales (SWIR, Visible, LWIR)
- Image to Image Alignment** – compensates for operator helmet motion, detects residual motion
- Continuous Background Modeling** – maintains robustness
- Disparity Detection & Verification** – perceives differences between two aligned images, and substantiates based on target appearance, size, shape, and motion characteristics.



BMAIS Custom Functions

Display Format and Drivers

OSD (On Screen Display) Support – Flight Data, Status, Alerts, Queues

External Interface Communications – Other Aircraft Data and Imagery Sources

System Controls/Operating Modes – Mission Specific Configurations and Processing Functions



Acadia II Processing Options

Parallax Correction

Unit can support a geometric correction algorithm that will provide the user with a display that presents an image on axis to the line of sight

Near Field Focus

Unit can implement Dynamic Multi-Modal Registration that allows automatic correction of overlap even at very close operating distances (2ft to 3ft)

Digital Zoom

A 2X to 4X digital zoom can be implemented with interpolation to allow a improved viewing of distant objects



BMAIS – Display Requirements

Subsystem:
 SWIR
 Processor
 Image Processing
 Display
 Controls

The minimum performance requirements are defined as follows:

- Binocular configuration
- 40°FOV with 100% overlap-1:1 magnification
- 640x512 format with symbology overlay or synthetic or augmented imagery
- 30 to 60Hz frame rate
- SWIR only with computer input capability

Augmented mid term and long term performance would be:
 1280x1024 to 2560x2048 pixels (20:20 in a 40°FOV)



BMAIS Display Candidates

Source	Type	Format	FOV	WT	Power	Interface
eMagin	OLED	852 x 600	42° with SVGA+ OLED	11g	200mW	RGB
Holoeye	LCoS	800 x 600	28° Lens Selectable	23g + lens	400mw +Illumination	RGB A or D
Lumus	Microdisplay Dependent (see through)	800 x 600	32° Expandable	70g	2-3W	RGB

Other candidates were also considered.

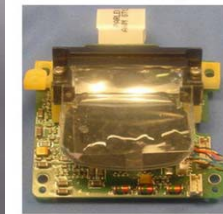


BMAIS Display Subsystem

Proposed:

eMagin 852 x 600 OLED with Prism Optic
39.5° FOV
22mm Focal Length

Drive From ACADIA
RGB
I²C



WF05 Prism Optic

- eMagin OLED
- 800x600 format
- Nominal 42° FOV
- 22mm Focal Length
- Less than 11g

Potential Problem:

Left-Right microdisplay drive
Could see 1 frame delay between the images



BMAIS Display Futures

Futures:

eMagin 1280 x 1024 OLED
Kopin 1280 x 1024 LCD
LCOS NTE & Projection Type
Other entries, e.g. mems based



Subsystem:
SWIR
Processor
Image Processing
Display
Controls

BMAIS SYSTEM CONTROLS

Operating Mode

- SWIR Only
- External Imaging
- Symbology Overlay (OSD)
- System Set-Up
- Status Monitor
- Display Brightness

System Set-Up

- Camera 1 - 2 Operating Parameters
- Symbology Programming
- ACADIA Processing Set-Up
- ACADIA Algorithm Updates



Operating Modes/Controls

PC based GUI driven set-up, control and status

Flexible
Scalable
Expandable
Legacy/Update Compatibility

BMAIS Control Unit

Portable Control Computer (MR-1)



1.8" x 6.6" x 4.8" – 2.4#
5.6" WSVGA display – outdoor viewable
80 GB HDD or 64 GB SSD
Wireless options Multiple
I/O configurations Sealed
keyboard, backlit
6 hour battery life MIL-STD
810F and 810G

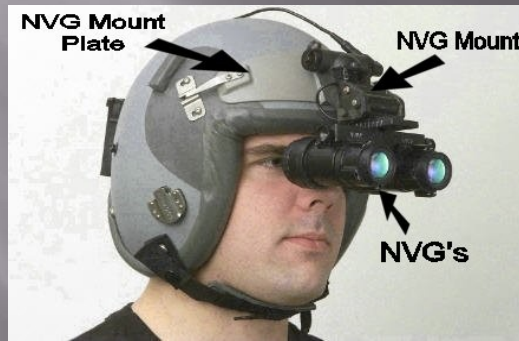


BMAIS Design Configuration Issues

Design Concepts
Section Views
Mass Distribution
Moment Arm Comparison
Cockpit Examples
Subunit Power/Weight Breakout



Example NVG Configuration



Design Concepts

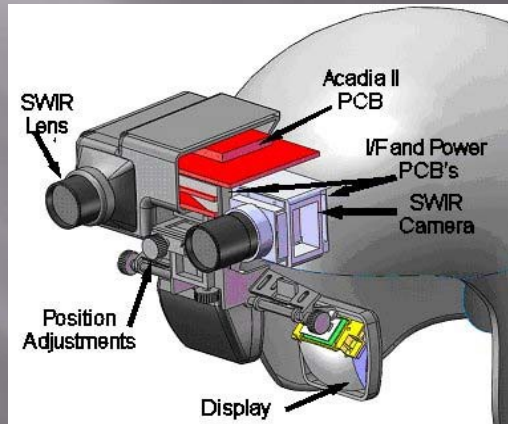
Proposal Concept:



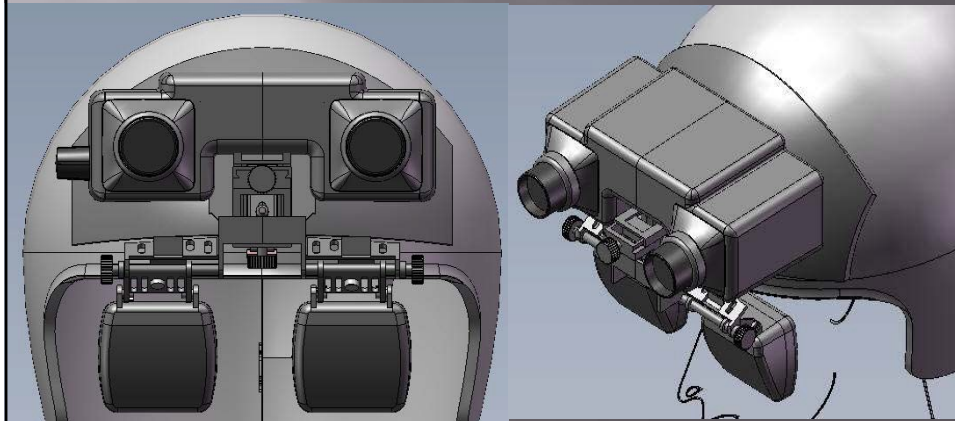
Alternative Concept:



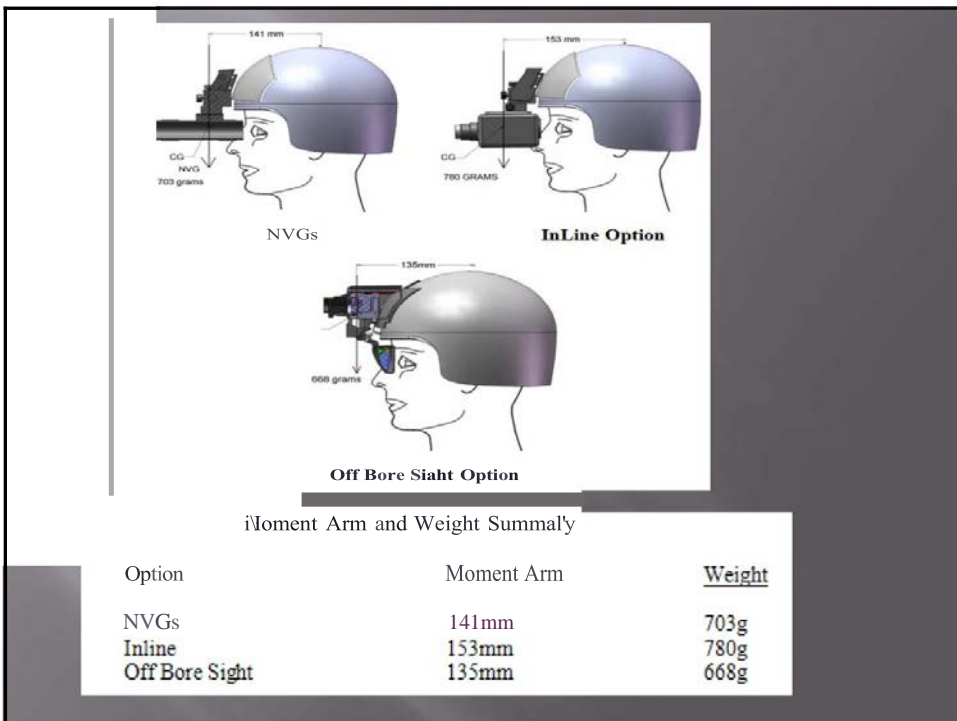
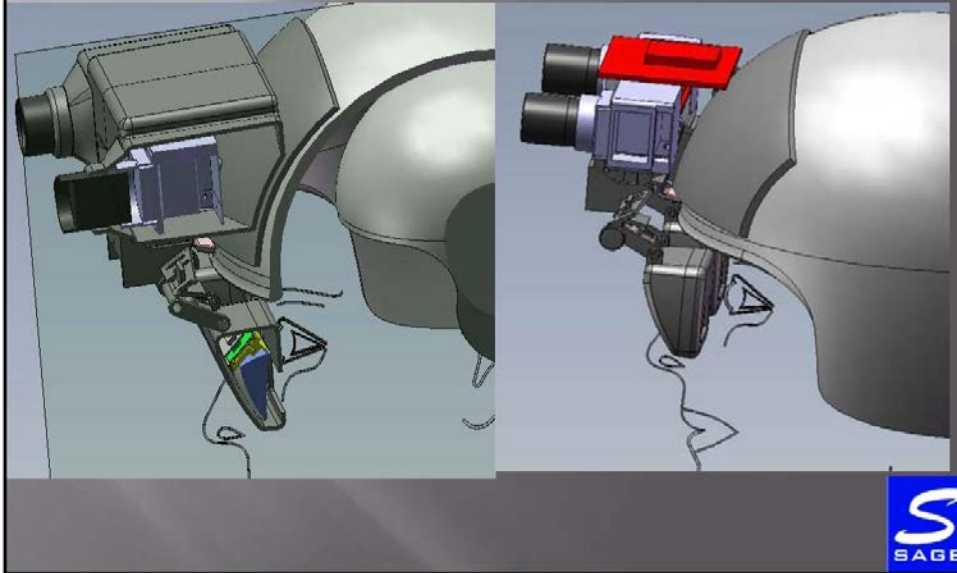
Concept Breakout



Subunit Distribution



Section Views



Futures/Ancillary Issues

- Evaluation Platform and Scenarios
- Cockpit Adaptation Issues
- Related Developments
 - SWIR Camera
 - ACADIA Development
 - Integration Issues
 - Alternative Display Implementations



CDU Keyboards – New / Old



CDU-800X-5

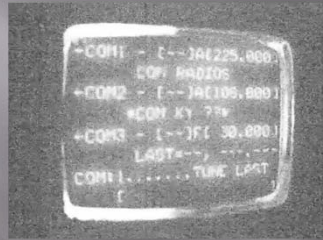


CCD-814-10

Minimal External Illumination (320x240 Res) w/SWIR



CDU Displays – Old / New



CCD-814-10



CDU-800X-5

No Illumination (320x240 Res) w/SWIR



BMAIS Physical Characteristics

<u>Sub-System/component</u>	<u>Weight(gm)</u>	<u>Power(mW)</u>
Front End Optics (2 each per)	120	0
SWIR Camera Core (2 each per)	160	4,200
Processing Board	43	1,000
Power/Interface PCB	20	800
Display Chip (2 each per)	32	400
Display optics (2 each per)	50	0
Housing	150	0
Mounting	60	0
TOTALS	635 (~22 ozs)	6,400



BMAIS – GENTEX Support

Helmet Issues

- 3D Model
- Variations in dimensions/mass distribution
- Ergonomic analyses/studies/recommendations
- Helmet model types and variances
- HMD provisions/problems/issues

Mounting Issues

- Incremental mass distribution
- Weight/balance studies
- Force analyses under operational scenarios
 - Maneuvering
 - Take off/landing
 - Ditching
 - Eject/bailout



BMAIS Challenges

- Unit packaging/mounting for minimum weight and moment arm
- Power consumption within small form factor
- Ability to control hyperstereopsis with image translation
- Frame delay between left/right image display
- 30 Hz response of SWIR camera in a highly dynamic environment
- Compatibility of cockpit instruments, gauges, displays, indicators

