



Insight Technology

***A Focus On Traditional
Night Vision: Our
Reliable Friend Has a
Powerful New Trick***

**9th NATO Military
Sensing Symposium**

May 30, 2017

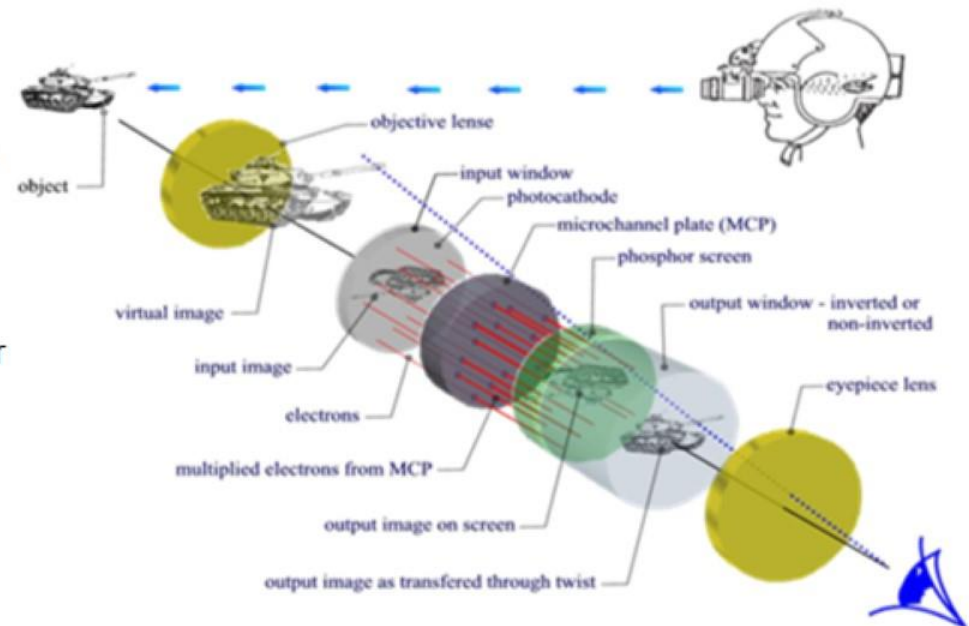
**This document consists of general capabilities information that is not defined
as controlled technical data under ITAR Part 120.10 or EAR Part 772
L3 Technologies, Inc.**

- Anatomy of a night vision system with a focus on Wide-FOV
- A few basic definitions
- Description of the primary design trades
 - Resolution, field of view, eye box, and eye relief with a nod to weight
- Survey of existing solutions ranging through this trade-space
 - The baseline 40° NVG
 - Ground Panoramic NVG (GPNVG)
 - Foveal NVG
- Image Intensification tube performance improvements & how we utilize them
- Using higher resolution to increase FOV
- Conclusions



Anatomy of a night vision system with a focus on Wide-FOV

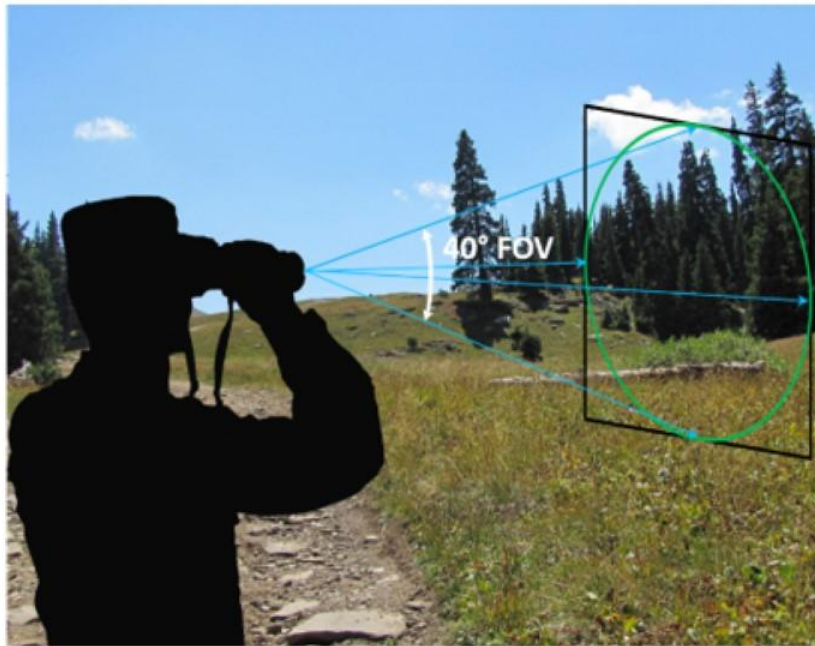
- Objective lens
 - Captures the scene and images it onto the input of the Image Intensification tube
 - Its size and weight are not negatively impacted by designing for additional FOV
 - Increasing FOV and maintaining current performance increases cost
 - You're designing it to do more
 - No time is spent in this presentation on the objective lens since its design options are not major system drivers
- Image Intensification (I^2) tube
 - Takes the image at its input and amplifies the light level making it significantly brighter (~60,000x)
 - When increasing the FOV, you have 3 options: decrease overall performance, decrease performance except for the very center of the FOV (foveal design), or significantly improve the I^2 tube
- Eyepiece lens
 - Captures the image at the output of the tube and projects it to the eye
 - Here is the biggest penalty of increasing FOV
 - You have the option of degrading many performance factors or increasing cost and weight



Estrera J. P., Ostromeck T., Bacarella A., Isbell W., Iosue M.J., Saldana M. and Beystrum T. (2003) Advanced Image Intensifier Night Vision System Technologies: Status and Summary, Proc. SPIE 4796, 49.

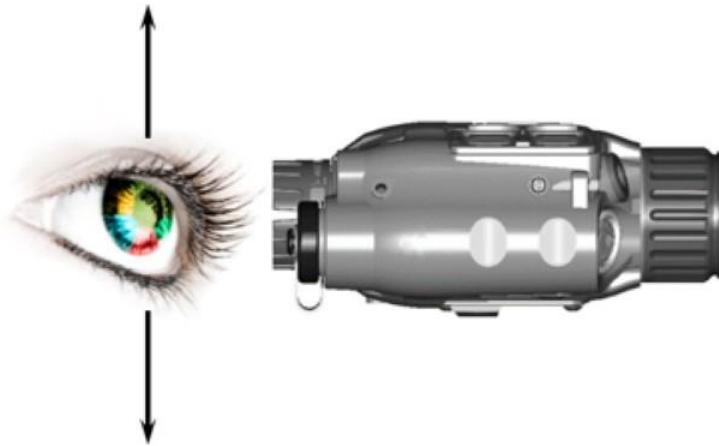
A few basic definitions

- Field Of View (FOV) – Describes how much of the world your image will include
- Resolution – Describes the amount of detail your image will have

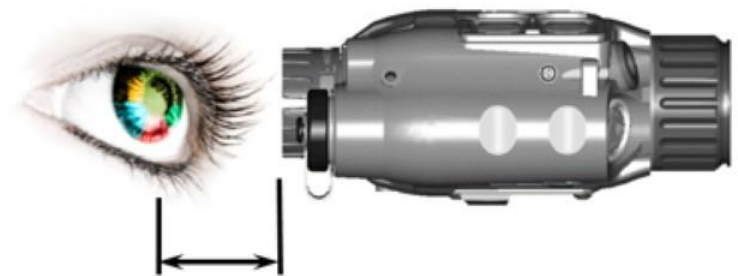


A few basic definitions

- Eye Box – Describes the amount of movement your eye can have while still comfortably viewing the image



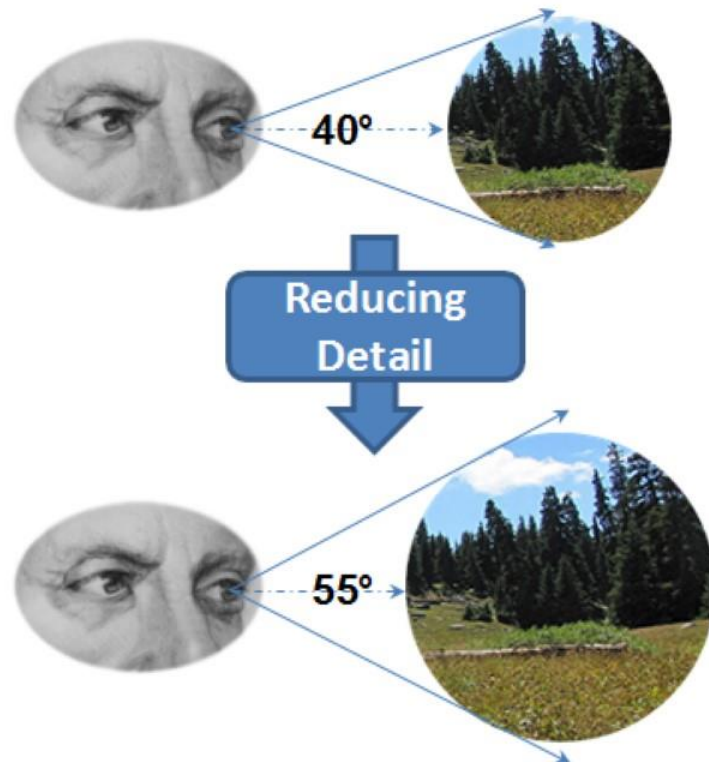
- Eye Relief Distance (ERD) – The distance from your eye to the closest lens



Description of the primary trades

1. FOV vs. resolution

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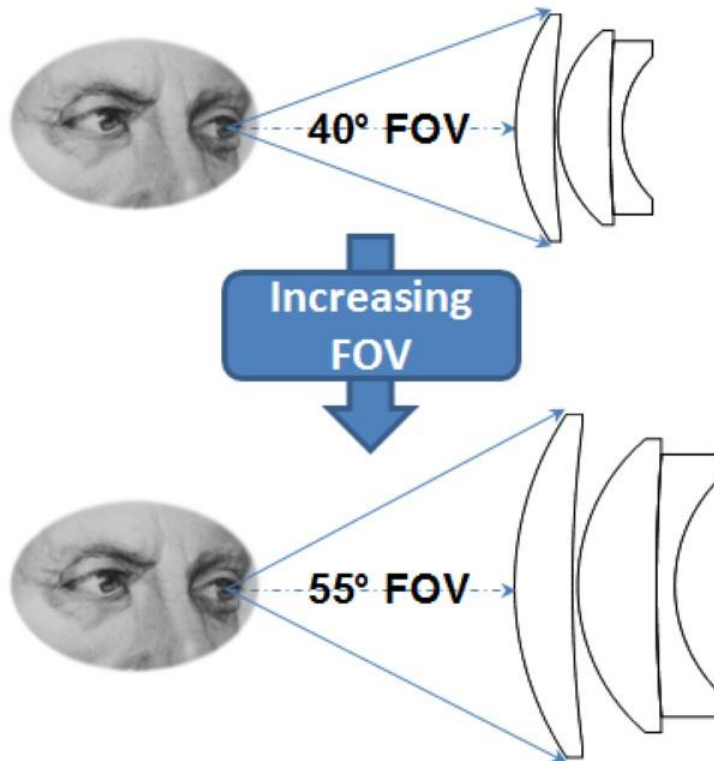


- As FOV increases, if sensor performance does not improve, the amount of detail seen will degrade
 - You're asking the same sensor to capture more information

Note: In this case, it's not a size/weight impact; it's performance. This means the ability to detect and identify is reduced for the sake of more situational awareness. Improving the sensor is necessary to maintain performance over larger fields of view.

Description of the primary trades

2. FOV vs. size and weight



- As FOV increases, the eyepiece lens diameter must increase in order to get the entire image to your eye
- Any 'cheat' to reduce this eyepiece growth comes with degraded eye box and/or eye relief
 - Reducing these values limit usability and therefore acceptance

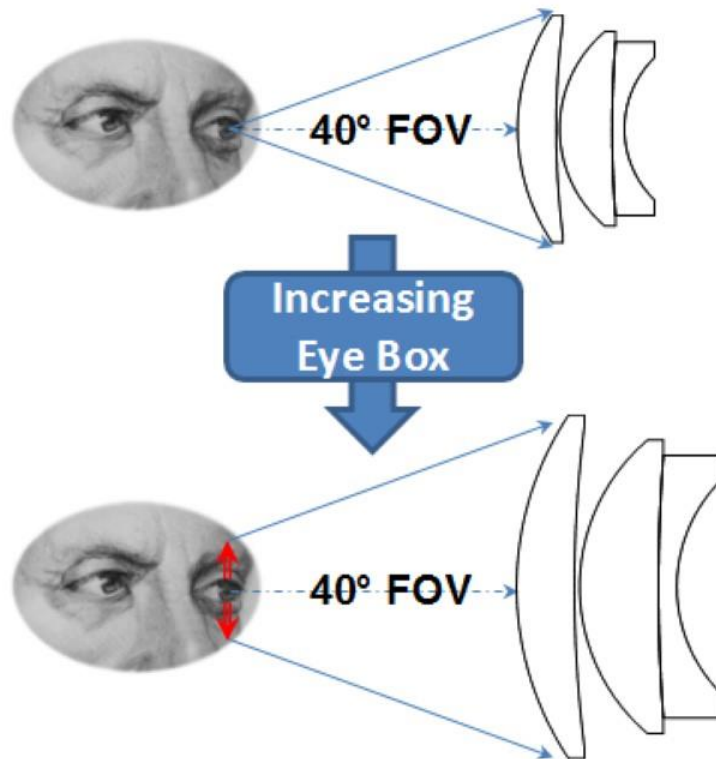
Note: These '*Description of the primary trades*' slides follow the same rules

- Only one design parameter is changing (FOV in this case), showing the impact on size and weight
- There is zero exaggeration: all images are accurately to scale

Description of the primary trades

3. Eye box vs. size and weight

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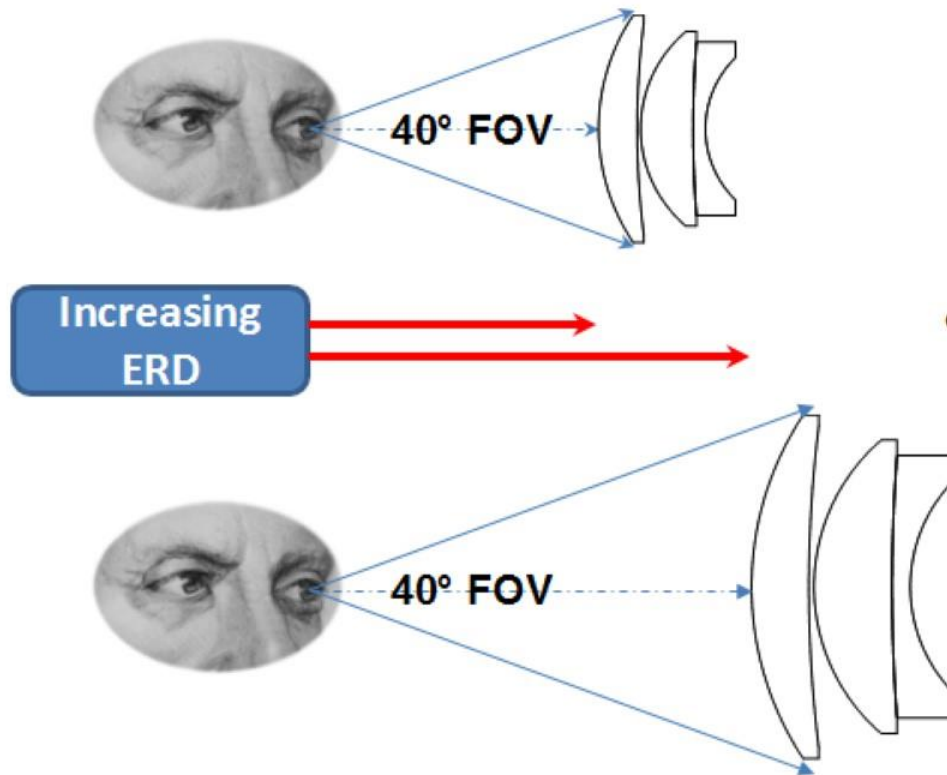
- As eye box increases, the eyepiece lens diameter must increase in order to get the entire image to your eye as it moves off center
- Reducing eye box is a way to claim back lens growth caused by increasing FOV
 - This is a risky trade, since a small eye box requires more precise alignment between the Operator and the NVG
 - This is fine for stabilized use, but problematic when mobile



Description of the primary trades

4. Eye relief vs. size and weight

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- As Eye Relief Distance increases, the eyepiece lens diameter must increase in order to get the entire image to your eye
- Reducing ERD is a way to claim back lens growth caused by increasing the FOV
 - This is a risky trade, since it impacts Operator comfort as well as the ability to wear PPE
 - If the NVG is worn outside its designed ERD, you won't see the larger FOV
 - So why bother?

- Specifications (AN/PVS-31A):
 - 40° circular FOV
 - ≥ 25 mm eye relief
 - < 450 grams (with AA battery)
- Pros
 - Cost
 - Weight
- Cons
 - Limited to 40° circular FOV



Existing Wide-FOV I² systems

1. Ground Panoramic NVG (GPNVG)

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- Specifications:
 - 97° horizontal x 40° vertical FOV
 - ≥ 25 mm eye relief
 - < 800 grams (without batteries)
- Pros
 - Performance
 - Central 40° region provides binocular image quality equal to the highest performance NVGs (AN/PVS-31A)
 - Periphery channels provide an extra 57° of non-binocular FOV with no loss of visual acuity
- Cons
 - Cost
 - These systems are over 3x the cost of 40° NVGs of identical performance
 - Weight

Note that there was an earlier variant for aviators (AN/AVS-10) utilizing 16mm tubes

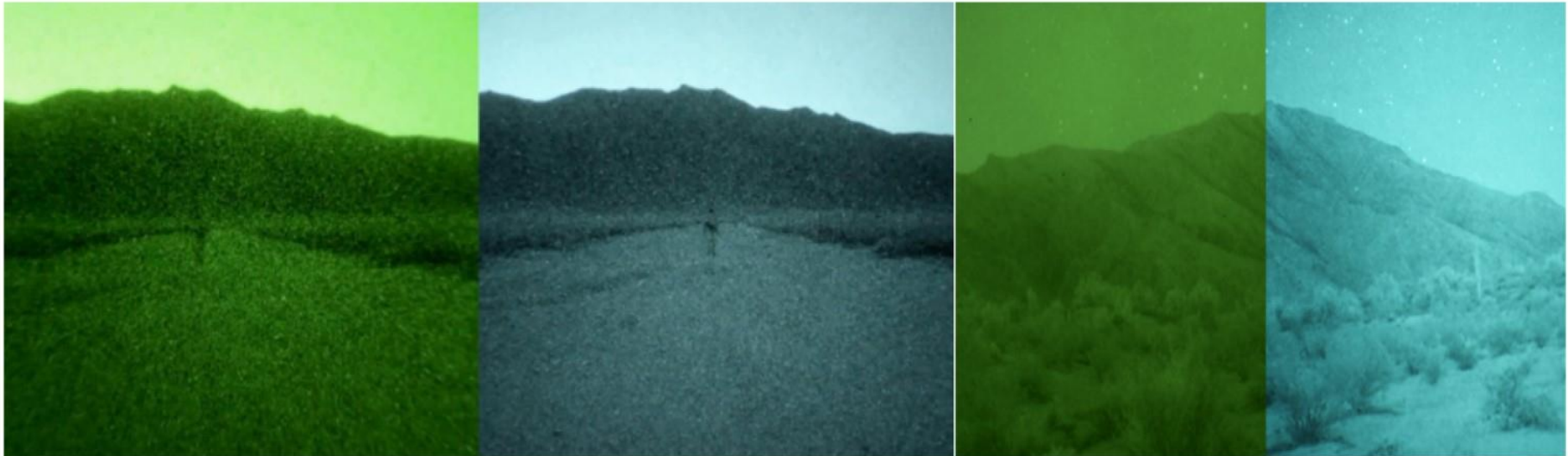


An example image is not shown since available images do not match user feedback

- Specifications:
 - 80° circular FOV
 - 15 mm eye relief
 - 676 grams (with AA battery)
- Pros
 - This technique provides additional FOV while still using a typical I² tube
- Cons
 - Eye relief
 - Full FOV eye relief does not allow for PPE use
 - FOV is limited to 56° at a 25 mm eye relief
- Somewhere in-between...
 - Performance
 - Image quality continues to degrade as you look beyond the center of the FOV
 - This matches the way the eye performs
 - The eye can rotate, but here the neck must pivot leading to additional fatigue
 - Cost
 - 2x a typical 40° FOV NVG
 - 1x a typical 40° FOV NVG cost if purchased as an upgrade kit for existing AN/PVS-15 goggles
 - Weight
 - 50% heavier (226 grams) than a 40° NVG (AN/PVS-31A)
 - 18% lighter (124 grams) than a 97° x 40° NVG (GPNVG)

I² tube performance improvements & how we utilize them

- Advanced material and process developments have resulted in significant tube resolution improvements
 - In 2008 the high performance tube benchmark was 64 lp/mm resolution
 - By 2012 production tubes were being delivered at 72 lp/mm
 - Currently, state-of-the-art in tube production is at 81 lp/mm
- Today's high resolution capability can be used to provide either:
 - Extended detection, recognition, and identification ranges
 - Replace your existing tube with a higher resolution tube to improve image clarity as shown in the images below
 - Increased FOV without sacrificing any detection, recognition, or identification performance
 - A new system must be designed to provide the additional FOV (objective and eyepiece lens costs increase)
 - A more limited improvement in both FOV & performance



Substantial image clarity improvements can be seen above when going from a 64 lp/mm green tube to an 81 lp/mm white tube. Panels at left show a standing man located at 50 meters (both zoomed equally). Images were captured simultaneously using two identical AN/PVS-14 systems under clear starlight (no moon) for direct side-by-side performance comparison.

Using higher resolution to increase FOV



Product is in late development.
Example images are not yet
available.

- Specifications:
 - 70° horizontal x 55° vertical FOV
 - ≥ 25 mm eye relief
 - <560 grams (with AA battery)
- Pros
 - Performance
 - Central 40° region provides binocular image matching AN/PVS-31 requirements
 - An extra 30° of non-binocular FOV is provided with no loss of visual acuity
 - Weight
 - This is the lightest Wide-FOV NVG known
 - 20% heavier than a 40° NVG
 - 20 % lighter than a 80° foveal NVG
 - 40% lighter than a 97° x 40° NVG
- Cons
- Somewhere in-between...
 - Cost
 - TBD, but may be 2x a typical 40° FOV NVG

This additional FOV does not come without a performance cost. Tubes have advanced to where a WFOV system can be designed to meet current 40° NVG requirements. But, tube improvements are driving actual 40° NVG performance markedly above their requirements.

- Increasing FOV, eye box, and/or eye relief increases eyepiece size and weight unless one of these other parameters is reduced to compensate
- Increasing FOV drives resolution (detection, recognition, and identification ranges) down unless both the tube and optics are improved (or in the case of GPNVG, weight is markedly increased)
 - Higher performing optics or adding additional tubes and optics will drive cost up 2x-3x
- Even with tube improvements, you will be left with the choice: Do you use screaming tubes to improve FOV or resolution?
- Many thanks to L3 Technologies Electron Tube Operations for driving tube performance to where we can discuss these system trades

