FINAL TECHNICAL REPORT

(3119041)

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Coherent Laser Vision System (CLVS)
Option Phase

Work Performed Under Contract:
DE-AR21-94MC31190

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Figures

1. CLVS System Block Diagram.....	11
2. Phase 1 Scanner.....	12
3. Option Phase Scanner	14
4. Electronic Configuration.....	15

Enclosures

1. Bragg Cell Testing.....	20
2. Option Phase Scanner Mechanical Drawings.....	21

1. Executive Summary

The purpose of this research project was to develop a prototype fiber-optic based Coherent Laser Vision System (CLVS) suitable for DOE's EM Robotic program. The system provides three-dimensional (3D) vision for monitoring situations in which it is necessary to update the dimensional spatial data on the order of once per second. The system has total immunity to ambient lighting conditions.

The CLVS plan required implementation in two phases of the contract, a Base Contract and an Option Phase.

The Base Contract Phase 1 Prototype system was successfully demonstrated and the results outlined in the Phase 1 Final Technical Report previously provided as Data Item 3119041.

The Option Phase included correction of Phase 1 deficiencies and improvements to the system performance. The deficiencies were identified and corrected. The design of the improvements was in process when funding was exhausted. Stop Work Contract Mod (M017) was issued May 14, 1999 and this Final Report outlines the technical issues encountered/resolved and remaining efforts that would be required to complete the contract work when additional funding is received.

The technical issues that were encountered and resolved are summarized below:

- The University of Colorado, the Phase 1 Scanner supplier, decided to pull out of the Option Phase several months into the scanner improvement process. CRC explored without success several alternate approaches including other potential sources. CRC then undertook the effort that was to be provided by the University of Colorado.
- Extensive evaluation of the Bragg Cells/associated mechanical mounting design was required to use the cells.
- During the Phase 1 testing a number of problems that could have been software, hardware or both were identified. These were isolated and corrected during the Option phase. These included:
 1. Numerous errors in the FFT bins were observed and thought to be a problem in the Catalina DSP board. It was determined that the problem was in a custom fabricated cable rather than the DSP board. The cable was fixed and FFT bin number errors no longer occurred.
 2. Several other sources primarily software index problems were corrected.
 3. Several C40 coding errors were found that caused the appearance of the C40's being overloaded. These were corrected. Additionally, the C40 code was upgraded to support DMA of data between the sub processors which allows expansion capability to agilely access each pixel by storing previous range and signal strength information. Prior to the discovery that the coding errors were causing the appearance of the C40's being overloaded, a design task was started to create a new interface board which would include a device that would take over some of the C40 tasks. Some of the interface

board devices required the creation of electronic models in order to use the board design tools.

4. During the Phase 1 testing/evaluation, it was observed that there was signal loss due to polarization drift/fade. Early in the Option Phase, Polarization Maintaining (PM) amplifiers became available. They were evaluated and found to be suitable for use on the Vision project. The Phase 1 fiber optic transceiver was redesigned to use all PM fiber components to eliminate system loss due to Polarization drift.

At the time of the Stop Work Order the design effort was well along as summarized below:

- Phase 1 deficiencies were identified and resolved.
- Evaluation of the key solid state scanner element, the Bragg cell, was completed. The efficiency of the cells was low but within the usable range.
- The mechanical design effort was completed but parts were not ordered.
- The design of an electronic interface board was in process and the effort was put on hold.
- The software development was approximately 90% complete and the effort was put on hold.
- The mechanical assembly of the electronics chassis (VME) was in process and was put on hold.

Additional funding would be required to restart the program and complete the contractual tasks.

It is recommended that the contract effort be completed to baseline the current technology and that additional effort be funded to evaluate additional new technologies that may offer enhanced capability as the Bragg cells but at potentially lower cost.

2. Project Objective and Task Description:

The objective of this project is to develop a prototype fiber-optic based coherent laser vision system (CLVS) suitable for DOE's EM Robotics program. The CLVS will provide three dimensional (3D) vision for monitoring situations in which it is necessary to update three-dimensional spatial data on the order of once per second. Further, real-time digitized 3D scene views will be available.

The CLVS is being developed using the contractor's proprietary fiber optic coupled frequency modulated continuous wave coherent laser radar technology. The radar uses the relatively large tuning range of injection laser diodes to achieve greater precision than available with other techniques. The CLVS will implement innovations in no moving parts scanning and digital receiver design which yield improved range accuracy with reduced receiver processor loading. The project will integrate commercially available state-of-the-art fiber optic components as necessary.

In the Base Contract a laboratory bench vision system was developed and demonstrated. The Base Contract system consisted of two crossed Bragg cell beam deflectors designed by CRC and subcontractor Colorado University (CU). The Bragg cells were fabricated by NEOS Technologies. Functional specifications of the Base Contract system included 128 x 128 pixels per frame, one frame per second operation with one millimeter rms accuracy on each pixel measurement. The depth of field was fixed at 1.5 meters and the system operated at ranges up to 1.5 meters. Although all functional specifications were met and demonstrated at Coleman Research Corporation (CRC) in November 1996, performance was limited by excessive signal losses in the solid state scanner. Losses were overcome during testing by utilizing highly reflective surfaces. Tests indicated that the design of the Bragg cells was correct but that fabrication did not meet the design specifications. Tests also identified several errors in the operational software and possible problems with the special purpose digital signal processing board.

In the Option Phase a second scanner is being obtained and the vision system upgraded to meet the ultimate functional specifications set forth below:

- * One image frame per second (16,384 Hz pixel rate)
- * 256 x 256 pixel image frame
- * Operating range beyond 5 meters
- * Accuracy of 1 millimeter rms or better for each pixel
- * Prototype system packaged for field use.

This will be accomplished by following the contract work breakdown structure (CWBS) from the Management Plan dated February 20, 1997.

Summaries of the work to be performed under each task are provided below:

Task-001 Scanner Development

Design, fabricate, integrate, and test a fieldable randomly addressable fiber optic vision scanner. CRC will purchase the scanner components and construct the scanner. The key components include the Bragg cells (from NEOS corporation), and the optical elements. In addition, reference pixel(s) or fiber(s) will be added to the design for automatic calibration and the scanner will be packaged for field use.

Task-002 Software Algorithms

Upgrade and modify the Base Contract system software correcting the deficiencies found during testing and improving imaging capability. This includes "smart scanning" capability allowing images of 256 x 256 pixels to be updated once per second with a basic data rate limitation of 16,384 measurements per second.

Task-003 Enhanced Range

Increase working range from the 1.5 meters provided by the Base Contract system to at least 5 meters. This task includes modifying the fiber-optic laser radar tray, incorporating reference pixel(s) or fiber(s) for automatic calibration, and modifying system software.

Task-004 GUI and Data Interfaces

Develop and implement user interface for controlling the CLVS, image display formats, and a digital interface for the measurement data.

Task-005 System Integration

Integrate the laser radar subsystem developed by CRC and the solid state scanner. Prepare a CLVS User Manual to be delivered at the end of the integration period.

Task-006 System Test at CRC

Test the integrated system at CRC. Modify the Base Contract Test Plan to satisfy the needs of the Option Phase testing. Conduct the test at CRC. Coordinate the draft and final test plans with the customer.

Task-007 Field Test

Test the integrated system at a site specified by DOE. Prepare a draft Field Test Plan coordinating with DOE personnel. Conduct the field test.

Task-008 Final Report

Prepare a final report. Draft to be submitted 60 days before the end of the contract. DOE comments to be included in the final document.

3. Major Milestones Status

Milestone Description	Baseline	Revised	Actual	Notes
Award of Option	N/A		01/27/97	
Cost Plan	02/28/97		02/20/97	
			09/12/97	
			09/18/97	Include Commitments
			10/02/98	
High Risk Property Report	10/15/97		11/19/97	
Management Plan	02/28/97		02/20/97	
Milestone Schedule Plan	02/28/97		02/20/97	
			10/15/97	
			10/02/98	
Semi-annual Property	04/15/97		04/07/97	
Report	10/15/97		11/17/97	
	04/15/98		05/23/98	
Scanner Parts Received	09/05/97	01/15/98	05/22/98	
Enhance Range Hardware	06/27/97	02/14/98	02/13/98	
Scanner Complete	03/28/97	05/28/99		Stop Work Order Received 5/14/99
Enhanced Range Software	09/05/97	05/28/99		
Software Algorithms	09/05/97	05/28/99		
Field Test Plan Submitted	08/15/97	06/18/99		60 days prior to test
GUI and Data Interface	09/05/97	05/28/99		
Draft Final Report	09/26/97	07/30/99		
Integration Complete	09/19/97	07/23/99		
System Test at CRC	10/03/97	07/28/99		
Demo at DOE Site	Nov 97	08/18/99		Site TBD
Contract Complete	11/30/97	09/30/99		
Final Report	11/30/97	09/30/99		
Final Property Report	11/30/97	09/30/99		

System Delivered	09/19/97	09/30/99
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4. Chronological Listing of Significant Events and Accomplishments:

4.1 Significant Events

Base Contract

<u>Date</u>	<u>Description</u>
11/8-9/94	Visited potential vendor for receiver-processors, Catalina Research, Colorado Springs, CO.
12/16/94	Met with COR for Base Contract Kick-Off Meeting in Morgantown, WV.
01/18/95	Technical and management discussions with prospective subcontractor for scanner fabrication, Essex Corp., Columbia, MD.
03/28/95	Letter subcontract let with Essex Corp. for scanner fabrication
04/26/95	Review with Essex Corp. on scanner performance, modeling, and analysis effort.
04/28/95	Initiated alternative scanner design.
05/26/95	Letter subcontract let with University of Colorado to develop A-O scanner cell.
08/10/95	Formal subcontract let with University of Colorado to develop A-O scanner cell.
08/15/95	Received new laser diode type from GEC Marconi which promises superior, unforeseen performance for CLVS.
10/03/95	Presented CLVS technology at METC Environmental Technology Poster Session
03/14/96	Laser diode received.
05/96	No cost extension to 30 Sept. 1996 granted.
05/96	Contract extension granted to subcontractor CU.
05/96	Scanner received from CU.
08/05/96	Final Property Report submitted.
08/07/96	Draft Interim Report submitted.
09/96	Contract extension to 30 Nov. 1996.
09/17/96	Submitted updated Cost Plan and Milestone Management Plan.
09/17/96	Submitted Draft Test Plan.
09/27/96	Accepted CU Scanner.
09/30/96	System integration complete.
10/25/96	System test complete.
11/12/96	System Test Report Final Draft completed.
11/13/96	Program review and briefing, including a laboratory demonstration at CRC, Springfield, VA.
11/18/96	Submission of material supporting the continuation phase.
12/10/96	Test Report submitted.

12/96 Bragg cells returned to UC.
 01/27/97 Contract amendment A010 received activating the continuation phase. POP extended to November 30, 1997.
 02/13/97 Base Program Interim Phase Topical Report (Final) submitted.

Option Phase

<u>Date</u>	<u>Description</u>
02/20/97	Management Plan, Milestone Schedule Plan, and Cost Plan delivered.
03/25/97	Option Phase Kickoff meeting held at FETC.
05/01/97	CRC started evaluating options for the 1550 nm solid state scanner because of Colorado University's non-responsiveness to our RFP.
06/25/97	University of Colorado informed us that they will not be able to support the Phase II effort because of loss of key personnel and over-commitments to other contracts.
07/01/97	Bob Clark, Director of Photonics Division, assumes roles of Program Manager and Principal Investigator.
07/30/97	CRC received Phase I Scanner back from University of Colorado.
09/15/97	Program Review Meeting with COR
10/22/97	Presented CLVS Poster Paper at Industry Partnership to Deploy Environmental Technology Conference at Morgantown.
11/24/97	Contract extended to June 30, 1998.
03/06/98	Initiated discussions with Oak Ridge National Laboratory concerning a CLVS demonstration.
9/30/98	Contract extended to March 30, 1999.
1/30/99	Relocation to new facility completed, Phase 1 hardware unpacked, setup and tested. Initial testing of Bragg cells has begun.
3/30/99	Contract extended to September 1999.
4/1/99	75% Notification Provided.
4/13/99	Estimate to Complete Submitted.
4/16/99	Off-Site Contractors Property Management System Self-Evaluation Questionnaire Submitted.
5/14/99	Contract Mod M017 Stop Work Order Issued.

4.2 To Date Accomplishments

Base Contract

<u>Date</u>	<u>Description</u>
03/24/95	Finalized receiver design.
01/27/95	Finalized scanner design and identified subcontractor.
04/14/95	Finalized transmitter design.
05/20/95	Reviewed initial scanner design/ceased further work on that approach.
05/20/95	Selected alternative scanner design.
06/30/95	AO scanner design optimization software completed.
07/10/95	2D Crossed-Bragg-cell scanner loss map created.
07/31/95	Laser diode shipped by GEC Marconi.
08/31/95	Confirmed superior performance of GEC Marconi Laser Diode in the laboratory.
09/27/95	Approach developed for dissipation of excessive thermal energy in the Bragg Cell.
09/29/95	All parts for AO scanner received or on order.
10/31/95	Almost all AO scanner parts received.
01/29/96	Receiver input filters designed and ordered.
01/31/96	Bragg cell assembly complete.
02/23/96	Bragg cells received and tested.
02/23/96	Computer control of PTS160 waveform generators established.
05/96	End-to-end operation of the receiver achieved at one frame per second, 128 x 128 pixels per frame.
06/96	PC to TMS320C40 communications and control MMI established.
07/31/96	Receiver development completed.
08/30/96	End-to-end operation of electronics achieved. Beam scanning in elevation demonstrated.

Option Phase

<u>Date</u>	<u>Description</u>
02/97	Report preparation modified to provide electronic .PDF documents.
04/97	Identified source of major data errors as an interface cable rather than the Catalina board. Fixed problem.
09/97	Finalized scanner design.
10/97	All major parts on order including Scanner crystals from NEOS.
02/98	1550 nm fiber amplifier received.
05/98	The first bragg cells were received.
1/30/99	Relocation to new facility completed, Phase 1 hardware unpacked, setup, and tested. Initial testing of Bragg cells has begun.

3/31/99 Testing of the Bragg Cells was completed.
4/30/99 The mechanical design of the Bragg cell/associated mechanical parts was completed.

5. **Final Technical Status/Accomplishments**

The CLVS System Block Diagram is provided as Figure 1.

Task-001 Scanner Development

The solid state scanning is accomplished through the use of two Bragg cells to steer the laser beam. One cell is used to steer the beam in the Azimuth direction and the other in the Elevation direction.

Bragg cells, or acousto-optic modulators, are solid state crystals that exhibit the property of being able to deflect an optical beam when excited by an acoustic wave. The amount of angular deflection is proportional to the frequency of the acoustic wave. To generate this wave, a transducer is fabricated on one face of the crystal. A RF signal is used to excite the transducer to produce the acoustic wave in the crystal. An optical beam traveling in the crystal perpendicular to the acoustic wave is deflected in angle in the direction of the wave. Typically this deflection is on the order of a few degrees and is only produced for certain angular orientations between the crystal axes and the light beam. By varying the frequency of the RF signal, the amount of optical deflection can be varied. Due to the nature of this interaction, the efficiency is not very high. Only a fraction of the light is deflected. In order to increase the amount of deflected light, the RF energy is increased. At a certain point, the localized heating due to the high RF energy can cause the crystal to crack or it can destroy the transducer. Therefore, there is a fine line between efficient operation and a broken Bragg cell. Because they are the means to scan the beam, the Bragg cells are the most critical component to the no-moving-parts scanner.

In the Phase 1 effort, the entire scanner including the Bragg cells was designed and supplied by the University of Colorado as shown in Figure 2.

Several months after the Option Phase Award, the University of Colorado, who was to improve the Phase 1 scanner decided to pull out. CRC explored without success several alternate approaches including other potential sources. CRC then undertook the effort that was to be provided by the University of Colorado. CRC began work to improve the scanner design/package for field use. Additionally effort was initiated directly with the Bragg cell manufacturer including an internally funded alternate design approach which was believed to be superior to the Phase 1 design. The main improvement was in the development of a superior transducer that has a thicker

CLVS System Block Diagram

Figure 1. CLVS System Block Diagram

Scanner Configuration

Figure 2. Phase 1 Scanner

silver layer and a single anti-reflection layer. We expected the new design to have better response over the total RF bandwidth and have superior thermal characteristics.

Extensive evaluation/characterization at medium power levels was conducted on Phase 1 configuration Bragg cells and the alternate design Bragg cells. Several sets of the cells were identified as having usable frequency responses. In general, the alternate design parts exhibited slightly better diffraction efficiency at the power levels tested. The output was not as high as was hoped but still within usable range. Higher power testing was planned to be conducted at the system integration level. Bragg Cell testing data is provided in Enclosure 1.

The mechanical design effort for mounting the Bragg cells and associated mechanical parts that make up the scanner was started during the evaluation process and finalized after completion of the testing. The Option Phase Scanner design is shown in Figure 3 and the individual drawings are provided in Enclosure 2. The drawings were sent out for quotation. Because of the funding issue the mechanical parts were not ordered.

The repackaging and assembly of the reusable Phase 1 parts into the Electronics VME chassis was started following an update to the chassis layout. The current chassis configuration is shown in Figure 4. Additional effort is required to complete it.

Upon receipt of the Stop Work Order no further effort was expended on this task.

Task-002 Software Algorithms

During the Phase 1 testing a number of problems that could have been software, hardware or both were identified. These were isolated and corrected during the Option phase. These included:

- Numerous errors in the FFT bins were observed and thought to be a problem in the Catalina DSP board. It was determined that the problem was in a custom fabricated cable rather than the DSP board. The cable was fixed and FFT bin number errors no longer occurred.
- Several other sources primarily software index problems were corrected.
- Several C40 coding errors were found that caused the appearance of the C40's being overloaded. These were corrected. Additionally, the C40 code was upgraded to support DMA of data between the sub processors which allows expansion capability to agilely access each pixel by storing previous range and signal strength information.

The Phase 1 OS/2 system software was converted to operate on Windows NT. The NT drivers were implemented and validated for the waveform board and C40 Spectrum board. A problem in the Spectrum supplied software library was resolved so that the C40's can provide range, azimuth and

Scanner Configuration

Figure 3. Option Phase Scanner

Electronics Configuration

*RF
Components*

*FFT
Processor
(VME)*

*User
Interface
(Pentium PC)*

Figure 4. Electronics VME Chassis

elevation information through interrupts. This change was validated in Windows NT but not implemented in the C40 code.

The "Smart Scanning" algorithm development to achieve 256x256 resolution was not started.

Task-003 Enhanced Range

During the Phase 1 testing/evaluation, it was observed that there was signal loss due to polarization drift/fade. Early in the Option Phase, Polarization Maintaining (PM) amplifiers became available. They were evaluated and found to be suitable for use on the Vision project. The Phase 1 fiber optic transceiver was redesigned to use all PM fiber components to eliminate system loss due to Polarization drift.

The redesigned fiber optic circuit with PM components was assembled, tested and utilized in the laser waveform linearization effort. Improvements to the laser waveform known as "linearization" lowers the laser noise which directly contributes to the system sensitivity. The upswing portion of laser waveform linearization was completed. The down sweep portion was not completed and the effort put on hold.

During Phase 1 testing/evaluation, it appeared that the C40 Digital Signal Processing (DSP) processors were being overloaded thus in the Option phase some of the C40 tasks were planned to be off loaded into a new FPGA device that would be located on a new interface board. Well after the board design was started, it was discovered that there were a few coding errors in the C40 code that caused the appearance of an overload situation. The design of the interface board was not completed at the time the Stop Work Order was received and the completion was put on hold. It is recommended that when the contract effort is restarted that an assessment be made of the partial design, assess alternate approaches that would provide the same functionality and implement the most suitable approach.

Software to implement the fixed focus for each pixel for the enhanced range portion of the task was not started when the effort was put on hold.

Task-004 GUI and Data Interfaces

The Phase 1 OS/2 system control software was converted to operate on Windows NT. A data interface between the C40 board and the interface board was developed that uses the C40 board's COM port. Previously under OS/2 this was accomplished through the DSPLINK port. The Windows NT drivers and documentation for the Bit3 and Catalina boards was obtained and effort was started but not completed or validated to develop a Windows NT data interface to these boards.

A Windows NT application was developed that incorporate the hardware data interfaces. It allows the selection of the laser waveform, setting of waveform triggers and interfacing with the C40 DSPs. That portion of the application to initialize the Bit3 board and initialize and load the Catalina board was not completed

Task-005 System Integration

Task has not begun.

Task-006 System Test at CRC

Task has not begun.

Task-007 Field Test

Task has not begun.

Task-008 Final Report

Task has not begun.

6. Remaining Effort

Assuming additional Contract funding is received to restart this program, the following effort will be required to fully complete the contract requirements:

- Order mechanical parts, assemble and test the scanner.
- Assess the incomplete interface board design, assess alternate approaches that would provide the same functionality and implement the most suitable approach.
- Complete the VME chassis assembly, resolve a potential short in the back plane and procure parts/assemble the cabling.
- Complete the remaining software including Linearization.
- System Integration
- System Test
- Field Test
- Final Report

7. Alternate Technologies

The current technology utilized for this contract effort was proposed in December 1993. The technology used in the Vision System uses two Bragg cells, one to steer the beam in azimuth and one to steer the beam in elevation. The Bragg cells are very fast, with switching speeds on the order of 10 micro-seconds, making them compatible with the overall system speed of one (1) frame per second.

They have one drawback in that they attenuate 90% of the laser signal on each passage thus the return signal is very low but usable. This attenuation is overcome through the use of a fiber photo-amplifier.

In recent years, several new alternate approaches to beam steering have been developed along with multiple, parallel receivers. These are outlined briefly below.

- Transmissive Optical Phased Array: Under DOD and internal funding, Raytheon and others have developed Liquid Crystal devices which function as optical phased arrays (OPA), allowing the laser beam to be steered in much the same way as is done currently with Bragg cells. These devices have transmission efficiency above 90%, eliminating the need for photo-amplification. They are also relative inexpensive (under \$1,500) to produce in moderate volume. Their current drawback is speed, requiring several milliseconds to switch. These companies believe faster devices are coming, but in the meantime, a combined Bragg cell-OPA approach appears feasible, using the Bragg cell for one axis, and the OPA for the other axis.
- Reflective Optical Phased Array: Recently, OPA's working on a semiconductor chip with addressable reflective properties has also been demonstrated. These devices were developed for optically base computing, but it appears to be capable of steering the laser radar beam with under 10 microsecond speeds. Optical efficiencies above 90% are claimed.
- High-speed mirrors: Servo mounted mirror assemblies with millisecond speeds, used in conjunction with a Bragg cell, offer promise for meeting speed requirements in the same way as the Transmissive OPA.
- Focal Plane Receiver Array: In conjunction with Thermo Electron's Optek subsidiary, it appears possible to create a receiver array with up to 256 x 256 elements. In this configuration, the laser radar signal would be "broadcast" to the scene as opposed to scanning over the scene, and the reflected signal would be collected by the focal plane array in much the same way that a CCD camera collects light. This array of laser radar receivers would have to feed a suitably powerful DSP bank, probably relying on an optically based FFT calculating device, which has been developed under DOD funds.

9. Recommendations

Restart the contract effort with additional funding, complete the system and baseline the technology.

Investigate and baseline alternate technologies to insure the “final” system encompass the best of the latest technologies.

This approach would provide the “Best” system at the lowest cost for that portion of the Deactivation and Decommission (D&D) mission which requires “Eyes” to see in total darkness that could be encountered while accomplishing the D&D mission(s).

Enclosure 1
Bragg Cell Testing Data

Bragg Cell Testing

Purpose:

To evaluate all possible candidate Bragg cells and rank each cell according to its responsivity over the acoustic bandwidth of interest.

Theory:

Linearly polarized laser light exiting from a fiber is collimated and made to pass through the acousto-optic cell. A varying RF (50 to 100 MHz) signal is acoustically coupled into the crystal. The vibrating crystal's varying optical index of refraction appears as a diffraction grating to the light passing through the crystal. Just as the directional change of light is determined by the slit spacing in a diffraction grating, the angular deflection of light in a Bragg cell is determined by the acoustic wavelength. The amount of deflected light compared to the undeflected light is a measure of the diffraction efficiency.

In acousto-optic Bragg cells, diffraction efficiency is governed by two major factors. The most important is the coupling of the acoustic energy into the cell. The TeO_2 Bragg cell is intimately contacted with a layer of In . On top of the In sits a LiNbO_3 phased array transducer which takes the electrical energy and creates acoustic waves. The In thickness is specified to closely match the acoustic impedance between the LiNbO_3 and the TeO_2 over the acoustic frequency bandwidth of interest. This optimizes the energy transfer into the cell.

The other major element determining diffraction efficiency is the entrance angle of the collimated beam into the Bragg cell. While the acoustic coupling efficiency is determined at the time of manufacture and unchangeable, the entrance angle is adjusted at the time of setup and use. When using a Bragg cell for beamsteering, it is important to look for high diffraction efficiency over the entire steering frequency bandwidth. There are specific angles that allow for this behavior. They are analogous to the +1 and -1 order of a standard diffraction grating.

Method:

Each Bragg cell was fixtured in a rotatable optical mount. This allowed for simple angular adjustment. The cell was fed an RF linear chirp starting at 50 MHz and ending at 100 MHz. The diffracted light was then detected as a voltage on a photodetector. Plots for each cell are included. Some of the Bragg cells had two electrode sets. These are denoted as L and R on the graphs. Those with one are denoted by 'O'. The numbers in the legend are the arbitrary angle which corresponded to the +2, +1, -1, or -2 diffraction order.

Analysis:

Although the diffracted intensities are labeled as arbitrary units, the plot to plot scale is consistent. Thus one can see that Cell 636 had a markedly better broadband response than Cell 594. It is also apparent that the manufacturing process used on these cells left each one unique.

Cell 594

Cell 596

Cell 636

Cell 637

Cell 638

Cell 639

Cell 640

Cell 641

Cell 642

Cell 643

Enclosure 2

Option Phase Scanner Mechanical Drawings

Option Phase Scanner Mechanical Drawings

Drawing No.	Title
-	Option Phase Scanner 3-D View without Cover
-	Option Phase Scanner 3-D view with Cover
6325001	Optics Tray, Front Panel
6325002	Optics Tray, Rear Panel
6325003	Optics Tray Base
6325004	Lenslet Array Mount, 1550 NM
6325005	Elevation Tilt Actuator
6325006	Elevation Tilt Base
6325007	Elevation Tilt Turret
6325008	Elevation Tilt Turret
6325009	Azimuth Bragg Cell Base
6325010	Azimuth Bragg Cell Translator
6325011	Azimuth Bragg Cell Rotator
6325012	FT Y Trans, Bottom
6325013	FT Y Trans, Top
6325014	10.8 Degree Mount
6325015	Collimator Trans
6325016	Fiber/Collimator Interface
6325017	FT Lens Mount
6325018	Shell, Front
6325019	Top Shell
6325020	Shell, Left
6325021	Shell, Right
6325022	Base
6325023	FT Z Trans
6325024	Ft X Trans, Bottom
6325025	FT X Trans, Top
6325026	Z Bracket
6325027	FT Z Trans, Top
6325028	Z Bracket Interface

Option Phase Scanner 3-D View without Cover

Option Phase Scanner 3-D view with Cover

NOTES:

1. MODIFICATIONS TO EXISTING PIECE.

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

21-D

<p>NEXT ASSY</p> <p>USED ON</p> <p>APPLICATION</p>		<p>DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 FRAC± 1/32 .XXX±003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES.</p>	CONTRACT NO. 6325		<p>CRC</p>	Coleman Research Corporation 6551 Loisdale Court, Suite 800 Springfield, VA 22150 703-719-9200 FAX (703) 719-9229	
			<p>SIGNATURES</p> <p>DR G. Byron</p> <p>CKD A. Slotwinski</p> <p>ENG</p>			<p>DATE</p> <p>03/03/98</p> <p>03/03/98</p>	
<p>MATERIAL</p> <p>ALUMINUM</p> <p>FINISH BARE</p>		<p>APPD</p> <p>APPD</p>	<p>SIZE</p> <p>A</p> <p>SCALE</p> <p>1:3</p>	<p>FSCM NO</p>	<p>DWG NO</p> <p>6325001</p>	<p>REV</p> <p>SHEET 1 OF 1</p>	

NOTES:
1. MATERIAL THICKNESS IS .060 INCHES.

DETAIL C

DETAIL 8

DETAIL A

	DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC.	CONTRACT NO. <u>6325</u>	Coleman 6551 Loisdale Court, Suite 800 Research Springfield, VA 22150 Corporation 703-719-9200 FAX (703) 719-9229
	TOLERANCES ARE: DEC:XX± .01 FRAC± 1/32 .XXX±003 ANG± 0.1°	SIGNATURES DR G. Byron CKD A. Slotwinski	
	REMOVE BURRS. BREAK SHARP EDGES.	DATE 03/03/98	
NEXT ASSY	MATERIAL ALUMINUM	APPD	
USED ON	FINISH BARE	APPD	
APPLICATION

[illegible]

REVISIONS		DESCRIPTION	DATE	APPROVED
REV

DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 FRAC± 1/32 .XXX±003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES. MATERIAL ALUMINUM FINISH BLACK ANODIZE	CONTRACT NO. 6325		DATE 03/20/98	
	DR G. Byron	CKD A. Slotwinski	ENG	
NEXT ASSY	USED ON	APPD		APPD
APPLICATION		TITLE LENSLET ARRAY MOUNT, 1550 NM		REV
		SIZE A	FSCM NO	DWG NO 6325004
		SCALE 1:1	SHEET 1 OF 1	

NOTES:

1. DIMENSIONS APPLY AFTER PLATING.

REV

DESCRIPTION

DATE

APPROVED

ISOMETRIC VIEW

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX ± .01 | FRAC ± 1/32
.XXX ± .003 | ANG ± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL

ALUMINUM 6061-T6

FINISH MIL-A-8625F
TYPE II, CLASS 2 (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR G. Byron
CKD W. Velasquez
ENG G. Byron

DATE

04/06/99
04/06/99
04/06/99

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Newington, VA 22122

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TITLE

ELEVATION TILT
ACTUATOR

NEXT ASSY

USED ON

APPLICATION

APPD

APPD

SIZE

A

SCALE

1:1

FSCM NO

DWG NO

6325005

REV

SHEET

1 OF 1

DWG NO

6325006

SH REV

REVISIONS

REV

DESCRIPTION

DATE

APPROVED

NOTES:

1. DIMENSIONS APPLY AFTER PLATING.

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC±1/32
.XXX±.003 | ANG±0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL

ALUMINUM 6061-T6

FINISH MIL-A-8625F
TYPE II, CLASS 2, (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR G. Byron
CKD W. Velasquez
ENG G. Byron

DATE

04/06/99
04/06/99
04/06/99

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TITLE

ELEVATION TILT
BASE

SIZE
A

FSCM NO

DWG NO

6325006

REV

SCALE

1:1

SHEET

1 OF 1

NEXT ASSY

USED ON

APPLICATION

APPD

APPD

NOTES:

1. DIMENSIONS APPLY AFTER PLATING.

REV

DESCRIPTION

DATE

APPROVED

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC± 1/32
.XXX±.003 | ANG± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL

ALUMINUM 6061-T6

FINISH MIL-A-8625F
TYPE II, CLASS 2, (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR G. Byron
CKD W. Velasquez
ENG G. Byron

DATE

04/06/99
04/06/99
04/06/99

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TITLE

ELEVATION TILT
TURRET

SIZE
A

FSCM NO

DWG NO

6325007

REV

SCALE

2:1

SHEET

1 OF 1

NEXT ASSY

USED ON

APPLICATION

APPD

APPD

NOTES:

1. DIMENSIONS APPLY AFTER PLATING.

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

2X ϕ .220 THRU

SEE DETAIL A

ϕ .257

.187

DETAIL A

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:DEC.XX $\pm$.01 | FRAC $\pm$ 1/32
.XXX $\pm$.003 | ANG $\pm$ 0.1°REMOVE BURRS. BREAK SHARP EDGES.
MATERIAL

ALUMINUM 6061-T6

FINISH MIL-A-8625F
TYPE II, CLASS 2, (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR G. Byron
CKD W. Velasquez
ENG G. Byron

DATE

04/06/99
04/06/99
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TITLE

ELEVATION TILT
TURRETSIZE
A

FSCM NO

DWG NO

6325008

REV

SCALE

2:1

SHEET

1 OF 1

NEXT ASSY

USED ON

APPLICATION

21-K

REVISIONS

DESCRIPTION	DATE	APPROVED

REV

- NOTES:
1. INTERPRET DRAWING IAW ASME Y14.5M-1994.
 2. DIMENSIONS APPLY AFTER PLATING.

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<p>TITLE AZIMUTH BRAGG CELL BASE</p>		<p>SIGNATURES DR G. Byron CKD W. Velasquez ENG G. Byron</p>		<p>DATE 04/06/99 04/06/99 04/06/99</p>	
<p>SIZE FSCM NO DWG NO 6325009 REV</p>		<p>SCALE 1:1 SHEET 1 OF 1</p>		<p>APPLICATION</p>	
<p>NEXT ASSY USED ON</p>		<p>MATERIAL ALUMINUM 6061-T6 FINISH MIL-A-8625F TYPE II, CLASS 2, (BLACK)</p>		<p>APPD</p>	

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

- NOTES:
1. INTERPRET DRAWING IAW ASME Y14.5M-1994.
 2. DIMENSIONS APPLY AFTER PLATING.

DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 FRAC± 1/32 XXX±.003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES.	CONTRACT NO. 6325	SIGNATURES DR G. Byron CKD W. Velasquez ENG G. Byron	DATE 04/06/99 04/06/99 04/06/99	MATERIAL ALUMINUM 6061-T6 FINISH MIL-A-8625F TYPE II, CLASS 2, (BLACK)	NEXT ASSY	USED ON	APPLICATION	SIZE A	FSCM NO	DWG NO 6325010	REV
METRICVISION Gateway 95, Cinder Bed Road, Suite 150 Newington, VA 22122 703-550-2945 FAX (703) 550-2949 © Copyright 1999				TITLE AZIMUTH BRAGG CELL TRANSLATOR				SCALE 1:1 SHEET 1 OF 1			

REVISIONS

DATE

APPROVED

DESCRIPTION

REV

- NOTES:
1. INTERPRET DRAWING IAW ASME Y14.5M-1994.
 2. DIMENSIONS APPLY AFTER PLATING.

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TITLE AZIMUTH BRAGG CELL ROTATOR		
SIZE A	FSCM NO 6325011	REV
SCALE 1:1	SHEET 1 OF 1	

CONTRACT NO. 6325	DATE 04/06/99
SIGNATURES DR G. Byron CKD W. Velasquez ENG G. Byron	DATE 04/06/99 04/06/99 04/06/99
DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 FRAC± 1/32 .XXX±.003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES. MATERIAL ALUMINUM 6061-T6 FINISH MIL-A-8625F TYPE II, CLASS 2, (BLACK)	APPD APPD
NEXT ASSY	USED ON
APPLICATION	

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

21-0

NEXT ASSY	USED ON	DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX± .01 FRAC± 1/32 .XXX±003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES. MATERIAL ALUMINUM 6061-T6 FINISH 32 μm	CONTRACT NO. <u>6325</u>		DATE 04/13/99 04/13/99 04/13/99	SIGNATURES DR W. VELASQUEZ CKD G. BYRON ENG G. BYRON	METRICVISION Gateway 95, Cinder Bed Road, Suite 150 INC. Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949	TITLE FT Y TRANS, BOTTOM	SIZE A	FSCM NO	DWG NO 6325012	REV
			APPD	APPD								

REVISIONS

REV

DESCRIPTION

DATE

APPROVED

NOTE:

- 1.) SCREW HEAD MUST SIT BELOW MATERIAL SURFACE.

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC±1/32
.XXX±.003 | ANG±0.1°

REMOVE BURRS. BREAK SHARP EDGES

MATERIAL
ALUMINUM 6061

FINISH
32 μm

CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ
CKD G. BYRON
ENG G. BYRON

DATE

04/13/99
04/13/99
04/13/99

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TITLE

FT Y TRANS, TOP

NEXT ASSY

USED ON

APPLICATION

APPD

APPD

SIZE
A

FSCM NO

DWG NO

6325013

REV

SCALE

1:1

SHEET

1 OF 1

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

21-Q

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC± 1/32
.XXX±.003 | ANG± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL

ALUMINUM

FINISH

32 µm

CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ
CKD G. BYRON
ENG G. BYRON

DATE

04/13/99
04/13/99
04/13/99

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TITLE

10.8° MOUNT

SIZE
A

FSCM NO

DWG NO

6325014

REV

SCALE

1:1

SHEET

1 OF 1

NEXT ASSY

USED ON

APPLICATION

APPD

APPD

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TITLE COLLIMATOR TRANS

SIZE A FSCM NO DWG NO 6325015 REV
SCALE 2:1 SHEET 1 OF 1

CONTRACT NO. 6325		DATE 04/13/99	
SIGNATURES		DR W. VELASQUEZ	
DR CKD		G. BYRON	
ENG G. BYRON		APPD	
APPD		APPD	
DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 XXX±.003 FRAC± 1/32 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES.		MATERIAL ALUMINUM FINISH NONE	
NEXT ASSY		USED ON	
APPLICATION			

REVISIONS

REV

DESCRIPTION

DATE

APPROVED

21-S

<p>NEXT ASSY</p> <p>USED ON</p> <p>APPLICATION</p>		<p>DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX± .01 FRAC± 1/32 .XXX±.003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES.</p> <p>MATERIAL ALUMINUM 6061-T6</p> <p>FINISH MIL-F-495E</p>	<p>CONTRACT NO. 6325</p>		<p>SIGNATURES</p> <p>DR W. VELASQUEZ</p> <p>CKD G. BYRON</p> <p>ENG W. VELASQUEZ</p>		<p>DATE</p> <p>04/13/99</p> <p>04/13/99</p> <p>04/13/99</p>		<p>METRICVISION Gateway 95, Cinder Bed Road, Suite 150 Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949</p>	
			<p>TITLE FIBER/COLLIMATOR INTERFACE</p>		<p>SIZE A</p> <p>SCALE 1:1</p>		<p>DWG NO 6325016</p> <p>SHEET 1 OF 1</p>		<p>REV</p>	

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

21-T

<p>DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 FRAC± 1/32 .XXX±.003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES. MATERIAL ALUMINUM 6061-T6 FINISH MIL-F-495E</p>		<p>CONTRACT NO. 6325</p> <p>SIGNATURES DR W. VELASQUEZ CKD G. BYRON ENG G. BYRON</p> <p>DATE 04/06/99 04/13/99 04/13/99</p>		<p>METRICVISION Gateway 95, Cinder Bed Road, Suite 150 Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949</p>	
<p>NEXT ASSY</p> <p>USED ON</p> <p>APPLICATION</p>		<p>APPD</p> <p>APPD</p>		<p>TITLE FT LENS MOUNT</p> <p>SIZE A</p> <p>SCALE 1:1</p>	
				<p>DWG NO 6325017</p> <p>REV</p> <p>SHEET 1 OF 1</p>	

DWG NO

6325018

SH

REV

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

21-U

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC± 1/32
.XXX±.003 | ANG± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL

ALUMINUM 6061

FINISH

MIL-A-8625F TYPE II,
CLASS 2 (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ
CKD G. BYRON
ENG G. BYRON

APPD

APPD

DATE

04/13/99

04/13/99

04/13/99

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TITLE

SHELL, FRONT

SIZE
A

FSCM NO

DWG NO

6325018

REV

SCALE

1:2

SHEET

1 OF 1

NEXT ASSY

USED ON

APPLICATION

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

NEXT ASSY	USED ON	DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE:		CONTRACT NO. 6325		METRICVISION Gateway 95, Cinder Bed Road, Suite 150 INC. Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949			
		DEC.XX±.01	FRAC± 1/32	DR	W. VELASQUEZ	04/13/99	TITLE	TOP SHELL	
		.XXX±0.03	ANG± 0.1°	CKD	G. BYRON	04/13/99			
		REMOVE BURRS. BREAK SHARP EDGES.		ENG	G. BYRON	04/13/99			
APPLICATION		MATERIAL	ALUMINUM 6061-T6	APPD		SIZE	FSCM NO	DWG NO	REV
		FINISH	MIL-A-8625F TYPE II, CLASS 2 (BLACK)	APPD		A			6325019
						SCALE	1:2	SHEET	1 OF 1

APPLICATION	
NEXT ASSY	USED ON

APPLICATION	USED ON	NEXT ASSY

NOTE:

IRIDITE HOLES... ANODIZE THE REST...

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC± 1/32
.XXX±.003 | ANG± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL
ALUMINUM 6061-T6

FINISH MIL-A-8625F TYPE II,
CLASS 2 (GOLD)

CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ
CKD G. BYRON
ENG G. BYRON

DATE

04/14/99
04/14/99
04/14/99

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TITLE

BASE

SIZE FSCM NO

DWG NO

REV

A

SCALE

1:2

6325022

SHEET

1 OF 1

NEXT ASSY

USED ON

APPLICATION

SH REV

DWG NO 6325023

REVISIONS

APPROVED

DATE

DESCRIPTION

REV

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CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ

CKD G. BYRON

ENG G. BYRON

DATE 04/14/99

DATE 04/14/99

DATE 04/14/99

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 FRAC± 1/32

.XXX±003 ANG± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL

ALUMINUM 6061-T6

FINISH MIL-A-8625F TYPE II, CLASS 2 (BLACK)

TITLE

FT Z TRANS

SIZE FSCM NO

A

SCALE 1:1

DWG NO

6325023

SHEET 1 OF 1

REV

REV

REV

NEXT ASSY USED ON

APPLICATION

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

21AA

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC±1/32
.XXX±.003 | ANG±0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL
ALUMINUM 6061-T6

FINISH MIL-A-8625F TYPE II,
CLASS 2 (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ
CKD G. BYRON
ENG G. BYRON

DATE

04/13/99
04/13/99
04/13/99

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TITLE FT X TRANS, BOTTOM

NEXT ASSY

USED ON

APPLICATION

APPD

APPD

SIZE
A

SCALE

FSCM NO

1:1

DWG NO

6325024

SHEET

1 OF 1

REV

REV	DESCRIPTION	DATE	APPROVED

NOTE:

1.) MAKE C'SINKS DEEPER THAN NORMAL.

4x.096 THRU
V.0.172 82° CSK
.070 DEEP

21AB

NEXT ASSY	USED ON	DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE: DEC.XX±.01 FRAC± 1/32 .XXX±.003 ANG± 0.1° REMOVE BURRS. BREAK SHARP EDGES.	CONTRACT NO. 6325		METRICVISION Gateway 95, Cinder Bed Road, Suite 150 Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949
			SIGNATURES		
APPLICATION	FINISH	MATERIAL ALUMINUM 6061-T6	DR	W. VELASQUEZ	04/13/99
			CKD	G. BYRON	04/13/99
			ENG	G. BYRON	04/13/99
			APPD		
			APPD		
			SIZE A	FSCM NO	DWG NO 6325025
			SCALE 1:1		REV
			SHEET 1 OF 1		

DWG NO

6325026

SH

REV

REV

DESCRIPTION

REVISIONS

DATE

APPROVED

DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPEC.
TOLERANCES ARE:

DEC.XX±.01 | FRAC± 1/32
.XXX±.003 | ANG± 0.1°

REMOVE BURRS. BREAK SHARP EDGES.

MATERIAL
ALUMINUM 6061-T6

FINISH MIL-A-8625F TYPE II,
CLASS 2 (BLACK)

CONTRACT NO. 6325

SIGNATURES

DR W. VELASQUEZ
CKD G. BYRON
ENG G. BYRON

APPD

APPD

DATE

04/14/99

04/14/99

04/14/99

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703-550-2945 FAX (703) 550-2949

TITLE

Z BRACKET

SIZE

A.

SCALE

1:1

FSCM NO

DWG NO

6325026

SHEET

1 OF 1

REV

NEXT ASSY

USED ON

APPLICATION

21-AC

REV	DESCRIPTION	REVISIONS	DATE	APPROVED
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21-AD

NEXT ASSY	USED ON	APPLICATION	DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE:		CONTRACT NO. <u>6325</u>		METRICVISION Gateway 95, Cinder Bed Road, Suite 150 Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949
			DEC.XX±.01	FRAC± 1/32	SIGNATURES	DATE	
			.XXX±.003	ANG± 0.1°	DR W. VELASQUEZ	04/14/99	
			REMOVE BURRS. BREAK SHARP EDGES.	ENG G. BYRON	04/14/99		
MATERIAL ALUMINUM 6061-T6			APPD	APPD	TITLE FT Z TRANS, TOP		
FINISH NONE			APPD	APPD	SIZE A	FSCM NO	DWG NO 6325027
					SCALE 1:1		REV SHEET 1 OF 1

REVISIONS

REV

DESCRIPTION

DATE

APPROVED

21-AE

NEXT ASSY	USED ON	DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPEC. TOLERANCES ARE:		CONTRACT NO. <u>6325</u>			METRICVISION Gateway 95, Cinder Bed Road, Suite 150 Newington, VA 22122 ©COPYRIGHT 1999 703-550-2945 FAX (703) 550-2949			
		DEC.XX±.01 FRAC± 1/32		SIGNATURES			DATE		TITLE	
		.XXX±.003 ANG± 0.1°		DR W. VELASQUEZ			04/28/99		Z BRACKET INTERFACE	
		REMOVE BURRS. BREAK SHARP EDGES.		CKD G. BYRON			04/28/99			
MATERIAL		ALUMINUM 6061-T6		APPD		SIZE		FSCM NO	DWG NO	REV
FINISH		XXXXXXXX		APPD		SCALE		6325028		
APPLICATION						1:1		SHEET		1 OF 1