

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 27-01-03		2. REPORT TYPE Viewgraph Presentation		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE DSP Techniques for Positioning of Off-Axis Solar Concentrators				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Joseph N. Beasley				5d. PROJECT NUMBER 1011	
				5e. TASK NUMBER 0062	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRSO 8 Draco Drive Edwards AFB, CA 93524-7135				8. PERFORMING ORGANIZATION REPORT NUMBER AFRL-PR-ED-VG-2003-016	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S NUMBER(S) AFRL-PR-ED-VG-2003-016	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <div style="text-align: center; font-size: 2em; font-weight: bold;">20030304 032</div>					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT A	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Leilani Richardson
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code) (661) 275-5015

FILE

MEMORANDUM FOR PRS (In-House Publication)

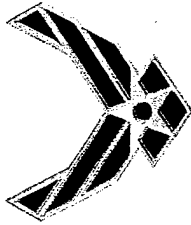
FROM: PROI (STINFO)

16 Jan 2003

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2003-016**
Joseph N. Beasley (AFRL/PRSO) "DSP Techniques for Positioning of Off-axis Solar Concentrators"

ASME/ISEC
(Hawaii, 15-18 March 2003) (Deadline: N/A)

(Statement A)



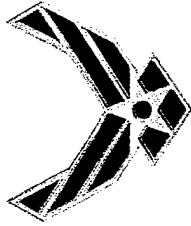
DSP Techniques for Positioning of Off-axis Solar Concentrators

Joe Beasley, USAF/AFRL, PRSO

Ph. D. Student

Claremont Graduate School

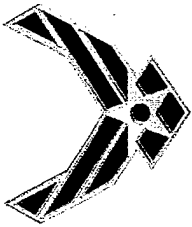
Cal. State Long Beach



Agenda



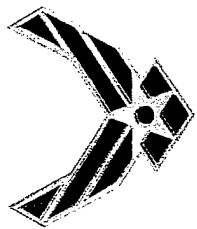
- **Introduction**
- **Problem Definition**
- **Solution Concept**
- **Experiment Description**
- **Result Presentation**
- **Conclusion and Future Work**



Introduction

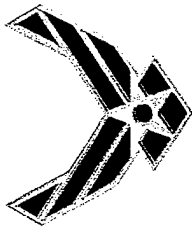


- A major requirement for using a solar propulsion system is the the proper placement of the focal spot on the thruster absorber plane. Without proper placement of the focal spot, solar energy is not transferred to the propellant gas or at worst case, a significantly smaller proportion of the incident energy is transferred to the gas.



Solar Thermal Spacecraft Configuration

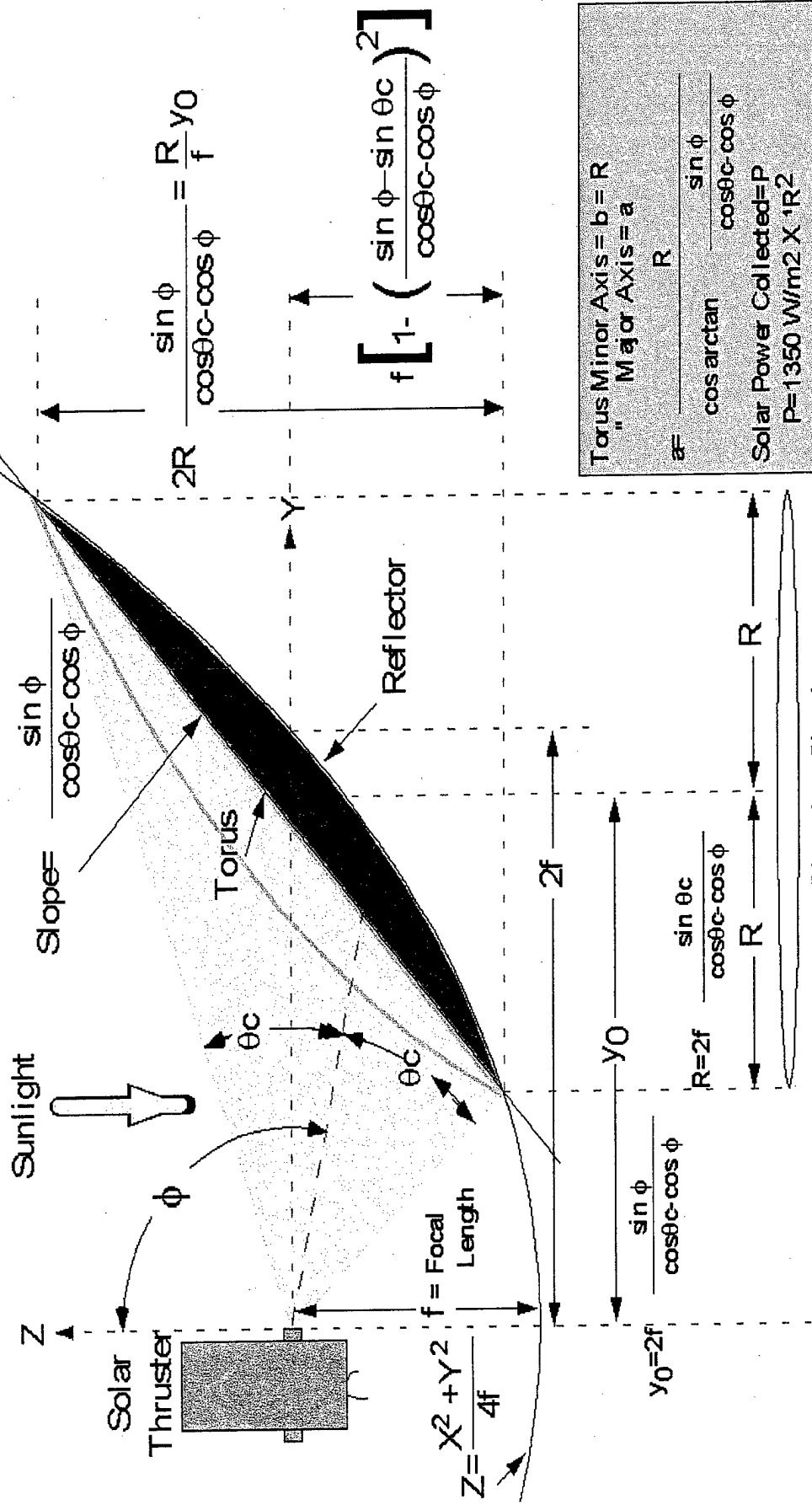




Geometry For Spacecraft



Solar Thruster Concentrator;
Torus Viewed Edge-On

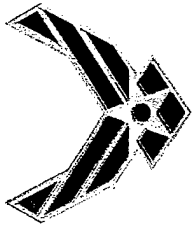


Torus Minor Axis = $b = R$
Major Axis = a

$$a = \frac{R}{\cos \arctan \frac{\sin \phi}{\cos \theta_c \cos \phi}}$$

Solar Power Collected = P
 $P = 1350 \text{ W/m}^2 \times 1R^2$

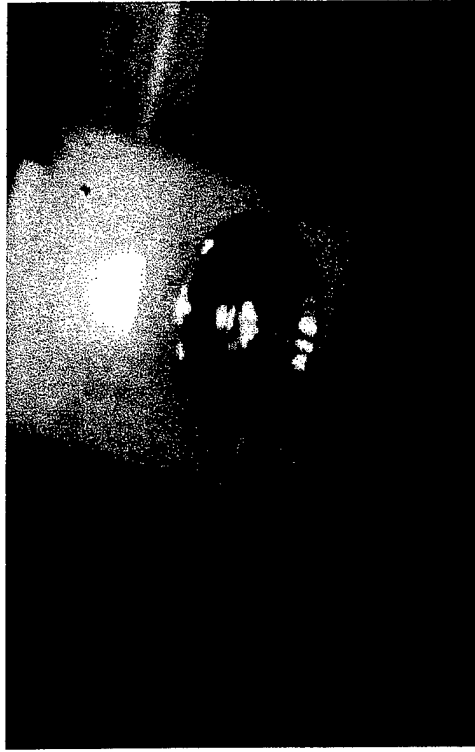
Peak = CR_{peak}
Concentration Ratio = $46,000 \sin^2 \theta_c$

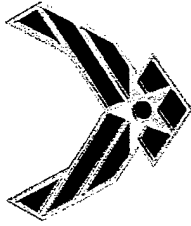


Problem



Determine location of solar focal spot on a visually complex thruster absorber and secondary concentrator. Visual complexity compounded by specular reflection from the secondary concentrator.

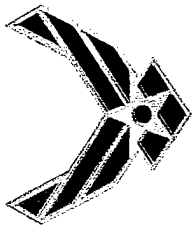




Problem Solution Concept



- **Use Charge Coupled Device(CCD) Camera as the primary fine focus sensor. Images of the thruster are taken by the camera to be analyzed.**
- **Develop digital signal processing(DSP) algorithm(s) for determining focal spot position from image of thruster absorber and secondary concentrator to produce control commands for the main concentrator.**

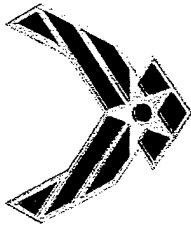


Experiment Description



Two portions of the experiment.

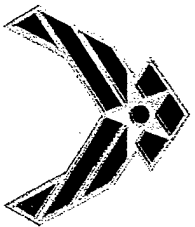
- First portion utilized data from a computer program that simulated the focal spot image from an off-axis solar concentrator.
 - Data from the program was analyzed using the 2-D Fast Fourier Transform (FFT) to see whether the coordinate location of the maximum of the focal spot intensity could be obtained.
 - Data was also analyzed using a modified Short Time Fourier Transform (STFT) to see whether the coordinate location of the maximum of the focal spot intensity could be obtained.
- Second portion will utilize real CCD images of the thruster with simulated solar light from a full scale concentrator were to be analyzed using DSP techniques.
- Second portion will also incorporate wavelet and pattern recognition methods of analyzing thruster image data.



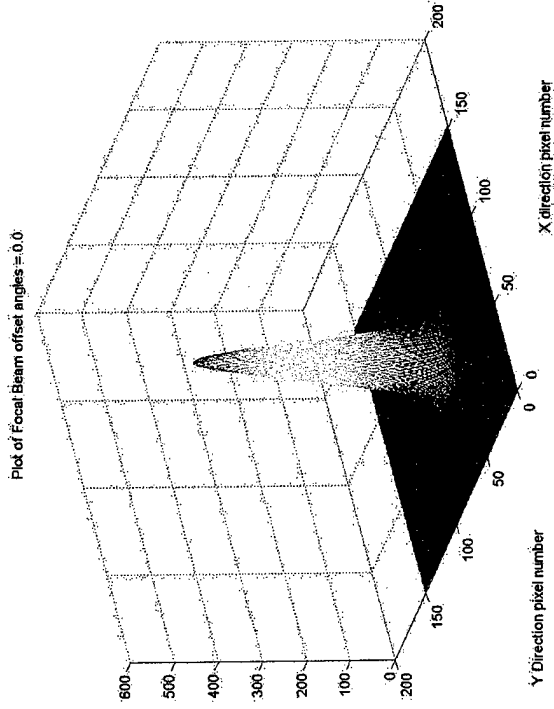
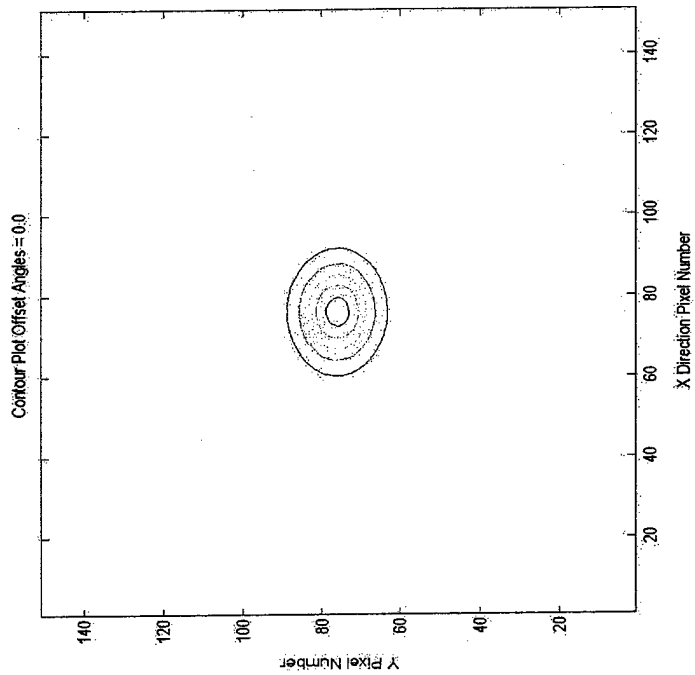
Experiment Description(cont) Mathematics

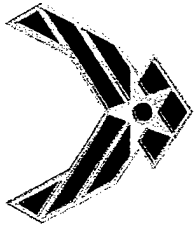


- 1 Dimensional Fourier Transform
 - Continuous Form: $\int x(t)e^{-j2\pi ft} dt$
 - Discrete Form: $\sum f(n)e^{-j2\pi n/N * k}$ (over n)
- 2 Dimensional Fourier Transform
 - $\iint f(x,y)e^{-j(\omega x + \eta y)} dx dy$
- Short Time Fourier Transform
 - “Windowed” Fourier Transform
 - $\int w(t-T)f(t)e^{-j\omega t} dt$



Experiment Description(cont) Plots of Simulated Data





Results



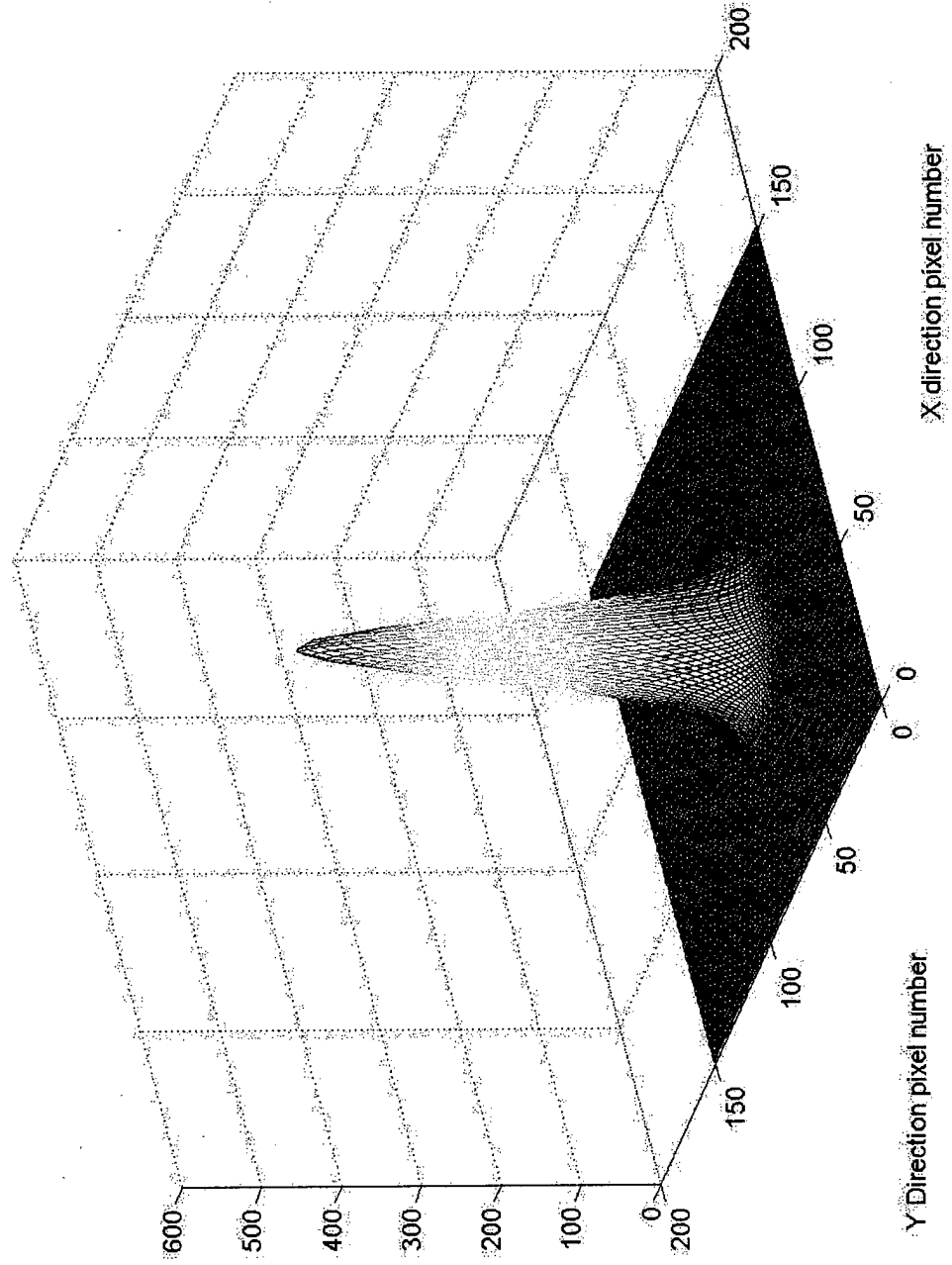
- Results from 2 D FFT limited for providing X, Y location of maximum focal spot .
- Results from 2 D STFT provides the ability to find X, Y location data useful for generating command information to the concentrators.
- Results from 2 D STFT did not indicate when the focal spot beam just changed intensity (did not move in X, Y) as when the concentrator needed to move the focal beam closer to the target or away from the target.

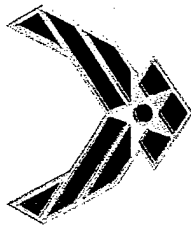


Results 2 D FFT

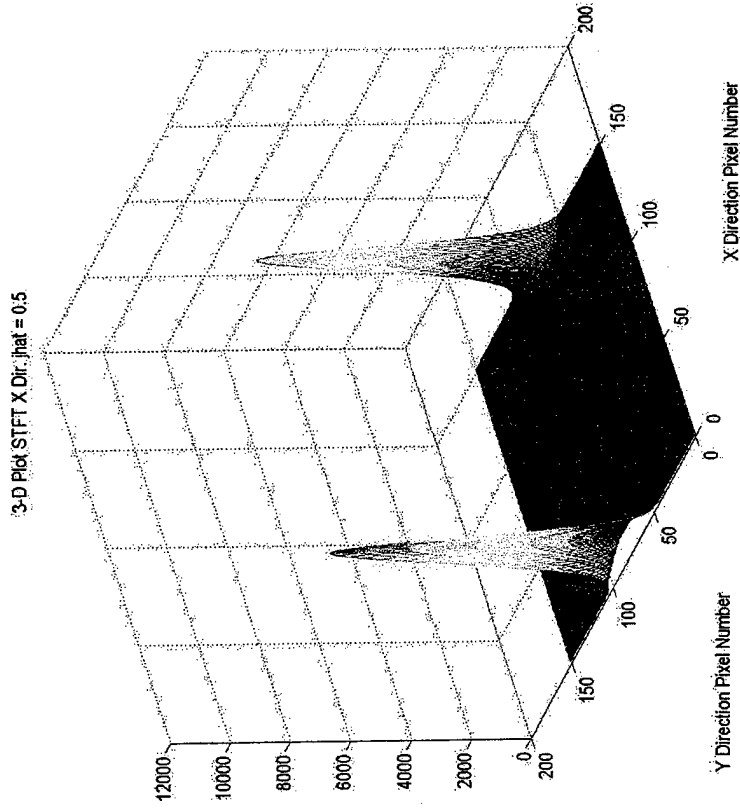
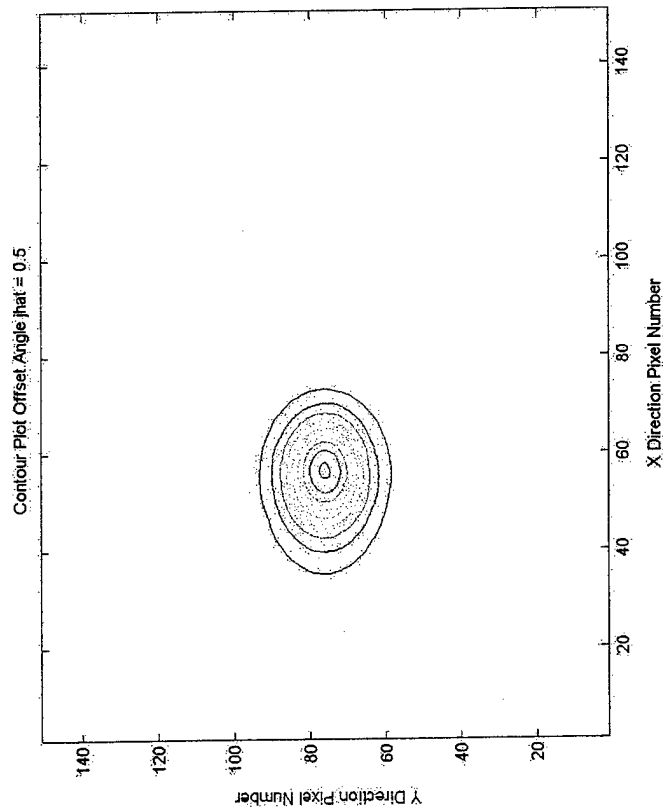


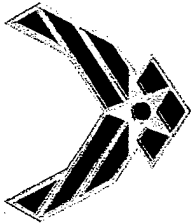
Plot of Focal Beam offset angles = 0.0





Plots STFT Data (Results)

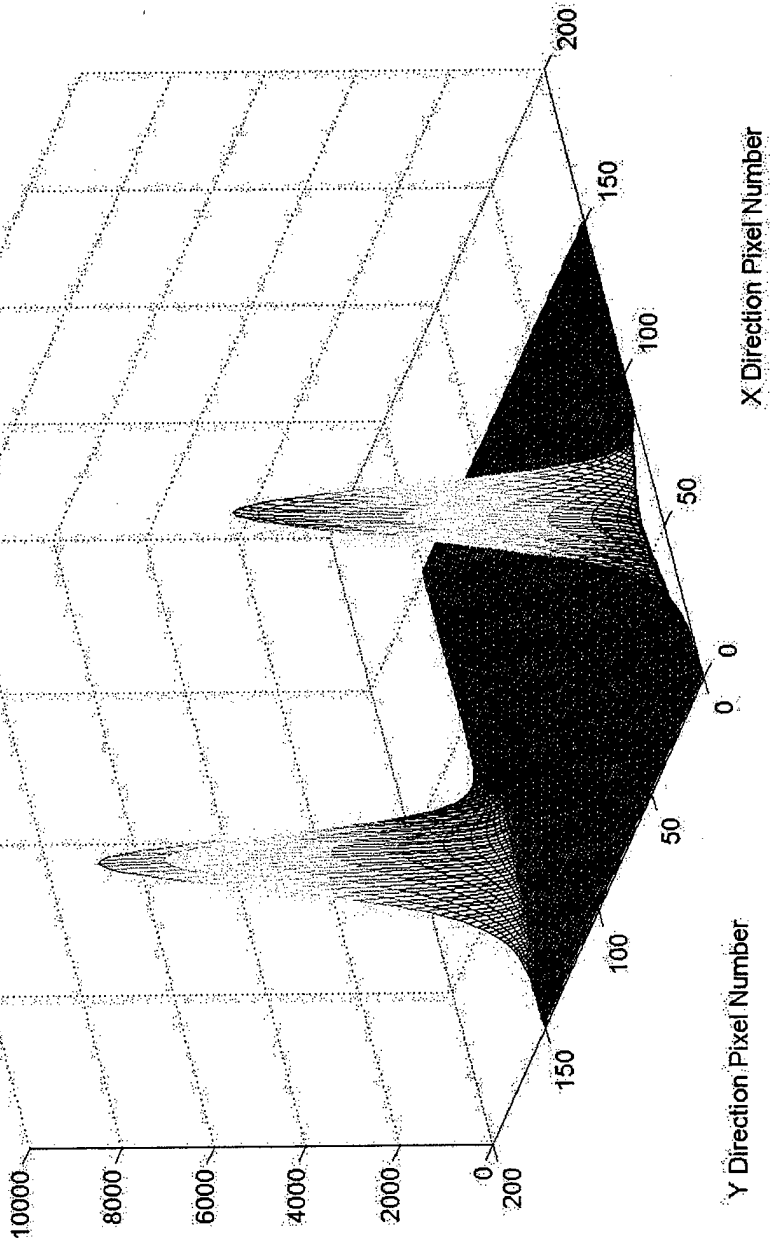


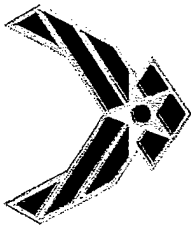


Plots STFT Data (Results cont)

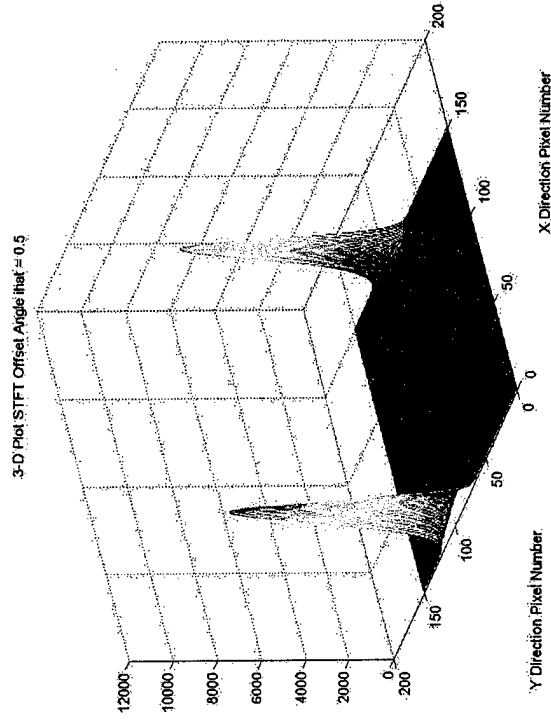
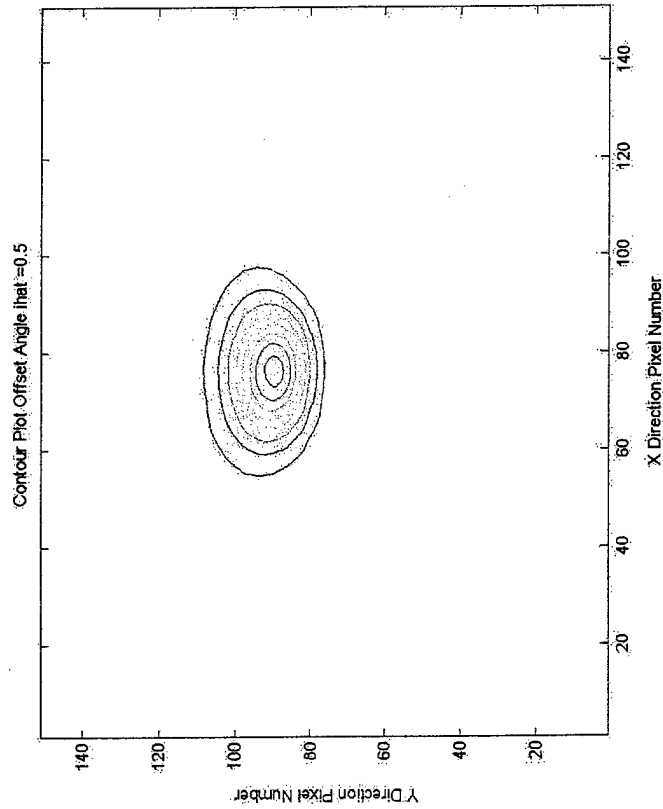


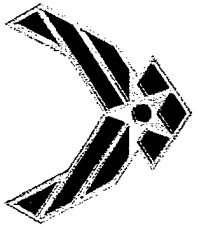
3-D Plot STFT Y Dir. \hat{j} hat = 0.5





Plots STFT Data (Results cont)

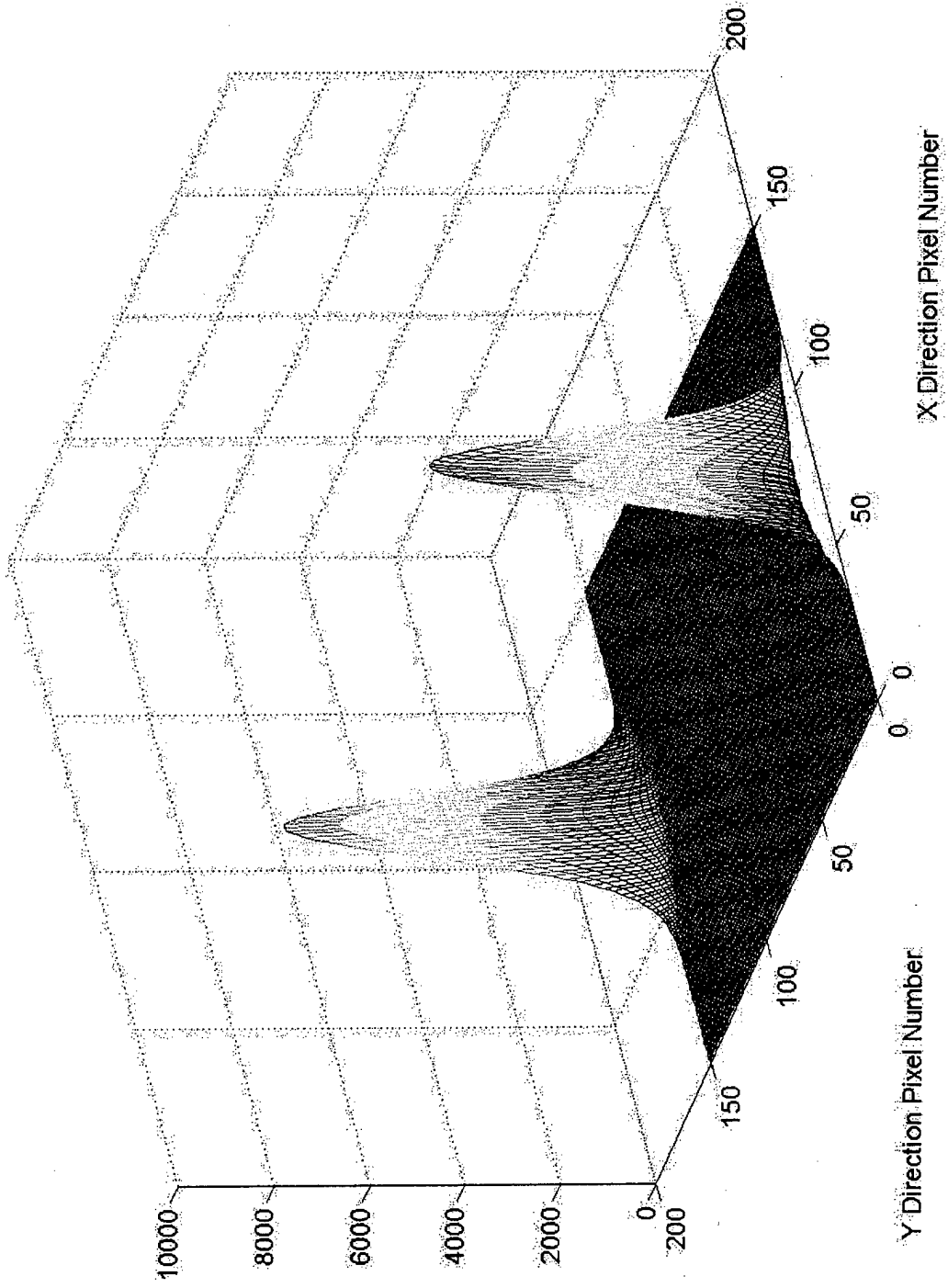


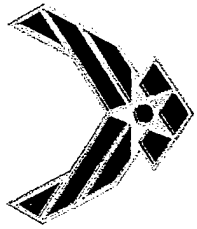


Plots STFT Data (Results cont)



3-D Plot STFT Y Dir. Offset Angle $\hat{\theta} = 0.5$





Conclusion and Future Work



- STFT concept works in defining current location for the focal spot in X, Y .
- Could use maximum value found in each direction (X, Y) of the STFT to determine location for the focal spot.
- Need method to determine when focal spot energy changes and not (X, Y) location.
- Need to study "real" CCD pictures of absorber and secondary concentrator.
- Investigate wavelet or multi-resolution method for focal spot location.
- Investigate pattern recognition methods in combination with wavelets for focal spot location.