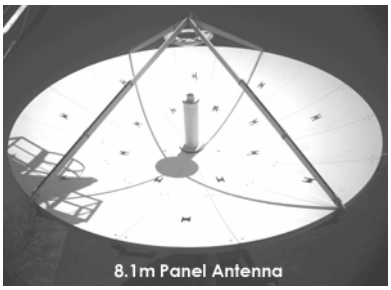
V-STARS Trial Measurements – Executive Summary



Task 1 - Panel Antenna Measurement

Primary Measurement Requirements:

- Determine the positions of 4 key points on each of 16 antenna panels.
- Determine the best-fit parabolic surface.

Project Summary:

Measured 96 targeted points on the reflector surface to an accuracy of better than 0.002" in less than an hour.

Time Summary:

The following is an estimate of the time taken to complete the measurement.

Targeting	30 minutes
Photography	10 minutes
Processing	15minutes
Analysis	30 minutes
Total	**85 minutes**

Measurement Benfits*

*(Refer to Discussion for full explanation)

1) *Non-contact measurement*
2) *Minimal temperature effect on object measurement*
3) *Shape analysis and visualization*
4) *Panel adjustment capability*
5) *Feed adjustment capability*
6) *Sub-reflector adjustment and surface measurement*
7) *System portability*
8) *Measurement in extreme temperatures*
9) *Measurement at different look angles (droop checking)*
10) *Panel measurement with feed attached*
11) *Measurement of panels in-situ in final configuration*

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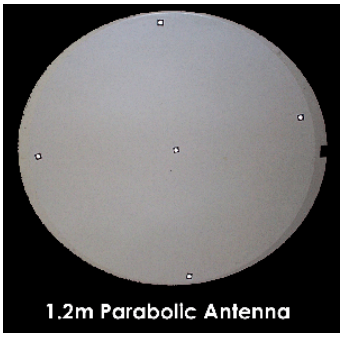
Task 2 - Parabolic Antenna Measurement



Primary Measurement Requirements:

- Determine the positions of 4 key points on each of 16 antenna panels.
- Determine the best-fit parabolic surface.

Measurement Summary:

Measured over 5,500 points to an accuracy of better than 0.0005" in less than five minutes without targets.

The following is an estimate of the time taken to complete the measurement.

Targeting	0 minutes
Photography	1 minute
Processing	2 minutes
Analysis	2 minutes
Total	**5 minutes**

Time Summary:

Measurement Benefits*

*(Refer to Discussion for full explanation)

1. *Non-contact, targetless*
2. *Variable point densities*
3. *Fast data acquisition*
4. *Capable of measuring antennas/panel to six meters in diameter*
5. *Portability*
6. *Shape analysis and visualization*

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V-STARS Trial Measurements

Introduction:

The following report is a summary of the V-STARS demonstration at the RSI facility in Duluth, Georgia on November 10th and 11th 1999.

Two measurements were undertaken. The first measurement involved the measurement of 16 panels that make up an 8.1m diameter shaped antenna. The second measurement was of a small 1.2m diameter Prodelin antenna. The objective of this measurement was to demonstrate GSI's new PRO-SPOT targetless measuring system's capabilities for measuring antennas and antenna panels.
The PRO-SPOT system is shown in the image on the left.

This report summarizes the results of each of the measurements. It also describes some of the benefits of V-STARS.

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Panel Antenna Measurement

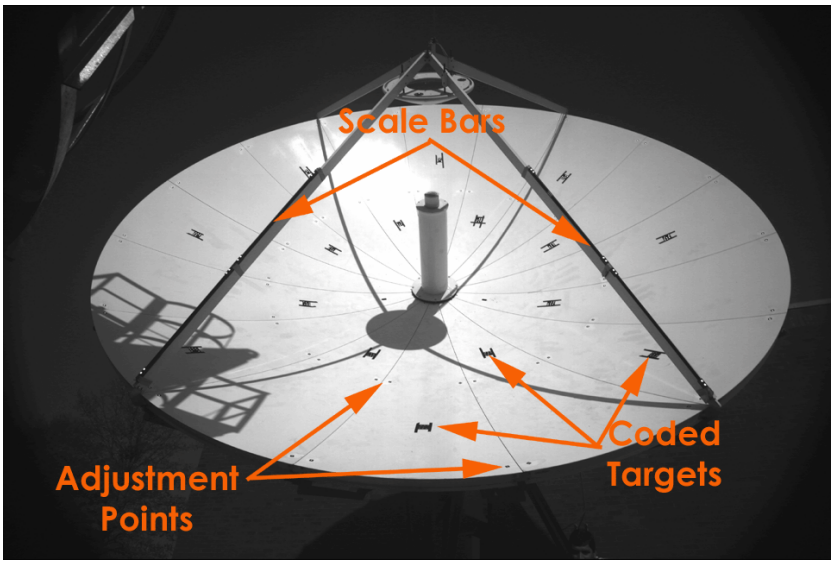
Primary Measurement Requirements:

- Determine the positions of 4 key points on each of 16 antenna panels.
- Determine the best-fit parabolic surface.

Measurement Procedure:

Targeting.

RSI personnel targeted the panels. Retro-reflective targets with a ½ inch dot were place in four locations on each of the 16 panels. The four locations corresponded to the panel adjustment points. Coded targets, an AutoBar and two scale bars were also added. One coded targets was placed on each panel and the AutoBar was placed in the middle for the best visibility. The scale bars were attached to two of the quadrupods. The adjacent diagram shows some of the key targeting elements and the general set up.



Targeting of the antenna consumed approximately 25-30 minutes.

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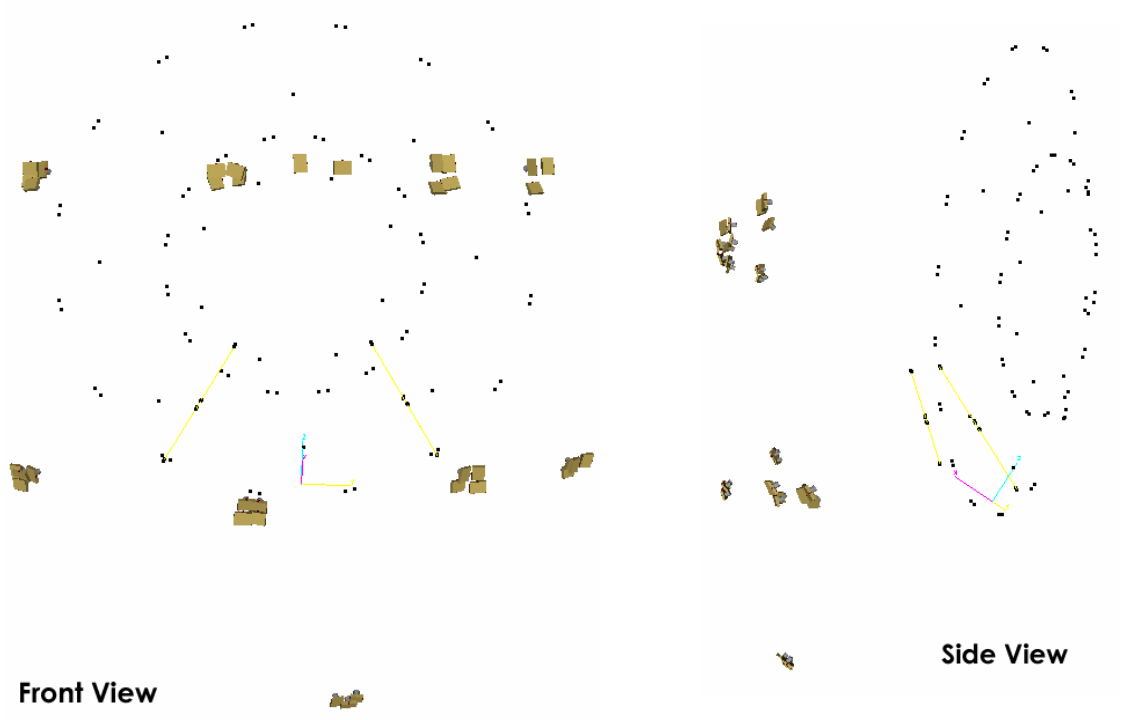
Photography

A total of 36 photographs were taken of the antenna. The photography was taken from two antenna towers located adjacent to the antenna. Photographs were taken at two levels on each tower. During the measurement the antenna was rotated in azimuth to improve the measurement angles to the panels. A few photos were also taken from ground level. Typically a man lift or ladder is used to reach the desired camera stations.

The network configuration is shown in the images below.



The photography of the panel was completed in approximately 10 minutes.

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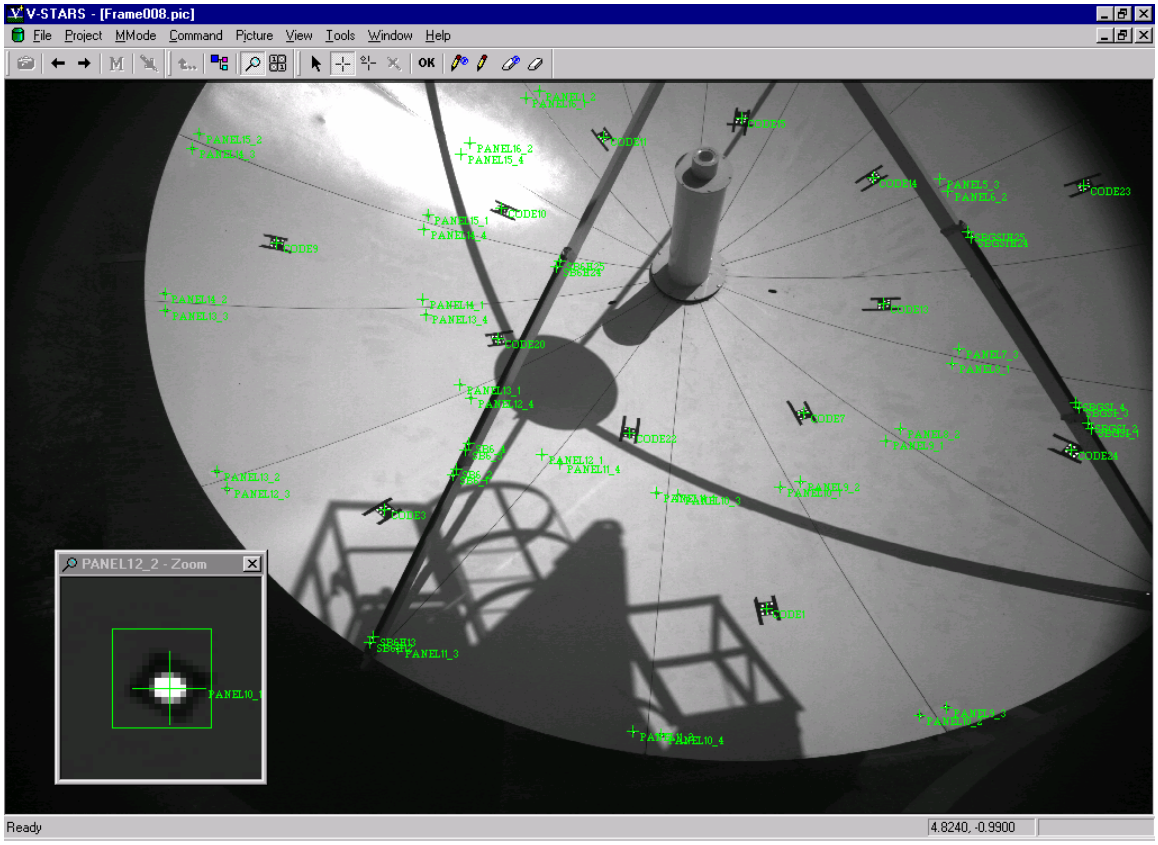
Processing

Seen below is an image taken as part of the antenna panel measurement.



The following is a summary of the measurement statistics from the measurement of the panel antenna

No of photos	36		
No of points	96		
No of scales	4		
Scale Agreement	0.0008"		
RMS(") X,Y,Z		X	0.0014
		Y	0.0012
		Z	0.0018

The processing was completed in less than 15 minutes.

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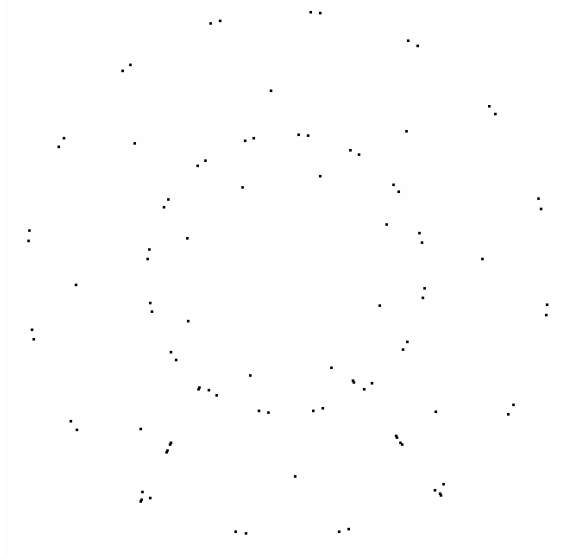
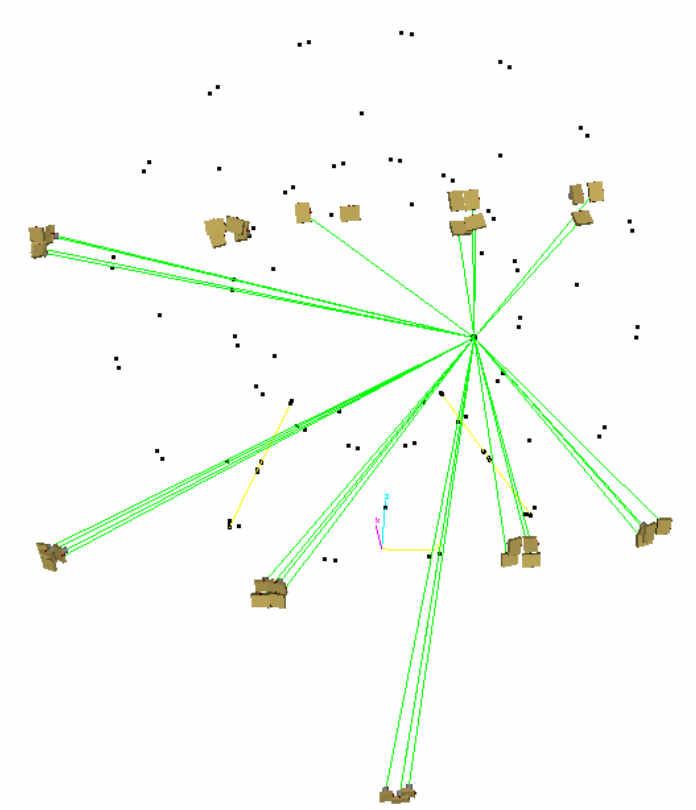
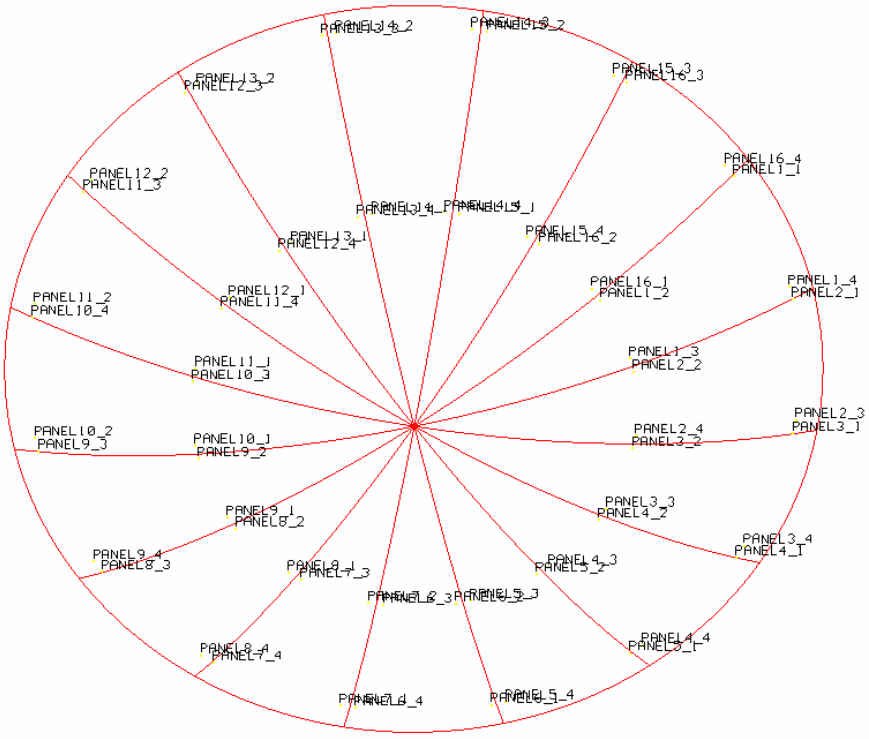
The sample intersection diagram and a point cloud are shown below:





Number Guide

The numbering scheme shown in the adjacent diagram was used. A panel number Panel1 to Panel16 was used to denote each of the 16 panel sections respectively. An internal numbering scheme was also used to identify the four individual points in the panel section. For example Panel1_1, Panel1_2, Panel1_3 and Panel1_4.



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Time Summary

The following is an estimate of the time taken to complete the measurement.

Targeting	30 minutes
Photography	10 minutes
Processing	15minutes
Analysis	30 minutes
Total	**85 minutes**

Analysis/Results

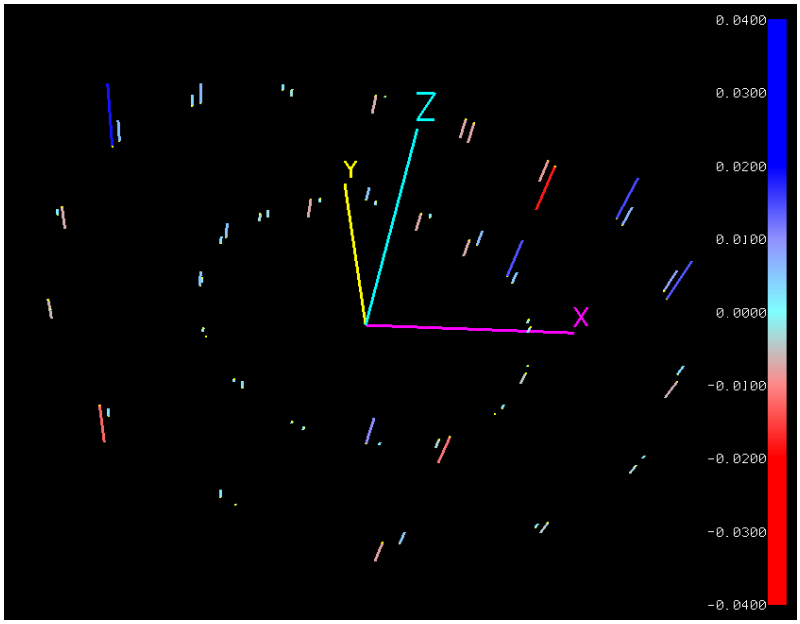
The panel data collected was used to compute the best-fit parabola for the antenna. Generally speaking the best-fit parabola is not representative of a shaped parabola. Nevertheless, it is possible to use the best-fit solution to get a fit that is fairly close to the shaped solution. The data was also used to compute surface and contour models.

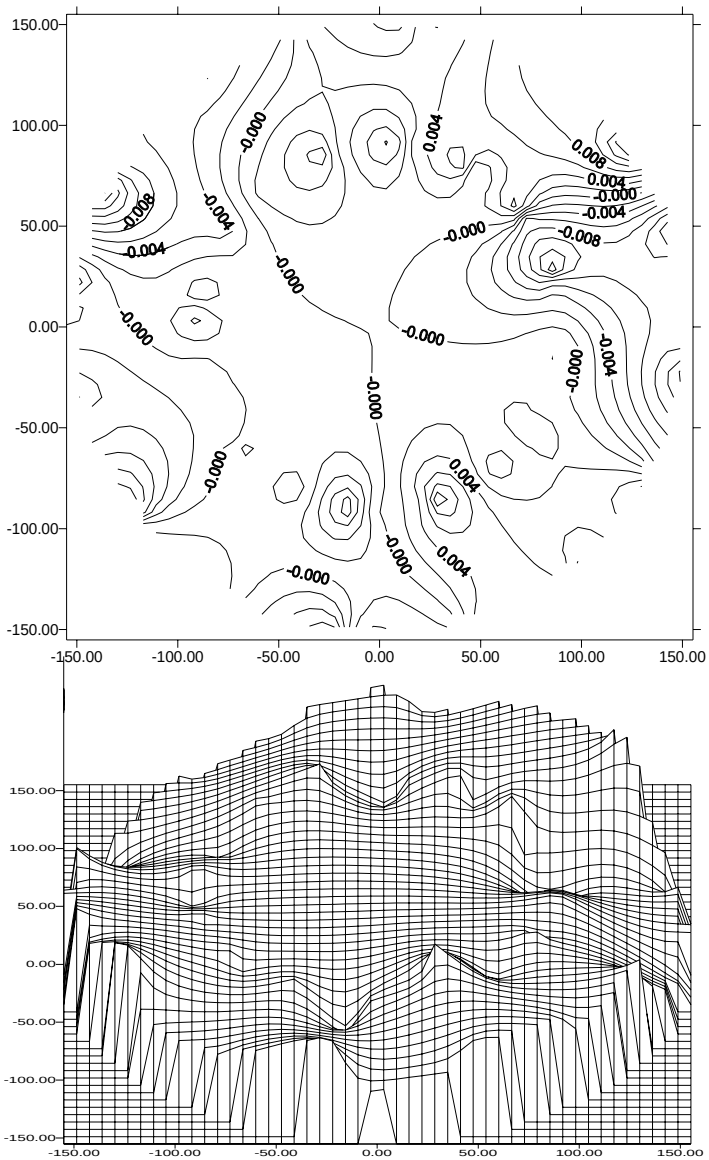
The results of the best fit are shown below.

Focal Length = 115.3791"
RMS Fit = 0.0077"
Max to Min Variation = 0.0225"

The analysis software can either constrain the parabola focal length to the design value or allow it to adjust. Results are presented graphically for the measurement on the following pages. The surface deviations from the design parabola are shown as "whisker plots", as contour maps, and as surface maps. The whisker plots were produced using GSI's optional SOLIDS software. The color and length of the whisker plots vectors indicate the size and direction of the deviations from the design surface. Also, the length of an individual whisker is displayed by placing the cursor over it.

The contour and surface maps were produced using an inexpensive third-party contouring program from Golden software called Surfer. The graphical results for the surface deviations from the best-fit parabolas are not included because they are nearly identical to these results.





Whisker Plot, Contour Plot and Surface Map for 8.1m panel antenna

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Discussion

The panel antenna measurement has shown that V-STARS can be a very powerful inspection tool. The results of the measurement are very accurate and more importantly were produced quickly. With correct planning and targeting this data acquisition time could even be reduced further.

There are some significant advantages photogrammetry has over other measurement technologies.

1) *Non-contact*

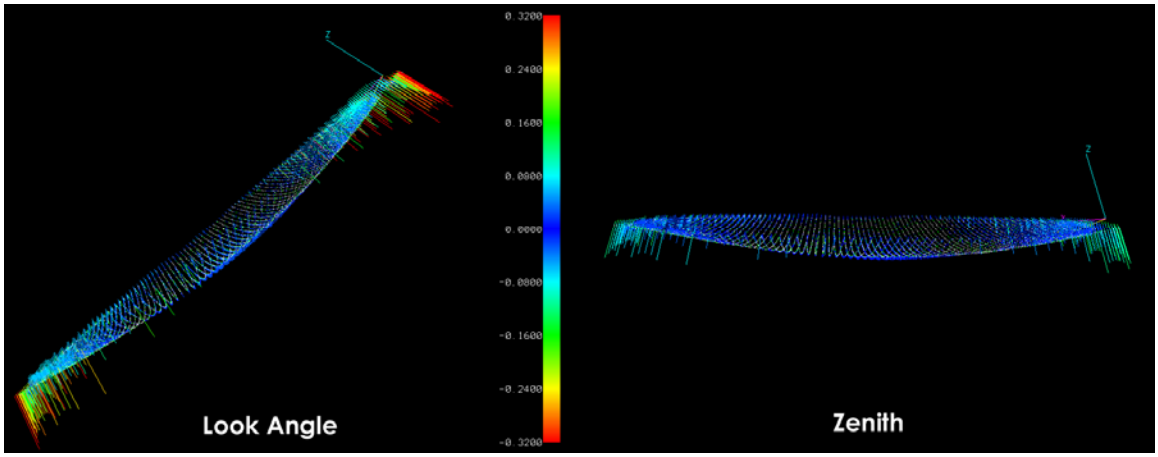
During the photography no contact is made with the antenna panels. This means that there is no deformation of the panels due the influence of a person in the vicinity.

2) *Minimal Temperature effect*

As the photography is completed in less than 10-15 minutes the effect of temperature differential between the start and end of measurement is greatly minimized.

3) *Structure Motion and Shape Analysis*

Photogrammetry is the only practical technology that allows the user to study how an antenna changes shape with attitude or over time. The antenna can be moved into different attitudes and the shape change studied. It is also possible to evaluate how the antenna is changing through the course of a day or perhaps over the course of a year. As the targets are already in place collection of this data is as easy as taking another set of photography.



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4) Panel Adjustment

During antenna installation it is possible to complete a measurement to quantify the amount of adjustment needed to bring the panels into the correct shape. Once adjustment has been completed repeat measurement will help verify the effects of the changes and the level of any re-adjustment needed. The advantage of this method is that with each adjustment the entire shape is re-evaluated. Other methods adjust each panel individually with no consideration of the effect this might have on the overall shape. Other methods also dictate that expensive targets be moved from panel to panel or removed at the completion of the adjustment. The retro-reflective targets used are cheap (10 cents each) and disposable. In fact, a typical retro reflective target will remain serviceable from 3-5 years. This means that the antenna can be re-evaluated each year to detect deformation effects.

5) Feed Adjustment

Traditionally adjustment of the feed once the antenna is installed has been difficult. Fortunately with photogrammetry it is possible to measure the feed prior to installation and then relate this information to the panels during the installation process. Targets on and around the feed can then be used to move the feed into its ideal position.

6) Portability

The entire system is battery operated and hence is highly portable. The system can be taken to even the remotest places. Once "size-wise" carry on case and a laptop computer is all the equipment needed to complete a measurement.

7) Extreme Temperatures

The system can operate in temperatures ranging from –20ºC to +40ºC.

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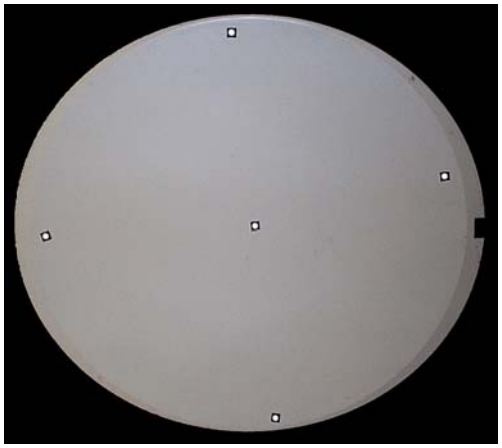
Antenna Measurement Using PRO-SPOT Projector



Primary Measurement Requirements:

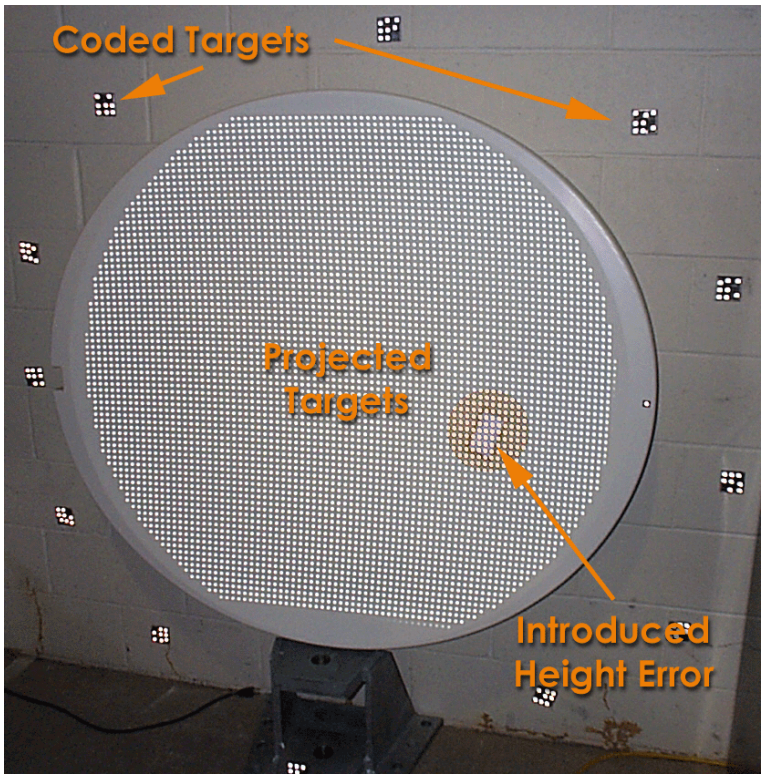
- Determine location of multiple surface points on a 1.2m Prodelin antenna.
- Compute the best-fit parabolic surface.

Measurement Procedure:

Targeting.

Targeting for this project was very simple. Coded targets, an AutoBar and two scale bars were added to the area surrounding the area of interest for the initial measurement. The AutoBar and scale bars were removed for subsequent measurements. This was done to mimic the manner in which the system would function in a production environment.

The surface targets were generated using the PRO-SPOT projector. A modeling light was used to focus and position the array of targets. Care was taken to ensure that the projected targets did not fall on any of the reference targets. A business card was also stuck to the surface of the antenna to simulate an introduced height error. The adjacent diagram shows some of the key targeting elements and the introduced height error.



Targeting of the piece consumed approximately a minute.

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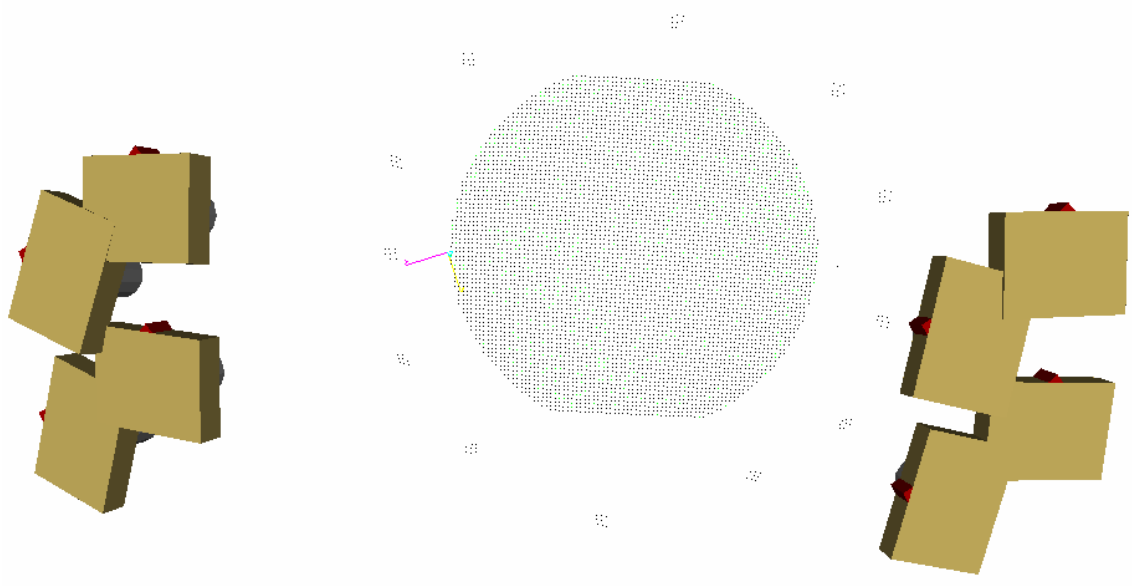
Photography

A total of eight photographs were taken of the antenna. These were distributed around the antenna.



The network configuration is shown in the image below.

Side View

The photography of the panel was completed in approximately two minutes.

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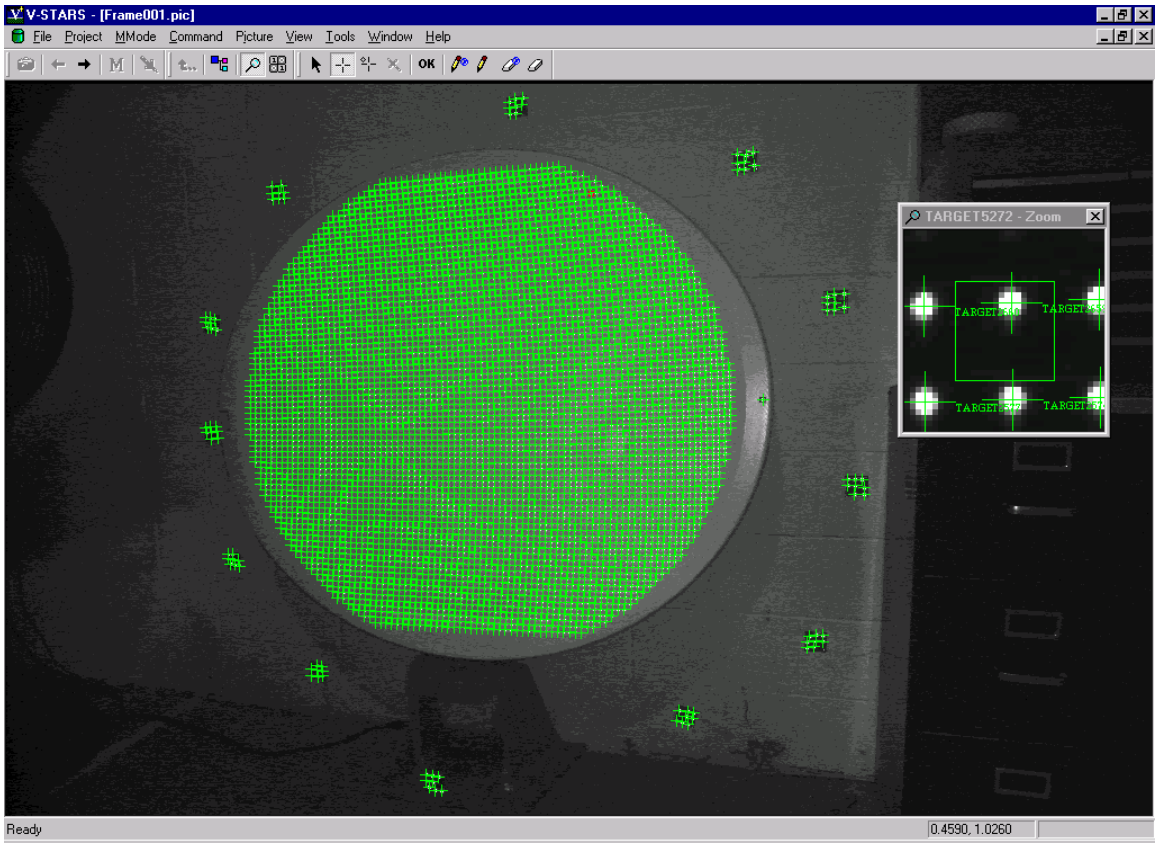
Processing

Seen below is an image taken as part of the antenna measurement.



The following is a summary of the measurement statistics from the measurement of the antenna.

No of photos	8		
No of points	5579		
RMS(") X,Y,Z		X	0.0002
		Y	0.0002
		Z	0.0004

The processing was completed in less than two minutes.

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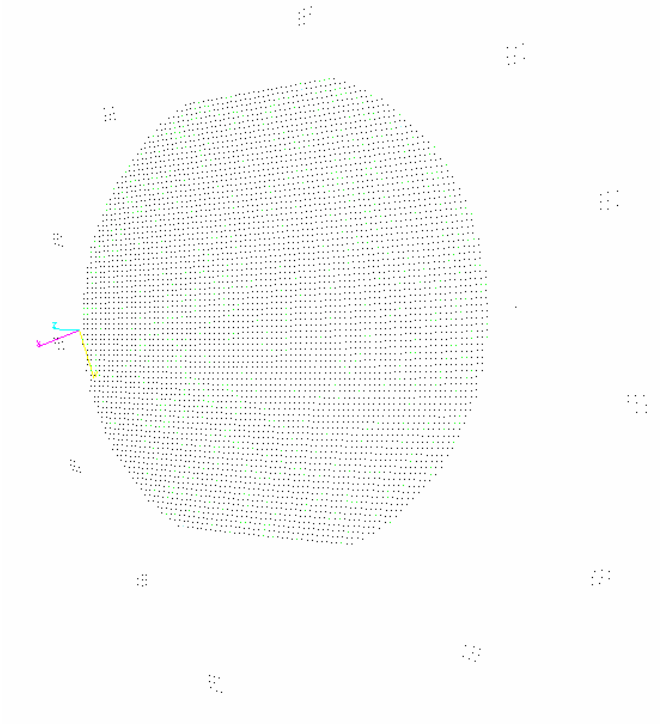
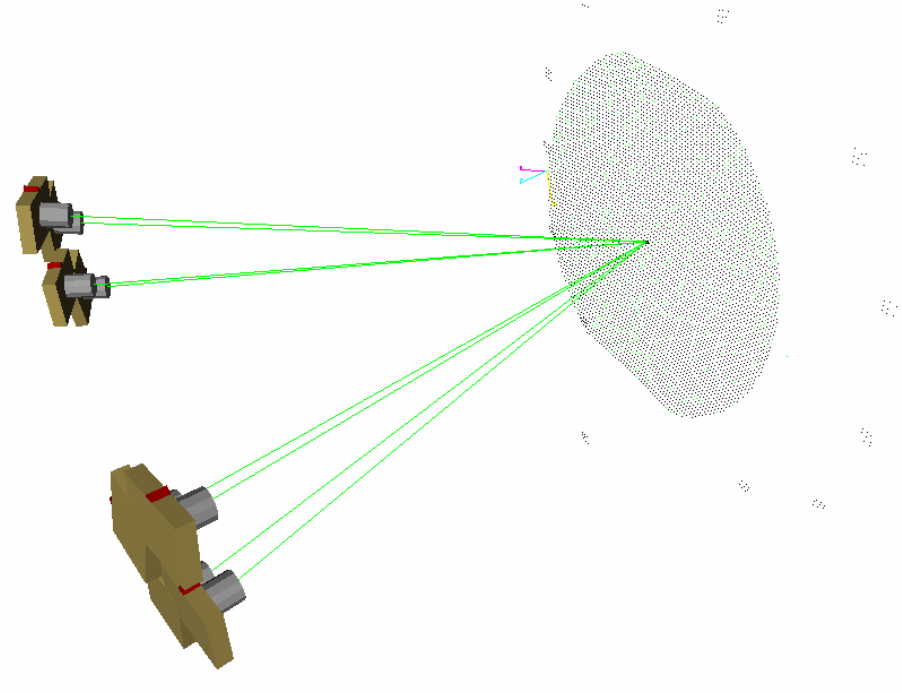
The point cloud and a sample intersection diagram are shown below:





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Time Summary

The following is an estimate of the time taken to complete the measurement.

Targeting	1 minutes
Photography	2 minutes
Processing	2 minutes
Total	**5 minutes**

Analysis/Results

The point data collected was used to compute the best-fit parabola for the antenna. The results of this best fit are reported below. The data was also used to compute surface and contour models.

The results of the best fit are shown below.

Focal Length = 38.3486"
RMS Fit = 0.0089"
Max to Min Variation = 0.0391"

As mentioned earlier a business card was added to introduce height error. This error is clearly shown in the image below. The deviations shown indicate how far the surface of the card is from the idea parabola.

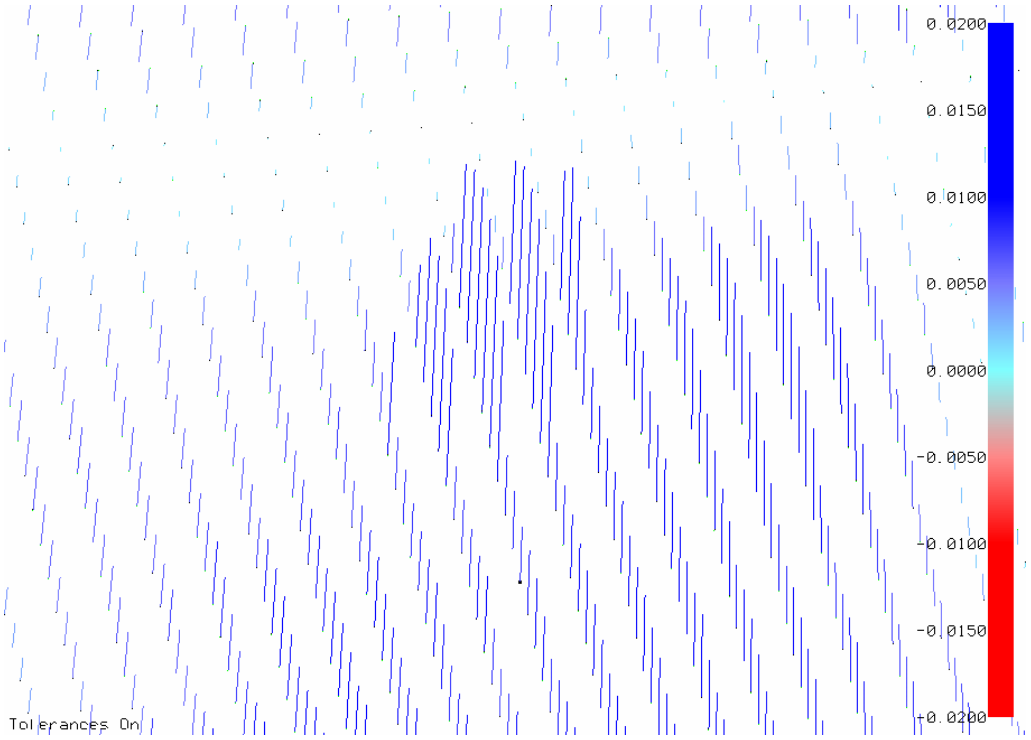

Image showing business card induced error

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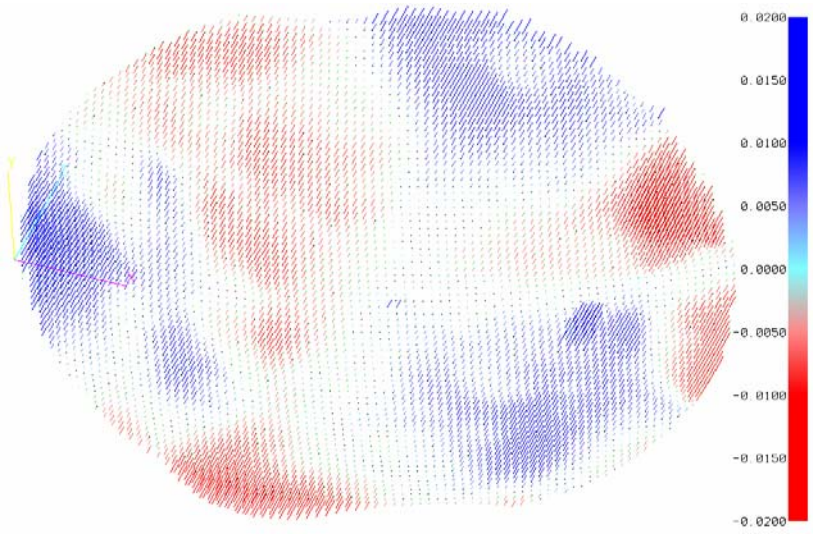

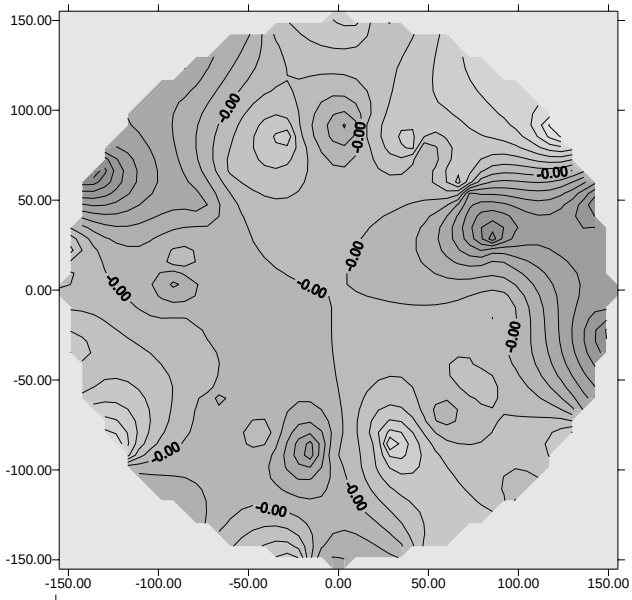

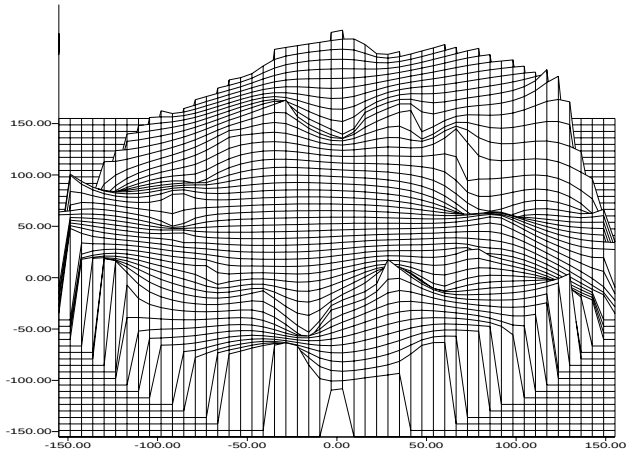

Whisker Plot, Contour Plot and Surface Map for 1.2m antenna

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Discussion

The PRO-SPOT projector system has demonstrated how large volumes of high accuracy surface data can be collected very quickly. Once again the results of the measurement are very accurate and more importantly were produced quickly. There is tremendous scope to incorporate this type of system directly into a production line.

Advantages of this technology over other measurement technologies include:-

7. *Non-contact*

Once again the measurement technique is completely non-contact. There is no surface deviation due to measurement contact with the surface.

8. *Variable data collection rates*

The number of points collected on the surface can vary from as few as 600 to as many as 6,000. The time needed to collect the point data is the same regardless of the different point densities.

9. *Fast Data Acquisition*

The information necessary to create the point data is collected in a matter of minutes. This makes the system ideal for a production environment where time constraints are critical.

10. *Flexibility*

The PRO-SPOT system is flexible enough to handle a wide variety of surface measurement tasks. For a large component, such as a 10m panel section, the projector can be moved to a new set up and the data incorporated together. Alternatively a second projector could be added.

11. *Portability*

The system can easily be packed up and carried to a supplier or customer for on site measurement tasks.

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Concluding Remarks:

The V-STARS/S single-camera measurement system is a well-established, accurate, reliable system for making targeted measurements of antennas, their components, and associated tooling. The system is extremely portable, fast, accurate, easy to use, and can measure in unstable environments. The measurements undertaken have shown just some of the potential of a V-STARS system. The new PRO-SPOT target projection system takes this potential to a new level. The results of the PRO-SPOT measurement were produced quickly, but not at the expense of accuracy.

GSI would like to thank RSI for welcoming us into their facility. We will be happy to discuss the results of this report or any other aspect of the technology presented.

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