blue technik
Virtuoso Robot Engineering

Robot Works

ROBOTWORKS CASE HISTORY

COMPLEX POLISHING PATH DEVELOPMENT

ABSTRACT

This Case History describes how RobotWorks was used to develop a series of complex robotic polishing paths. Path shape specifications were provided to Blue Technik. Paths were developed using RobotWorks+SolidWorks. Robot animations were recorded to verify robot motion, path geometry, and end effector accuracy. All communication was done remotely with customer via e-mail.

PROJECT DESCRIPTION

A customer contacted Blue Technik to develop a robotic polishing path application consisting of a variety of complex paths. The customer's own programming staff was not available and this project was on URGENT status. The requirement for the robot to carry a polishing end effector on an aircraft window. It was necessary to constrain the end effector path within the ellipsoid shaped window. The end effector was to be normal to the surface of the window at all points of the path.

The specification was well defined for the TYPE of paths:

- Vertically-oriented overlapping Figure-8 polishing path
- Horizontally-oriented overlapping Figure-8 polishing path
- Peripheral path along the edge of the window
- An additional requirement was added later to provide a spiral polishing path to start in the center of the window and and progress to the outward edge with continuously increasing radius while constrained to the ellipsoid shape.

The actual dimensions and details of the path were provided as shown here. It can be seen that these sketches are free-hand and lack specific detail.

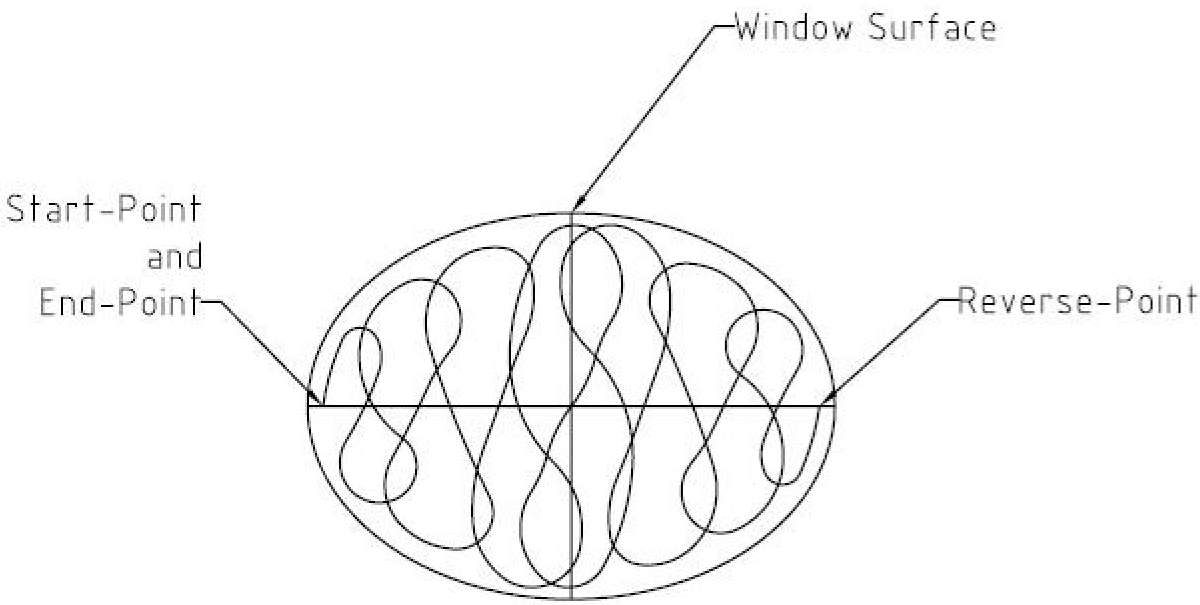

Figure 1: Vertically-oriented overlapping Figure-8 polishing path

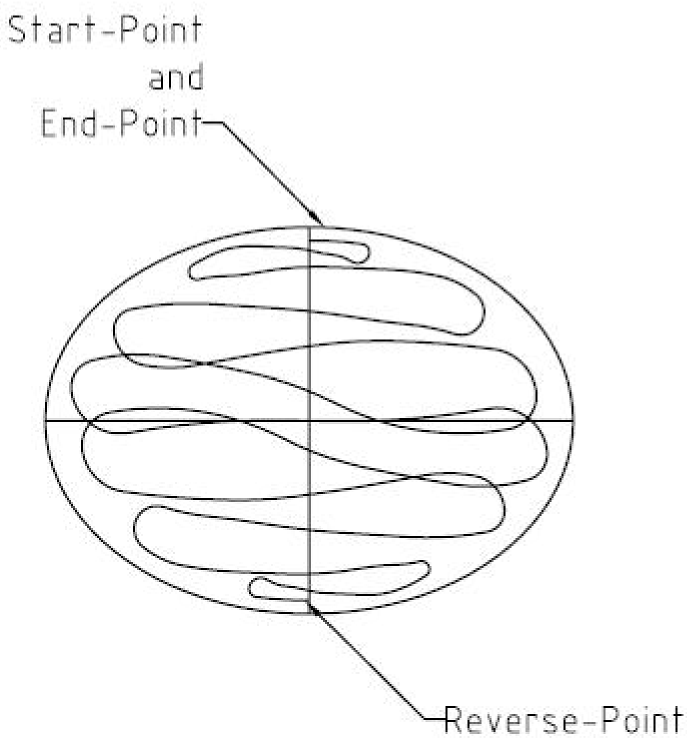

Figure 2: Horizontally-oriented overlapping Figure-8 polishing path

The customer provided CAD models created in Autodesk Inventor solid modeling software. A view of the total workcell is shown in Figure 3.

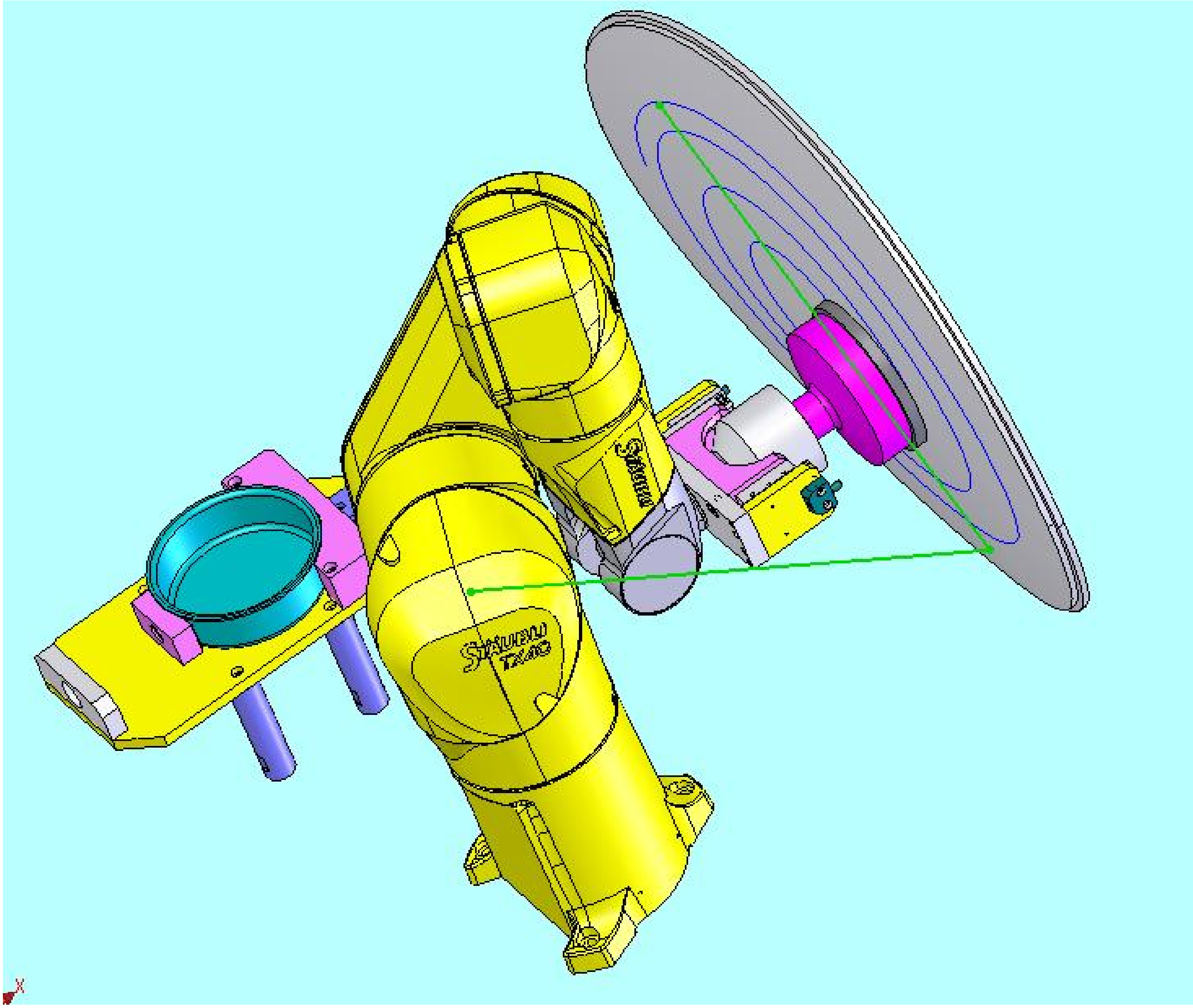

Figure 3: View of robotic airplane window polishing workcell

SOLUTION DESCRIPTION:

RobotWorks+SolidWorks was used to construct the Vertically- and Horizontally-oriented overlapping Figure-8 paths using the following steps:

1. Convert the Autodesk Inventor CAD files to SolidWorks format.
2. Reconstruct the workcell in SolidWorks.
3. Modify the window part:
   a. Create a SolidWorks Sketch over the working surface of the window part
   b. Create a grid pattern of lines on the Sketch to use as guide when creating the overlapping Figure-8 patterns
   c. Create another Sketch for the Figure-8 pattern and construct the pattern with freehand line+arc segment, point, and spline entities.

d. RobotWorks+SolidWorks cannot handle overlapping paths. Therefore it was necessary to modify the total path by inserting break points with the SolidWorks Split Entities tool.
e. A series of Sketches for each segment of the total path was then created. Each individual path segment was copied to the appropriate Sketch with the SolidWorks Convert Entities tool.
f. Each Sketch was then projected to the surface using the SolidWorks Project Curves tool to create a surface-conforming path
g. Each Curve entity was then converted to a SolidWorks Composite Curve entity using the Composite Curve tool

4. The series of individual Composite Curves was then selected as RobotWorks path entities for the total path.
5. The path was created and developed with RobotWorks.

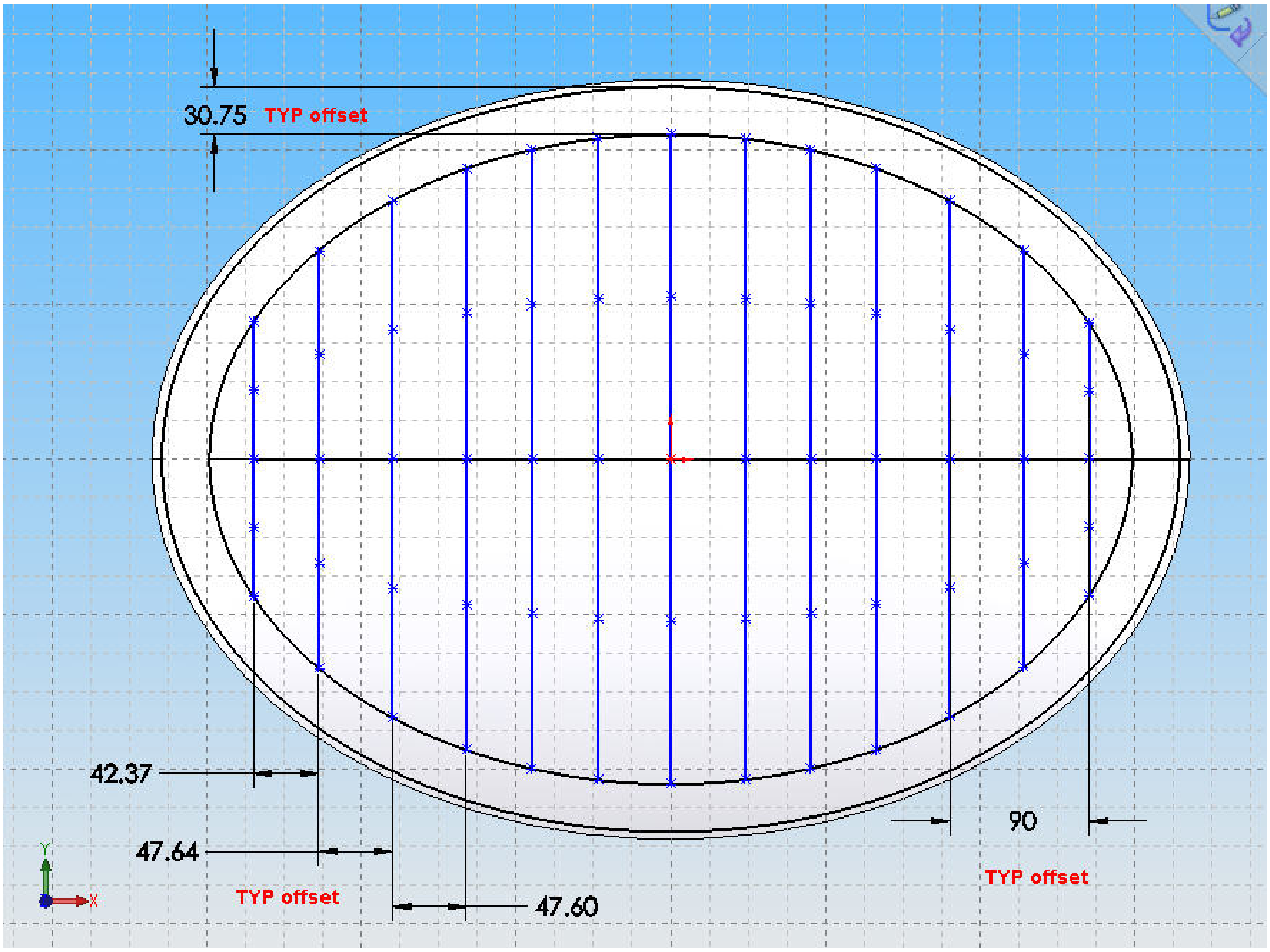

Figure 4: Grid lines created on a SolidWorks Sketch as guide lines and points for the overlapping Figure-8 paths.

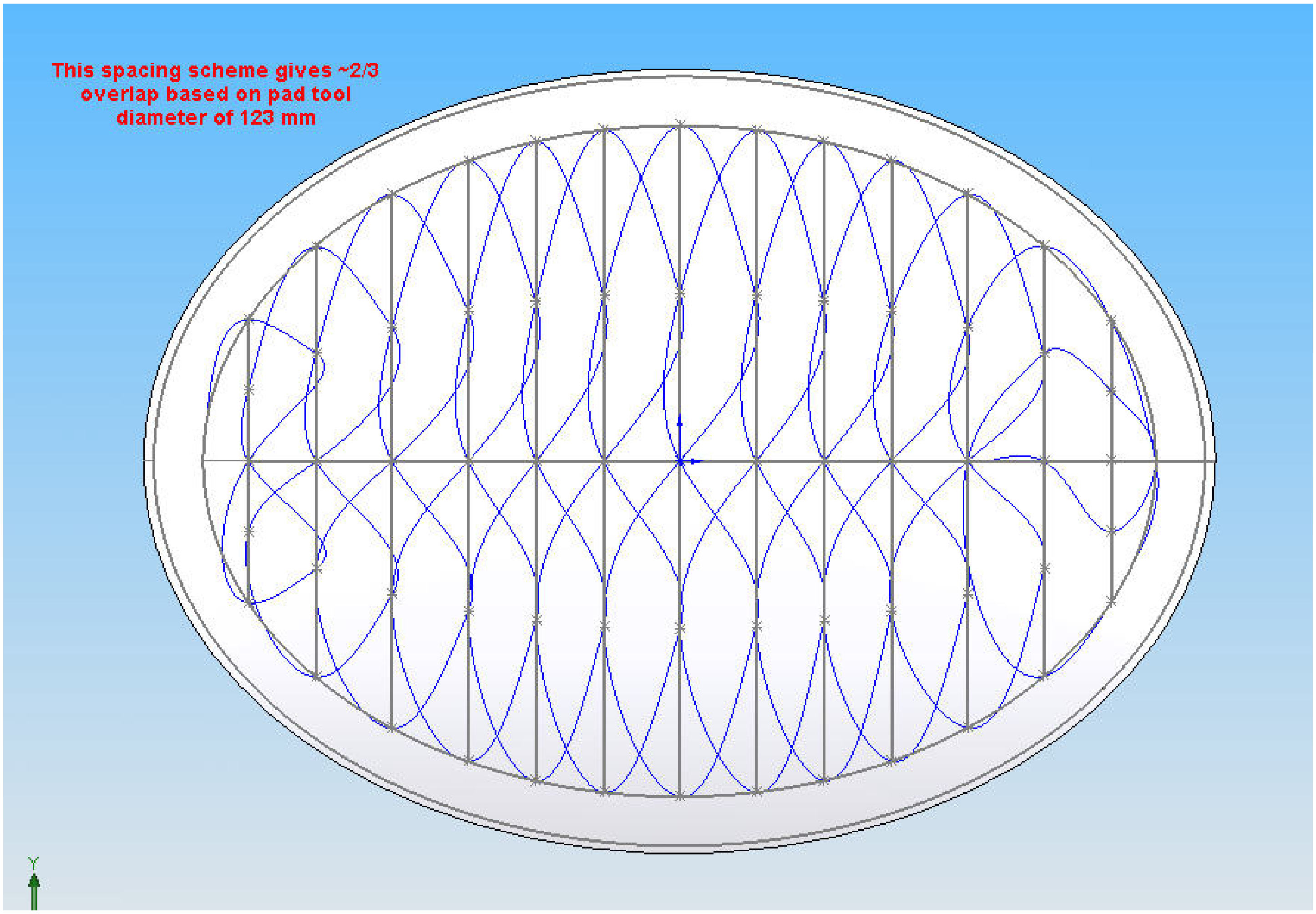

Figure 5: Vertically-oriented Overlapping Figure-8 path created on a SolidWorks Sketch

Customer verification was required. A movie of the robot motion an path geometry was made using the built-in screen capture feature of RobotWorks. The movie was then emailed to the customer. At this point the customer provided instruction on constraining the motion of the end effector within the edges of the part.

The path was easily modified to suit the customer requirements. The polishing path points were developed again in RobotWorks and exported to the customer via email. The same procedure was generally followed for both Figure-8 paths.

The same procedure was used for the Peripheral Edge path. At first this was a very simple task. The customer requested that the end effector have a 15-degree tilt instead of being normal to the surface. Path Geometry requirements dictated that the path be broken into segments and the contact point of the end effector modified from the center of the polishing pad disk to the edge. The total path had to be reconstructed from individually modified segments. Again, all contact with the customer was via movies and email.

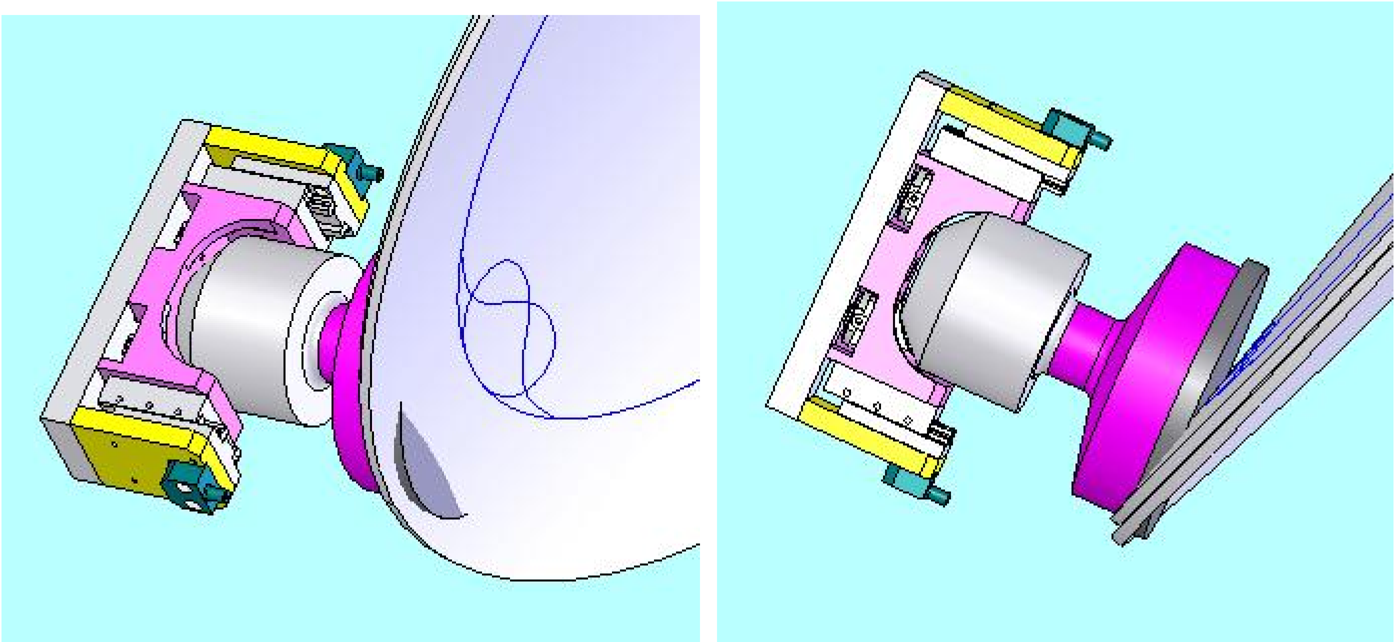

Figure 6: Initial development of Edge path showed interference

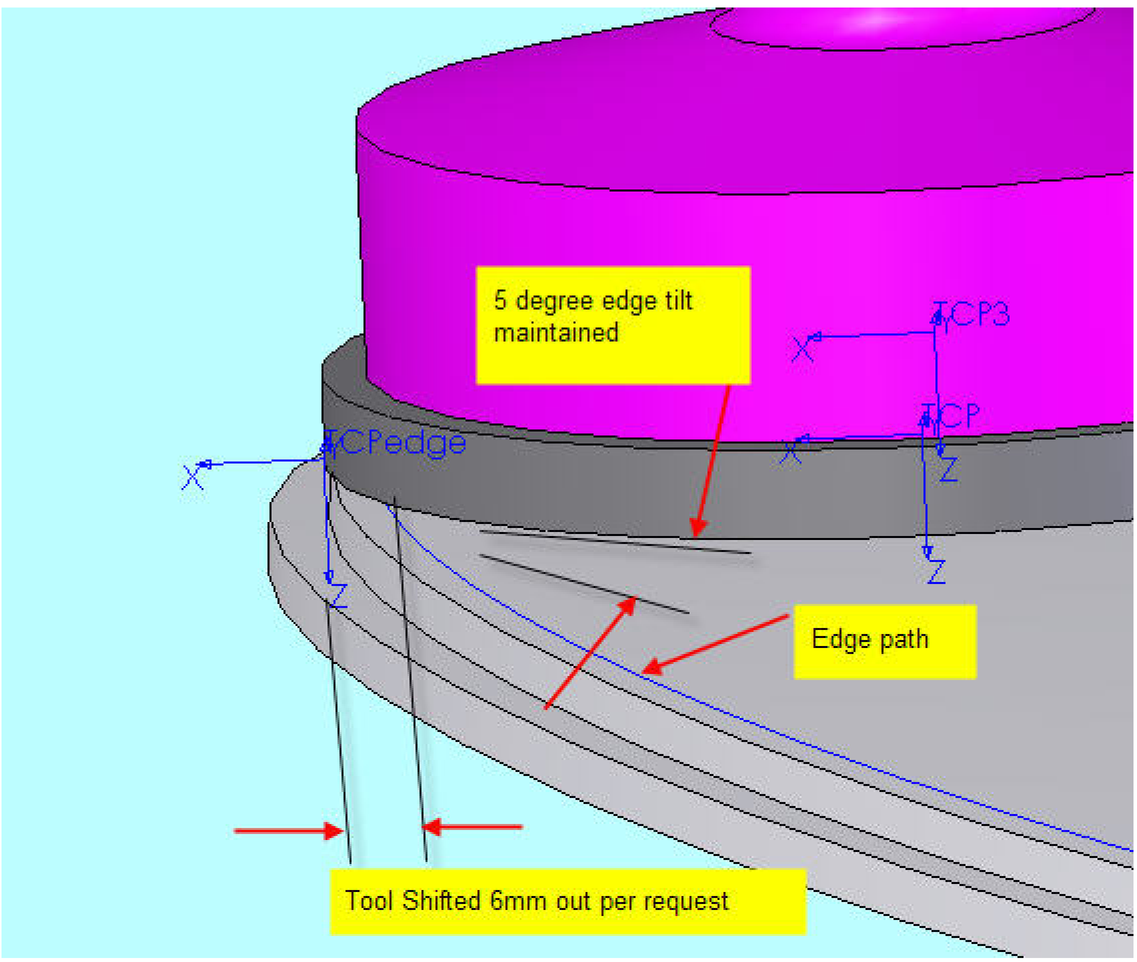

Figure 7: Screenshots of the path development process were taken using the Built-In Screen Capture feature of RobotWorks. This made communication with the customer very easy and efficient.

The Spiral Polishing path required more sophistication.

1. Mathematical formula for an ellipse were researched.
2. This formula was entered into a MSExcel spreadsheet. The independent variable was the degrees of rotation about the center of the spiral. The dependent variables were the { X, Y } point pairs along the spiral path. The spreadsheet was set up to provide the customer the option of varying the radius of the spiral and the step size between points. This MSExcel spreadsheet was emailed to the customer so that they could experiment to determine the optimal shape parameters for the spiral path.
3. The path point { X, Y } pairs were transcribed to a SolidWorks Sketch.
4. The Sketch Points were used to create a SolidWorks Spline entity.
5. The Spline was projected to the surface and robot path points created as in the Figure-8 paths.

Percentage of overlap for each spiral revolution	60.0%	variable
width of polishing pad (mm) from CAD data	133	static
MAX major axis distance (= 2a) from CAD data	524.61	static value, limits overlap of pad over edge
MAX minor axis distance (= 2b) from CAD data	348.28	static value, limits overlap of pad over edge
rotational step size (degrees)	30	variable
amount of radial growth per rotational step (mm)	3.325	calculated value

MAX -X value	-262.305

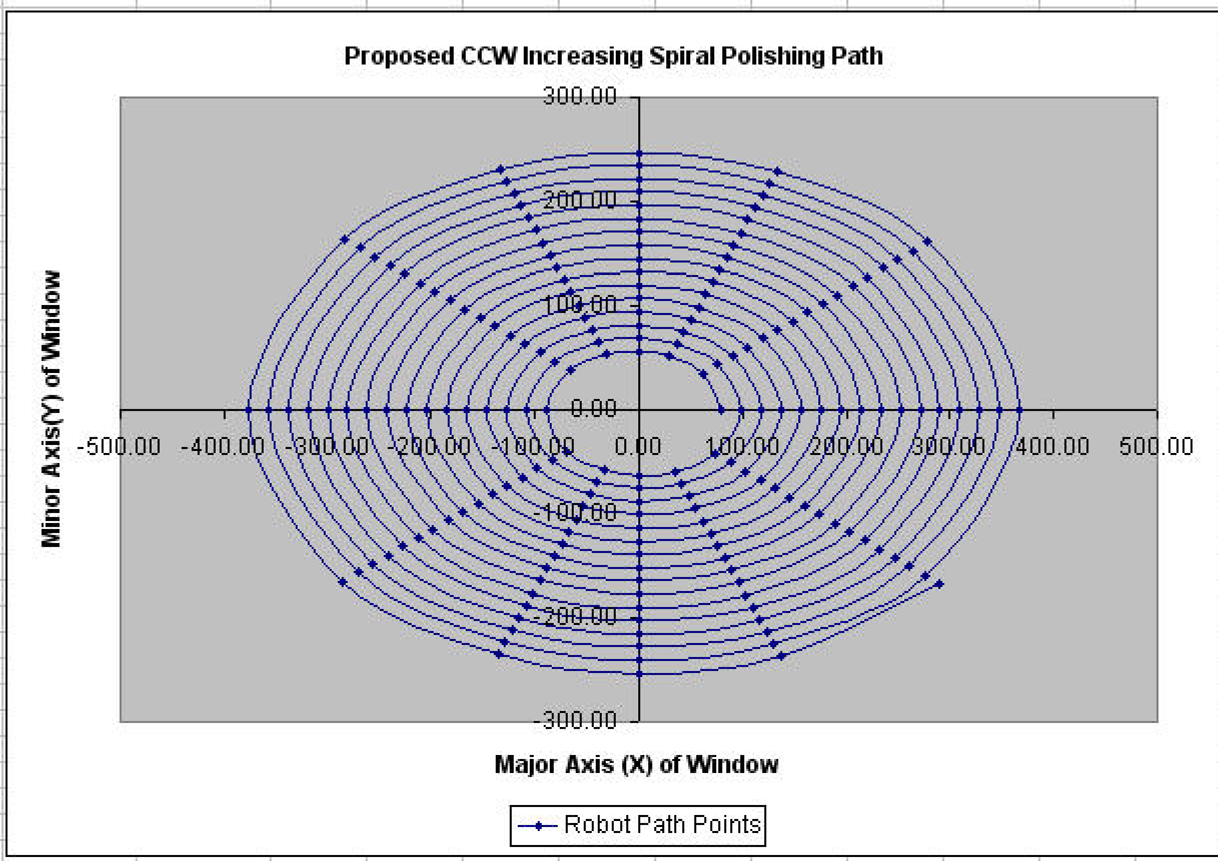

Figure 8: A MSExcel spreadsheet was created to provide the { X, Y } path point data calculation for the spiral of increasing radius.

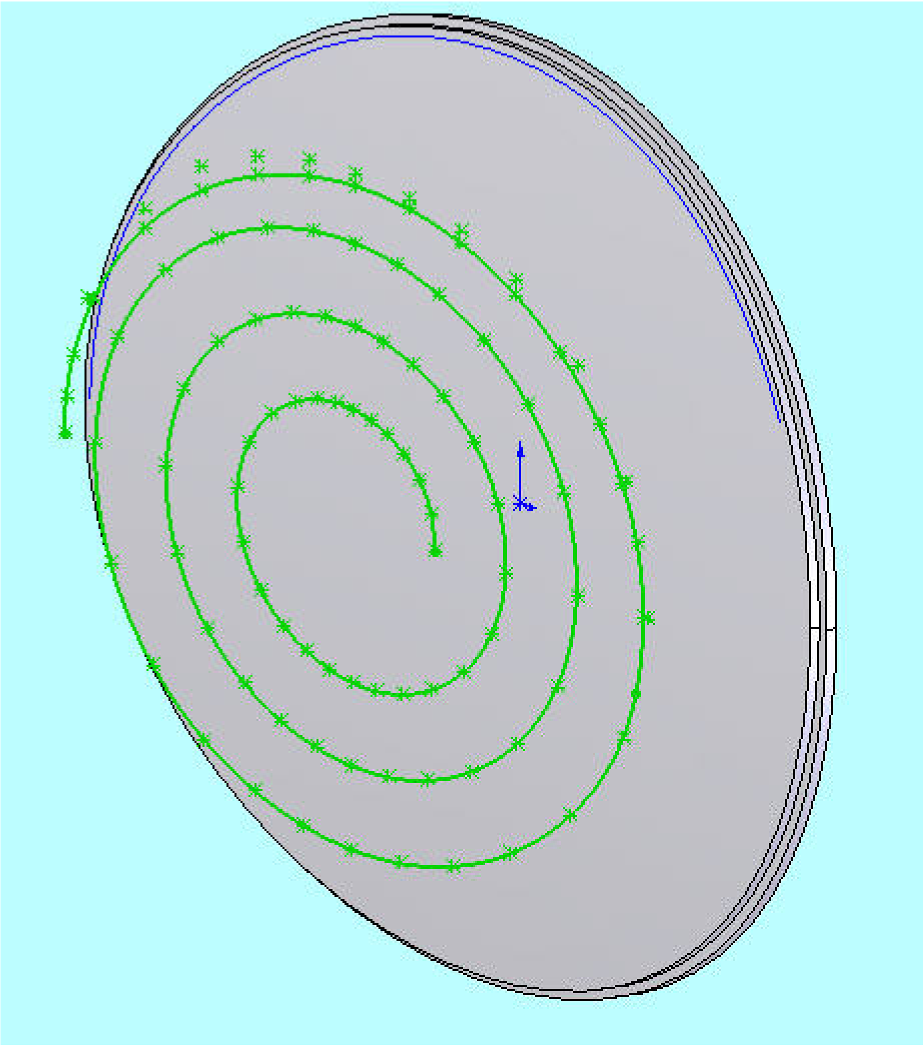

Figure 9: Path Point { X, Y } pairs were transcribed to a SolidWorks Sketch and used to create a SolidWorks Spline entity.

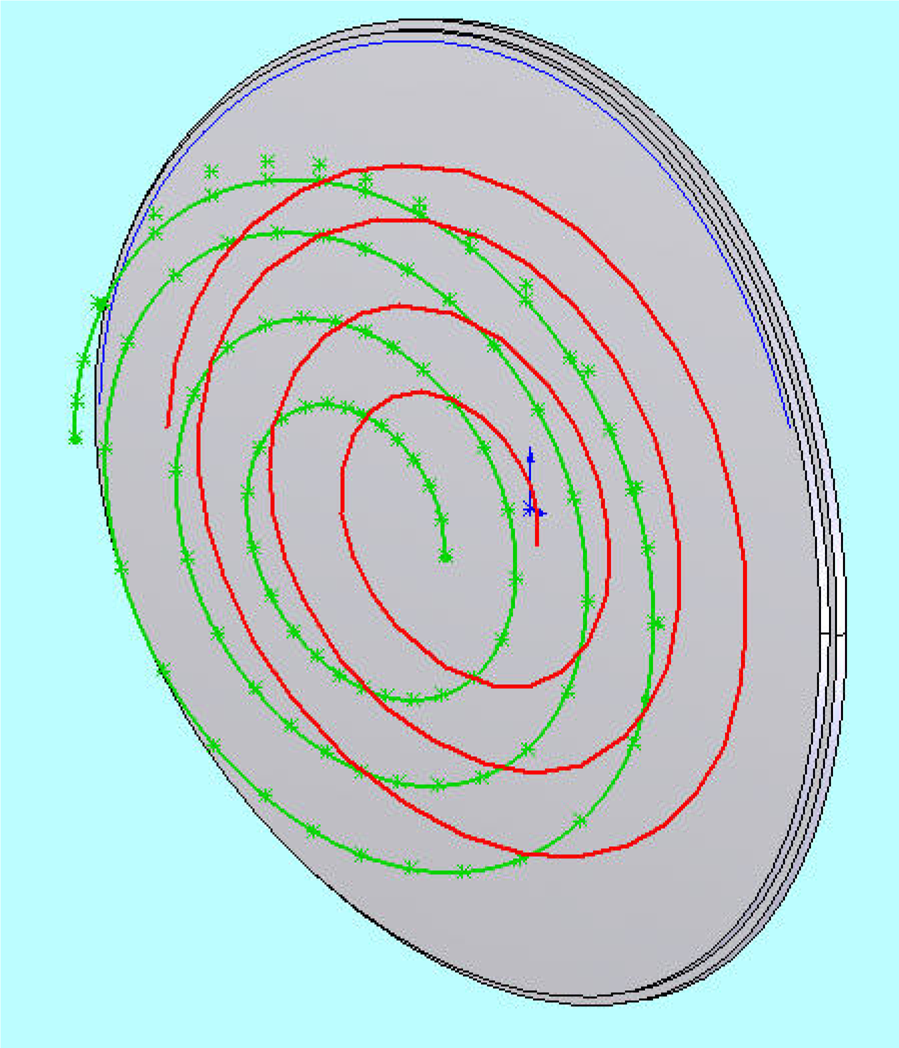

Figure 10: The Spline was then projected to the surface to create a surface-conforming path.

CONCLUSIONS:

The entire project was conducted remotely via email. The customer implemented path point data and all robot paths were perfect on the first pass. The customer admitted that the only way that his urgent project could have been completed with the normal vector / ellipsoid geometry constraint he imposed was with the use of RobotWorks software.

END OF DOCUMENT