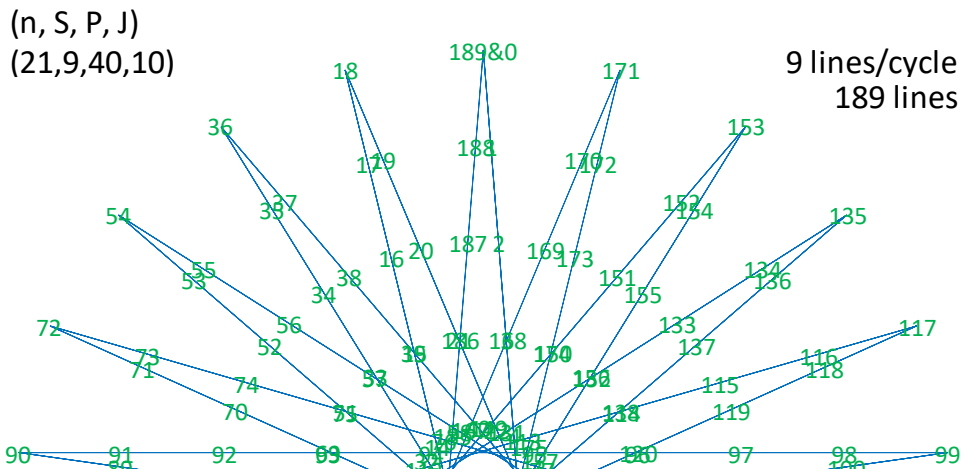


## Reverse Engineering *Needles with Shields*

[Needles with Shields](#) started off with a 23-needles image that was one-time around, but not single-step of a small number of steps. We found *single-step* of length 7 versions of *Needles with Shields* by focusing attention on  $J/n$  close to 0.5. Three versions were shown based on  $n, J$  of 31,15, 45,22, and 59,29, but additional versions are possible if you simply look including 48,23, and 53,26. Each is 3SST in which  $J$  is the largest value smaller than  $n/2$  that is not a multiple of 7 and  $n$  is also not a multiple of 7,  $S = 9$ , and  $P$  is controlled by [The 7-Line Generator Function](#). Of course, these *single-step* of length 7 images do not occur for all  $n$  since, as noted [elsewhere](#), not all  $n$  have 3SST base images.

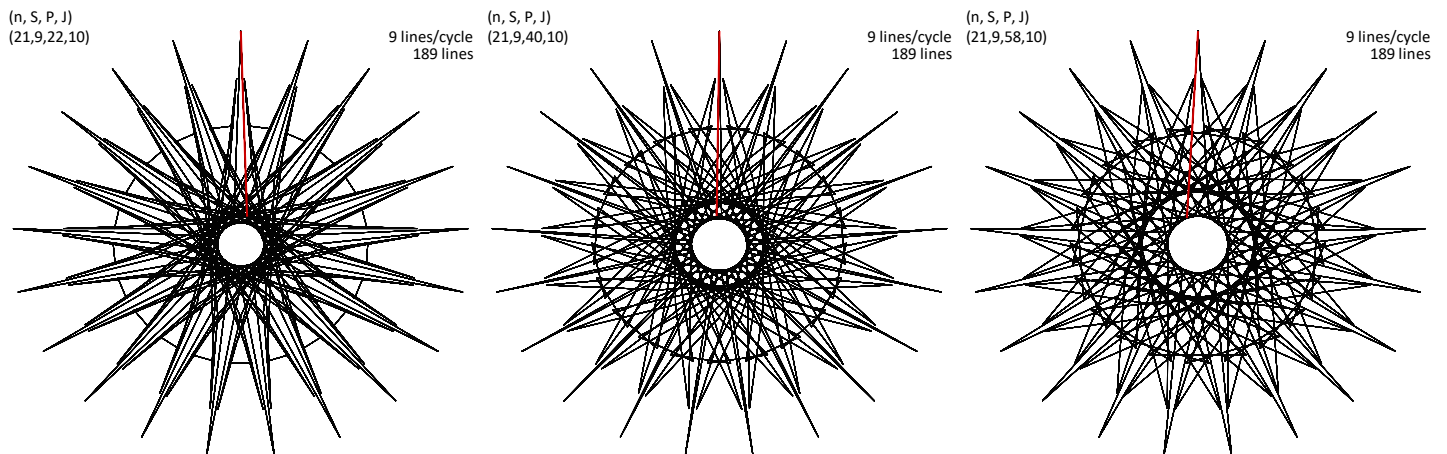
**Creating an  $n$ -needles version using numbered subdivision endpoints and VF.** Suppose you want to create a 21-needles version. *The image must have a first line that is almost vertical.* The end of the first line should end just above the center of the image on the innermost level, *Level 4*, given  $S = 9$  as discussed in [E7.1](#). This  $n$  was chosen for three reasons: 1)  $n$  is a multiple of 7 so that the resulting image will **NOT** be *single-step* of length 7; 2)  $n$  is smaller than the smallest version discussed above; and 3) A smaller  $n$  makes looking at the **green numbers** (from [E10.2.1](#)) easier to distinguish since there are only  $189 = 21 \cdot 9$  total endpoints.

We want the endpoint to be close to the vertical centerline on the 4<sup>th</sup> level in from vertices of the 21-gon. The numbers suggest 3 possible values: **4 more than 18** (vertex 20), **4 more than 36** (vertex 19) and **4 more than 54** (vertex 18). The images created using these three values of  $P$  are shown in the next row,  $P = 22, 40, 58$  from left to right. The first line is shown in each instance to focus attention on where the first line ends.



Of course, you cannot read the numbers in the middle, but you can see the numbers leading up along each **VF** line.

One can see the general structure of *needles with shields* for all three but the middle one has the sharpest needles. In each instance, just like with the original 23-needles image, the shield for the top needle is only started much later in the image drawing process. Put another way, the number of lines before achieving a *single-step* is much larger than 7. *Single-step* status occurs at line 43 for the left image, 52 for the middle image, and 88 for the right version.



One can have even longer needles before the shields occur by decreasing  $S$ . An odd  $S$  is needed to maintain  $SCF = 1$ . By setting  $S = 7$  with  $n = 21$  and  $J = 10$ , one obtains two viable versions,  $P = 17$  and  $P = 31$ .

With this as background, you should be able to create *needles with shields* images of any size using subdivision endpoints.