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# Introduction

**Change Record**

|  |  |  |  |
| --- | --- | --- | --- |
| **Issue** | **Date** | **Sections Affected** | **Change Description** |
| 0.1 |  |  | Creation of the document |
| 0.2 |  | 3.2 | Location of centres of FPUs defined |
| 0.3 | 17/12/15 | 3.1.4 | Collision avoidance zone updated for new arm design |
| 0.4 | 4/2/16 | 3.1.3 | Movement parameters of the motors added |
| 0.5 |  | 3.1.4 | Switch actuator avoidance zone added |
| 0.6 |  | 3.1.5 | Theta angle corrected to match co-ordinate definition |
| 0.7 |  | 3.1.2, 3.1.3, 3.1.5  4  All | Comments about calibration of movement errors added  Extents of supply for each WP added  Released |
| 0.8 | 18/3/16 |  | Numbering convention of FPUs changed to a raster pattern  Added FPU control parameters |
| 1.0 | 26/4/16 |  | Temperature sensors added and circulated for release |
| 1.1 | 18/5/16 | 3.3 | FPU Control Parameters updated |
| 1.2 | 2/6/16 | 3.4 | List of sensors added for comment |
| 1.3 | 2/7/16 | 3.3 | Wording changed for clarity |

## Reference Documents

|  |  |  |
| --- | --- | --- |
| Ref | Document Title | Document Number |
| AD1 | RFE Structure to Focal Plate ICD |  |
| AD2 | Metrology Camera to RFE ICD |  |
|  |  |  |

## Abbreviations

AD Applicable Document

ICD Interface Control Document

TBD To Be Determined

# General Definition

This ICD defines the interface between the RFE sub-system and the MOONS instrument software. This document is the definitive source of information concerning the interface and is subject to change control.

The information here will overlap with the interfaces between the hardware modules of the RFE and should be read in conjunction with those for a complete understanding of the system. The relevant documents are listed in the reference document section above.

## RFE

The RFE contains a number of different modules which interact with each other in order to create particular requirements on the software. The complexity of these interactions lead to a single ICD concerning all of the modules. These modules are defined further in the following sections.

### RFE structure

The RFE structure contains sensors which are reported to the instrument software.

### Field Corrector

The mapping of focal plane co-ordinates to the sky is defined by the design of the field corrector.

### Fibre Positioner Module

This is the set of 1000+ fibre positioners which are mounted on the focal plate. The positioners each have an interface with the rest of the system and collectively the focal plate has its own interface. Both of these interfaces are considered here.

### Metrology Cameras

A ring of metrology cameras around the focal plane are used to image the individual fibre positioners. This module consists of cameras, lights and a workstation which produces a list of positions.

The metrology system also incorporates fiducial markers on the focal plane for setting up the co-ordinate system for the measurement. These markers act as hazards for the FPU and must be avoided in the set-up.

### Acquisition cameras

These cameras sit on the focal plane and are used to provide centroid information to the ICS of pre-defined stars. The cameras also act as hazards for the FPU and must be avoided in the set-up.

## Instrument Software

This sub-system controls the fibre positioners in such a way that collisions will not occur. There are several parts to the positioner control and these also require interfaces to be defined. These interfaces are defined in the ISURS [RDxx].

## Interface Relationship

The n2 diagram of the various hardware and software packages is shown in

# Interface Requirements

## General Requirements

### Focal Plane Coordinate System

MOONS focal plane coordinates shall be described in polar coordinates (rfocal, θfocal), which are defined relative to the centre of rotation and aligned with the Nasmyth Z axis as shown in Figure 1. Radial coordinates, rfocal, are distances measured along the curved surface of the focal plane, where the radius of curvature of the plate is 4101.5 mm.



Figure 1: MOONS Focal Plane Coordinates

Note: the Cartesian coordiante system used for the specification of the plate manufacture will be the projected x, y, z where the centre of the system is at the centre of the plate, on the surface facing the Nasmyth rotator.

### Fibre Positioner Coordinate System

The reference point defining the centre of the patrol field for each fibre positioner is the point where the axis of the alpha motor intersects with the MOONS focal plane, as shown in Figure 2. Each positioner can be assumed to patrol in a flat plane. The local X axis of this coordinate system is defined by the orientation of the alpha arm when located at datum (see Figure 3 and Figure 4).



Figure 2: Reference Point for each Fibre Positioner

The configuration of each fibre positioner is described by two angles, α and β, giving the orientation of the inner (alpha) and outer (beta) arm. The alpha arm angle, α, shall be zero at the point where the alpha arm lies along the local X axis. The beta arm angle, β, shall be zero when the arm is parallel to the alpha arm and fully doubled-back (Figure 3, left). α and β angles increase when the arm rotates anti-clockwise when viewed from direction of the telescope.

Motor steps will be counted from a datum point (which may be indicated by a datum switch). The datum point for the alpha motor is, by definition, exactly at the zero angle position. The datum point for the beta motor will be near to the zero angle position. The offset between the beta arm datum point and zero angle will be calibrated for each fibre positioner.

 

Figure 3: MOONS Fibre Positioner Coordinates

The relationship between focal plane coordinates and positioner local coordinates is shown in Figure 3 (right). The angle between the Nasmyth Y axis and the local fibre positioner X axis (shown as α0) can be different for each positioner (depending how each positioner is installed on the focal plate). This offset will be calibrated and accounted for in the software. Note that this zero angle takes care of both the alpha datum switch offset and any mechanical variation in the orientation of each FPU.

### Positioner Movement

The area swept out by each arm as it moves is indicated in Figure 4. This shows the movement range of a single fibre positioner about its perfect centre.

There is a tolerance on the position caused by the centre offset for the 2 axes and the fibre and from the latency of the movement.

1. In rotation, the zero position will be calibrated with an error of +/- 20 μm.
2. The zero position will not be at the switch due to the tolerance in build. The tolerance is +/- 3 degrees so that the nominal zero position is +3 degrees from the switch.
3. Location of centre of rotation of the alpha axis may vary by +/ 0.2mm
4. Location of centre of beta arm rotation may vary by TBD
5. The latency in the movements between different FPUs is 20 ms. At a speed of 1 KHz this equates to a position uncertainty between FPUs of 2 steps.
6. Motor parameters

|  |  |  |  |
| --- | --- | --- | --- |
|  | Alpha axis | Beta axis | Notes |
| Gear ratio1 | 2050:1 | 1518:1 |  |
| Speed | 1000 steps/sec | 1000 steps/sec |  |
| Steps/revolution | 20 | 20 |  |

1 nominal value, rounded to nearest whole number. The gear profile will be calibrated on the final assembly with a look up table to define the actual against commanded offset.

Need to add the dimension of the fibre and holder.

|  |
| --- |
|  |

Figure 4 Fibre Positioner Movement details

### Collision Avoidance Zones

The parts of an arm which may collide are shown in Figure 5.

|  |
| --- |
| C:\Users\hpb84684\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.Outlook\GSP8RP2V\MOONSFibrePositionerAvoidanceZonesV3Part1 (2).png |
|  |

Figure 5 Arm Collision Zones

### Positioner Centres

Fibre positioners are assembled into a close approximation of a hexagonal grid of pitch 25 mm. Deviations from an exact grid are caused by the curvature of the focal plane.

Neighbouring fibre positioners are oriented as shown in Figure 6.

The centres are for the centre of rotation of the fibre positioners on the focal plane. The centres on the plate must be modified according to the height of the positioner and the local tilt.



Figure 6: Relative Orientations of Neighbouring Positioners in the Grid

The focal plate is required to cover 25 arc minutes diameter which at the nominal plate scale of 34.55 mm/arcmin is 431.875 mm radius [AD1].

The arm patrol field has an outer reach of 25 mm

The location of the centre of each of the fibre positioners is given in the table below. The nominal arm centres are defined in co-ordinates as defined in 3.1.1 and are defined as the location of the centre of rotation of the positioner at the focal plane. The “as-built” arm centres are expected to be close to these values, but accurate values will be determined by a calibration procedure and stored as a configuration parameter for each positioner.

Note the numbering scheme follows a raster pattern from the bottom left as shown

|  |
| --- |
|  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Positioner number | R | Theta | X | Y | Z |
| 1 | 746.9226 | -105.295 | -21.9343 | -113.084 | -413.496 |
| 2 | 736.5841 | -102.008 | -21.3358 | -87.9663 | -413.554 |
| 3 | 728.734 | -98.6391 | -20.8867 | -62.8397 | -413.598 |
| 4 | 723.4532 | -95.2087 | -20.5873 | -37.7065 | -413.627 |
| 5 | 720.7983 | -91.7405 | -20.4375 | -12.5693 | -413.642 |
| 6 | 723.4532 | -84.7913 | -20.5873 | 37.7065 | -413.627 |
| 7 | 728.734 | -81.3609 | -20.8867 | 62.83973 | -413.598 |
| 8 | 736.5841 | -77.9917 | -21.3358 | 87.96631 | -413.554 |
| 9 | 746.9226 | -74.7047 | -21.9343 | 113.0836 | -413.496 |
| 10 | 748.2049 | -114.182 | -22.0091 | -175.905 | -391.726 |
| 11 | 731.36 | -111.052 | -21.0364 | -150.81 | -391.816 |
| 12 | 716.7976 | -107.784 | -20.2129 | -125.699 | -391.892 |
| 13 | 704.659 | -104.392 | -19.5387 | -100.576 | -391.954 |
| 14 | 695.0714 | -100.893 | -19.0142 | -75.441 | -392.003 |
| 15 | 688.1413 | -97.3111 | -18.6394 | -50.2984 | -392.037 |
| 16 | 683.9495 | -93.6705 | -18.4144 | -25.1505 | -392.058 |
| 17 | 682.5465 | -90 | -18.3394 | 2.40E-14 | -392.065 |
| 18 | 683.9495 | -86.3295 | -18.4144 | 25.15054 | -392.058 |
| 19 | 688.1413 | -82.6889 | -18.6394 | 50.29842 | -392.037 |
| 20 | 695.0714 | -79.1066 | -19.0142 | 75.44096 | -392.003 |
| 21 | 704.659 | -75.6084 | -19.5387 | 100.5755 | -391.954 |
| 22 | 716.7976 | -72.2163 | -20.2129 | 125.6994 | -391.892 |
| 23 | 731.36 | -68.9483 | -21.0364 | 150.81 | -391.816 |
| 24 | 748.2049 | -65.8175 | -22.0091 | 175.9047 | -391.726 |
| 25 | 744.3515 | -120 | -21.7847 | -213.61 | -369.983 |
| 26 | 723.4532 | -116.996 | -20.5873 | -188.533 | -370.088 |
| 27 | 704.659 | -113.822 | -19.5387 | -163.435 | -370.179 |
| 28 | 688.1413 | -110.485 | -18.6394 | -138.321 | -370.257 |
| 29 | 674.0674 | -106.996 | -17.8894 | -113.191 | -370.323 |
| 30 | 662.593 | -103.373 | -17.2892 | -88.0502 | -370.375 |
| 31 | 653.8552 | -99.6374 | -16.8389 | -62.8997 | -370.414 |
| 32 | 647.9645 | -95.8175 | -16.5386 | -37.7425 | -370.441 |
| 33 | 644.9989 | -91.9451 | -16.3884 | -12.5813 | -370.454 |
| 34 | 644.9989 | -88.0549 | -16.3884 | 12.58127 | -370.454 |
| 35 | 647.9645 | -84.1825 | -16.5386 | 37.74247 | -370.441 |
| 36 | 653.8552 | -80.3626 | -16.8389 | 62.89967 | -370.414 |
| 37 | 662.593 | -76.6272 | -17.2892 | 88.0502 | -370.375 |
| 38 | 674.0674 | -73.0039 | -17.8894 | 113.1914 | -370.323 |
| 39 | 688.1413 | -69.5153 | -18.6394 | 138.3206 | -370.257 |
| 40 | 704.659 | -66.1784 | -19.5387 | 163.4352 | -370.179 |
| 41 | 723.4532 | -63.0045 | -20.5873 | 188.5325 | -370.088 |
| 42 | 744.3515 | -60 | -21.7847 | 213.6098 | -369.983 |
| 43 | 748.2049 | -125.818 | -22.0091 | -251.292 | -348.201 |
| 44 | 723.4532 | -123.004 | -20.5873 | -226.239 | -348.318 |
| 45 | 700.5661 | -120 | -19.3139 | -201.162 | -348.422 |
| 46 | 679.7319 | -116.802 | -18.1895 | -176.063 | -348.515 |
| 47 | 661.1447 | -113.413 | -17.2142 | -150.946 | -348.595 |
| 48 | 644.9989 | -109.842 | -16.3884 | -125.813 | -348.662 |
| 49 | 631.4817 | -106.102 | -15.7124 | -100.666 | -348.718 |
| 50 | 620.7649 | -102.216 | -15.1865 | -75.5089 | -348.761 |
| 51 | 612.9953 | -98.2132 | -14.8106 | -50.3437 | -348.792 |
| 52 | 608.2859 | -94.1278 | -14.5851 | -25.1732 | -348.81 |
| 53 | 606.708 | -90 | -14.5099 | 2.14E-14 | -348.816 |
| 54 | 608.2859 | -85.8722 | -14.5851 | 25.1732 | -348.81 |
| 55 | 612.9953 | -81.7868 | -14.8106 | 50.34373 | -348.792 |
| 56 | 620.7649 | -77.7837 | -15.1865 | 75.50893 | -348.761 |
| 57 | 631.4817 | -73.8979 | -15.7124 | 100.6661 | -348.718 |
| 58 | 644.9989 | -70.1583 | -16.3884 | 125.8127 | -348.662 |
| 59 | 661.1447 | -66.5868 | -17.2142 | 150.9459 | -348.595 |
| 60 | 679.7319 | -63.1979 | -18.1895 | 176.0631 | -348.515 |
| 61 | 700.5661 | -60 | -19.3139 | 201.1617 | -348.422 |
| 62 | 723.4532 | -56.9955 | -20.5873 | 226.239 | -348.318 |
| 63 | 748.2049 | -54.1825 | -22.0091 | 251.2924 | -348.201 |
| 64 | 731.36 | -128.948 | -21.0364 | -263.918 | -326.513 |
| 65 | 704.659 | -126.178 | -19.5387 | -238.867 | -326.629 |
| 66 | 679.7319 | -123.198 | -18.1895 | -213.791 | -326.732 |
| 67 | 656.7807 | -120 | -16.989 | -188.692 | -326.825 |
| 68 | 636.0194 | -116.582 | -15.9378 | -163.574 | -326.906 |
| 69 | 617.6688 | -112.947 | -15.0361 | -138.438 | -326.975 |
| 70 | 601.9495 | -109.107 | -14.2843 | -113.287 | -327.033 |
| 71 | 589.072 | -105.079 | -13.6826 | -88.1249 | -327.079 |
| 72 | 579.2261 | -100.893 | -13.2311 | -62.953 | -327.113 |
| 73 | 572.5681 | -96.5868 | -12.93 | -37.7745 | -327.137 |
| 74 | 569.2099 | -92.2042 | -12.7795 | -12.5919 | -327.148 |
| 75 | 569.2099 | -87.7958 | -12.7795 | 12.59194 | -327.148 |
| 76 | 572.5681 | -83.4132 | -12.93 | 37.77447 | -327.137 |
| 77 | 579.2261 | -79.1066 | -13.2311 | 62.953 | -327.113 |
| 78 | 589.072 | -74.9209 | -13.6826 | 88.12487 | -327.079 |
| 79 | 601.9495 | -70.8934 | -14.2843 | 113.2874 | -327.033 |
| 80 | 617.6688 | -67.0527 | -15.0361 | 138.4379 | -326.975 |
| 81 | 636.0194 | -63.418 | -15.9378 | 163.5738 | -326.906 |
| 82 | 656.7807 | -60 | -16.989 | 188.6923 | -326.825 |
| 83 | 679.7319 | -56.8021 | -18.1895 | 213.7909 | -326.732 |
| 84 | 704.659 | -53.8216 | -19.5387 | 238.8669 | -326.629 |
| 85 | 731.36 | -51.0517 | -21.0364 | 263.9176 | -326.513 |
| 86 | 746.9226 | -134.705 | -21.9343 | -301.556 | -304.681 |
| 87 | 716.7976 | -132.216 | -20.2129 | -276.539 | -304.805 |
| 88 | 688.1413 | -129.515 | -18.6394 | -251.492 | -304.918 |
| 89 | 661.1447 | -126.587 | -17.2142 | -226.419 | -305.02 |
| 90 | 636.0194 | -123.418 | -15.9378 | -201.322 | -305.112 |
| 91 | 612.9953 | -120 | -14.8106 | -176.203 | -305.193 |
| 92 | 592.3176 | -116.33 | -13.833 | -151.066 | -305.263 |
| 93 | 574.2399 | -112.411 | -13.0053 | -125.913 | -305.322 |
| 94 | 559.0143 | -108.258 | -12.3277 | -100.746 | -305.371 |
| 95 | 546.8792 | -103.898 | -11.8005 | -75.569 | -305.408 |
| 96 | 538.0438 | -99.367 | -11.4238 | -50.3838 | -305.435 |
| 97 | 532.6721 | -94.715 | -11.1977 | -25.1932 | -305.451 |
| 98 | 530.8695 | -90 | -11.1223 | 1.87E-14 | -305.457 |
| 99 | 532.6721 | -85.285 | -11.1977 | 25.19321 | -305.451 |
| 100 | 538.0438 | -80.633 | -11.4238 | 50.38376 | -305.435 |
| 101 | 546.8792 | -76.1021 | -11.8005 | 75.56896 | -305.408 |
| 102 | 559.0143 | -71.7415 | -12.3277 | 100.7462 | -305.371 |
| 103 | 574.2399 | -67.5891 | -13.0053 | 125.9127 | -305.322 |
| 104 | 592.3176 | -63.6705 | -13.833 | 151.0659 | -305.263 |
| 105 | 612.9953 | -60 | -14.8106 | 176.2031 | -305.193 |
| 106 | 636.0194 | -56.582 | -15.9378 | 201.3216 | -305.112 |
| 107 | 661.1447 | -53.4132 | -17.2142 | 226.4188 | -305.02 |
| 108 | 688.1413 | -50.4847 | -18.6394 | 251.4921 | -304.918 |
| 109 | 716.7976 | -47.7837 | -20.2129 | 276.5387 | -304.805 |
| 110 | 746.9226 | -45.2953 | -21.9343 | 301.5562 | -304.681 |
| 111 | 736.5841 | -137.992 | -21.3358 | -314.165 | -282.958 |
| 112 | 704.659 | -135.608 | -19.5387 | -289.155 | -283.078 |
| 113 | 674.0674 | -133.004 | -17.8894 | -264.113 | -283.188 |
| 114 | 644.9989 | -130.158 | -16.3884 | -239.044 | -283.288 |
| 115 | 617.6688 | -127.053 | -15.0361 | -213.95 | -283.378 |
| 116 | 592.3176 | -123.67 | -13.833 | -188.832 | -283.458 |
| 117 | 569.2099 | -120 | -12.7795 | -163.695 | -283.528 |
| 118 | 548.6292 | -116.037 | -11.8758 | -138.541 | -283.588 |
| 119 | 530.8695 | -111.787 | -11.1223 | -113.371 | -283.639 |
| 120 | 516.222 | -107.269 | -10.5193 | -88.1903 | -283.679 |
| 121 | 504.9576 | -102.52 | -10.0668 | -62.9997 | -283.709 |
| 122 | 497.3063 | -97.5891 | -9.76504 | -37.8025 | -283.729 |
| 123 | 493.4362 | -92.5429 | -9.61415 | -12.6013 | -283.739 |
| 124 | 493.4362 | -87.4571 | -9.61415 | 12.60128 | -283.739 |
| 125 | 497.3063 | -82.4109 | -9.76504 | 37.8025 | -283.729 |
| 126 | 504.9576 | -77.4802 | -10.0668 | 62.99972 | -283.709 |
| 127 | 516.222 | -72.7305 | -10.5193 | 88.19027 | -283.679 |
| 128 | 530.8695 | -68.2132 | -11.1223 | 113.3715 | -283.639 |
| 129 | 548.6292 | -63.9632 | -11.8758 | 138.5406 | -283.588 |
| 130 | 569.2099 | -60 | -12.7795 | 163.6952 | -283.528 |
| 131 | 592.3176 | -56.3295 | -13.833 | 188.8323 | -283.458 |
| 132 | 617.6688 | -52.9473 | -15.0361 | 213.9495 | -283.378 |
| 133 | 644.9989 | -49.8417 | -16.3884 | 239.0441 | -283.288 |
| 134 | 674.0674 | -46.9961 | -17.8894 | 264.1133 | -283.188 |
| 135 | 704.659 | -44.3916 | -19.5387 | 289.1546 | -283.078 |
| 136 | 736.5841 | -42.0083 | -21.3358 | 314.1654 | -282.958 |
| 137 | 728.734 | -141.361 | -20.8867 | -326.767 | -261.22 |
| 138 | 695.0714 | -139.107 | -19.0142 | -301.764 | -261.335 |
| 139 | 662.593 | -136.627 | -17.2892 | -276.729 | -261.441 |
| 140 | 631.4817 | -133.898 | -15.7124 | -251.665 | -261.538 |
| 141 | 601.9495 | -130.893 | -14.2843 | -226.575 | -261.626 |
| 142 | 574.2399 | -127.589 | -13.0053 | -201.46 | -261.705 |
| 143 | 548.6292 | -123.963 | -11.8758 | -176.324 | -261.774 |
| 144 | 525.4246 | -120 | -10.8962 | -151.17 | -261.834 |
| 145 | 504.9576 | -115.693 | -10.0668 | -125.999 | -261.885 |
| 146 | 487.5734 | -111.052 | -9.38779 | -100.816 | -261.927 |
| 147 | 473.6113 | -106.102 | -8.85947 | -75.621 | -261.959 |
| 148 | 463.3809 | -100.893 | -8.48197 | -50.4185 | -261.982 |
| 149 | 457.1328 | -95.4964 | -8.25543 | -25.2106 | -261.996 |
| 150 | 455.031 | -90 | -8.17991 | 1.60E-14 | -262.001 |
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| 408 | 504.9576 | -17.4802 | -10.0668 | 277.1988 | -87.295 |
| 409 | 546.8792 | -16.1021 | -11.8005 | 302.2758 | -87.2595 |
| 410 | 589.072 | -14.9209 | -13.6826 | 327.3209 | -87.221 |
| 411 | 631.4817 | -13.8979 | -15.7124 | 352.3314 | -87.1794 |
| 412 | 674.0674 | -13.0039 | -17.8894 | 377.3047 | -87.1348 |
| 413 | 716.7976 | -12.2163 | -20.2129 | 402.2382 | -87.0871 |
| 414 | 731.36 | -171.052 | -21.0364 | -414.728 | -65.3027 |
| 415 | 688.1413 | -170.485 | -18.6394 | -389.813 | -65.3396 |
| 416 | 644.9989 | -169.842 | -16.3884 | -364.857 | -65.3742 |
| 417 | 601.9495 | -169.107 | -14.2843 | -339.862 | -65.4065 |
| 418 | 559.0143 | -168.258 | -12.3277 | -314.832 | -65.4365 |
| 419 | 516.222 | -167.269 | -10.5193 | -289.768 | -65.4643 |
| 420 | 473.6113 | -166.102 | -8.85947 | -264.674 | -65.4897 |
| 421 | 431.236 | -164.705 | -7.3489 | -239.551 | -65.5129 |
| 422 | 389.173 | -163.004 | -5.98802 | -214.403 | -65.5337 |
| 423 | 347.5357 | -160.893 | -4.77727 | -189.233 | -65.5522 |
| 424 | 306.4977 | -158.213 | -3.71702 | -164.043 | -65.5685 |
| 425 | 266.3361 | -154.715 | -2.80762 | -138.835 | -65.5824 |
| 426 | 227.5155 | -150 | -2.04934 | -113.612 | -65.5939 |
| 427 | 190.856 | -143.413 | -1.44243 | -88.3774 | -65.6032 |
| 428 | 157.8704 | -133.898 | -0.98708 | -63.1334 | -65.6102 |
| 429 | 131.3561 | -120 | -0.68344 | -37.8827 | -65.6148 |
| 430 | 115.8452 | -100.893 | -0.53159 | -12.628 | -65.6171 |
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| 447 | 731.36 | -8.94828 | -21.0364 | 414.7276 | -65.3027 |
| 448 | 748.2049 | -174.182 | -22.0091 | -427.197 | -43.5251 |
| 449 | 704.659 | -173.822 | -19.5387 | -402.302 | -43.5505 |
| 450 | 661.1447 | -173.413 | -17.2142 | -377.365 | -43.5743 |
| 451 | 617.6688 | -172.947 | -15.0361 | -352.387 | -43.5966 |
| 452 | 574.2399 | -172.411 | -13.0053 | -327.373 | -43.6174 |
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| 455 | 444.3731 | -170.174 | -7.80224 | -252.132 | -43.6706 |
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| 457 | 358.3988 | -167.784 | -5.08005 | -201.834 | -43.6984 |
| 458 | 315.7409 | -166.102 | -3.94428 | -176.652 | -43.71 |
| 459 | 273.4396 | -163.898 | -2.95922 | -151.451 | -43.72 |
| 460 | 231.6905 | -160.893 | -2.12519 | -126.233 | -43.7285 |
| 461 | 190.856 | -156.587 | -1.44243 | -101.003 | -43.7355 |
| 462 | 151.677 | -150 | -0.91118 | -75.7614 | -43.7409 |
| 463 | 115.8452 | -139.107 | -0.53159 | -50.5121 | -43.7447 |
| 464 | 87.57076 | -120 | -0.30379 | -25.2574 | -43.747 |
| 465 | 75.8385 | -90 | -0.22785 | 2.68E-15 | -43.7478 |
| 466 | 87.57076 | -60 | -0.30379 | 25.25737 | -43.747 |
| 467 | 115.8452 | -40.8934 | -0.53159 | 50.51207 | -43.7447 |
| 468 | 151.677 | -30 | -0.91118 | 75.76142 | -43.7409 |
| 469 | 190.856 | -23.4132 | -1.44243 | 101.0027 | -43.7355 |
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| 479 | 617.6688 | -7.05268 | -15.0361 | 352.3874 | -43.5966 |
| 480 | 661.1447 | -6.58678 | -17.2142 | 377.3647 | -43.5743 |
| 481 | 704.659 | -6.17839 | -19.5387 | 402.3021 | -43.5505 |
| 482 | 748.2049 | -5.81753 | -22.0091 | 427.1971 | -43.5251 |
| 483 | 723.4532 | -176.996 | -20.5873 | -414.772 | -21.7699 |
| 484 | 679.7319 | -176.802 | -18.1895 | -389.854 | -21.7822 |
| 485 | 636.0194 | -176.582 | -15.9378 | -364.895 | -21.7937 |
| 486 | 592.3176 | -176.33 | -13.833 | -339.898 | -21.8045 |
| 487 | 548.6292 | -176.037 | -11.8758 | -314.865 | -21.8145 |
| 488 | 504.9576 | -175.693 | -10.0668 | -289.799 | -21.8237 |
| 489 | 461.3076 | -175.285 | -8.40646 | -264.702 | -21.8322 |
| 490 | 417.6859 | -174.791 | -6.89542 | -239.577 | -21.8399 |
| 491 | 374.1025 | -174.182 | -5.53411 | -214.426 | -21.8469 |
| 492 | 330.5724 | -173.413 | -4.32297 | -189.253 | -21.8531 |
| 493 | 287.1199 | -172.411 | -3.26239 | -164.06 | -21.8585 |
| 494 | 243.7867 | -171.052 | -2.3527 | -138.849 | -21.8631 |
| 495 | 200.6498 | -169.107 | -1.59418 | -113.624 | -21.867 |
| 496 | 157.8704 | -166.102 | -0.98708 | -88.3868 | -21.8701 |
| 497 | 115.8452 | -160.893 | -0.53159 | -63.1401 | -21.8724 |
| 498 | 75.8385 | -150 | -0.22785 | -37.8867 | -21.8739 |
| 499 | 43.78538 | -120 | -0.07595 | -12.6294 | -21.8747 |
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| 510 | 461.3076 | -4.715 | -8.40646 | 264.7017 | -21.8322 |
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| 516 | 723.4532 | -3.00449 | -20.5873 | 414.7715 | -21.7699 |
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| 531 | 131.3561 | 180 | -0.68344 | -75.7654 | 0 |
| 532 | 87.57076 | 180 | -0.30379 | -50.5147 | 0 |
| 533 | 43.78538 | 180 | -0.07595 | -25.2587 | 0 |
| 534 | 0 | 0 | 0 | 0 | 0 |
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| 537 | 131.3561 | 0 | -0.68344 | 75.76543 | 0 |
| 538 | 175.1415 | 0 | -1.21478 | 101.0081 | 0 |
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| 547 | 569.2099 | 0 | -12.7795 | 327.3903 | 0 |
| 548 | 612.9953 | 0 | -14.8106 | 352.4061 | 0 |
| 549 | 656.7807 | 0 | -16.989 | 377.3847 | 0 |
| 550 | 700.5661 | 0 | -19.3139 | 402.3234 | 0 |
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| 552 | 723.4532 | 176.9955 | -20.5873 | -414.772 | 21.76986 |
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| 558 | 461.3076 | 175.285 | -8.40646 | -264.702 | 21.83223 |
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| 562 | 287.1199 | 172.4109 | -3.26239 | -164.06 | 21.85847 |
| 563 | 243.7867 | 171.0517 | -2.3527 | -138.849 | 21.8631 |
| 564 | 200.6498 | 169.1066 | -1.59418 | -113.624 | 21.86696 |
| 565 | 157.8704 | 166.1021 | -0.98708 | -88.3868 | 21.87005 |
| 566 | 115.8452 | 160.8934 | -0.53159 | -63.1401 | 21.87237 |
| 567 | 75.8385 | 150 | -0.22785 | -37.8867 | 21.87391 |
| 568 | 43.78538 | 120 | -0.07595 | -12.6294 | 21.87468 |
| 569 | 43.78538 | 60 | -0.07595 | 12.62935 | 21.87468 |
| 570 | 75.8385 | 30 | -0.22785 | 37.88672 | 21.87391 |
| 571 | 115.8452 | 19.10661 | -0.53159 | 63.14008 | 21.87237 |
| 572 | 157.8704 | 13.89789 | -0.98708 | 88.38676 | 21.87005 |
| 573 | 200.6498 | 10.89339 | -1.59418 | 113.6241 | 21.86696 |
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| 579 | 461.3076 | 4.715004 | -8.40646 | 264.7017 | 21.83223 |
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| 582 | 592.3176 | 3.670497 | -13.833 | 339.8982 | 21.80448 |
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| 584 | 679.7319 | 3.19794 | -18.1895 | 389.854 | 21.78216 |
| 585 | 723.4532 | 3.004492 | -20.5873 | 414.7715 | 21.76986 |
| 586 | 748.2049 | 174.1825 | -22.0091 | -427.197 | 43.52512 |
| 587 | 704.659 | 173.8216 | -19.5387 | -402.302 | 43.55048 |
| 588 | 661.1447 | 173.4132 | -17.2142 | -377.365 | 43.57432 |
| 589 | 617.6688 | 172.9473 | -15.0361 | -352.387 | 43.59664 |
| 590 | 574.2399 | 172.4109 | -13.0053 | -327.373 | 43.61743 |
| 591 | 530.8695 | 171.7868 | -11.1223 | -302.324 | 43.6367 |
| 592 | 487.5734 | 171.0517 | -9.38779 | -277.243 | 43.65443 |
| 593 | 444.3731 | 170.1736 | -7.80224 | -252.132 | 43.67063 |
| 594 | 401.2996 | 169.1066 | -6.36617 | -226.995 | 43.68529 |
| 595 | 358.3988 | 167.7837 | -5.08005 | -201.834 | 43.69841 |
| 596 | 315.7409 | 166.1021 | -3.94428 | -176.652 | 43.70999 |
| 597 | 273.4396 | 163.8979 | -2.95922 | -151.451 | 43.72003 |
| 598 | 231.6905 | 160.8934 | -2.12519 | -126.233 | 43.72852 |
| 599 | 190.856 | 156.5868 | -1.44243 | -101.003 | 43.73547 |
| 600 | 151.677 | 150 | -0.91118 | -75.7614 | 43.74088 |
| 601 | 115.8452 | 139.1066 | -0.53159 | -50.5121 | 43.74473 |
| 602 | 87.57076 | 120 | -0.30379 | -25.2574 | 43.74705 |
| 603 | 75.8385 | 90 | -0.22785 | 2.68E-15 | 43.74782 |
| 604 | 87.57076 | 60 | -0.30379 | 25.25737 | 43.74705 |
| 605 | 115.8452 | 40.89339 | -0.53159 | 50.51207 | 43.74473 |
| 606 | 151.677 | 30 | -0.91118 | 75.76142 | 43.74088 |
| 607 | 190.856 | 23.41322 | -1.44243 | 101.0027 | 43.73547 |
| 608 | 231.6905 | 19.10661 | -2.12519 | 126.2334 | 43.72852 |
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| 616 | 574.2399 | 7.589089 | -13.0053 | 327.373 | 43.61743 |
| 617 | 617.6688 | 7.052677 | -15.0361 | 352.3874 | 43.59664 |
| 618 | 661.1447 | 6.586776 | -17.2142 | 377.3647 | 43.57432 |
| 619 | 704.659 | 6.178391 | -19.5387 | 402.3021 | 43.55048 |
| 620 | 748.2049 | 5.817526 | -22.0091 | 427.1971 | 43.52512 |
| 621 | 731.36 | 171.0517 | -21.0364 | -414.728 | 65.30266 |
| 622 | 688.1413 | 170.4847 | -18.6394 | -389.813 | 65.33956 |
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| 624 | 601.9495 | 169.1066 | -14.2843 | -339.862 | 65.40651 |
| 625 | 559.0143 | 168.2585 | -12.3277 | -314.832 | 65.43655 |
| 626 | 516.222 | 167.2695 | -10.5193 | -289.768 | 65.46429 |
| 627 | 473.6113 | 166.1021 | -8.85947 | -264.674 | 65.48974 |
| 628 | 431.236 | 164.7047 | -7.3489 | -239.551 | 65.51288 |
| 629 | 389.173 | 163.0039 | -5.98802 | -214.403 | 65.53372 |
| 630 | 347.5357 | 160.8934 | -4.77727 | -189.233 | 65.55225 |
| 631 | 306.4977 | 158.2132 | -3.71702 | -164.043 | 65.56846 |
| 632 | 266.3361 | 154.715 | -2.80762 | -138.835 | 65.58236 |
| 633 | 227.5155 | 150 | -2.04934 | -113.612 | 65.59394 |
| 634 | 190.856 | 143.4132 | -1.44243 | -88.3774 | 65.60321 |
| 635 | 157.8704 | 133.8979 | -0.98708 | -63.1334 | 65.61016 |
| 636 | 131.3561 | 120 | -0.68344 | -37.8827 | 65.61479 |
| 637 | 115.8452 | 100.8934 | -0.53159 | -12.628 | 65.6171 |
| 638 | 115.8452 | 79.10661 | -0.53159 | 12.62802 | 65.6171 |
| 639 | 131.3561 | 60 | -0.68344 | 37.88271 | 65.61479 |
| 640 | 157.8704 | 46.10211 | -0.98708 | 63.1334 | 65.61016 |
| 641 | 190.856 | 36.58678 | -1.44243 | 88.37741 | 65.60321 |
| 642 | 227.5155 | 30 | -2.04934 | 113.612 | 65.59394 |
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| 644 | 306.4977 | 21.78679 | -3.71702 | 164.0425 | 65.56846 |
| 645 | 347.5357 | 19.10661 | -4.77727 | 189.233 | 65.55225 |
| 646 | 389.173 | 16.99609 | -5.98802 | 214.4035 | 65.53372 |
| 647 | 431.236 | 15.29534 | -7.3489 | 239.5512 | 65.51288 |
| 648 | 473.6113 | 13.89789 | -8.85947 | 264.6736 | 65.48974 |
| 649 | 516.222 | 12.73053 | -10.5193 | 289.768 | 65.46429 |
| 650 | 559.0143 | 11.74153 | -12.3277 | 314.8317 | 65.43655 |
| 651 | 601.9495 | 10.89339 | -14.2843 | 339.8622 | 65.40651 |
| 652 | 644.9989 | 10.15833 | -16.3884 | 364.8567 | 65.37418 |
| 653 | 688.1413 | 9.515338 | -18.6394 | 389.8127 | 65.33956 |
| 654 | 731.36 | 8.948276 | -21.0364 | 414.7276 | 65.30266 |
| 655 | 716.7976 | 167.7837 | -20.2129 | -402.238 | 87.08712 |
| 656 | 674.0674 | 166.9961 | -17.8894 | -377.305 | 87.13479 |
| 657 | 631.4817 | 166.1021 | -15.7124 | -352.331 | 87.17942 |
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| 659 | 546.8792 | 163.8979 | -11.8005 | -302.276 | 87.25952 |
| 660 | 504.9576 | 162.5198 | -10.0668 | -277.199 | 87.29498 |
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| 663 | 381.7121 | 156.5868 | -5.76108 | -201.802 | 87.38292 |
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| 665 | 303.354 | 150 | -3.64126 | -151.427 | 87.42616 |
| 666 | 266.3361 | 145.285 | -2.80762 | -126.213 | 87.44315 |
| 667 | 231.6905 | 139.1066 | -2.12519 | -100.987 | 87.45705 |
| 668 | 200.6498 | 130.8934 | -1.59418 | -75.7494 | 87.46786 |
| 669 | 175.1415 | 120 | -1.21478 | -50.504 | 87.47558 |
| 670 | 157.8704 | 106.1021 | -0.98708 | -25.2534 | 87.48021 |
| 671 | 151.677 | 90 | -0.91118 | 5.36E-15 | 87.48175 |
| 672 | 157.8704 | 73.89789 | -0.98708 | 25.25336 | 87.48021 |
| 673 | 175.1415 | 60 | -1.21478 | 50.50405 | 87.47558 |
| 674 | 200.6498 | 49.10661 | -1.59418 | 75.74939 | 87.46786 |
| 675 | 231.6905 | 40.89339 | -2.12519 | 100.9867 | 87.45705 |
| 676 | 266.3361 | 34.715 | -2.80762 | 126.2133 | 87.44315 |
| 677 | 303.354 | 30 | -3.64126 | 151.4265 | 87.42616 |
| 678 | 341.9747 | 26.3295 | -4.62585 | 176.6237 | 87.40608 |
| 679 | 381.7121 | 23.41322 | -5.76108 | 201.8022 | 87.38292 |
| 680 | 422.2509 | 21.05172 | -7.04659 | 226.9593 | 87.35668 |
| 681 | 463.3809 | 19.10661 | -8.48197 | 252.0924 | 87.32737 |
| 682 | 504.9576 | 17.48017 | -10.0668 | 277.1988 | 87.29498 |
| 683 | 546.8792 | 16.10211 | -11.8005 | 302.2758 | 87.25952 |
| 684 | 589.072 | 14.92086 | -13.6826 | 327.3209 | 87.221 |
| 685 | 631.4817 | 13.89789 | -15.7124 | 352.3314 | 87.17942 |
| 686 | 674.0674 | 13.00391 | -17.8894 | 377.3047 | 87.13479 |
| 687 | 716.7976 | 12.21635 | -20.2129 | 402.2382 | 87.08712 |
| 688 | 746.9226 | 165.2953 | -21.9343 | -414.64 | 108.8147 |
| 689 | 704.659 | 164.3916 | -19.5387 | -389.73 | 108.8762 |
| 690 | 662.593 | 163.3728 | -17.2892 | -364.779 | 108.9339 |
| 691 | 620.7649 | 162.2163 | -15.1865 | -339.79 | 108.9877 |
| 692 | 579.2261 | 160.8934 | -13.2311 | -314.765 | 109.0378 |
| 693 | 538.0438 | 159.367 | -11.4238 | -289.707 | 109.084 |
| 694 | 497.3063 | 157.5891 | -9.76504 | -264.618 | 109.1264 |
| 695 | 457.1328 | 155.4964 | -8.25543 | -239.5 | 109.165 |
| 696 | 417.6859 | 153.0045 | -6.89542 | -214.358 | 109.1997 |
| 697 | 379.1925 | 150 | -5.68543 | -189.193 | 109.2306 |
| 698 | 341.9747 | 146.3295 | -4.62585 | -164.008 | 109.2576 |
| 699 | 306.4977 | 141.7868 | -3.71702 | -138.805 | 109.2808 |
| 700 | 273.4396 | 136.1021 | -2.95922 | -113.588 | 109.3001 |
| 701 | 243.7867 | 128.9483 | -2.3527 | -88.3587 | 109.3155 |
| 702 | 218.9269 | 120 | -1.89764 | -63.12 | 109.3271 |
| 703 | 200.6498 | 109.1066 | -1.59418 | -37.8747 | 109.3348 |
| 704 | 190.856 | 96.58678 | -1.44243 | -12.6253 | 109.3387 |
| 705 | 190.856 | 83.41322 | -1.44243 | 12.62534 | 109.3387 |
| 706 | 200.6498 | 70.89339 | -1.59418 | 37.87469 | 109.3348 |
| 707 | 218.9269 | 60 | -1.89764 | 63.12003 | 109.3271 |
| 708 | 243.7867 | 51.05172 | -2.3527 | 88.35868 | 109.3155 |
| 709 | 273.4396 | 43.89789 | -2.95922 | 113.588 | 109.3001 |
| 710 | 306.4977 | 38.21321 | -3.71702 | 138.8052 | 109.2808 |
| 711 | 341.9747 | 33.6705 | -4.62585 | 164.0078 | 109.2576 |
| 712 | 379.1925 | 30 | -5.68543 | 189.1929 | 109.2306 |
| 713 | 417.6859 | 26.99551 | -6.89542 | 214.358 | 109.1997 |
| 714 | 457.1328 | 24.50363 | -8.25543 | 239.5005 | 109.165 |
| 715 | 497.3063 | 22.41091 | -9.76504 | 264.6175 | 109.1264 |
| 716 | 538.0438 | 20.633 | -11.4238 | 289.7066 | 109.084 |
| 717 | 579.2261 | 19.10661 | -13.2311 | 314.765 | 109.0378 |
| 718 | 620.7649 | 17.78365 | -15.1865 | 339.7902 | 108.9877 |
| 719 | 662.593 | 16.62717 | -17.2892 | 364.7794 | 108.9339 |
| 720 | 704.659 | 15.6084 | -19.5387 | 389.7302 | 108.8762 |
| 721 | 746.9226 | 14.70466 | -21.9343 | 414.6398 | 108.8147 |
| 722 | 736.5841 | 162.0083 | -21.3358 | -402.132 | 130.5961 |
| 723 | 695.0714 | 160.8934 | -19.0142 | -377.205 | 130.6676 |
| 724 | 653.8552 | 159.6374 | -16.8389 | -352.238 | 130.7345 |
| 725 | 612.9953 | 158.2132 | -14.8106 | -327.234 | 130.7968 |
| 726 | 572.5681 | 156.5868 | -12.93 | -302.196 | 130.8546 |
| 727 | 532.6721 | 154.715 | -11.1977 | -277.125 | 130.9078 |
| 728 | 493.4362 | 152.5429 | -9.61415 | -252.026 | 130.9563 |
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| 730 | 417.6859 | 146.9955 | -6.89542 | -201.749 | 131.0397 |
| 731 | 381.7121 | 143.4132 | -5.76108 | -176.577 | 131.0744 |
| 732 | 347.5357 | 139.1066 | -4.77727 | -151.386 | 131.1045 |
| 733 | 315.7409 | 133.8979 | -3.94428 | -126.18 | 131.13 |
| 734 | 287.1199 | 127.5891 | -3.26239 | -100.96 | 131.1508 |
| 735 | 262.7123 | 120 | -2.73181 | -75.7293 | 131.167 |
| 736 | 243.7867 | 111.0517 | -2.3527 | -50.4907 | 131.1786 |
| 737 | 231.6905 | 100.8934 | -2.12519 | -25.2467 | 131.1856 |
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| 741 | 262.7123 | 60 | -2.73181 | 75.72932 | 131.167 |
| 742 | 287.1199 | 52.41091 | -3.26239 | 100.9599 | 131.1508 |
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| 744 | 347.5357 | 40.89339 | -4.77727 | 151.3864 | 131.1045 |
| 745 | 381.7121 | 36.58678 | -5.76108 | 176.5769 | 131.0744 |
| 746 | 417.6859 | 33.00449 | -6.89542 | 201.7487 | 131.0397 |
| 747 | 455.031 | 30 | -8.17991 | 226.8992 | 131.0003 |
| 748 | 493.4362 | 27.45708 | -9.61415 | 252.0256 | 130.9563 |
| 749 | 532.6721 | 25.285 | -11.1977 | 277.1253 | 130.9078 |
| 750 | 572.5681 | 23.41322 | -12.93 | 302.1958 | 130.8546 |
| 751 | 612.9953 | 21.78679 | -14.8106 | 327.2342 | 130.7968 |
| 752 | 653.8552 | 20.3626 | -16.8389 | 352.2381 | 130.7345 |
| 753 | 695.0714 | 19.10661 | -19.0142 | 377.2048 | 130.6676 |
| 754 | 736.5841 | 17.9917 | -21.3358 | 402.1317 | 130.5961 |
| 755 | 728.734 | 158.6391 | -20.8867 | -389.606 | 152.3783 |
| 756 | 688.1413 | 157.3111 | -18.6394 | -364.664 | 152.459 |
| 757 | 647.9645 | 155.8175 | -16.5386 | -339.682 | 152.5344 |
| 758 | 608.2859 | 154.1278 | -14.5851 | -314.665 | 152.6044 |
| 759 | 569.2099 | 152.2042 | -12.7795 | -289.615 | 152.6691 |
| 760 | 530.8695 | 150 | -11.1223 | -264.533 | 152.7284 |
| 761 | 493.4362 | 147.4571 | -9.61415 | -239.424 | 152.7824 |
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| 763 | 422.2509 | 141.0517 | -7.04659 | -189.133 | 152.8742 |
| 764 | 389.173 | 136.9961 | -5.98802 | -163.956 | 152.912 |
| 765 | 358.3988 | 132.2163 | -5.08005 | -138.761 | 152.9444 |
| 766 | 330.5724 | 126.5868 | -4.32297 | -113.552 | 152.9715 |
| 767 | 306.4977 | 120 | -3.71702 | -88.3306 | 152.9931 |
| 768 | 287.1199 | 112.4109 | -3.26239 | -63.1 | 153.0093 |
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| 774 | 306.4977 | 60 | -3.71702 | 88.33059 | 152.9931 |
| 775 | 330.5724 | 53.41322 | -4.32297 | 113.5519 | 152.9715 |
| 776 | 358.3988 | 47.78365 | -5.08005 | 138.7611 | 152.9444 |
| 777 | 389.173 | 43.00391 | -5.98802 | 163.9556 | 152.912 |
| 778 | 422.2509 | 38.94828 | -7.04659 | 189.1328 | 152.8742 |
| 779 | 457.1328 | 35.49637 | -8.25543 | 214.2899 | 152.831 |
| 780 | 493.4362 | 32.54292 | -9.61415 | 239.4243 | 152.7824 |
| 781 | 530.8695 | 30 | -11.1223 | 264.5334 | 152.7284 |
| 782 | 569.2099 | 27.79577 | -12.7795 | 289.6145 | 152.6691 |
| 783 | 608.2859 | 25.87219 | -14.5851 | 314.665 | 152.6044 |
| 784 | 647.9645 | 24.18247 | -16.5386 | 339.6822 | 152.5344 |
| 785 | 688.1413 | 22.68889 | -18.6394 | 364.6635 | 152.459 |
| 786 | 728.734 | 21.36088 | -20.8867 | 389.6063 | 152.3783 |
| 787 | 723.4532 | 155.2087 | -20.5873 | -377.065 | 174.1589 |
| 788 | 683.9495 | 153.6705 | -18.4144 | -352.108 | 174.2481 |
| 789 | 644.9989 | 151.9451 | -16.3884 | -327.113 | 174.3311 |
| 790 | 606.708 | 150 | -14.5099 | -302.084 | 174.4081 |
| 791 | 569.2099 | 147.7958 | -12.7795 | -277.023 | 174.479 |
| 792 | 532.6721 | 145.285 | -11.1977 | -251.932 | 174.5437 |
| 793 | 497.3063 | 142.4109 | -9.76504 | -226.815 | 174.6023 |
| 794 | 463.3809 | 139.1066 | -8.48197 | -201.674 | 174.6547 |
| 795 | 431.236 | 135.2953 | -7.3489 | -176.511 | 174.701 |
| 796 | 401.2996 | 130.8934 | -6.36617 | -151.33 | 174.7412 |
| 797 | 374.1025 | 125.8175 | -5.53411 | -126.133 | 174.7751 |
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| 799 | 330.5724 | 113.4132 | -4.32297 | -75.7012 | 174.8245 |
| 800 | 315.7409 | 106.1021 | -3.94428 | -50.472 | 174.84 |
| 801 | 306.4977 | 98.21321 | -3.71702 | -25.2373 | 174.8492 |
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| 804 | 315.7409 | 73.89789 | -3.94428 | 50.47195 | 174.84 |
| 805 | 330.5724 | 66.58678 | -4.32297 | 75.70124 | 174.8245 |
| 806 | 350.283 | 60 | -4.85297 | 100.9225 | 174.8029 |
| 807 | 374.1025 | 54.18247 | -5.53411 | 126.1331 | 174.7751 |
| 808 | 401.2996 | 49.10661 | -6.36617 | 151.3303 | 174.7412 |
| 809 | 431.236 | 44.70466 | -7.3489 | 176.5114 | 174.701 |
| 810 | 463.3809 | 40.89339 | -8.48197 | 201.6739 | 174.6547 |
| 811 | 497.3063 | 37.58909 | -9.76504 | 226.815 | 174.6023 |
| 812 | 532.6721 | 34.715 | -11.1977 | 251.9321 | 174.5437 |
| 813 | 569.2099 | 32.20423 | -12.7795 | 277.0226 | 174.479 |
| 814 | 606.708 | 30 | -14.5099 | 302.0837 | 174.4081 |
| 815 | 644.9989 | 28.05488 | -16.3884 | 327.1129 | 174.3311 |
| 816 | 683.9495 | 26.3295 | -18.4144 | 352.1076 | 174.2481 |
| 817 | 723.4532 | 24.79128 | -20.5873 | 377.065 | 174.1589 |
| 818 | 720.7983 | 151.7405 | -20.4375 | -364.509 | 195.9356 |
| 819 | 682.5465 | 150 | -18.3394 | -339.538 | 196.0325 |
| 820 | 644.9989 | 148.0549 | -16.3884 | -314.532 | 196.1225 |
| 821 | 608.2859 | 145.8722 | -14.5851 | -289.492 | 196.2057 |
| 822 | 572.5681 | 143.4132 | -12.93 | -264.421 | 196.2819 |
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| 824 | 504.9576 | 137.4802 | -10.0668 | -214.199 | 196.4137 |
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| 826 | 444.3731 | 129.8264 | -7.80224 | -163.886 | 196.5178 |
| 827 | 417.6859 | 125.2087 | -6.89542 | -138.702 | 196.5595 |
| 828 | 394.0684 | 120 | -6.13929 | -113.504 | 196.5942 |
| 829 | 374.1025 | 114.1825 | -5.53411 | -88.2932 | 196.622 |
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| 832 | 341.9747 | 93.6705 | -4.62585 | -12.616 | 196.6637 |
| 833 | 341.9747 | 86.3295 | -4.62585 | 12.61598 | 196.6637 |
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| 835 | 358.3988 | 72.21635 | -5.08005 | 63.07322 | 196.6428 |
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| 837 | 394.0684 | 60 | -6.13929 | 113.5037 | 196.5942 |
| 838 | 417.6859 | 54.79128 | -6.89542 | 138.7023 | 196.5595 |
| 839 | 444.3731 | 50.17357 | -7.80224 | 163.8861 | 196.5178 |
| 840 | 473.6113 | 46.10211 | -8.85947 | 189.0526 | 196.4692 |
| 841 | 504.9576 | 42.51983 | -10.0668 | 214.1991 | 196.4137 |
| 842 | 538.0438 | 39.367 | -11.4238 | 239.3228 | 196.3513 |
| 843 | 572.5681 | 36.58678 | -12.93 | 264.4213 | 196.2819 |
| 844 | 608.2859 | 34.12781 | -14.5851 | 289.4918 | 196.2057 |
| 845 | 644.9989 | 31.94512 | -16.3884 | 314.5317 | 196.1225 |
| 846 | 682.5465 | 30 | -18.3394 | 339.5383 | 196.0325 |
| 847 | 720.7983 | 28.2595 | -20.4375 | 364.509 | 195.9356 |
| 848 | 720.7983 | 148.2595 | -20.4375 | -351.94 | 217.7063 |
| 849 | 683.9495 | 146.3295 | -18.4144 | -326.957 | 217.8101 |
| 850 | 647.9645 | 144.1825 | -16.5386 | -301.94 | 217.9062 |
| 851 | 612.9953 | 141.7868 | -14.8106 | -276.891 | 217.9947 |
| 852 | 579.2261 | 139.1066 | -13.2311 | -251.812 | 218.0756 |
| 853 | 546.8792 | 136.1021 | -11.8005 | -226.707 | 218.1488 |
| 854 | 516.222 | 132.7305 | -10.5193 | -201.578 | 218.2143 |
| 855 | 487.5734 | 128.9483 | -9.38779 | -176.427 | 218.2721 |
| 856 | 461.3076 | 124.715 | -8.40646 | -151.258 | 218.3223 |
| 857 | 437.8538 | 120 | -7.57559 | -126.073 | 218.3647 |
| 858 | 417.6859 | 114.7913 | -6.89542 | -100.874 | 218.3994 |
| 859 | 401.2996 | 109.1066 | -6.36617 | -75.6651 | 218.4264 |
| 860 | 389.173 | 103.0039 | -5.98802 | -50.4479 | 218.4457 |
| 861 | 381.7121 | 96.58678 | -5.76108 | -25.2253 | 218.4573 |
| 862 | 379.1925 | 90 | -5.68543 | 1.34E-14 | 218.4612 |
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| 866 | 417.6859 | 65.20872 | -6.89542 | 100.8744 | 218.3994 |
| 867 | 437.8538 | 60 | -7.57559 | 126.0729 | 218.3647 |
| 868 | 461.3076 | 55.285 | -8.40646 | 151.2581 | 218.3223 |
| 869 | 487.5734 | 51.05172 | -9.38779 | 176.4273 | 218.2721 |
| 870 | 516.222 | 47.26947 | -10.5193 | 201.5777 | 218.2143 |
| 871 | 546.8792 | 43.89789 | -11.8005 | 226.7069 | 218.1488 |
| 872 | 579.2261 | 40.89339 | -13.2311 | 251.812 | 218.0756 |
| 873 | 612.9953 | 38.21321 | -14.8106 | 276.8905 | 217.9947 |
| 874 | 647.9645 | 35.81753 | -16.5386 | 301.9397 | 217.9062 |
| 875 | 683.9495 | 33.6705 | -18.4144 | 326.957 | 217.8101 |
| 876 | 720.7983 | 31.7405 | -20.4375 | 351.9398 | 217.7063 |
| 877 | 723.4532 | 144.7913 | -20.5873 | -339.359 | 239.4684 |
| 878 | 688.1413 | 142.6889 | -18.6394 | -314.365 | 239.5784 |
| 879 | 653.8552 | 140.3626 | -16.8389 | -289.338 | 239.6799 |
| 880 | 620.7649 | 137.7837 | -15.1865 | -264.281 | 239.773 |
| 881 | 589.072 | 134.9209 | -13.6826 | -239.196 | 239.8577 |
| 882 | 559.0143 | 131.7415 | -12.3277 | -214.086 | 239.934 |
| 883 | 530.8695 | 128.2132 | -11.1223 | -188.952 | 240.0018 |
| 884 | 504.9576 | 124.3066 | -10.0668 | -163.799 | 240.0612 |
| 885 | 481.6392 | 120 | -9.16139 | -138.629 | 240.1121 |
| 886 | 461.3076 | 115.285 | -8.40646 | -113.444 | 240.1545 |
| 887 | 444.3731 | 110.1736 | -7.80224 | -88.2464 | 240.1884 |
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| 894 | 444.3731 | 69.82643 | -7.80224 | 88.24637 | 240.1884 |
| 895 | 461.3076 | 64.715 | -8.40646 | 113.4436 | 240.1545 |
| 896 | 481.6392 | 60 | -9.16139 | 138.6288 | 240.1121 |
| 897 | 504.9576 | 55.69338 | -10.0668 | 163.7993 | 240.0612 |
| 898 | 530.8695 | 51.78679 | -11.1223 | 188.9524 | 240.0018 |
| 899 | 559.0143 | 48.25847 | -12.3277 | 214.0856 | 239.934 |
| 900 | 589.072 | 45.07914 | -13.6826 | 239.1961 | 239.8577 |
| 901 | 620.7649 | 42.21635 | -15.1865 | 264.2812 | 239.773 |
| 902 | 653.8552 | 39.6374 | -16.8389 | 289.3385 | 239.6799 |
| 903 | 688.1413 | 37.31111 | -18.6394 | 314.3651 | 239.5784 |
| 904 | 723.4532 | 35.20872 | -20.5873 | 339.3585 | 239.4684 |
| 905 | 728.734 | 141.3609 | -20.8867 | -326.767 | 261.2199 |
| 906 | 695.0714 | 139.1066 | -19.0142 | -301.764 | 261.3352 |
| 907 | 662.593 | 136.6272 | -17.2892 | -276.729 | 261.4413 |
| 908 | 631.4817 | 133.8979 | -15.7124 | -251.665 | 261.5383 |
| 909 | 601.9495 | 130.8934 | -14.2843 | -226.575 | 261.626 |
| 910 | 574.2399 | 127.5891 | -13.0053 | -201.46 | 261.7046 |
| 911 | 548.6292 | 123.9632 | -11.8758 | -176.324 | 261.7739 |
| 912 | 525.4246 | 120 | -10.8962 | -151.17 | 261.8341 |
| 913 | 504.9576 | 115.6934 | -10.0668 | -125.999 | 261.8849 |
| 914 | 487.5734 | 111.0517 | -9.38779 | -100.816 | 261.9266 |
| 915 | 473.6113 | 106.1021 | -8.85947 | -75.621 | 261.959 |
| 916 | 463.3809 | 100.8934 | -8.48197 | -50.4185 | 261.9821 |
| 917 | 457.1328 | 95.49637 | -8.25543 | -25.2106 | 261.996 |
| 918 | 455.031 | 90 | -8.17991 | 1.60E-14 | 262.0006 |
| 919 | 457.1328 | 84.50363 | -8.25543 | 25.21058 | 261.996 |
| 920 | 463.3809 | 79.10661 | -8.48197 | 50.41848 | 261.9821 |
| 921 | 473.6113 | 73.89789 | -8.85947 | 75.62104 | 261.959 |
| 922 | 487.5734 | 68.94828 | -9.38779 | 100.8156 | 261.9266 |
| 923 | 504.9576 | 64.30662 | -10.0668 | 125.9994 | 261.8849 |
| 924 | 525.4246 | 60 | -10.8962 | 151.17 | 261.8341 |
| 925 | 548.6292 | 56.03677 | -11.8758 | 176.3245 | 261.7739 |
| 926 | 574.2399 | 52.41091 | -13.0053 | 201.4603 | 261.7046 |
| 927 | 601.9495 | 49.10661 | -14.2843 | 226.5748 | 261.626 |
| 928 | 631.4817 | 46.10211 | -15.7124 | 251.6653 | 261.5383 |
| 929 | 662.593 | 43.37283 | -17.2892 | 276.7292 | 261.4413 |
| 930 | 695.0714 | 40.89339 | -19.0142 | 301.7639 | 261.3352 |
| 931 | 728.734 | 38.63912 | -20.8867 | 326.7666 | 261.2199 |
| 932 | 736.5841 | 137.9917 | -21.3358 | -314.165 | 282.9582 |
| 933 | 704.659 | 135.6084 | -19.5387 | -289.155 | 283.0781 |
| 934 | 674.0674 | 133.0039 | -17.8894 | -264.113 | 283.1881 |
| 935 | 644.9989 | 130.1583 | -16.3884 | -239.044 | 283.2881 |
| 936 | 617.6688 | 127.0527 | -15.0361 | -213.95 | 283.3782 |
| 937 | 592.3176 | 123.6705 | -13.833 | -188.832 | 283.4582 |
| 938 | 569.2099 | 120 | -12.7795 | -163.695 | 283.5283 |
| 939 | 548.6292 | 116.0368 | -11.8758 | -138.541 | 283.5884 |
| 940 | 530.8695 | 111.7868 | -11.1223 | -113.371 | 283.6385 |
| 941 | 516.222 | 107.2695 | -10.5193 | -88.1903 | 283.6786 |
| 942 | 504.9576 | 102.5198 | -10.0668 | -62.9997 | 283.7087 |
| 943 | 497.3063 | 97.58909 | -9.76504 | -37.8025 | 283.7287 |
| 944 | 493.4362 | 92.54292 | -9.61415 | -12.6013 | 283.7387 |
| 945 | 493.4362 | 87.45708 | -9.61415 | 12.60128 | 283.7387 |
| 946 | 497.3063 | 82.41091 | -9.76504 | 37.8025 | 283.7287 |
| 947 | 504.9576 | 77.48017 | -10.0668 | 62.99972 | 283.7087 |
| 948 | 516.222 | 72.73053 | -10.5193 | 88.19027 | 283.6786 |
| 949 | 530.8695 | 68.21321 | -11.1223 | 113.3715 | 283.6385 |
| 950 | 548.6292 | 63.96323 | -11.8758 | 138.5406 | 283.5884 |
| 951 | 569.2099 | 60 | -12.7795 | 163.6952 | 283.5283 |
| 952 | 592.3176 | 56.3295 | -13.833 | 188.8323 | 283.4582 |
| 953 | 617.6688 | 52.94732 | -15.0361 | 213.9495 | 283.3782 |
| 954 | 644.9989 | 49.84167 | -16.3884 | 239.0441 | 283.2881 |
| 955 | 674.0674 | 46.99609 | -17.8894 | 264.1133 | 283.1881 |
| 956 | 704.659 | 44.3916 | -19.5387 | 289.1546 | 283.0781 |
| 957 | 736.5841 | 42.0083 | -21.3358 | 314.1654 | 282.9582 |
| 958 | 746.9226 | 134.7047 | -21.9343 | -301.556 | 304.6812 |
| 959 | 716.7976 | 132.2163 | -20.2129 | -276.539 | 304.8049 |
| 960 | 688.1413 | 129.5153 | -18.6394 | -251.492 | 304.9179 |
| 961 | 661.1447 | 126.5868 | -17.2142 | -226.419 | 305.0202 |
| 962 | 636.0194 | 123.418 | -15.9378 | -201.322 | 305.1118 |
| 963 | 612.9953 | 120 | -14.8106 | -176.203 | 305.1926 |
| 964 | 592.3176 | 116.3295 | -13.833 | -151.066 | 305.2627 |
| 965 | 574.2399 | 112.4109 | -13.0053 | -125.913 | 305.322 |
| 966 | 559.0143 | 108.2585 | -12.3277 | -100.746 | 305.3706 |
| 967 | 546.8792 | 103.8979 | -11.8005 | -75.569 | 305.4083 |
| 968 | 538.0438 | 99.367 | -11.4238 | -50.3838 | 305.4353 |
| 969 | 532.6721 | 94.715 | -11.1977 | -25.1932 | 305.4515 |
| 970 | 530.8695 | 90 | -11.1223 | 1.87E-14 | 305.4569 |
| 971 | 532.6721 | 85.285 | -11.1977 | 25.19321 | 305.4515 |
| 972 | 538.0438 | 80.633 | -11.4238 | 50.38376 | 305.4353 |
| 973 | 546.8792 | 76.10211 | -11.8005 | 75.56896 | 305.4083 |
| 974 | 559.0143 | 71.74153 | -12.3277 | 100.7462 | 305.3706 |
| 975 | 574.2399 | 67.58909 | -13.0053 | 125.9127 | 305.322 |
| 976 | 592.3176 | 63.6705 | -13.833 | 151.0659 | 305.2627 |
| 977 | 612.9953 | 60 | -14.8106 | 176.2031 | 305.1926 |
| 978 | 636.0194 | 56.58202 | -15.9378 | 201.3216 | 305.1118 |
| 979 | 661.1447 | 53.41322 | -17.2142 | 226.4188 | 305.0202 |
| 980 | 688.1413 | 50.48466 | -18.6394 | 251.4921 | 304.9179 |
| 981 | 716.7976 | 47.78365 | -20.2129 | 276.5387 | 304.8049 |
| 982 | 746.9226 | 45.29534 | -21.9343 | 301.5562 | 304.6812 |
| 983 | 731.36 | 128.9483 | -21.0364 | -263.918 | 326.5133 |
| 984 | 704.659 | 126.1784 | -19.5387 | -238.867 | 326.6286 |
| 985 | 679.7319 | 123.1979 | -18.1895 | -213.791 | 326.7324 |
| 986 | 656.7807 | 120 | -16.989 | -188.692 | 326.8247 |
| 987 | 636.0194 | 116.582 | -15.9378 | -163.574 | 326.9055 |
| 988 | 617.6688 | 112.9473 | -15.0361 | -138.438 | 326.9748 |
| 989 | 601.9495 | 109.1066 | -14.2843 | -113.287 | 327.0325 |
| 990 | 589.072 | 105.0791 | -13.6826 | -88.1249 | 327.0787 |
| 991 | 579.2261 | 100.8934 | -13.2311 | -62.953 | 327.1134 |
| 992 | 572.5681 | 96.58678 | -12.93 | -37.7745 | 327.1365 |
| 993 | 569.2099 | 92.20423 | -12.7795 | -12.5919 | 327.1481 |
| 994 | 569.2099 | 87.79577 | -12.7795 | 12.59194 | 327.1481 |
| 995 | 572.5681 | 83.41322 | -12.93 | 37.77447 | 327.1365 |
| 996 | 579.2261 | 79.10661 | -13.2311 | 62.953 | 327.1134 |
| 997 | 589.072 | 74.92086 | -13.6826 | 88.12487 | 327.0787 |
| 998 | 601.9495 | 70.89339 | -14.2843 | 113.2874 | 327.0325 |
| 999 | 617.6688 | 67.05268 | -15.0361 | 138.4379 | 326.9748 |
| 1000 | 636.0194 | 63.41798 | -15.9378 | 163.5738 | 326.9055 |
| 1001 | 656.7807 | 60 | -16.989 | 188.6923 | 326.8247 |
| 1002 | 679.7319 | 56.80206 | -18.1895 | 213.7909 | 326.7324 |
| 1003 | 704.659 | 53.82161 | -19.5387 | 238.8669 | 326.6286 |
| 1004 | 731.36 | 51.05172 | -21.0364 | 263.9176 | 326.5133 |
| 1005 | 748.2049 | 125.8175 | -22.0091 | -251.292 | 348.2009 |
| 1006 | 723.4532 | 123.0045 | -20.5873 | -226.239 | 348.3177 |
| 1007 | 700.5661 | 120 | -19.3139 | -201.162 | 348.4223 |
| 1008 | 679.7319 | 116.8021 | -18.1895 | -176.063 | 348.5146 |
| 1009 | 661.1447 | 113.4132 | -17.2142 | -150.946 | 348.5946 |
| 1010 | 644.9989 | 109.8417 | -16.3884 | -125.813 | 348.6623 |
| 1011 | 631.4817 | 106.1021 | -15.7124 | -100.666 | 348.7177 |
| 1012 | 620.7649 | 102.2163 | -15.1865 | -75.5089 | 348.7608 |
| 1013 | 612.9953 | 98.21321 | -14.8106 | -50.3437 | 348.7916 |
| 1014 | 608.2859 | 94.12781 | -14.5851 | -25.1732 | 348.8101 |
| 1015 | 606.708 | 90 | -14.5099 | 2.14E-14 | 348.8162 |
| 1016 | 608.2859 | 85.87219 | -14.5851 | 25.1732 | 348.8101 |
| 1017 | 612.9953 | 81.78679 | -14.8106 | 50.34373 | 348.7916 |
| 1018 | 620.7649 | 77.78365 | -15.1865 | 75.50893 | 348.7608 |
| 1019 | 631.4817 | 73.89789 | -15.7124 | 100.6661 | 348.7177 |
| 1020 | 644.9989 | 70.15833 | -16.3884 | 125.8127 | 348.6623 |
| 1021 | 661.1447 | 66.58678 | -17.2142 | 150.9459 | 348.5946 |
| 1022 | 679.7319 | 63.19794 | -18.1895 | 176.0631 | 348.5146 |
| 1023 | 700.5661 | 60 | -19.3139 | 201.1617 | 348.4223 |
| 1024 | 723.4532 | 56.99551 | -20.5873 | 226.239 | 348.3177 |
| 1025 | 748.2049 | 54.18247 | -22.0091 | 251.2924 | 348.2009 |
| 1026 | 744.3515 | 120 | -21.7847 | -213.61 | 369.9831 |
| 1027 | 723.4532 | 116.9955 | -20.5873 | -188.533 | 370.0876 |
| 1028 | 704.659 | 113.8216 | -19.5387 | -163.435 | 370.1791 |
| 1029 | 688.1413 | 110.4847 | -18.6394 | -138.321 | 370.2575 |
| 1030 | 674.0674 | 106.9961 | -17.8894 | -113.191 | 370.3229 |
| 1031 | 662.593 | 103.3728 | -17.2892 | -88.0502 | 370.3752 |
| 1032 | 653.8552 | 99.6374 | -16.8389 | -62.8997 | 370.4144 |
| 1033 | 647.9645 | 95.81753 | -16.5386 | -37.7425 | 370.4406 |
| 1034 | 644.9989 | 91.94512 | -16.3884 | -12.5813 | 370.4537 |
| 1035 | 644.9989 | 88.05488 | -16.3884 | 12.58127 | 370.4537 |
| 1036 | 647.9645 | 84.18247 | -16.5386 | 37.74247 | 370.4406 |
| 1037 | 653.8552 | 80.3626 | -16.8389 | 62.89967 | 370.4144 |
| 1038 | 662.593 | 76.62717 | -17.2892 | 88.0502 | 370.3752 |
| 1039 | 674.0674 | 73.00391 | -17.8894 | 113.1914 | 370.3229 |
| 1040 | 688.1413 | 69.51534 | -18.6394 | 138.3206 | 370.2575 |
| 1041 | 704.659 | 66.17839 | -19.5387 | 163.4352 | 370.1791 |
| 1042 | 723.4532 | 63.00449 | -20.5873 | 188.5325 | 370.0876 |
| 1043 | 744.3515 | 60 | -21.7847 | 213.6098 | 369.9831 |
| 1045 | 748.2049 | 114.1825 | -22.0091 | -175.905 | 391.7261 |
| 1046 | 731.36 | 111.0517 | -21.0364 | -150.81 | 391.816 |
| 1047 | 716.7976 | 107.7837 | -20.2129 | -125.699 | 391.892 |
| 1048 | 704.659 | 104.3916 | -19.5387 | -100.576 | 391.9543 |
| 1049 | 695.0714 | 100.8934 | -19.0142 | -75.441 | 392.0027 |
| 1050 | 688.1413 | 97.31111 | -18.6394 | -50.2984 | 392.0374 |
| 1051 | 683.9495 | 93.6705 | -18.4144 | -25.1505 | 392.0581 |
| 1052 | 682.5465 | 90 | -18.3394 | 2.40E-14 | 392.065 |
| 1053 | 683.9495 | 86.3295 | -18.4144 | 25.15054 | 392.0581 |
| 1054 | 688.1413 | 82.68889 | -18.6394 | 50.29842 | 392.0374 |
| 1055 | 695.0714 | 79.10661 | -19.0142 | 75.44096 | 392.0027 |
| 1056 | 704.659 | 75.6084 | -19.5387 | 100.5755 | 391.9543 |
| 1057 | 716.7976 | 72.21635 | -20.2129 | 125.6994 | 391.892 |
| 1058 | 731.36 | 68.94828 | -21.0364 | 150.81 | 391.816 |
| 1059 | 748.2049 | 65.81753 | -22.0091 | 175.9047 | 391.7261 |
| 1060 | 746.9226 | 105.2953 | -21.9343 | -113.084 | 413.4959 |
| 1061 | 736.5841 | 102.0083 | -21.3358 | -87.9663 | 413.5543 |
| 1062 | 728.734 | 98.63912 | -20.8867 | -62.8397 | 413.5981 |
| 1063 | 723.4532 | 95.20872 | -20.5873 | -37.7065 | 413.6273 |
| 1064 | 720.7983 | 91.7405 | -20.4375 | -12.5693 | 413.6419 |
| 1065 | 720.7983 | 88.2595 | -20.4375 | 12.56928 | 413.6419 |
| 1066 | 723.4532 | 84.79128 | -20.5873 | 37.7065 | 413.6273 |
| 1067 | 728.734 | 81.36088 | -20.8867 | 62.83973 | 413.5981 |
| 1068 | 736.5841 | 77.9917 | -21.3358 | 87.96631 | 413.5543 |
| 1069 | 746.9226 | 74.70466 | -21.9343 | 113.0836 | 413.4959 |
|  |  |  |  |  |  |

### Plate Dead Zones

The no-fly zones on the plate caused by the acquisition cameras are indicated in

Drawing of each exclusion zone TBD

18 Acquisition cameras are located on the focal plane.

An indication of the chosen geometry is given in Figure 7

Macintosh HD:Users:wdt:moons:front_end:guide_cameras:cameraPositionsSprialOnly.pdf

Figure 7 Chosen acquisition camera layout, with 18 cameras

The positioner numbers which are replaced by the acquisition cameras are 534, 568, 532, 429, 538, 399, 294, 775, 526, 797, 544, 211, 951, 938, 91, 520, 550 and 42

The metrology fiducials should not be obscured. The clear zones on the plate are defined in AD1

### Metrology Camera Field of View

The metrology cameras are identified as camera 1 to 12 with the location on the Nasmyth rotator as shown in AD2

The field of view of each camera on the plate is defined in AD2. NB this definition is required if one of the cameras fails it may be necessary to know which FPUs are affected.

#### Location Of Fiducial Marks

The fiducial markers shall be located at FPU positions TBD

### Positioner to Spectrograph Mapping

The final mapping of slit position to FPU will be determined during MAIT as part of the calibration. The initial allocation is shown below.

|  |  |  |
| --- | --- | --- |
| Postioner ref | Spectrograph | Slit Position\* |
| 1 | A | 1 |
| 2 | A | 2 |
|  |  |  |
| 500 | A | 512 |
| 501 | B | 1 |
| 502 | B | 2 |
|  |  |  |

* Definition of the slit positions is contained in the spectrograph mechanisms ICD

## Focal plane definition

TBD

## FPU control parameters

The low level FPU commands used to define each motor’s travel profile shall be derived from a list of arm angles and times generated by the path analysis. The arm angles are in a fixed series of time steps and are executed simultaneously by each motor axis.

The ICS shall ensure that the following rules are applied

1. Minimum Frequency at Alpha output shaft (RPM) = 0.73
2. Maximum Frequency at Alpha output shaft (RPM)= 2.78
3. Minimum Frequency at Beta output shaft (RPM) = 0.98
4. Maximum Frequency at Beta output shaft (RPM) = 3.75
5. Maximum Change in Frequency between times steps for Alpha arm = 40%
6. Maximum Change in Frequency between times steps for Beta arm = 40%
7. Maximum Number of time steps in waveform = 128 (TBD)
8. Each waveform step shall be a fixed time increment which meets the constraints described in 1-7
9. The motors shall not immediately change direction. A “no-move” time step will exist between direction changes (TDB)\*.
10. The motors must start at their minimum velocity after being stationary. This includes the first entry in the waveform table and any movements after a motors has paused (e.g. before a direction change).

\*Steps can be dropped when changing motor direction if a delay of at least 4ms is not added.  Either the ICS can fix this by ensuring there is a “no-move” step between direction changes (i.e. keep the arm angle static for one time step); or the electronics could monitor for direction changes and add in a delay when they occur (then increase the step frequency to compensate).”

## Sensors and Alarms

Temperature sensors shall be provided in the RFE for computation of the metrology offsets and fine adjustment of the FPU positions. The location of the temperature sensors is

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sensor Ref** | **Location** | **Type** | **Qty** | **Alarm** | **Warning** | **Notes** |
| FP  .TEMP i | FPU Plate | PT100 – Beckoff | 13 | N | N | Used for positioner correction.  i = 1-13 |
| TBD | RFE cabinets temperature |  | 1 | N | Y | Over temperature alarm provided by standard ESO cabinet controller and shut down of cabinet |
| TBD | RFE electronics box temperature |  | 3 | N | Y | As above – TBC? |
| RFE  .TEMP i | Calibration screen motor temperature |  | 4 | N | Y | Readout TBD  i = 1-4 |
| RFE  .TEMP i | Retractor motor temperature |  | 3 | N | Y | i = 5-7 |
| RFE  .TEMP i | Acquisition camera temperature |  | 20 | N | Y | Directly reported on Ethernet?  i = 8-27 |
| TBD | Metrology lamp ON/OFF sensors | Photoresistor to Beckoff | 24 | N | N | 4 per module |
| RFE  .TEMP i | Metrology camera temperature |  |  | N | Y | Reported on Ethernet via metrology computer  i = 28-51 |
| TBD | Retractor position | resolver |  | N | N |  |
| RFE  .LOCK i | RFE cover switch | TBD | 1 | Y | Y | Rotation interlock controlled |
| RFE.TEMPi | RFE internal structure temperature | PT100 via Beckoff | 4 | N | N | i = 52-55 |

# Work-package Extents of Supply

## RFE Work-package

As-built plate scale shall be defined.

### Acquisition Cameras

The acquisition camera workpackage shall provide all sufficient hardware and software to provide centroids and raw image frames via an Ethernet connection.

### Metrology Cameras

The metrology camera workpackage shall provide all sufficient hardware and software to provide positioner locations via an Ethernet connection.

### Calibration Source

The calibration source module workpackage shall provide all sufficient hardware and software to provide a flat field to the instrument when commanded.

The calibration source module shall provide internal diagnostics which are independent of the ICS.

### Fibre Positioners

Fibre positioners module shall drive the FPU along the exact path commanded by the ICS. No knowledge of the external system is required within the FPM.