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Disclaimer

Neither the authors nor the United Kingdom Atomic Energy Authority accept responsibility for consequences arising from any errors either in the present documentation or the SpaceClaim tools, or for reliance upon the information contained in the data or its completeness or accuracy.

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Executive Summary

This document is a user manual for the SpaceClaim tools developed at UKAEA using the SpaceClaim API. These tools are intended for streamlining some of the processes common in simplifying a CAD model suitable for conversion to a radiation transport code input. Instruction is provided for installation through a getting started section as well as a detailed description on the use of each of the tools. The suite of tools is hosted on *Github*. UKAEA recognises that there are areas of improvement for all of the tools, and part of the motive for making them open source was to allow the community to participate in their development.

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1 Overview

In the conventional workflow for neutronics analysis, a 3D CAD model is the starting point. This model is converted to the particle transport code input file, for example, MCNP [1], which is a CSG representation of the geometry. The conversion is performed using software such as SuperMC [2] or McCAD [3].

Prior to converting the CAD model, the analyst is required to simplify the model. This is to meet the requirements for the transport code, the conversion software and to remove any underlying issues with the model that is received. Simplifications include the removal of:

- Splines
- Off-axis tori
- Inteferences
- Non-manifold geometry or other topological errors.

This list is by no means exhaustive and only gives the minimum requirements to allow conversion. Often, there are many further modelling activities undertaken such as splitting complex geometries or removing small features such as rounds and holes. It is down the analyst to ensure that whilst performing these revisions to the model, only geometry which is critical to particle transport is retained, whilst ensuring the simplified model is an accurate representation of the original CAD.

In fact, preparation of the 'neutronics CAD model' can be very time consuming, and can account for over 50% of the entire workflow. Many of the simplification procedures are repetitive and performed by default for all models. Therefore, automating these tasks can significantly increase the efficiency of the simplification process and therefore the entire analysis. This was the original motive for developing the tools which are detailed herein.

SpaceClaim was originally identified as a CAD platform with great potential for the purposes of fusion neutronics in 2011. It is now the most commonly adopted CAD program by the community. Many of the in-built features are useful to the analyst performing simplification. The SpaceClaim API was first introduced in XXXX, providing a powerful method for exploiting these features in development of specific tool. Documentation and examples of the API are distributed with SpaceClaim. The API is as wrapper adopting the .NET framework allowing users to code in several programming languages. The user is required to have Visual Studio for compilation. Detail on compiling for the specific case of the tools developed here is given in section 2.

More recently, python scripting has become possible directly in SpaceClaim. The tools detailed in this report are either written in C# or python. An exhaustive list of the developed tools and adopted programming language is given in Table 1. The python tools have been integrated with the C# tools to create a single suite of tools. This means all tools are accessible in the SpaceClaim design ribbon once compiled by the user.

C# Tools	**Python Tools**
Pipe tools (3.1)	Geometry assessor (3.7)
Tori tools (3.2)	Cylinder-plane locator (3.8)
Export tool (3.3)	Cylinder-plane splitter (3.9)
Max surfaces (3.4)	Cylinder-cylinder splitter (3.10)
Lost particles (3.5)	Volume assessor (3.11)
Body/Surface filter (3.6)	Void generator (3.12)
	Mesh tally writer (3.13)
	Mesh tally checker (3.14)

Table 1: List of tools developed by UKAEA and detailed in this report in the given section numbers

2 Getting Started

To compile and install the CCFE SpaceClaim tools it is recommended that Visual Studios Community edition (which is free to use on opensource projects) is installed. This provides a relatively quick and easy way to compile and install the tools into SpaceClaim.

These instructions use Visual Studios 2019, but should be relatively similar for all versions of Visual Studios. It should be noted that .NET Framework version 4 or later is required.

First you will need to clone the github repository by clicking on clone repository in the File menu:

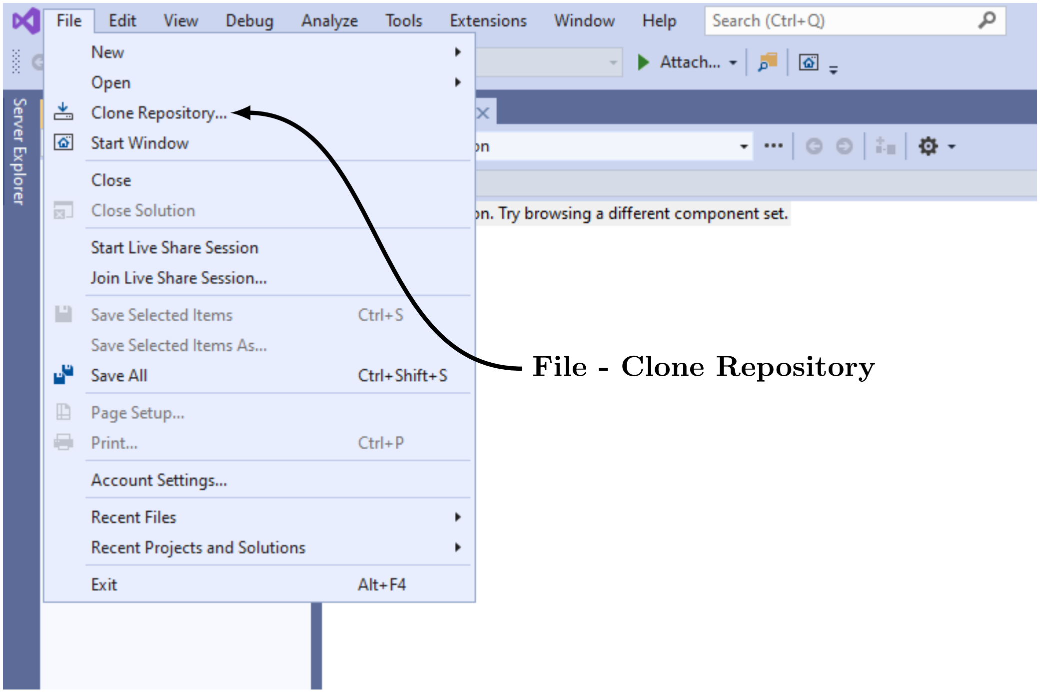


Figure 1: Cloning the github repository part 1.

Enter the github address of the repository in the first box and the local location of the folder you want to store the repository in the second box:

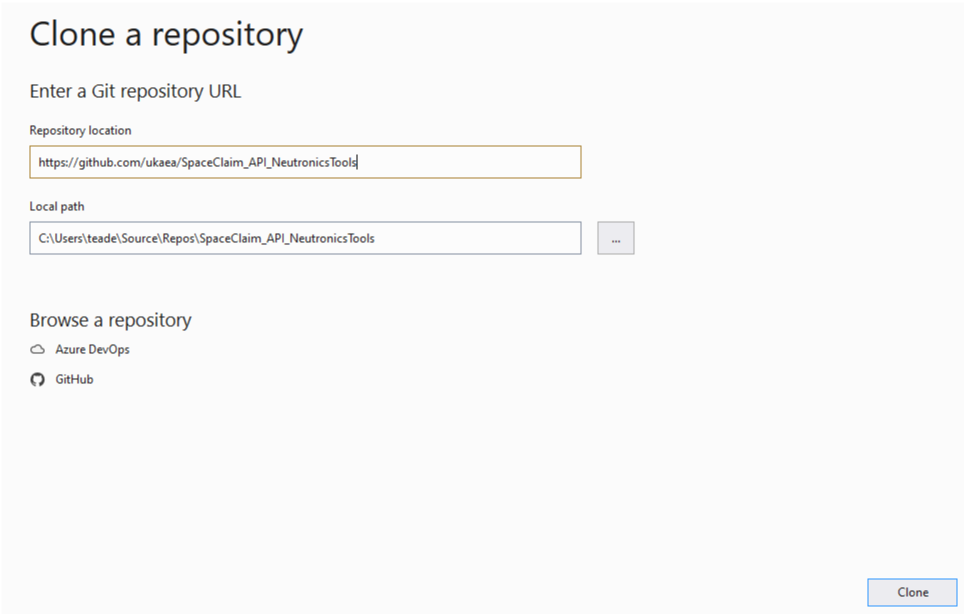


Figure 2: Cloning the github repository part 2.

Once cloned you will need to re-point the project to the SpaceClaim API Library. This can be done by deleting **SpaceClaim.Api.V16** and **SpaceClaim.Api.V16.Scripting** from the *'References'* in the solution explorer.

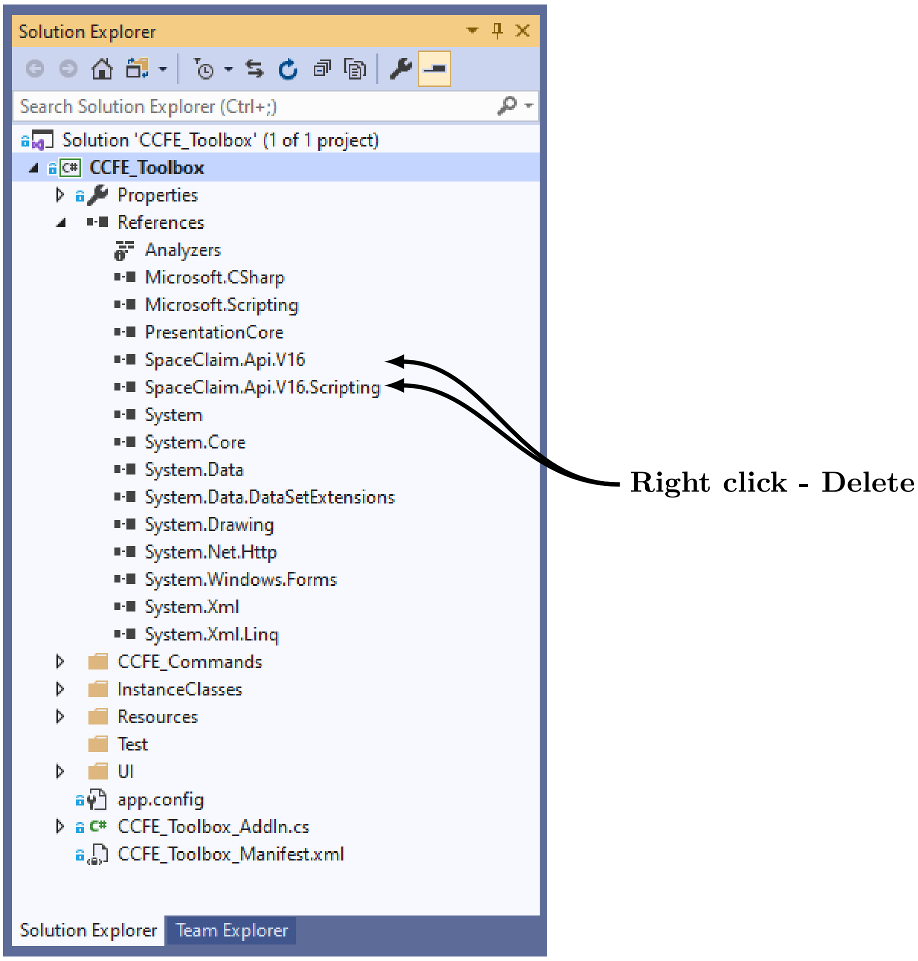


Figure 3: Deleting the SpaceClaim API library reference.

And then re-adding them by right-clicking on *'References'* and selecting *'Add Reference. . . '*:

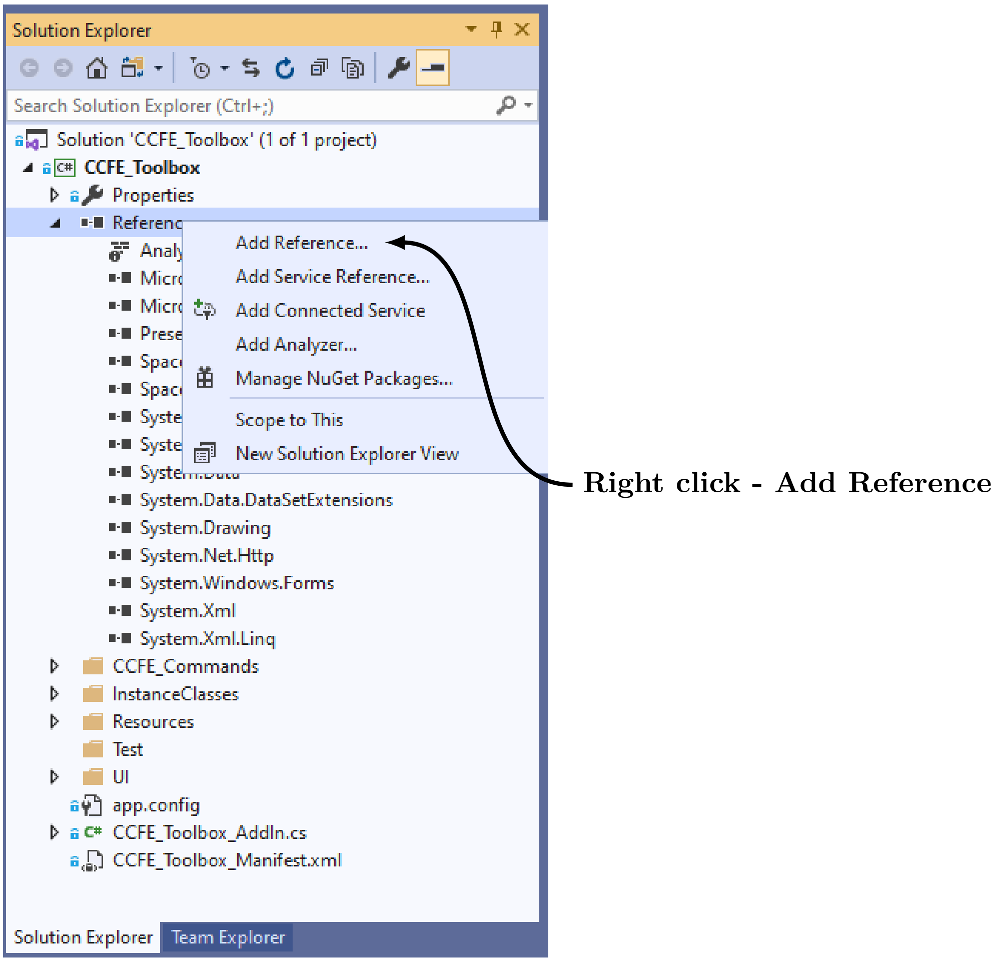


Figure 4: Re-adding the SpaceClaim API library reference - Part 1.

Click browse and navigate to: C:\Program Files\ANSYS Inc\v192\scdm\SpaceClaim.Api.V16\(or the location SpaceClaim is installed if it is not installed as part of ANSYS):

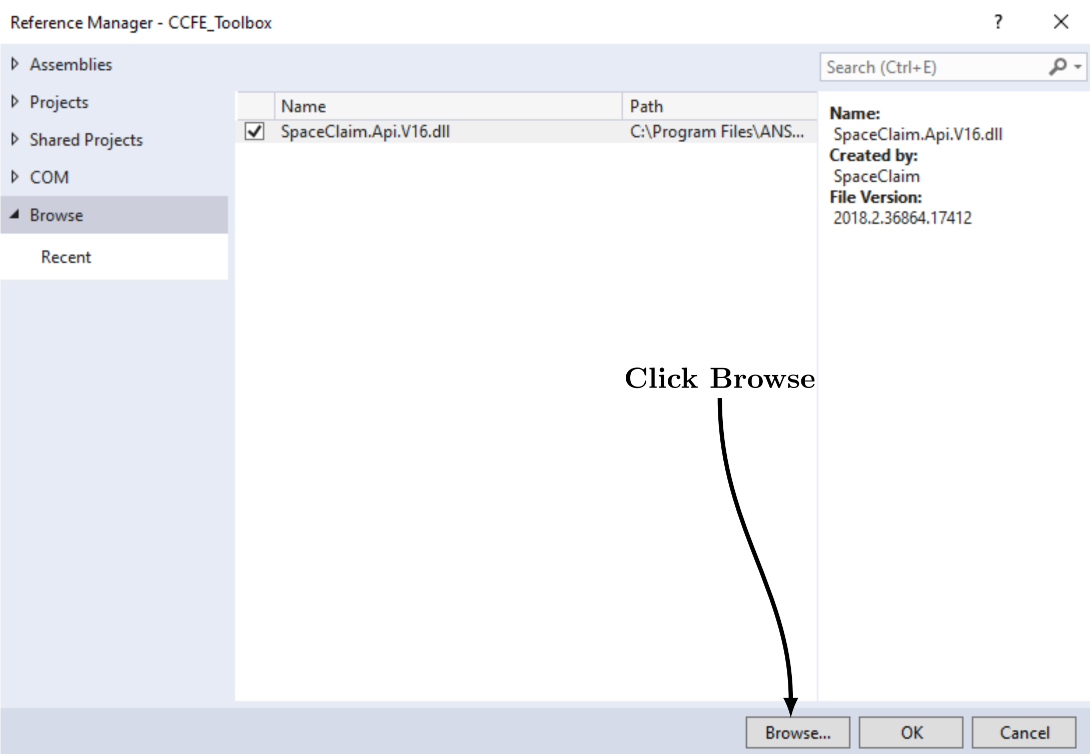


Figure 5: Re-adding the SpaceClaim API library reference - Part 2.

Add **SpaceClaim.Api.V16.dll**:

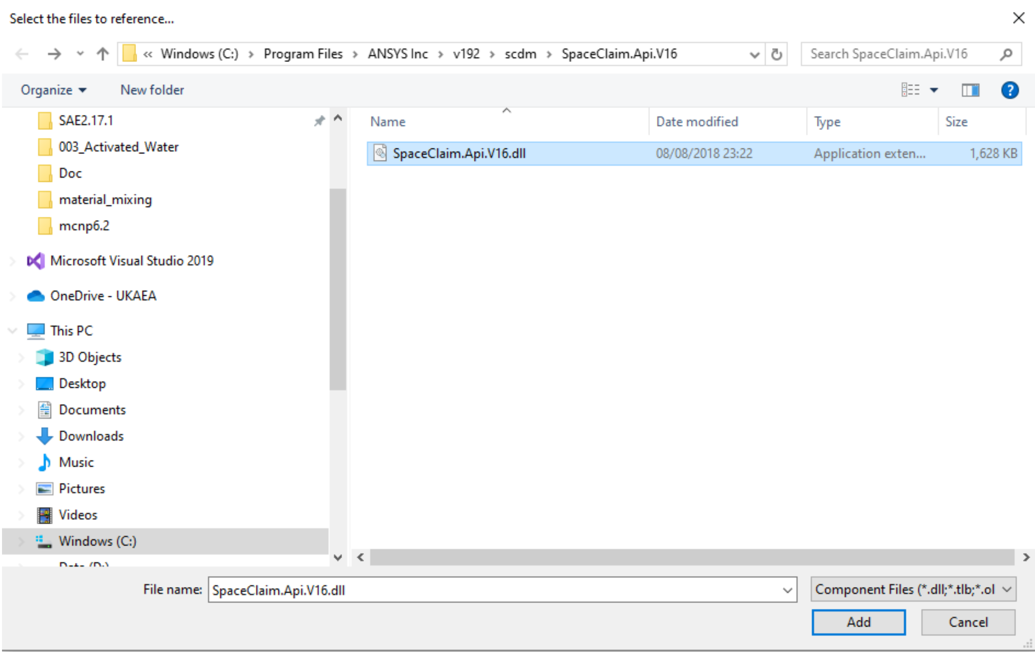


Figure 6: Re-adding the SpaceClaim API library reference - Part 3

Add **SpaceClaim.Api.V16.Scripting.dll**
(found in C:\Program Files\ANSYS Inc\v192\scdm\).

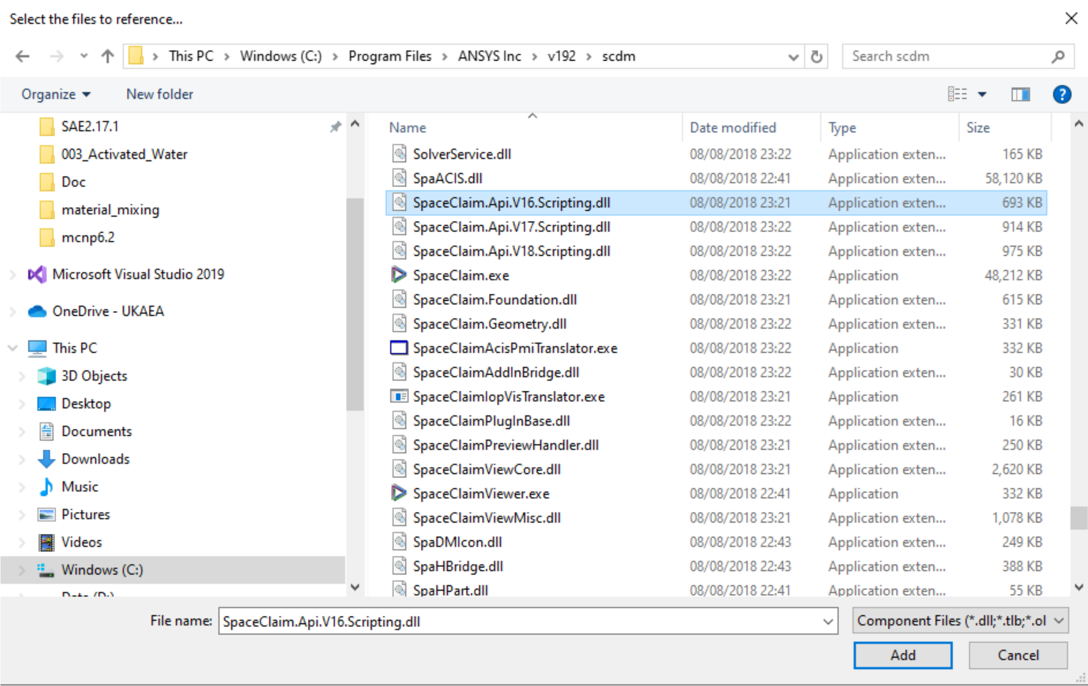


Figure 7: Re-adding the SpaceClaim API library reference - Part 4

The next step is to make sure the output is placed into the correct folder, which can then be loaded by SpaceClaim when it opens. To do this the projects *'Properties'* should be opened in the solution explorer.

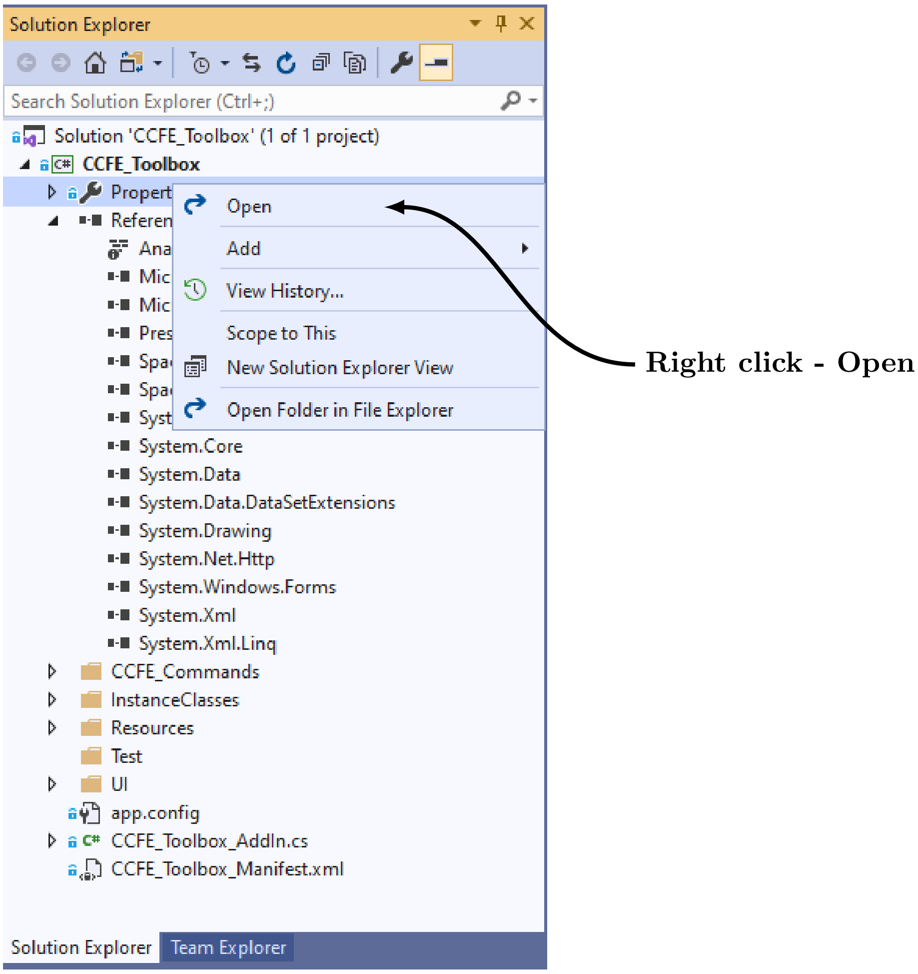


Figure 8: Checking the location of the output - Part 1.

Check that the Output path is set to:
C:\ProgramData\SpaceClaim\AddIns\Samples\V16\CCFE_Toolkit\ (Or the location of your ProgramData directory if this is not on your C drive.)

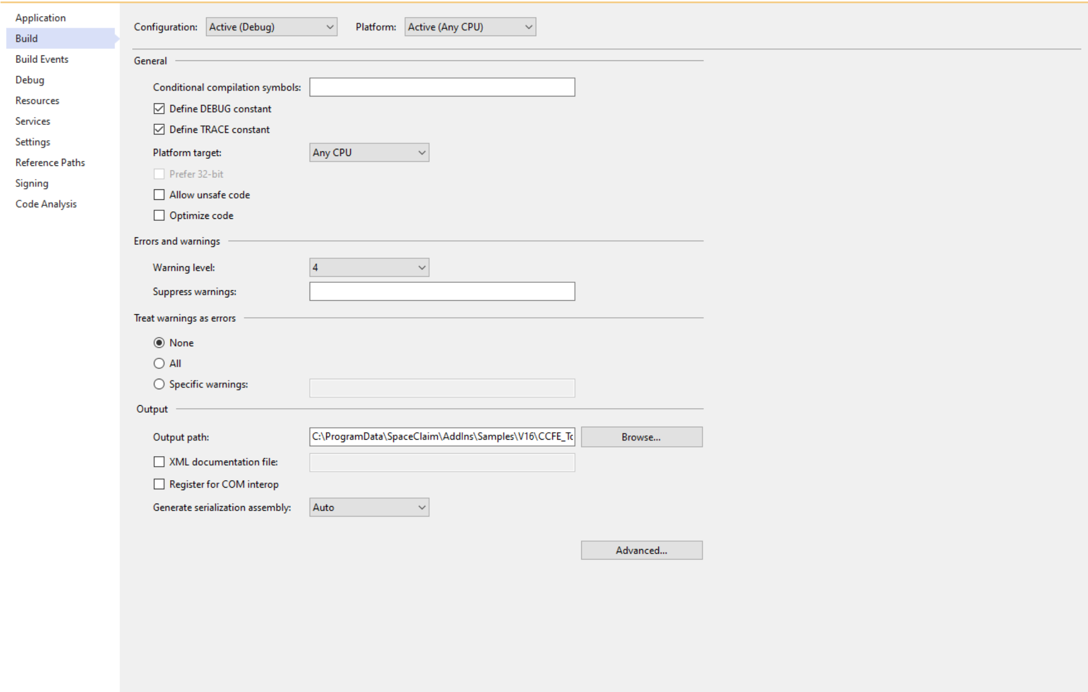


Figure 9: Checking the location of the output - Part 2.

3 Available Tools

3.1 Pipe tools

Purpose
Pipe simplification can be a time-consuming task for particle transport models. The pipe simplification tool aims to speed this simplification up, automating the simplification of pipes made from a combination of cylinders and tori into just cylinders. An example of the type of pipe the tool can be used with is given in Figure 10.

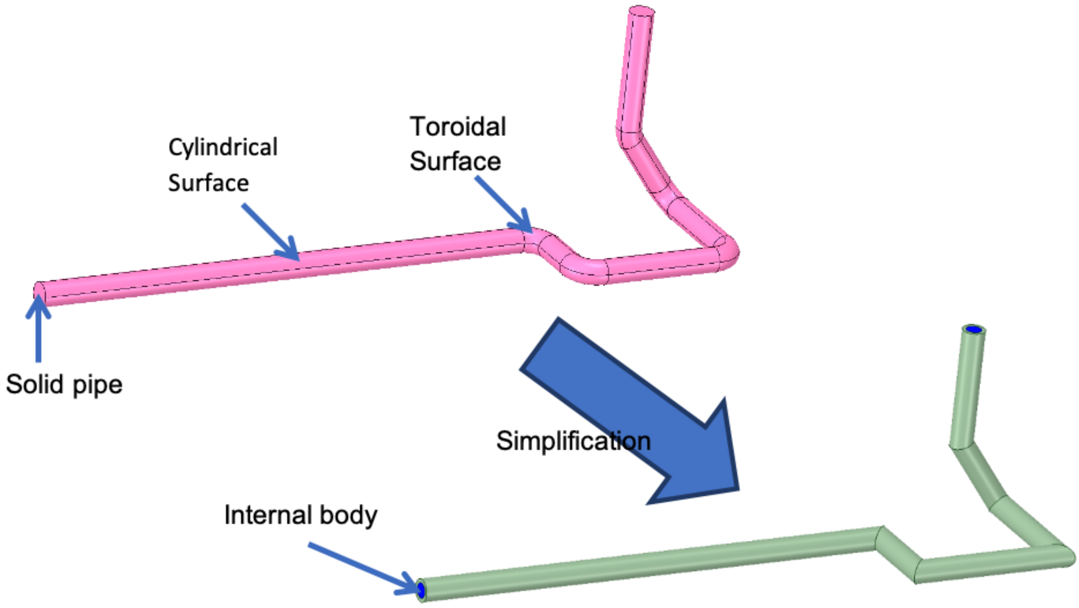


Figure 10: Pipe simplification.

Output
The tool outputs the simplified pipes into a component labelled 'Simplified Pipes' (and if used the DN and schedule number). If any pipes fail to simplify, copies of the failed pipes are placed in a component called 'Broken Pipe'.

SC ribbon

Use

The tool can be selected when one or more pipe bodies have been selected in SpaceClaim. When the button is pressed the user is given several options, see Figure 11.

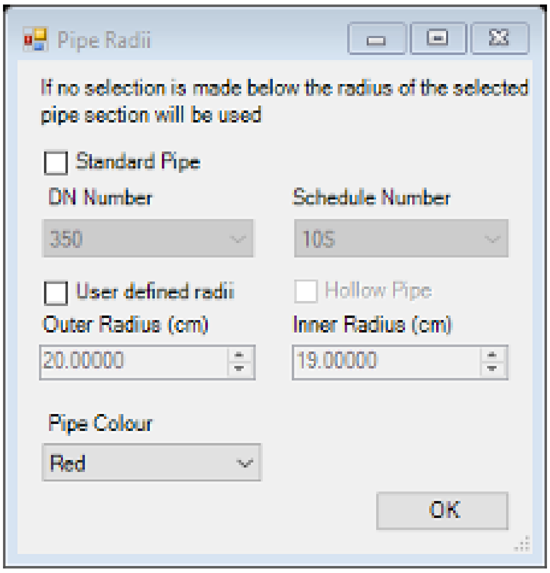


Figure 11: Pipe simplification form.

By selecting no pipe radii the radius of the pipe being simplified is used. If the standard pipe checkbox is ticked the user is allowed to select a standard pipe DN and schedule number based on the ASME standard [4][5]. If the user selects the user defined radii button a outer radius of the pipe can be specified. If the hollow pipe button is then selected a user specified inner radius can be entered too. Please note that these radii should be in cm. A final option allows the colour of the pipe to be defined from a list of 7 predefined colours. This allows for grouping of pipes, an example of where this might be useful is for hot and cold feeds where different densities for coolant water are needed. By clicking OK the tool will simplify the pipes.

3.2 Tori tools

Purpose: The tori simplify tool converts a toroidal body into a number of cylindrical bodies which can be converted easily into MCNP CSG. A example of this can be seen in Figure 12.

Output
The tool outputs the simplified toroidal bodies into a component called 'Simp Tori n', where n is the index of the toroidal body being simplified.

SC ribbon:

Use
The tool can be used when one or more toroidal bodies are selected. By pressing the

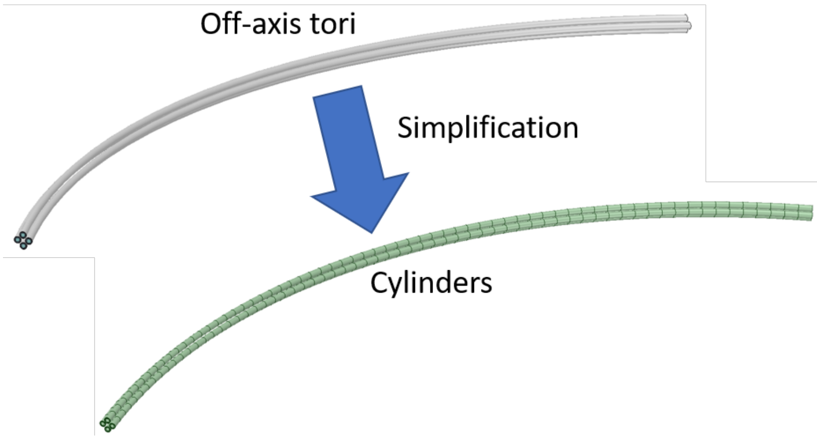


Figure 12: Tori simplification.

'Simplify Tori' button on the ribbon the user is prompted by a pop-up box to fill in a number of user specified options, see Figure 13.

The first box on the form allows the user to specify a maximum deviation of the newly created cylinders to the tori. This is given in degrees. A smaller number gives more cylindrical bodies and more closely matches the original torus. The next options allow the toroidal minor radii to be specified. This can either be done using a standard pipe inner and outer diameters (with a DN and schedule number) or using user defined radii. Up to 4 user defined radii can be specified from smallest to largest. For each cylindrical segment the tool then creates concentric cylinders.

The last option available to the user, 'Full torus', makes the tool ignore the planes at the end of the toroidal segment. The tool then produces cylinders as if the body being simplified was a full torus. This is useful if the end planes of the segment are not perpendicular to the toroidal body. For these cases the tool can struggle to correctly calculate the angular extent of the segment.

3.3 Export tool

Purpose
This tools exports SpaceClaim designs to separate .SAT files based on material. This allows the different materials to be assigned easily.

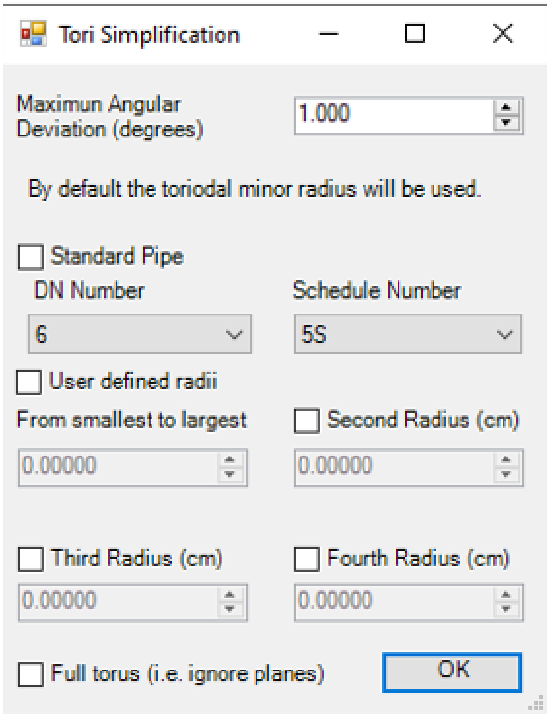
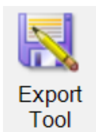


Figure 13: Pipe simplification form.

Output
A .SAT file is produced for each independent colour defined in the geometry - this tool assumes that different materials are grouped by colour.

SC ribbon



Use
On selection, the file explorer window appears to allow the user to select the location to save the .SAT files. The tool is then executed.

3.4 Max surfaces

Purpose

The max surfaces tool highlights any bodies present in the design which have more faces than a user-input value. Analysts may be working under project-imposed constraints for the allowable number of surfaces per body in order to reduce the complexity of transport code input files. This tool is useful for these instances and also in general to ensure to model is simplified to a suitable level.

Output

Bodies which fail to meet the criteria are highlighted for user inspection.

SC ribbon

Use

Once this tool is selected, the user is prompted to enter the maximum number of faces per body limit and also whether to colour the problem bodies.

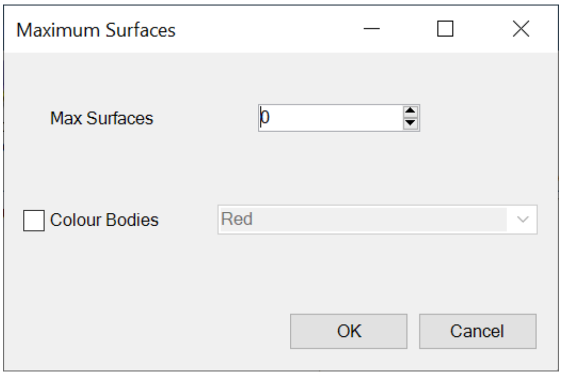


Figure 14: Max surfaces prompt window.

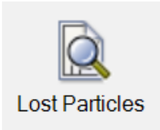
3.5 Lost particles

Purpose

Lost particles are a common issue in neutronics, often arising from problems in the geometry. The locations where particles are lost indicate where the geometry problems lie but often it is hard to visualise this. This tool plots lost particles locations on top of the geometry for user inspection and to make it easier to identify issues at source

Output
The lost particles are plotted on top of the geometry.

SC ribbon



Use
On selection, the tool prompts for the file containing the lost particle locations which can be the MCNP output file. It also gives the option of whether the vectors should be shown and provides an option to limit the number plotted (useful if there are many). The colour assigned can also be selected for ease of visualisation. Then the lost particles are plotted on the geometry.

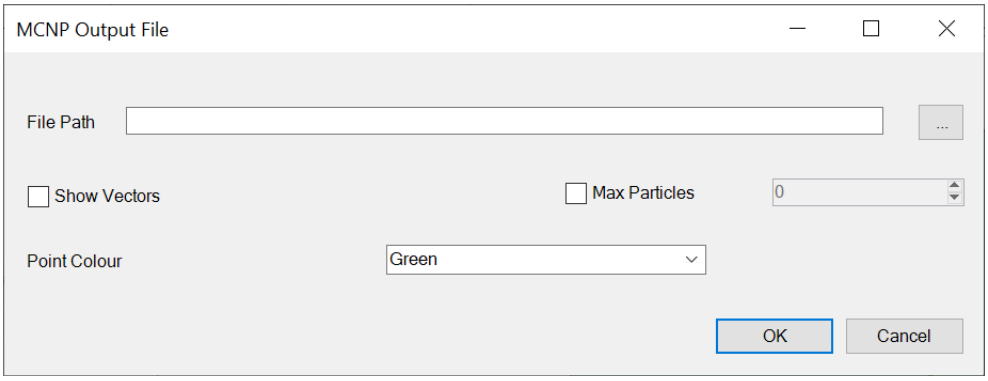


Figure 15: Lost Particles prompt window.

3.6 Body/Face filter

Purpose
This tool can be used to identify cones and tori in the geometry. It can also find bodies and surfaces below a certain volume/area as well as holes below a certain radius. It is useful in the initial simplification stages to find surfaces that should be simplified or bodies that can be removed.

Output

The geometry is unchanged - the specified bodies and/or surfaces are highlighted.

SC ribbon

Use

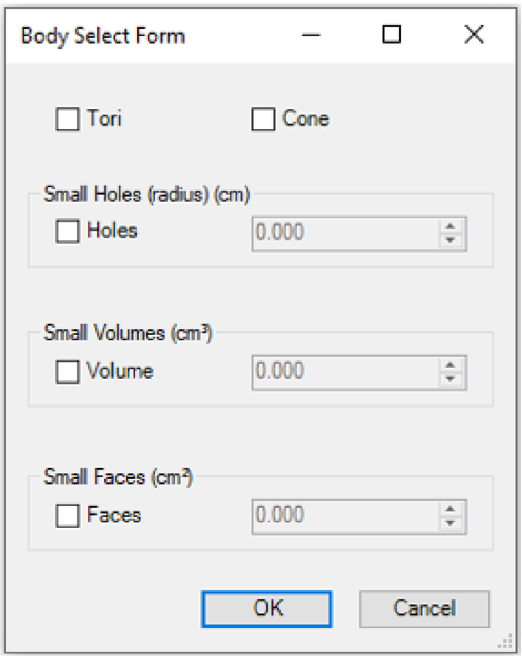


Figure 16: Body/surface selection form

The window allows selection of either cones or tori. The user can input the volume, area of radius of the bodies volumes or holes that they would like to isolate.

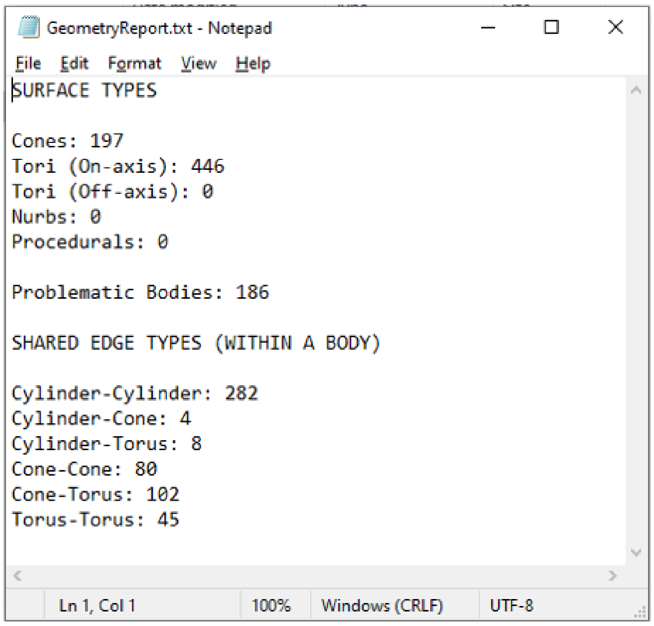
3.7 Geometry assessor

Purpose

The purpose of this tool is to check that the simplification performed is aligned with the conversion requirements. This tool should be used once the analyst believes that the CAD is in a conversion-ready state, as a final check to ensure all potential issues are resolved.

Output

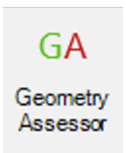
Text document quantifying potential issues. These are also highlighted in the geometry and non-problematic geometry is hidden in the design window.




```
SURFACE TYPES

Cones: 197
Tori (On-axis): 446
Tori (Off-axis): 0
Nurbs: 0
Procedurals: 0

Problematic Bodies: 186

SHARED EDGE TYPES (WITHIN A BODY)

Cylinder-Cylinder: 282
Cylinder-Cone: 4
Cylinder-Torus: 8
Cone-Cone: 80
Cone-Torus: 102
Torus-Torus: 45
```

Figure 17: Example output from the geometry assessor tool

SC ribbon



Use

All of the geometry should be visible in the design window. On selection, the user is prompted to select a file path for the output file and the colours to be assigned to the different surface types. The tool will then run and edit the the transparency, visibility and colour of the objects to highlight different potential problem areas. The default colour conventions are shown in Figure 18.

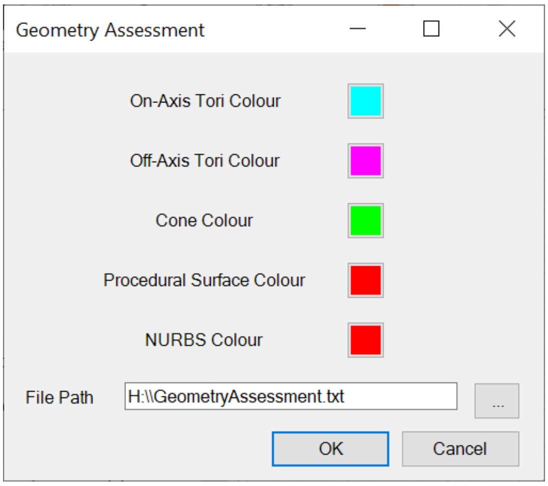


Figure 18: The geometry assessor tool prompt window.

3.8 Cylinder-plane locator

Purpose

The intent of this tool is to identify shared edges between cylinders and planes. Once identified, it is at the users discretion how they should be simplified. Typically, these types of edges should be split for ease of conversion. This process is automated by the cylinder-plane splitter tool (section 3.9).

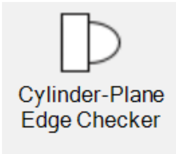
Output

The visibility of the CAD in the design window is modified so that only solid bodies with a shared edge between a cylinder and a plane remain visible. The problematic edges are highlighted. If no problem edges are found then an error message is returned.

SC ribbon

Use

On selection of the button, the tool will be executed.

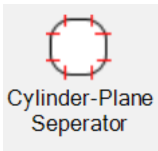


3.9 Cylinder-plane splitter

Purpose: If a body contains shared edges between cylinders and planes, then this tool will separate the body along that edge. This tool can be used after such edges have been identified using the Cylinder-plane locator (3.8), and as explained above, is necessary to ease CAD conversion but also to allow more precise tallying. Rounded rectangles are commonplace in reactor designs and contain these problematic edges.

Output
New bodies are formed due to the separation(s) and planes are formed where the splits occur.

SC ribbon:



Use
On selection, the tool will split any relevant bodies along their cylinder-plane edges and form planes at these edges. If no appropriate geometry is found then the tool returns an error. It is recommended to use the Cylinder-plane locator (3.8) prior to this tool to get an insight into what separations will occur.

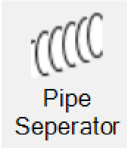
3.10 Cylinder-cylinder splitter

Purpose
Once pipes have been simplified into cylinders, for example using Pipe Tools (3.1), this separator can be used to divide bodies made up of multiple cylinders into individual cylindrical bodies. This is required because intersections between cylinders within a body can lead to problems with CAD conversion.

Output

New cylindrical bodies as a result of the separation(s).

SC ribbon



Use
On selection, the tool looks for any appropriate intersections and separates the problem bodies along these intersections. The user has the responsibility to provide appropriate geometry, an error is returned if no such geometry is present.

3.11 Volume assessor

Purpose
In the simplifcation process, it is important the volume of the original CAD model is preserved. It is common to make a volume comparison to identify where there is large differences from the original CAD volume which may be the result of over simplification.

Output
The output is a text file which lists the volumes to the user selected level. Volumes are reported in cm^3

SC ribbon

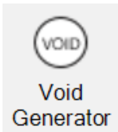
Use
The user is prompted to select the depth in the structure tree to which they would like the volumes to be reported.

3.12 Void generator

Purpose
The purpose of this tool is to generate void cells for the geometry as required by MCNP under the premise that all problem space must be defined. It helps to avoid overly complex void cells in MCNP and can produce internal voids which are not modelled using automatic void generation in SuperMC. It works by subtracting the geometry away from an automatically generated void body, and then iteratively simplifies resulting cells through recursive splitting.

Output
New bodies representing the void cells in the CAD geometry. Any problem bodies in the geometry that fail to subtract from the void are set visible for easy identification. This often indicates a problem with the geometry itself and not the tool. The user is encouraged to use the 'check geometry' available in SpaceClaim.

SC ribbon:



Use
Selection of the button will display the window where the user can specify the maximum number of times that the original void cell can be subdivided and the maximum number of faces allowed in a single void cell.

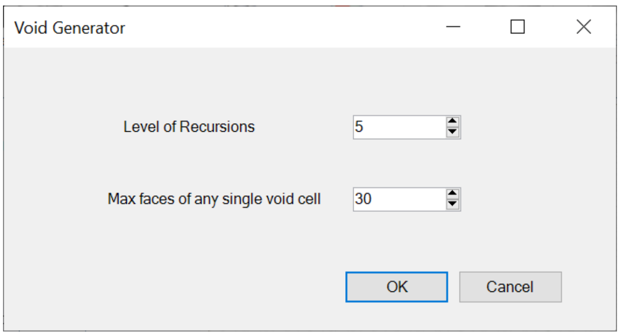


Figure 19: Void generator: void properties prompt.

3.13 Mesh tally writer

Purpose
The purpose of this tool is to generate mesh tallies by modelling them within the CAD geometry. The alternative is to manually write the tallies into the MCNP code which

can lead to errors in the positioning, dimensions and resolution of the meshes. Being able to visualise the mesh tallies within the CAD geometry before the MCNP code is written, mitigates these errors and simplifies the process for the user.

Output: Text file containing the MCNP mesh tally input(s).

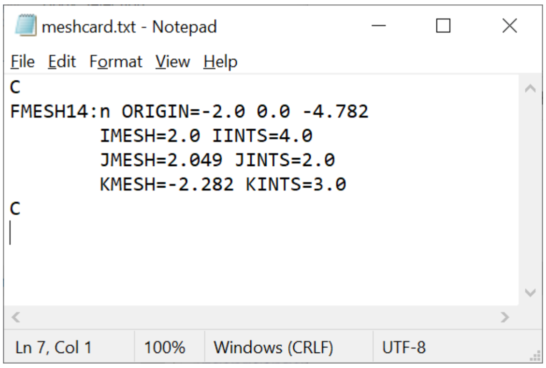


Figure 20: Example output from the Mesh Tally writer tool with one mesh.

SC ribbon

Use

To use this tool, build cuboids in the CAD geometry representing the mesh tallies. Place these objects inside of a new SpaceClaim top-level component called ‘MESH’. On selection, the tool prompts the user for the desired file path for the output text file. The tool then prompts the user for the mesh tally properties: tally number, particle type and cartesian resolution, for each of the meshes. On completion, the output file is displayed.

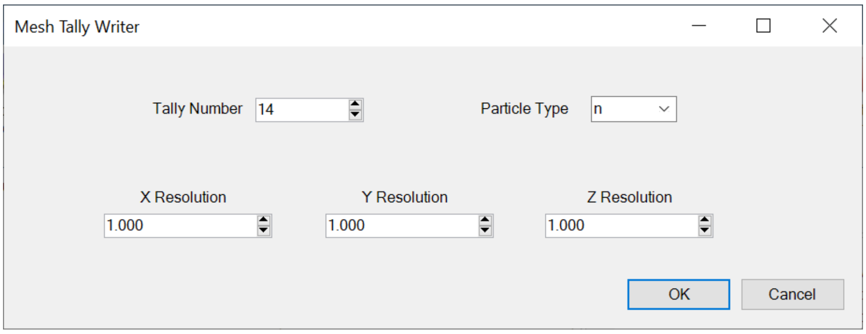


Figure 21: Mesh Tally writer mesh properties prompt.

Restrictions:

- This tool can only be used for rectangular meshes.
- All meshes must be placed within one 'MESH' component.
- The mesh properties are assigned to the meshes in the order they are placed in the structure tree.

3.14 Mesh tally checker

Purpose
Mesh tallies written into MCNP input code can be modelled in CAD geometry using this tool. This visualisation helps when checking written mesh tallies.

Output
A cuboid shape representing the mesh tally is produced in the CAD. Depending on the user's preference, this new object can have planes overlaid on it to represent the resolution of the mesh tally and the object can even be split up into the resolution for full visualisation.

SC ribbon

Use
The user is prompted to include planes and splitting for mesh resolution visualisation

and then asked to supply the MCNP 'FMESH' input code in a readable text file format. The splitting of the created body for resolution visualisation is only possible if the resolution planes have also been included, the prompt window ensures this. This tool can only be used for rectangular meshes and one mesh at a time.

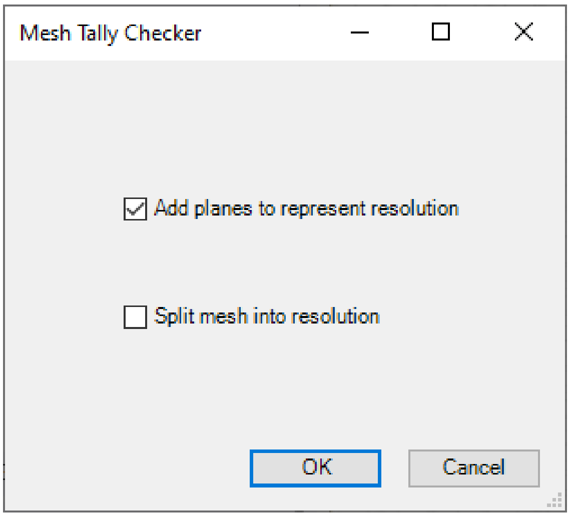


Figure 22: Mesh Tally Checker: Mesh resolution visualisation prompt.

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