GMGW-1
2017

# Participant Questionnaires: Initial Analysis


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**1st AIAA Geometry & Mesh Generation &**
**3rd AIAA High Lift Prediction Workshops**

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# Outline

- Introduction
- The Participant Questionnaire (PQ)
- Synthesis of Responses
- Closing Remarks

# Introduction: (1/3) Context & Objectives



- The human effort and expertise involved in Geometry and Mesh Generation remains crucial to the successful deployment of CFD
- In order to address the associated challenges posed by the 2030 Vision, it will be necessary to identify which aspects of current practice work well and to understand why others are problematic
- To this end, each Participant who submitted a mesh to either GMGW-1 or HLPW-3, was required to complete a Participant Questionnaire (PQ)
- These slides summarise the findings of an initial analysis of the responses received
  - A more comprehensive report will be presented at AIAA SciTech
  - This will include correlations with analyses of mesh quality and flow solutions

## Introduction: (2/3) Evolution



- This is not the first time the AIAA MVCE TC have tried to survey the strengths and weaknesses of current practice
  - A questionnaire was circulated in the summer of 2015
    - 1 response received
  - A second, shorter, questionnaire was made available to help seed a panel discussion at AVIATION 2016
    - 162 responses received
- The current PQ went through several drafts and a trial-run by the MVCE TC suppliers of baseline meshes for HLPW-3 …
  - Sample response: “It feels like I am taking a 3-hour final exam”
  - -> number of questions reduced from 55 to 37
- … before making Issue 1 available to Workshop Participants

# Introduction: (3/3) Scope & Approach



- The following slides present select findings of an initial analysis of the responses
  - This analysis has been undertaken independently of all other workshop information (geometry; mesh quality; flow solutions)
  - The time allocated to this presentation precludes addressing all responses here
  - Rather than attempting to focus on the details, a broad brush approach has been adopted
    - Much of the detail will have been addressed during the individual Participant Presentations
    - A more considered analysis will be presented at SciTech in January
- However, before proceeding further:

  **Many thanks to all of you who completed a PQ**
  - Without you, none of the following would be possible

# The Questionnaire

- Consisted of 36 questions arranged in the following sections:
  - Geometry; Initial Meshing; Mesh Families; Adaptation; Post-Solution Modifications; I/O; Miscellaneous
- General themes addressed:
  - Tooling; Process Overview; Problems Encountered; Resource & Expertise Required
  - Intended to address those aspects that would not necessarily be identified via direct analysis of the meshes themselves
- Participants who generated meshes in both GMGW-1 and HLPW-3 were required to submit one completed questionnaire with each family of meshes
- In the event, 24 completed PQs were received

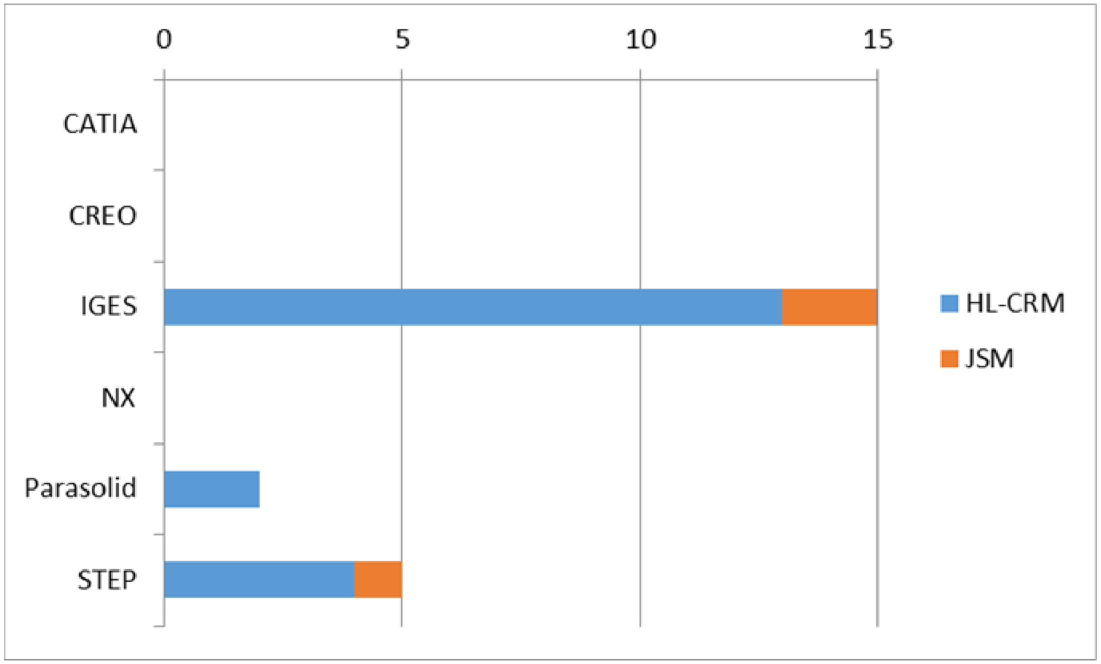
## Questionnaires Received



- 19 Participants completed PQs
  (Some Participants submitted multiple PQs,
  others combined multiple responses onto a single PQ)
  - 18 for HL-CRM:
    3 Industrial Organisations; 4 Research Agencies;
    4 COTS vendors; 3 Universities
  - 3 for JSM:
    2 Industrial Organisations; 1 Research Agency
- Mesh types covered:
  - HL-CRM:
    Hybrid (various flavours – including high-order, adapted);
    Structured (Multi-Block, Overset); Octree
  - JSM:
    Hybrid, Unstructured

# Responses: Geometry (1/4)

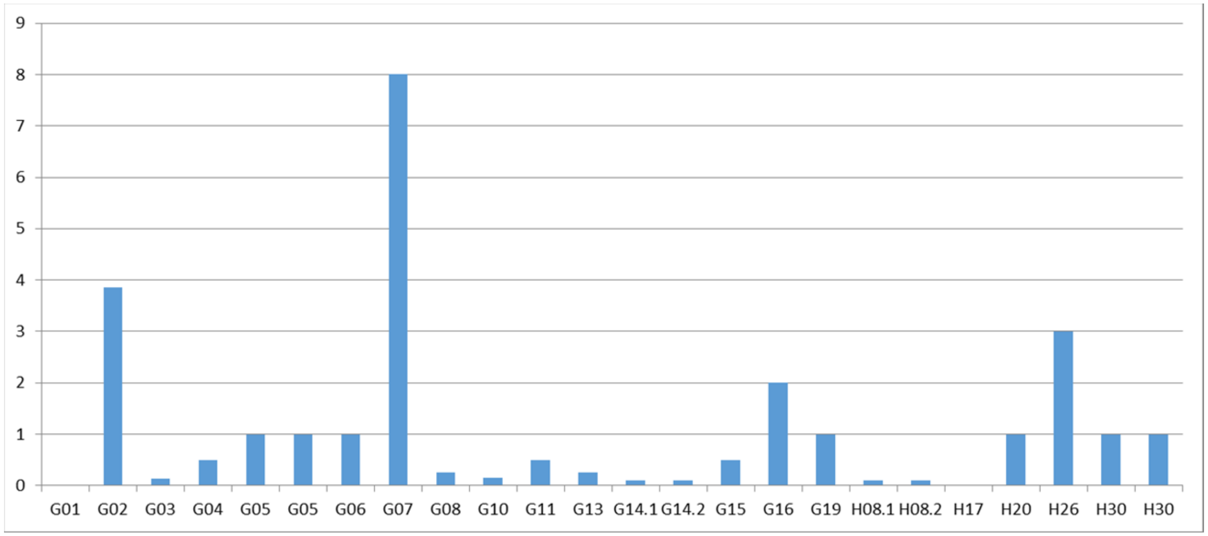
- Models Used




- NB:
  - No use of supplied MCAD models
    (NX or CREO; CATIA import was problematic)
  - Parasolid selected in view of native NX heritage

# Responses: Geometry (2/4)

- Time to import and prepare model prior to meshing (hr)

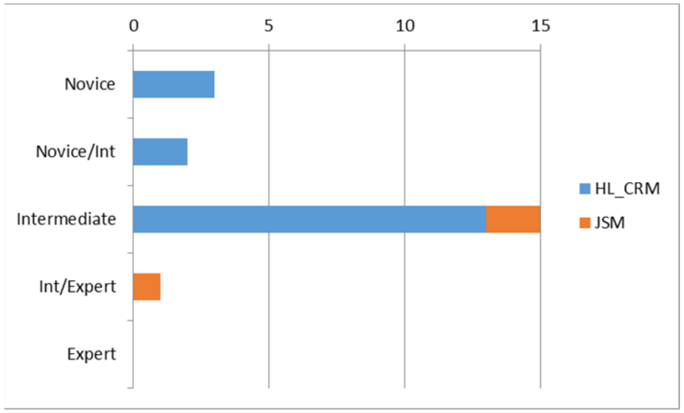



- Generally ~1hr (or less), except:
  - Prep for surface mesh (triangulate; discretise curves)
  - Modify OML (esp fuselage) to suit local meshing tool
  - Scribe LE to ease specification of local mesh control

# Responses: Geometry (3/4)

- Other aspects of geometry preparation process included:
  - Adding far-field bounding box; labelling model components
  - Joining short edges; changing co-ordinate systems (z- spanwise); splitting surface patches along iso-parametric lines (coving + LE) …
  - Repair:
    - IGES: Gaps near TEs & Fwd fairing/fuselage; Missing face; Overlapping geometry; Shrink-wrapping
    - STEP: Clean curvature spikes in surfaces & fix two self-intersecting faces

- Expertise Required:



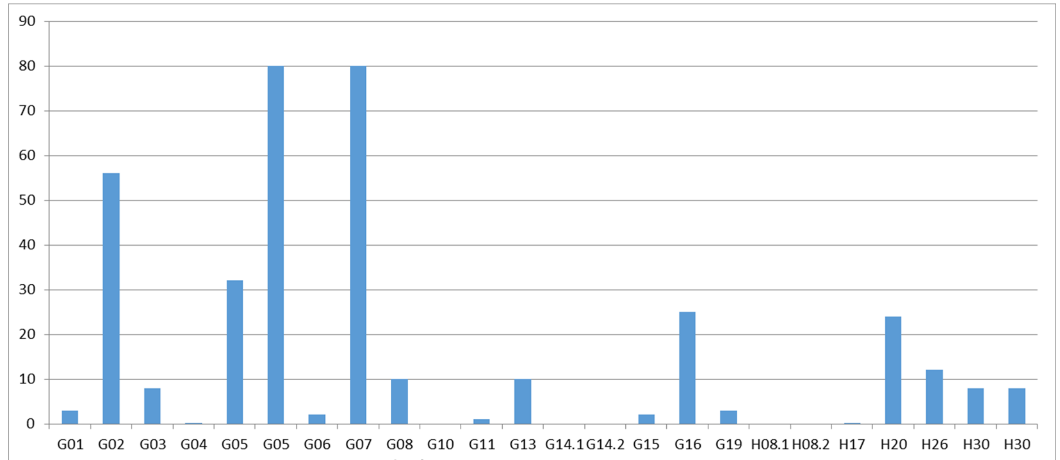
## Responses: Geometry (4/4)

- Additional Remarks:
- Although diverse problems were encountered with the supplied models, none appeared to be “substantial”
  - All problems were resolved in <1hr
- Largest efforts were anticipated
  - … and may not be representative of “real-world” scenarios (i.e. may be accommodated by suitably tailored end-to-end local process)
- All Participants required some manual interaction to import the supplied models
  - Some required (or chose to make) further modifications subsequently

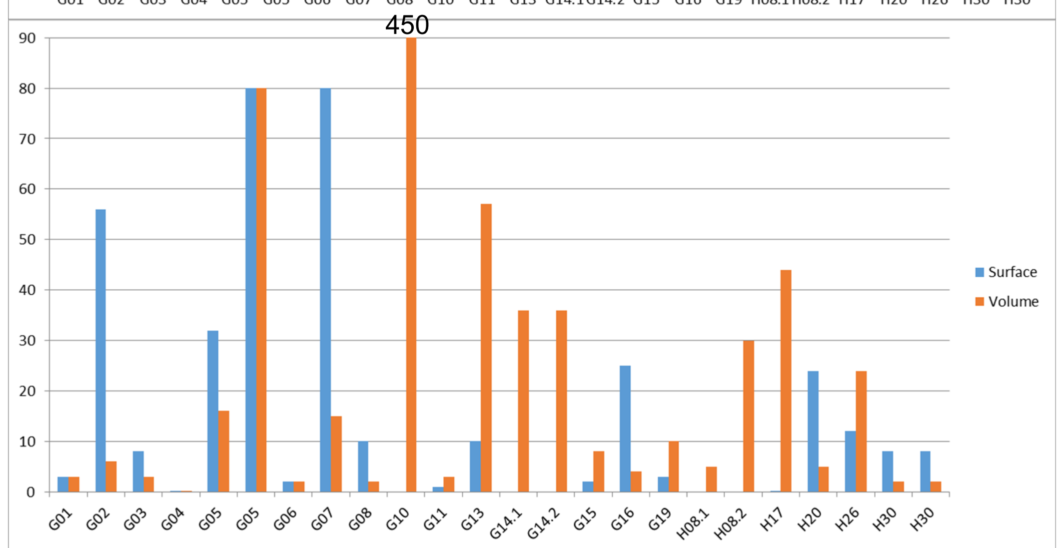
# Responses: Initial Meshing (1/6)

## Timescales

- Time required to generate initial surface mesh: (hr)



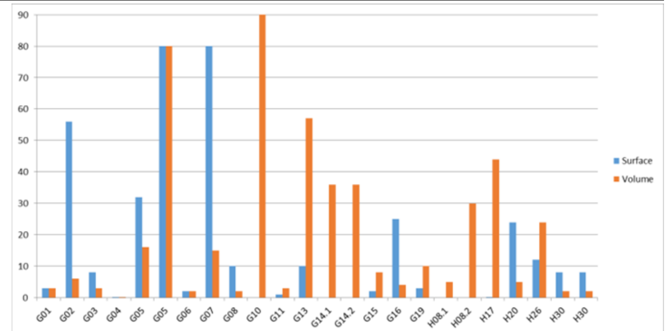

- cf time required to generate initial volume mesh: (hr)




NB: In view of the diversity of approaches adopted by Participants, providing a succinct summary of the responses is difficult

# Responses: Initial Meshing (2/6)

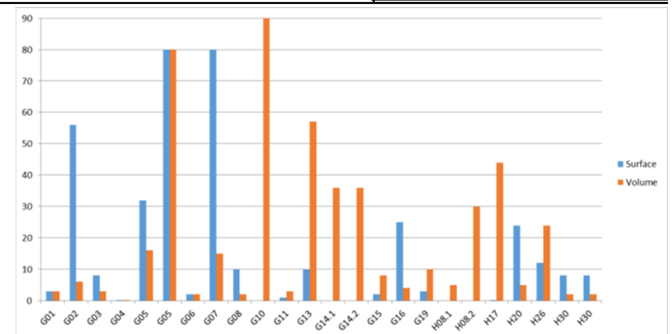





## Surface Meshing

- Simplified surface meshing groupings (based on elapsed time):
  - “Quick” (<1hr or N/A)
    - N/A: Meshing tools that project volume mesh onto the surface
    - Processes incorporating extensive automation
  - <= ~1 day
    - Processes that require a reasonable amount of user input and/or iteration (e.g. sources/target resolutions applied at edges or other geometric features) and incorporate varying degrees of automation (e.g. curvature-based) to achieve an acceptable mesh
  - Longer (->2mwks)
    - (Remaining) Structured meshes and “slower” 1-day-ers
      (Others are thought to be associated with data interpretation)

# Responses: Initial Meshing (3/6)




## Volume Meshing

- Simplified volume meshing groupings (based on elapsed time):
  - “Quick” (<1/2day)
    - Processes incorporating extensive automation (or are reliant on extant information - like Octree-based approaches)
  - <= 2-3 days
    - Processes that require a reasonable amount of user input and/or iteration (e.g. first layer height & growth rate(s)) and incorporate varying degrees of automation (e.g. wake refinement) to achieve an acceptable mesh
  - Longer (>1wk)
    - Structured meshes

# Responses: Initial Meshing (4/6)



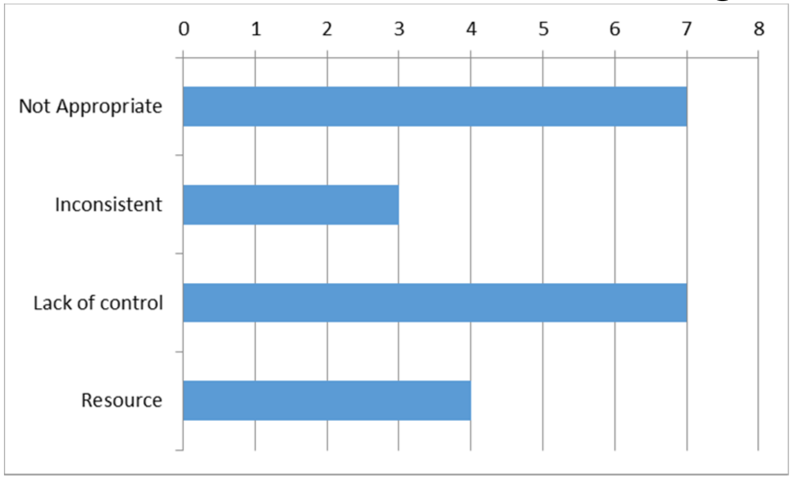
## Completion Criteria

- A wide range of approaches was adopted to assess initial suitability of the meshes, including:
- Surface mesh:
  - General checks, e.g.: No invalid elements; User judgement: Geometry (& “anticipated flow features”) captured/resolved; (Most) Meshing Guidelines respected; cf Baseline meshes(!)
  - Automated checks: embedded in process; User-intervention prohibited
  - Other Metrics / Best Practice: details largely unspecified – see subsequent slide
- Volume mesh:
  - General checks, e.g.: No invalid elements (volume mesher runs successfully; cell Jacobians); User judgement: Features well resolved; General compliance with Meshing Guidelines
  - Automated checks: embedded in process (may require running solver-specific pre-processor); User-intervention prohibited
  - Other Metrics / Best Practice: details largely unspecified – see subsequent slide
  - Run flow solver for verification / problem identification
- NB Dependence of volume mesh on surface mesh noted (sufficient for one Participant)

# Responses: Initial Meshing (5/6)

## Meshing Guidelines

- Many Participants reported achieving - usually after iteration - “a close match” or “a good balance between adhering to the guidelines and creating a good quality mesh”
- Reported challenges / reasons for non adherence were diverse, e.g.:
  - Inconsistent with local best practice (e.g. for “O” mesh @ TE)
  - Variance in practice wrt near surface boundary layer mesh
  - Resolving and/or alignment of mesh in wake regions
  - Controlling progressions in size




- One Participant reported projecting the IB Flap-end curves onto the Fuselage and using these to prescribe local mesh control

  -> avoid problems with disparities in mesh sizing on the Fuselage and Flap

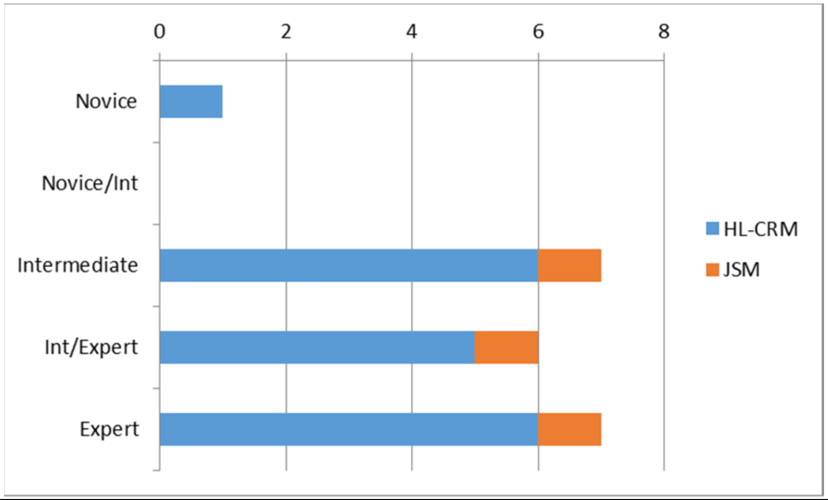
# Responses: Initial Meshing (6/6)



**A Priori Metrics**

- Responses to questions pertaining to a priori metrics were, again, diverse
- Some Participants followed local guidelines; where use of specific metrics was cited, those Participants referred to included:
  - Surface mesh: Area (+ve), Area ratio, Aspect ratio, Max. included angle, Skew
  - Volume mesh: B/L cell aspect ratio; Max. included angle; Max stretching ratio; Volume, Volume ratio

**Expertise Required:**



# Responses: Generating Mesh Families

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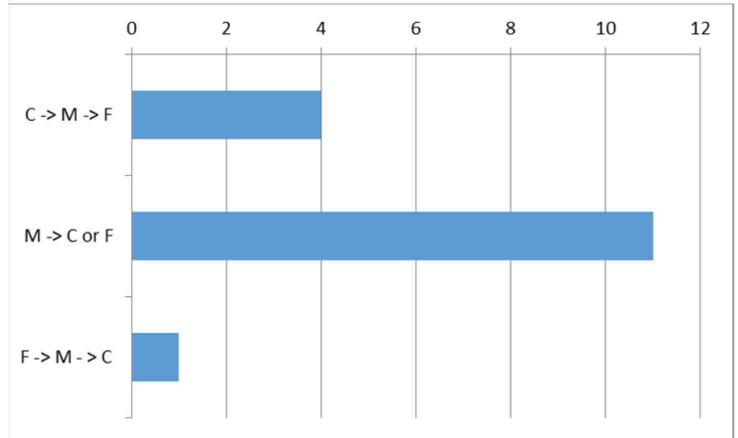



- Different strategies were adopted towards generating the mesh families:
- Most time consuming / tricky aspects included:
  - Estimating no of cells; optimising cell count
  - Scripting or manually re-specifying mesh control inputs for each level
  - Overset : Maintaining an optimum number of overlapping points in adjacent meshes
- Timings
  - CPU increased with mesh size;
  - Labour required for subsequent meshes was generally (25-50%) less than that required for the initial mesh
- Problems Encountered At Specific Levels
  - Coarse: Resolution / retention of geometrical features, especially in regions of high local curvature
  - Fine: Generation of cells with negative volumes
  - Extra-Fine: Resulting mesh was too large (200*10^6 points) –> I/O failure

# Responses: Post Solution Modifications

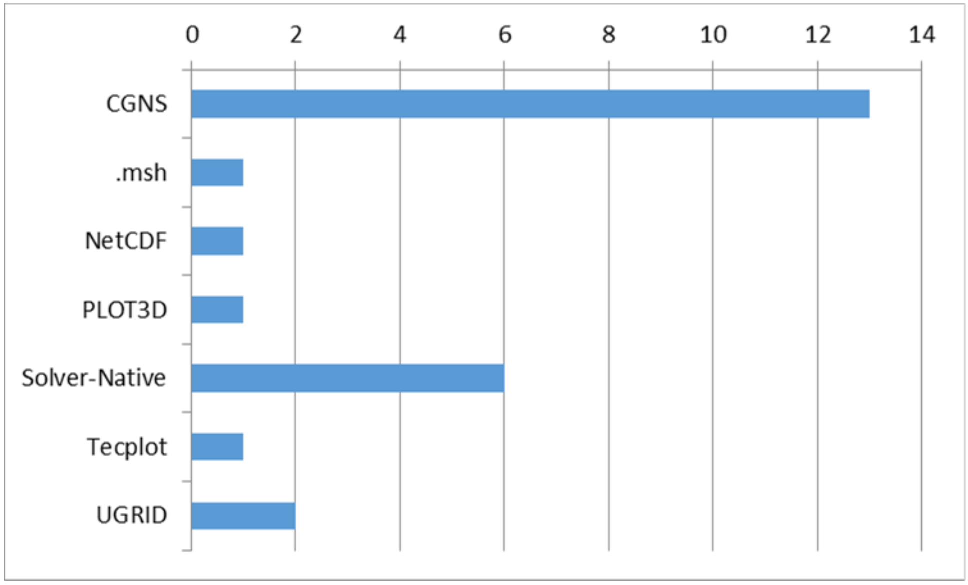


- Not all Participants undertook post-solution modifications
- Those reported included:
  - Structured meshes:
    - Modification of wake-sheet location and wake surface meshes [Multi-block]
    - Close proximity of hole boundary in far-field box mesh to OML discovered – and fixed [Overset]
  - High-order meshes:
    - Flow solver run to identify “hot-spots” in the solution; these were used to guide local mesh refinements
  - Adapted meshes:
    - Mesh adapted automatically (using Mach Hessian)
    - After 8$^{th}$ refinement, gap between trim curves on flap end > local mesh size
      - Repaired using “hybrid mesh/geometry” technique
        -> Only requirement for >Novice expertise
      - Adaptation process re-started two levels earlier
        (Cost: 30min Labour; 6Hrs CPU)

# Responses: I/O



- Meshes were uploaded in the following formats:




- The following problems were noted in transferring meshes between tools and Workshop Participants:
  - CGNS: no single format-variant seemed to work with all tools
  - UGRID: boundary condition information could be lost (if downstream process loaded it via a separate text file)

# Responses: Miscellaneous



Responses to:

"Are there any other aspects of your HL-CRM mesh generation experience that you would like to draw our attention to?"
NB (Only) 3 respondents

- Geometry Model:
    - A viewable on-line image of the geometry model would have been useful
    - Surfaces at the wing/body fairing were defined with a very large number of knots ... ->  resulted in excessive grid resolution
- Meshing Guidelines:
    - The specifications for coarse, medium fine, etc meshes are good, but some additional information could be useful e.g. indicative overall cell counts (surface and volume)
    - (…)
- Uploading Meshes:
    - The information provided on "how to" upload meshes is vague and could include some more detail

# Closing Remarks



- The submitted PQs include a wealth of information
  - Once again: Many Thanks to all of you who completed one!
- A diverse range of approaches was adopted by the Participants
- End-to-end (Receive Geometry -> Supply Mesh) process typically required:
  - Between a day or two and a couple of weeks
  - At least an Intermediate level of Expertise (at some stage)
- Analysis of the data continues – next report at SciTech
- When analysis is complete, it is intended that these data will be used as a benchmark by which to measure progress towards realising the 2030 Vision

# Thank you for your attention