Improvements to GlennICE Collection Efficiency Algorithm

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Outline

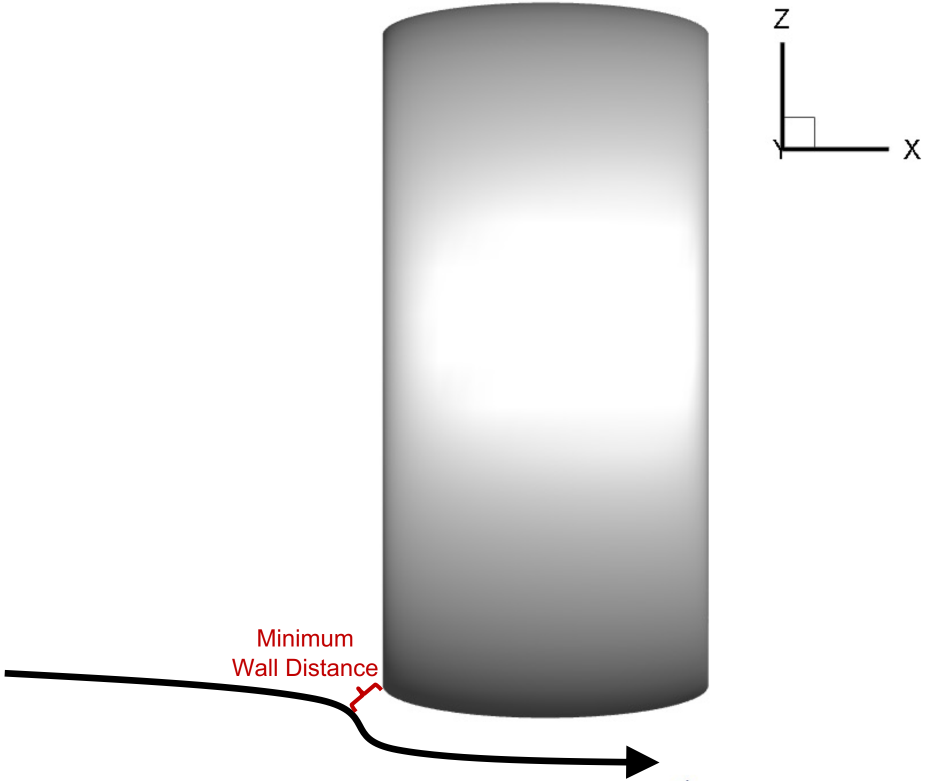
- Review of GlennICE collection efficiency process
- Refinement criteria
  - Version 3.2 (6/23)
  - Version 4.0 (10/23)
  - Bounded_faces (6/24)
- Results
  - Multi-wire
  - CRM-HL
- Conclusions

GlennICE Refinement Process

- GlennICE starts with an upstream grid of release points
- Each iteration, refinement occurs based on which points come closest to the surface
  - A particle that hits has a zero distance
- Refinement stops due to user-specified inputs
  - MAX_FACE_COUNT (600)
  - FRACTION_CONTAINED_TOL (0.5)
  - TURN_OFF_BOUNDED_FACES (.TRUE.)
  - USE_NONUNIFORM_TOLERANCE (.TRUE.)
  - PCT_CONVERGED_LIMIT (90%)

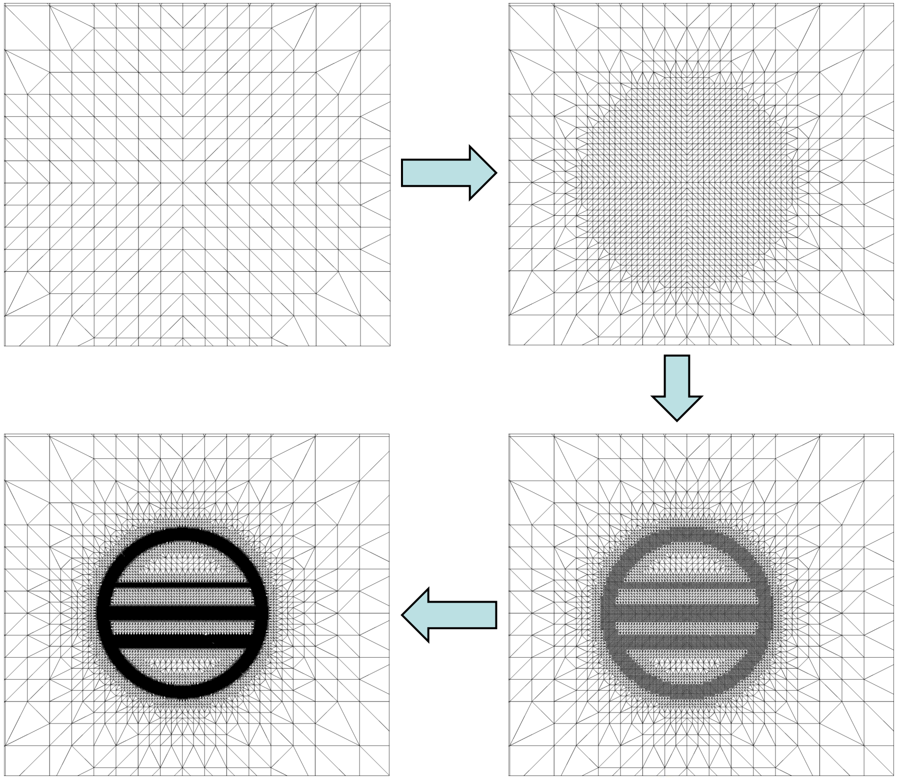
Minimum Wall Distance

- The minimum wall distance is the closest a trajectory comes to a surface of interest. This wall distance is now computed within GlennICE.



Adaptive Refinement Problem

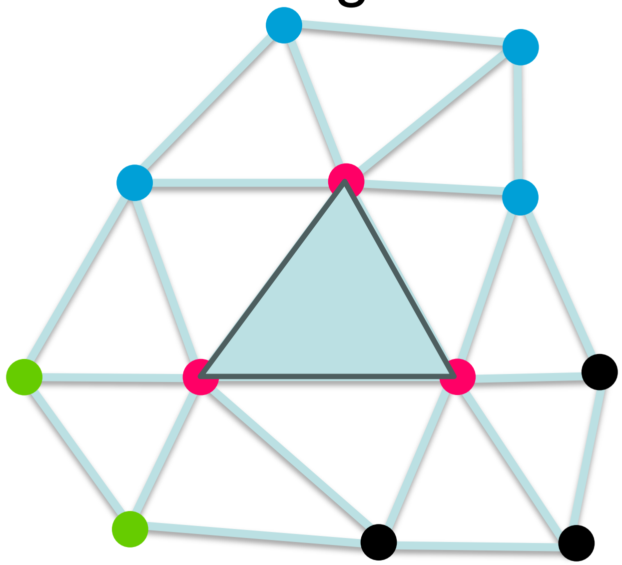
- Grid intersections are release points of trajectories going into the screen.
- The minimum wall distance of each trajectory can be stored at the seed point that led to that trajectory.
- The seed points are co-planar, and therefore the computational problem being solved is now two-dimensional.
- The problem is a minimum search on a discretized two-dimensional data set.
- The sink behavior of the problem is leveraged in the minimum search.



Fraction Contained

- Each hit trajectory transfers its mass to the CFD face it hits
- A hit is contained when the surrounding area is inside the CFD face

Refinement on a CFD is considered **converged** when contained_area/release_areas is > FRACTION_CONTAINED_TOL (0.5)



Dots show release points

Fraction Bounded

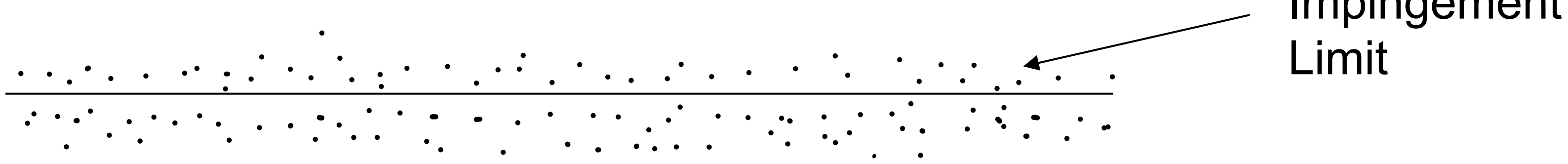
- When the three points of a release triangle all hit the same CFD face, that triangle is **bounded**.
- When TURN_OFF_BOUNDED_FACES = .TRUE., refinement of these triangles is stopped
  - This was previously found not to affect accuracy.
    - Porter AIAA 2022-3692

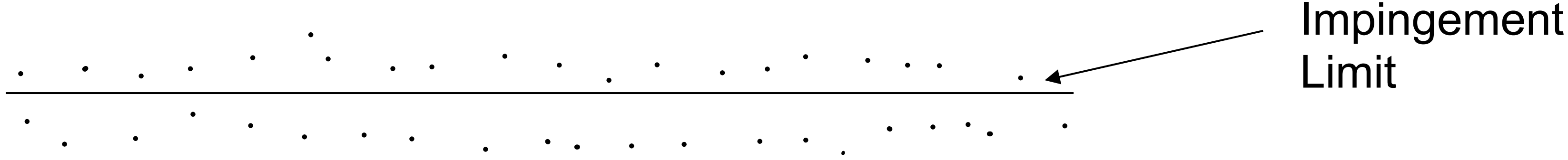
Non-Uniform Tolerance

- In regions of low mass flow, the listed tolerances (FRACTION_CONTAINED_TOL, and MASS_FLOW_TOL) are relaxed to limit the number of trajectories at the impingement limits when USE_NONUNIFORM_TOLERANCE = .TRUE.
- ratio = mass_flow(face)/max_mass_flow
- Local_tol= FRACTION_CONTAINED_TOL * $(1-(1-\text{ratio})^6)$

Improvements for GlennICE 4.0

- Use nonuniform tolerance to limit trajectories released near impingement limits
  - Previously, nonuniform tolerance only reduced the convergence tolerance

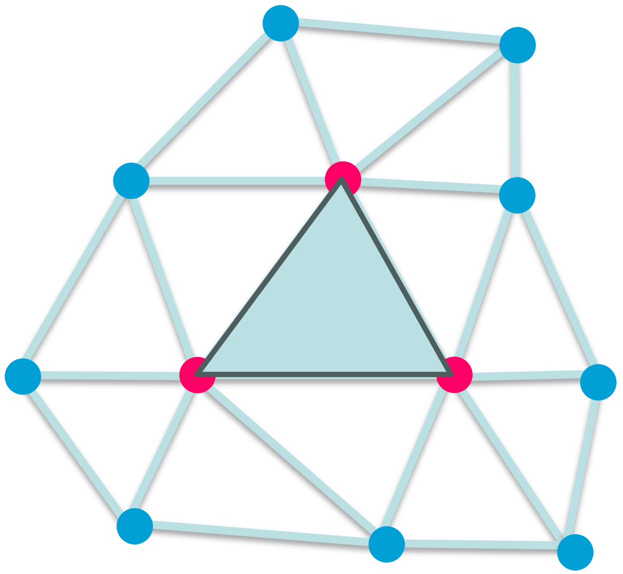




Improvements for GlennICE 4.0

➢ Strictly enforce MAX_FACE_COUNT criteria

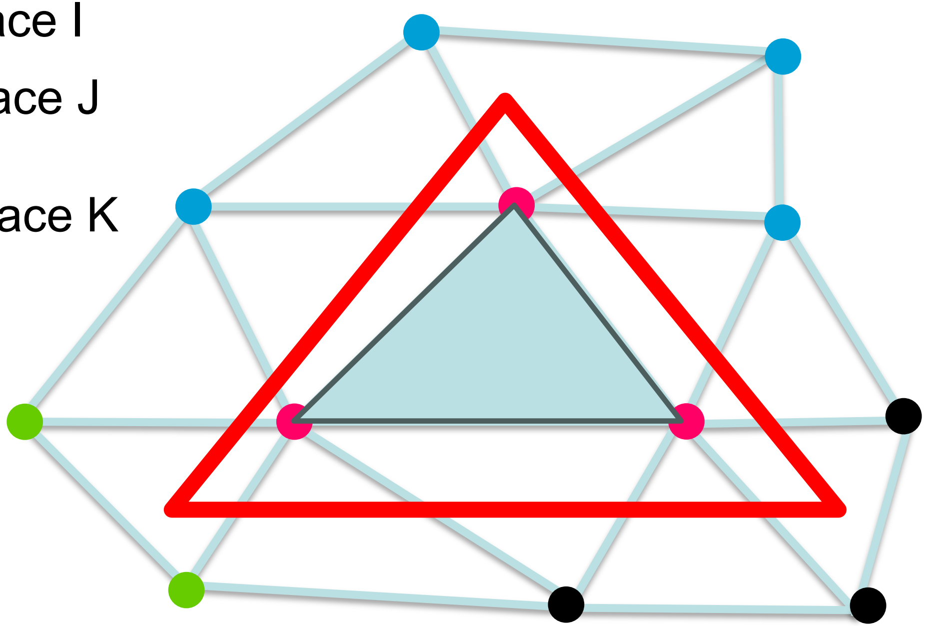
- Previously, all edges were refined (24 extra trajectories)
- With GlennICE 4.0, only 3 are added



- Hits CFD face where MAX_FACE_COUNT was not met
- Hits CFD face where MAX_FACE_COUNT was met

Improvements for Branch Bounded_Faces: Fraction Bounded Convergence Criteria

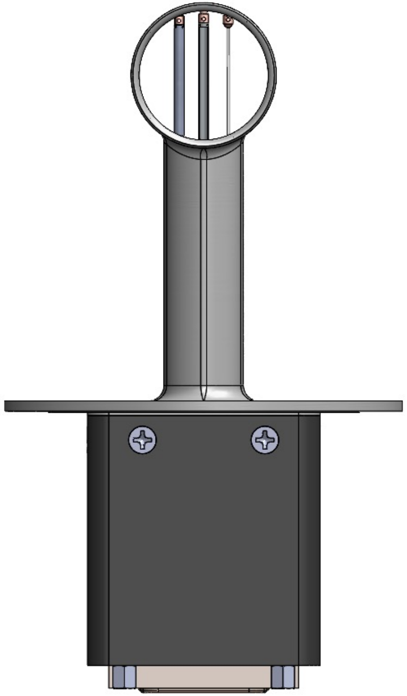
- Hit CFD face I
- Hit CFD face J
- Hit CFD face K
- Miss

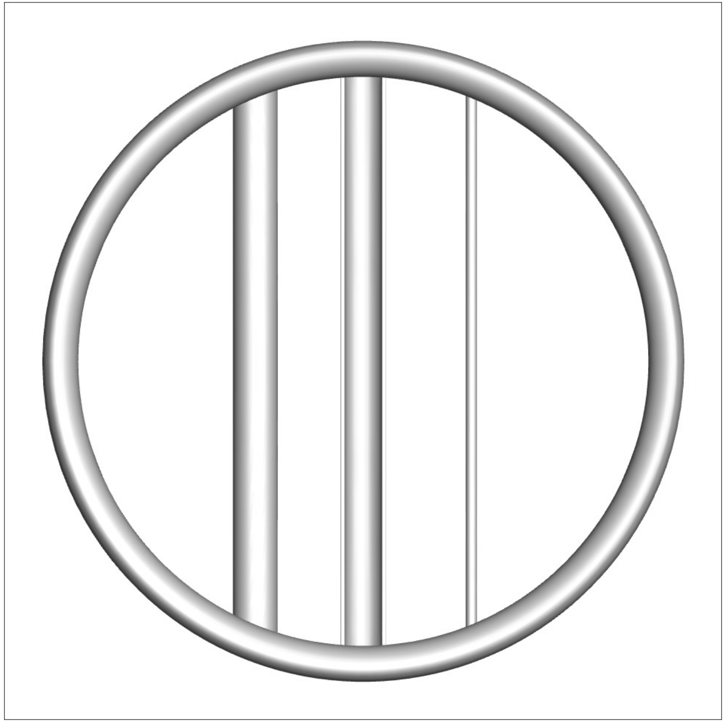


Fraction bounded (CFD face I) =
Area from shaded triangle /
Area of CFD face

Dots show hit points

Multiwire Geometry

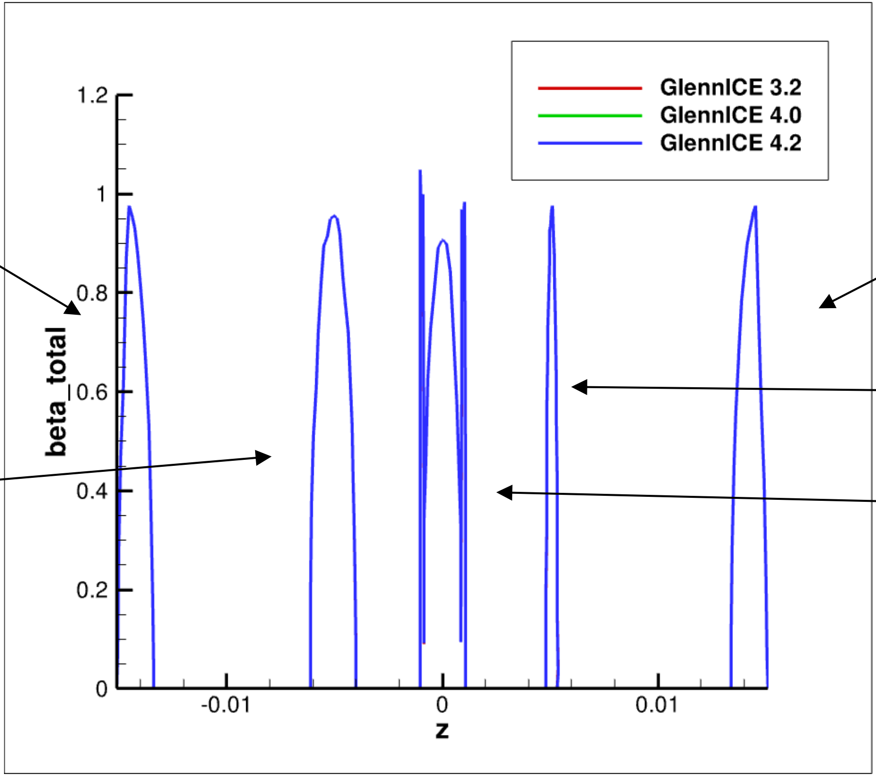




Multiwire Results – Three GlennICE Versions (21 μm)

Outer Cowling

0.083” convex half-pipe



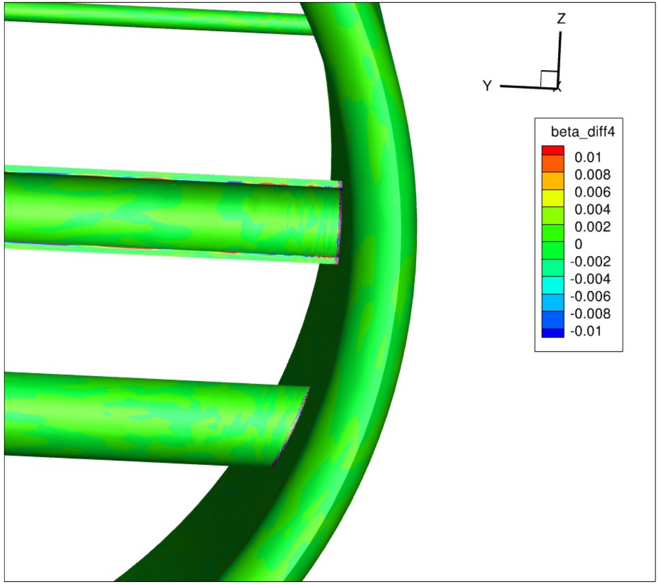
Outer Cowling

0.021” wire

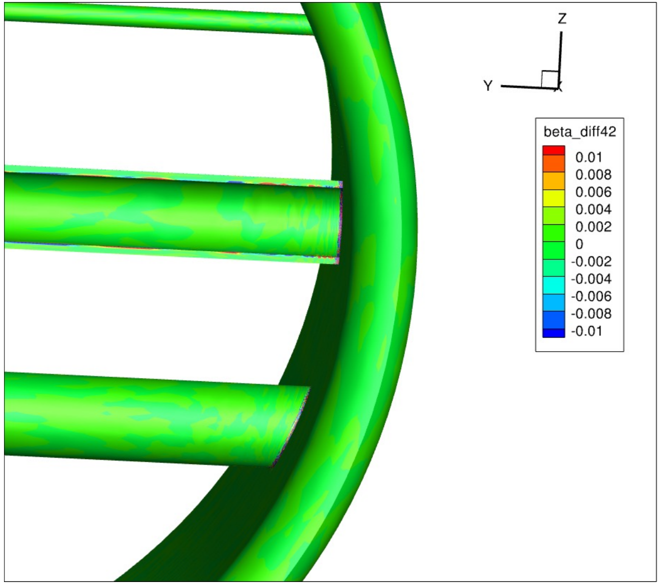
0.083” concave half-pipe

Collection Efficiency Differences (21 μm)

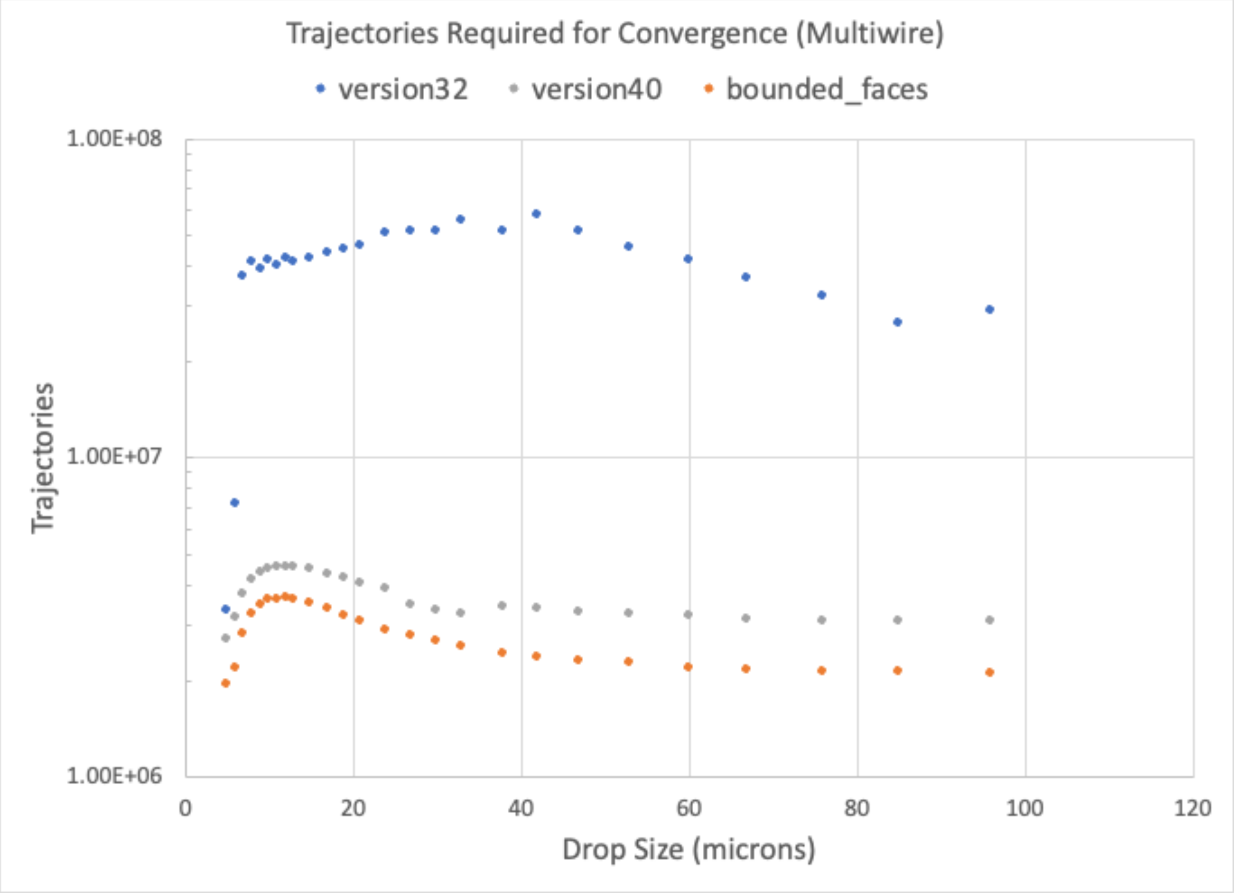
Difference in Collection Efficiency Version 4 vs Version 3.2



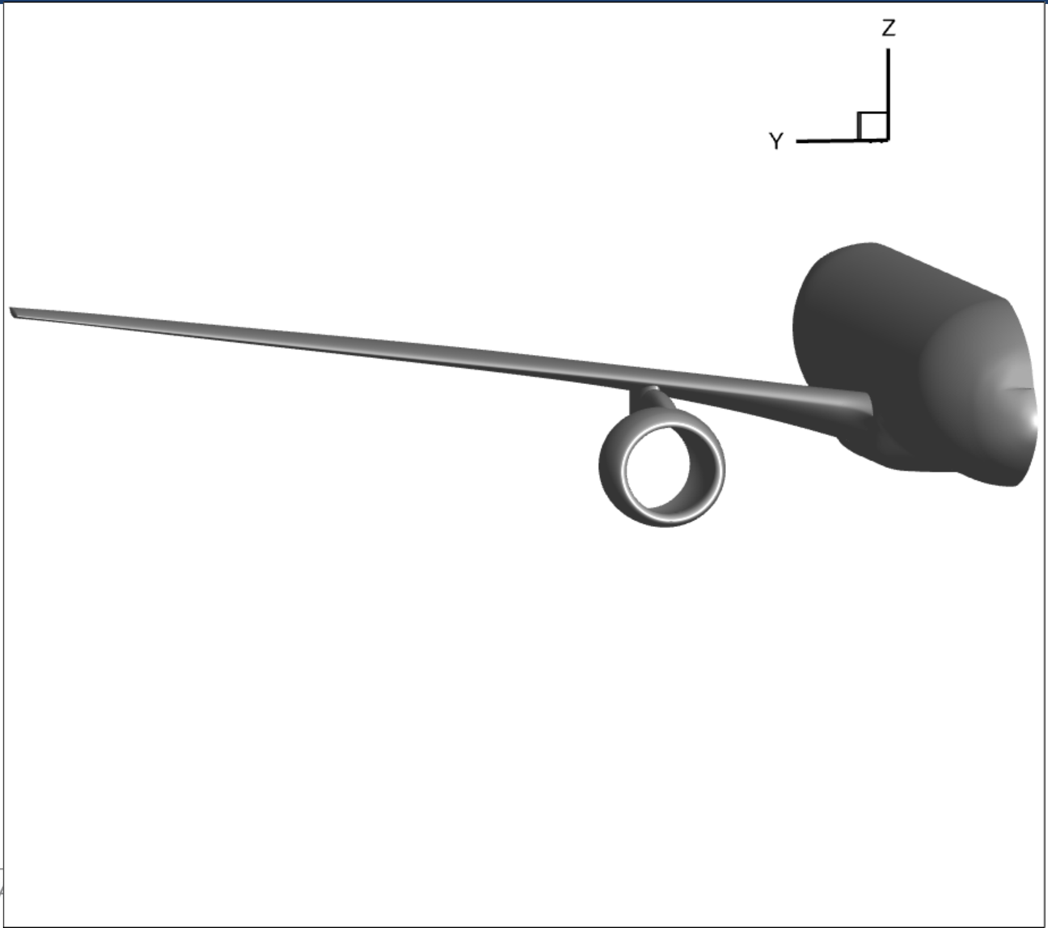
Difference in Collection Efficiency Bounded_faces vs Version 3.2



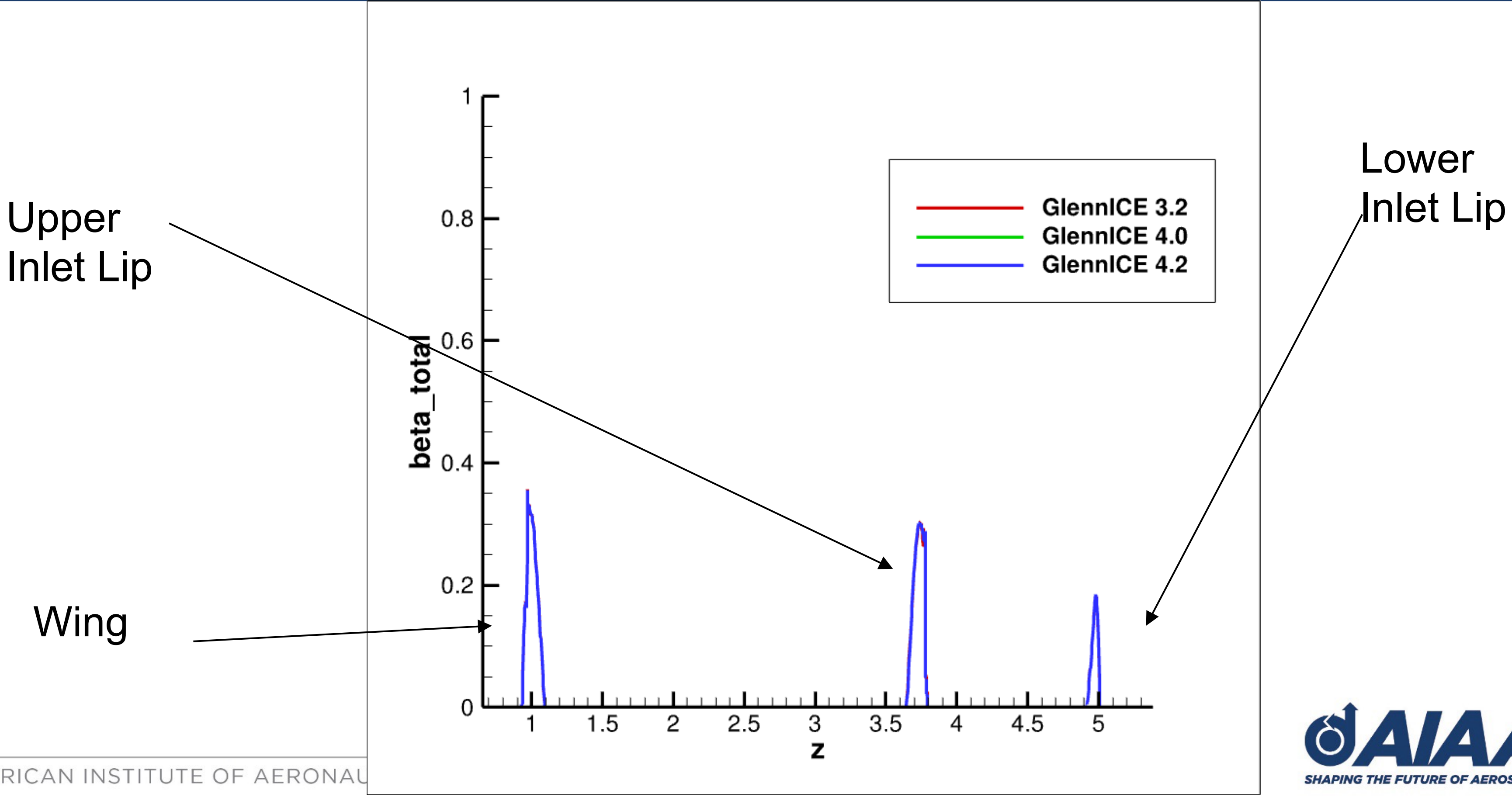
Efficiency Improvements – Multiwire Case



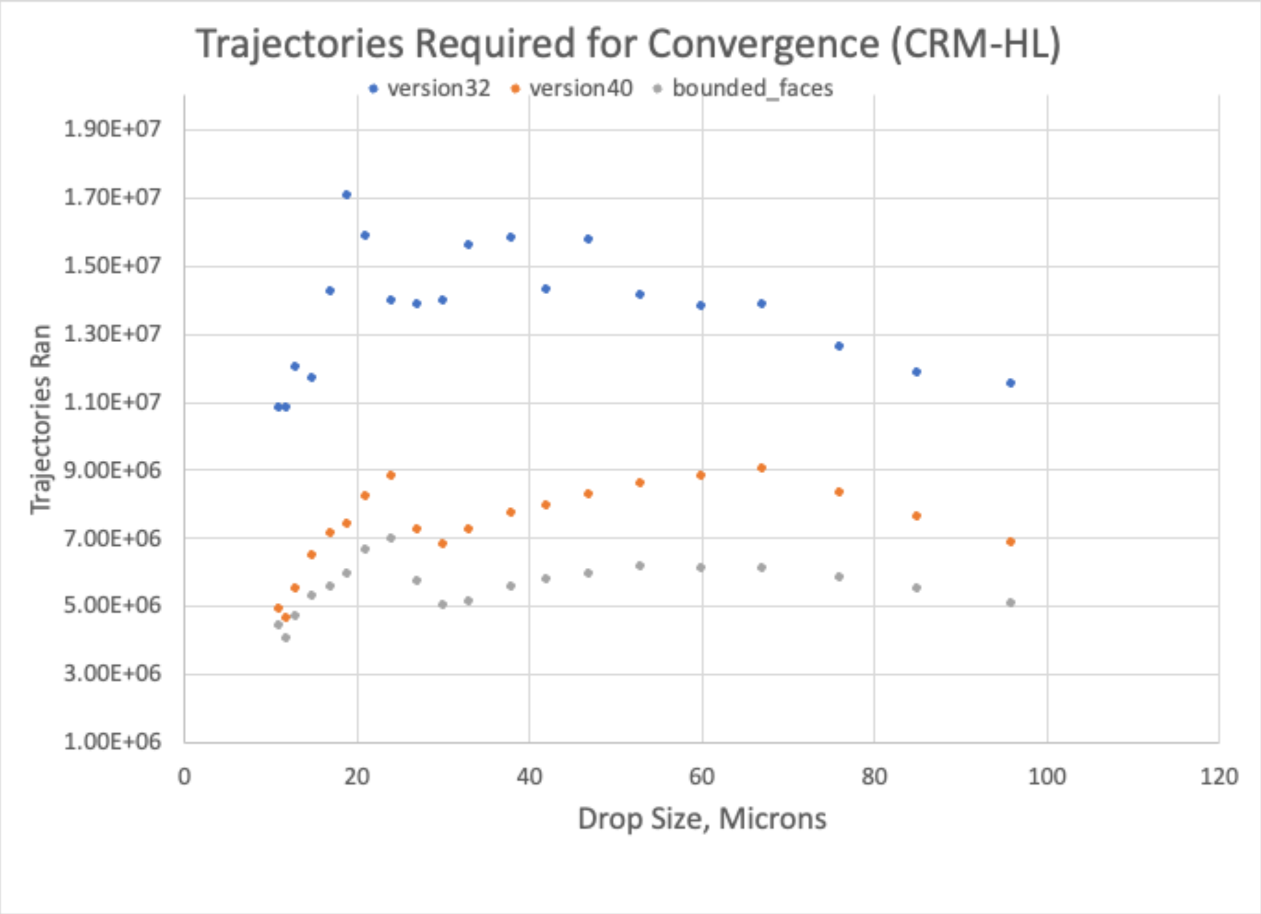
CRM-HL Geometry



CRM-HL Results (21 μm)



Efficiency Improvements – CRM-HL Case



SHAPING THE FUTURE OF AEROSPACE

Conclusions

- Changes were made to collection efficiency convergence metrics that had minimal impact on accuracy
- For multiwire geometry:
  - GlennICE 4.0 was 11x faster than GlennICE 3.2
  - Branch bounded_faces was 15x faster than GlennICE 3.2
    - GlennICE 4.2 30% faster than GlennICE 4.0
- For CRM-HL geometry:
  - GlennICE 4.0 was 2x faster than GlennICE 3.2
  - Branch bounded_faces was 2.5x faster than GlennICE 3.2
    - 30% faster than GlennICE 4.0

Acknowledgements

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