CRM65 Midspan Hybrid Ice Mass vs Time

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If the data is to be referenced, cite with:

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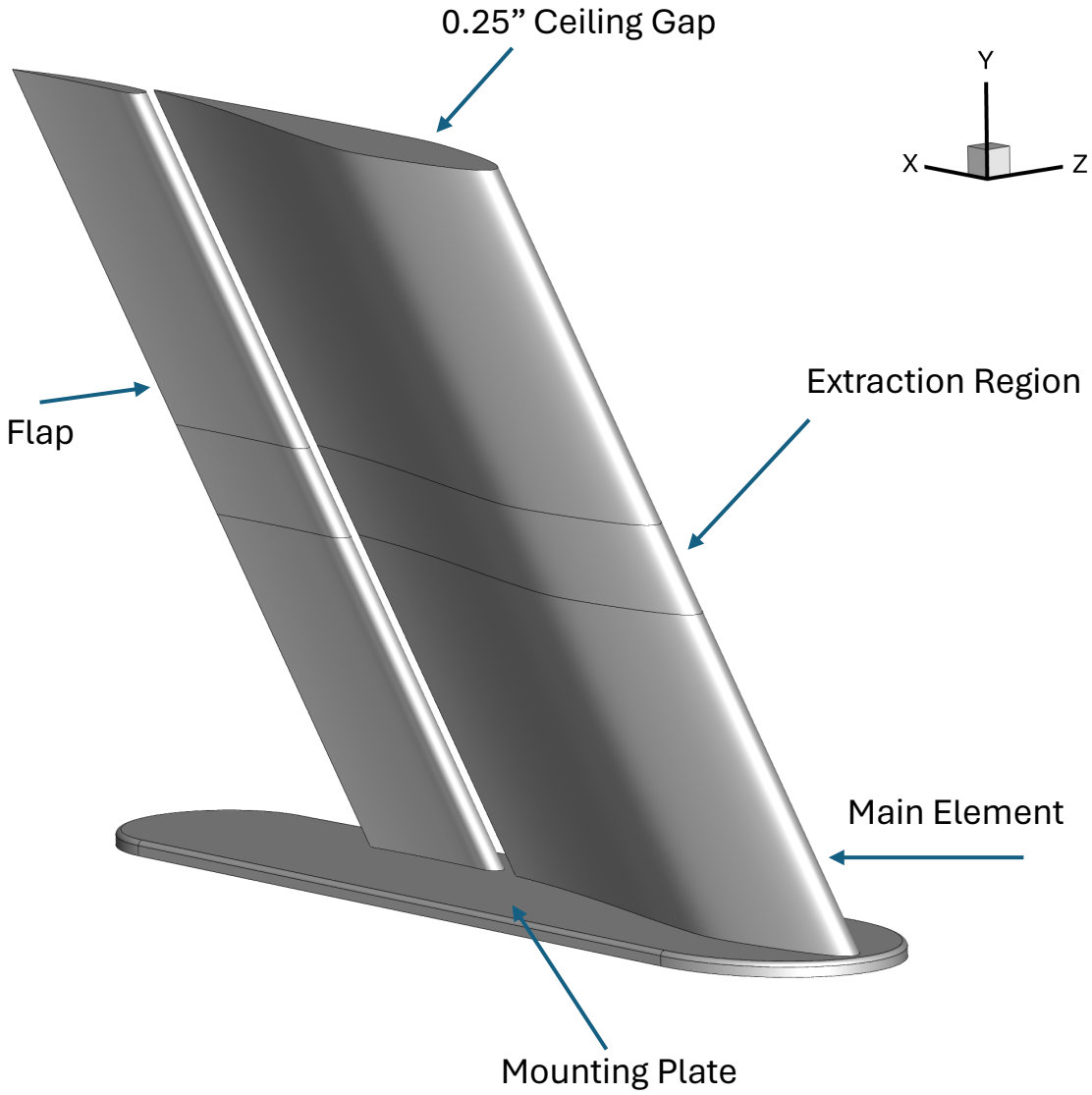
Geometry Definition

- Main element is set on a simplified mounting plate
  - Present experimentally, but has been simplified
  - Mounting plate ranges from Y = 0 inches to Y = 1.5 inches
  - The flap is offset from the mounting plate
- Geometry is extruded from the mounting plate
  - The main element is extruded from Y = 1.5 inches to Y = 71.75 inches
  - The flap is extruded from Y = 2.25 inches to Y = 71.75 inches
  - Contains a 0.25-inch gap between the model and the ceiling
- Both the main element and the flap are at an angle of 0.0-degrees
  - AOA = 0.0-degrees
  - Flap: ∂ = 0.0-degrees
  - Sweep: Λ = 37.15-degrees
- A unique patch exists from Y = 32-inches to Y = 40-inches that represents the ice extraction region
  - This is the portion of the geometry from which the experimental mass data was obtained
  - The mass was extracted from a constant streamwise region, consistent with the patch
  - It is recommended to have any mesh that is generated to be 'aligned' with the boundary for simplified extraction (Ozoroski et al., 2024) [1]
- The test section is recommended to be represented as a rectangular prism ranging from:
  - X ≈ -720 in. (upstream) – X ≈ 720. in (downstream) / This is adjustable based on preference (currently)
  - Y = 0 in. (floor) to Y = 72 in. (ceiling)
  - Z = -54 in. to Z = 54 in.



CFD Case Conditions

- Cp values are given at locations of Y = 18 inches, Y = 36 inches, Y = 54 inches, along with attachment line Cp values at Y = 36 inches
- Total Temperature, T_0 = -6.3˚C
- Static Temperature, T = -8.5˚C
- True Air Speed, Freestream Velocity:
  - U_∞ = 130 knots
  - U_∞ = 66.9 m/s
- Mach Number, M = 0.205
- Density (calculated), ρ = 1.265 kg/m^3
- It is suggested that the conditions match within ≈ 1% of provided
  - Density is excluded from this requirement
- This conditions represent a starting point for analysis
  - Finalized flow conditions will be provided by Ozoroski et al., Aviation 2024

Icing Cloud Conditions

- MVD = 25 µm
  - IRT 7-bin distribution shown in Table 1
  - Equivalent to the IRT MVD = 24.9 µm distribution [2]
- Cloud LWC = 1.0 g/m^3
- Spray times given in Table 2 with associated IRT run IDs given

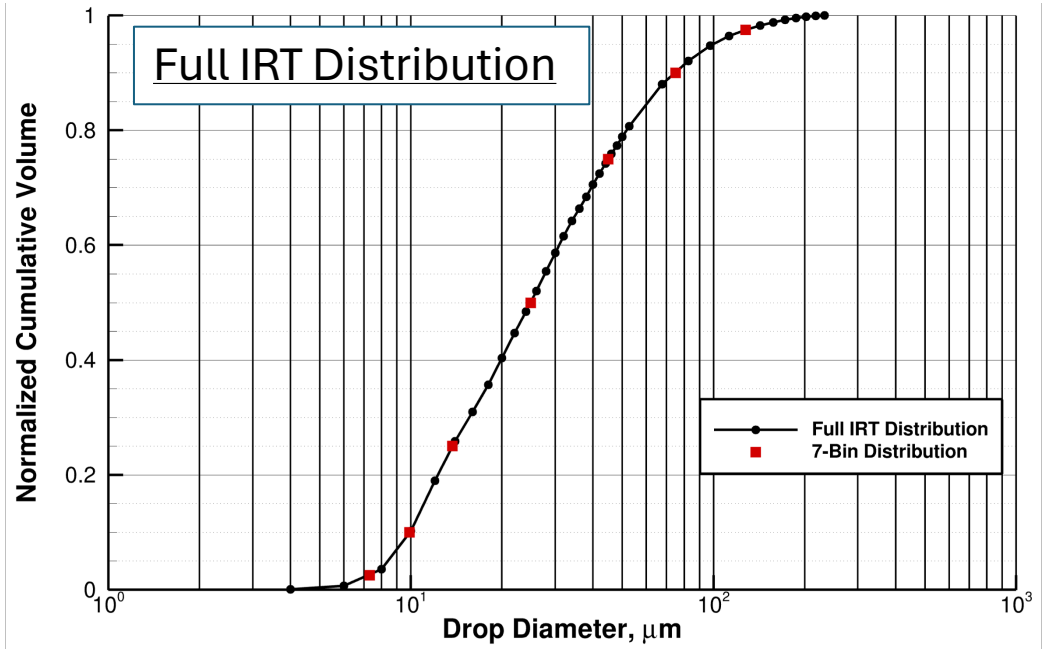


Table 1:

MVD = 25µm IRT 7-Bin Droplet Distribution							
Diameter, µm	7.3	9.9	13.7	24.9	44.9	74.9	127.6
TWC, %	5	10	20	30	20	10	5

Table 2: Spray Times

Minutes	Seconds	IRT Run ID
2.5	150	TH3005
5.0	300	TH2971
7.5	450	TH3004
10.0	600	TH2963
15.0	900	TH2964
20.0	1200	TH2965
25.0	1500	TH2966
29.0	1740	TH2968

Ice Accretion Data Summary

- All data is obtained within the extraction region shown previously
  - Spans from Y = 32 inches – Y = 40 inches
- Ice shape profiles are extracted based upon constant streamwise Y slices of the laser scanned data
- There is no adjustment to the positioning of the geometry or ice shape is needed
  - The CAD provided lines up with the experimental data provided
  - If you move the provided CAD, the data will not line up
- All of the spray times are independent of each other
  - I.e. The airfoil was cleaned after each spray

Nomenclature:

- MaxCCS: Maximum Combined Cross Section
- MeanCCS: Mean Combined Cross Section
- MinCCS: Minimum Combined Cross Section
- Scanned: Obtained via the laser scanning system.
- Bulk Volume: Volume of the ice measured based on ice shape representation
- Bulk Density: Ice Mass / Bulk Volume

Ice Accretion Data Summary Cont.

Table 4. Experimental ice mass versus accretion time.

T_0 = -6.3^{o}C, U = 130 kts, MVD = 25μm, LWC = 1.0 g/m^3, $\alpha = 0^o$

Accretion Time, min	2.5	5.0	7.5	10.0	15.0	20.0	25.0	29.0
Ice Mass, g	70.1	157.3	232.0	277.4	536.1	772.9	972.6	1171.5

Table 5. Experimental bulk volume of ice versus accretion time.

T_0 = -6.3^{o}C, U = 130 kts, MVD = 25μm, LWC = 1.0 g/m^3, $\alpha = 0^o$

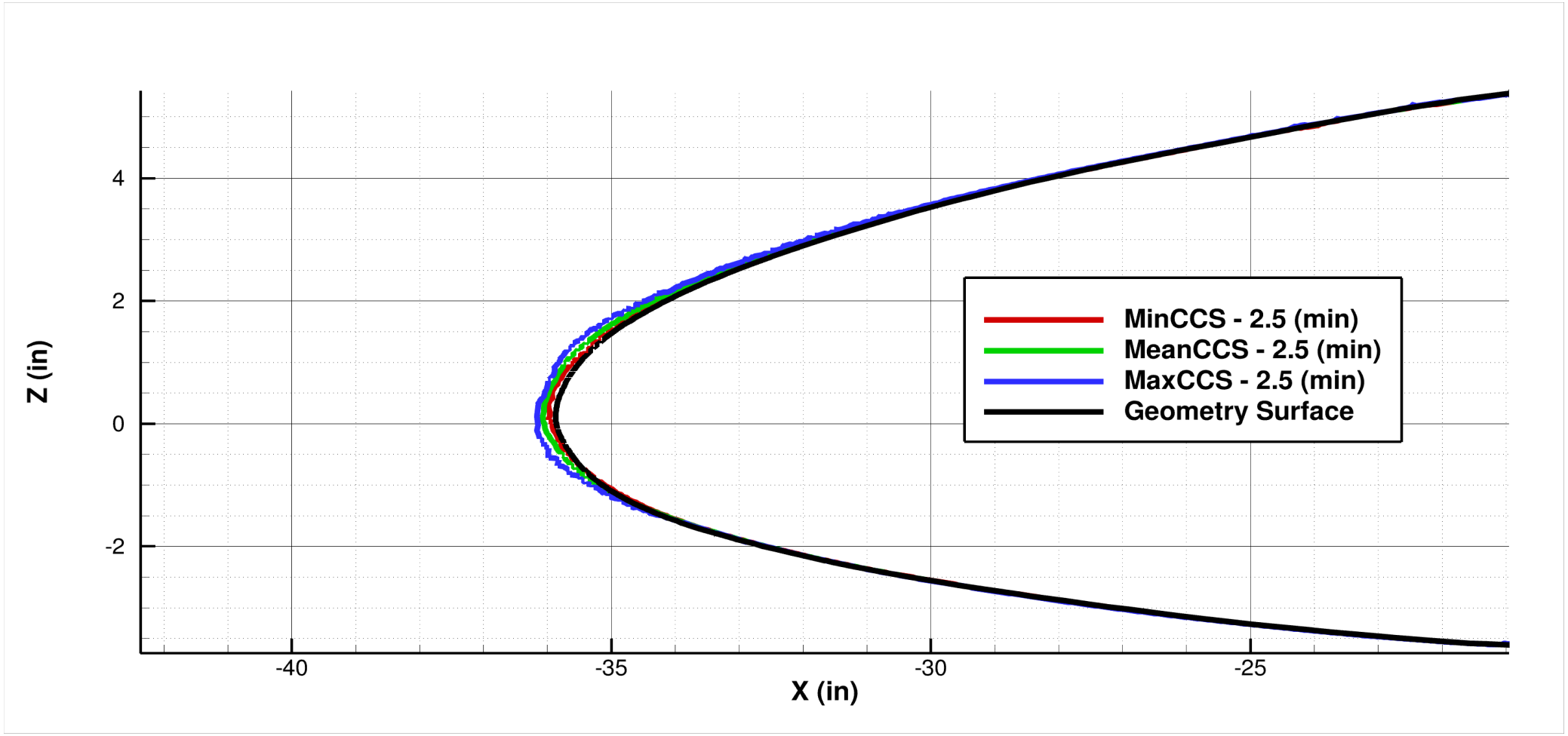
Accretion Time, min	2.5	5.0	7.5	10.0	15.0	20.0	25.0	29.0
Scanned Bulk Volume, in^3	6.4	13.7	24.1	33.6	52.4	75.9	92.0	119.1
MeanCCS Bulk Volume, in^3	8.8	16.0	27.2	36.0	56.0	83.2	100.8	128.8
MaxCCS Bulk Volume, in^3	14.4	29.6	56.0	72.8	117.6	168.0	210.4	248.0

Table 6. Experimental bulk density of ice versus accretion time.

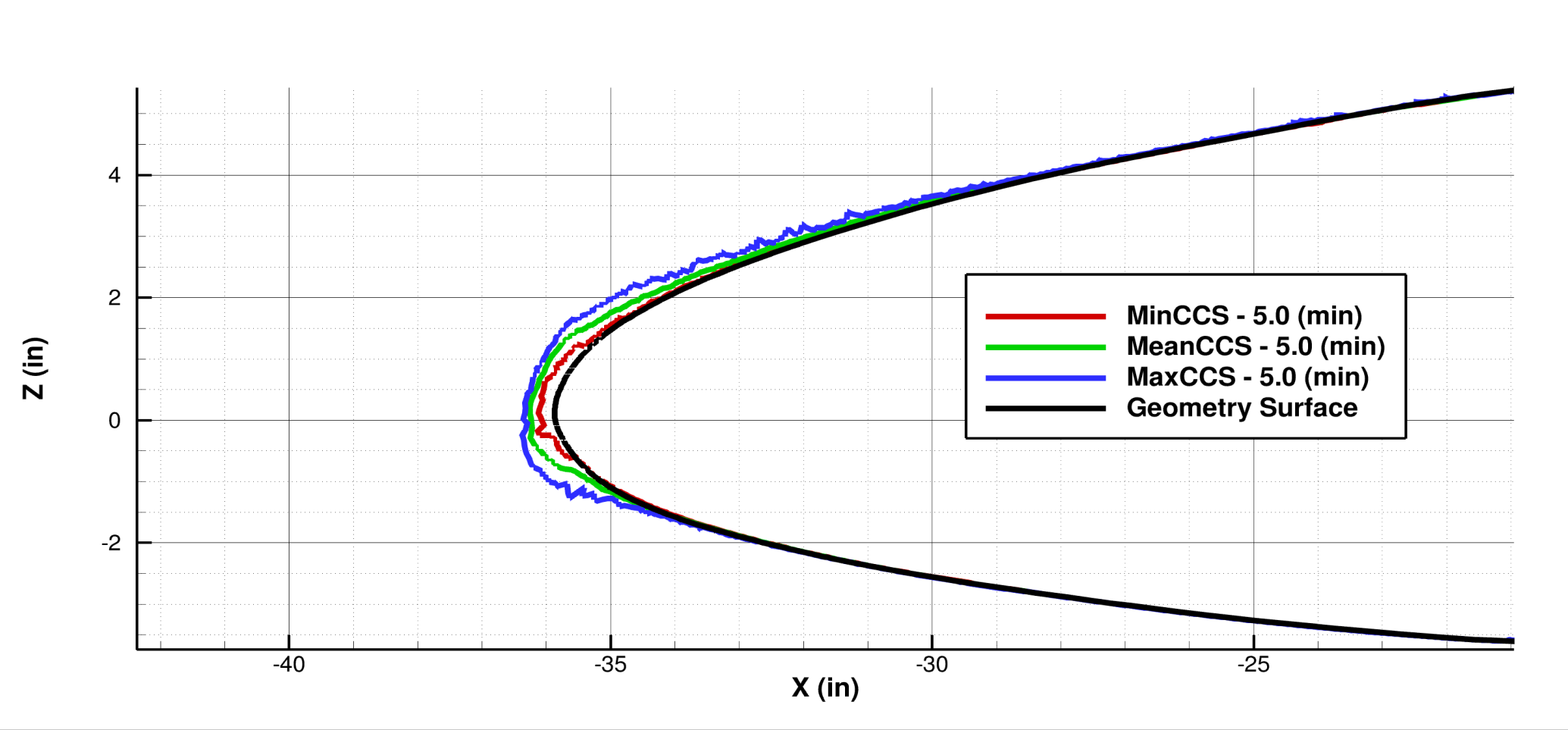
T_0 = -6.3^{o}C, U = 130 kts, MVD = 25μm, LWC = 1.0 g/m^3, $\alpha = 0^o$

Accretion Time, min	2.5	5.0	7.5	10.0	15.0	20.0	25.0	29.0	Mean
Scanned Bulk Density, kg/m^3	668.4	700.7	587.5	503.8	624.3	621.4	645.1	600.24	618.9
MeanCCS Bulk Density, kg/m^3	486.1	599.9	520.5	470.2	584.2	566.9	588.8	555.0	546.5
MaxCCS Bulk Density, kg/m^3	297.1	324.3	252.8	232.5	278.2	280.7	282.1	288.3	279.5

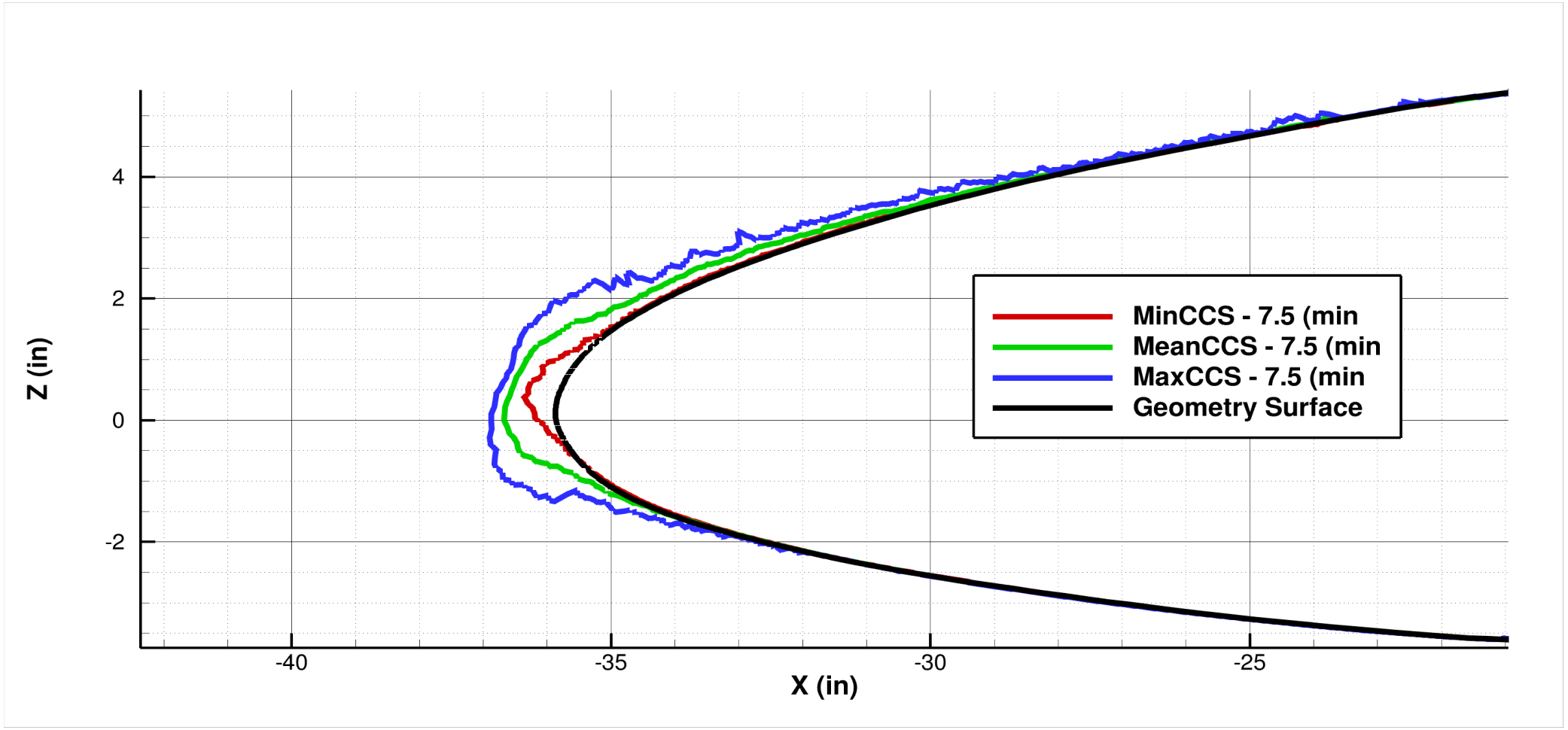
Ice Shape Profiles – Spray Time = 2.5 Minutes



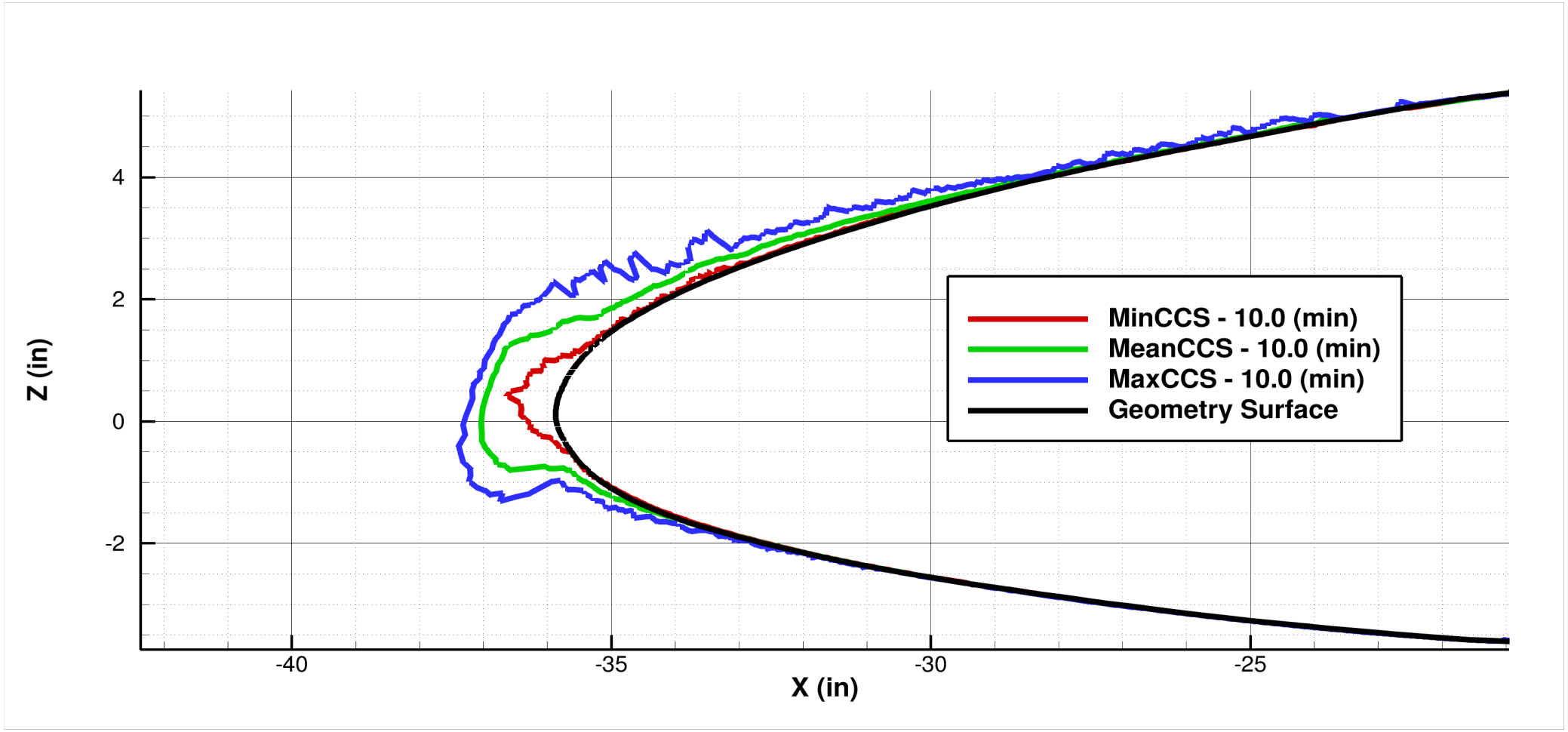
Ice Shape Profiles – Spray Time = 5.0 Minutes



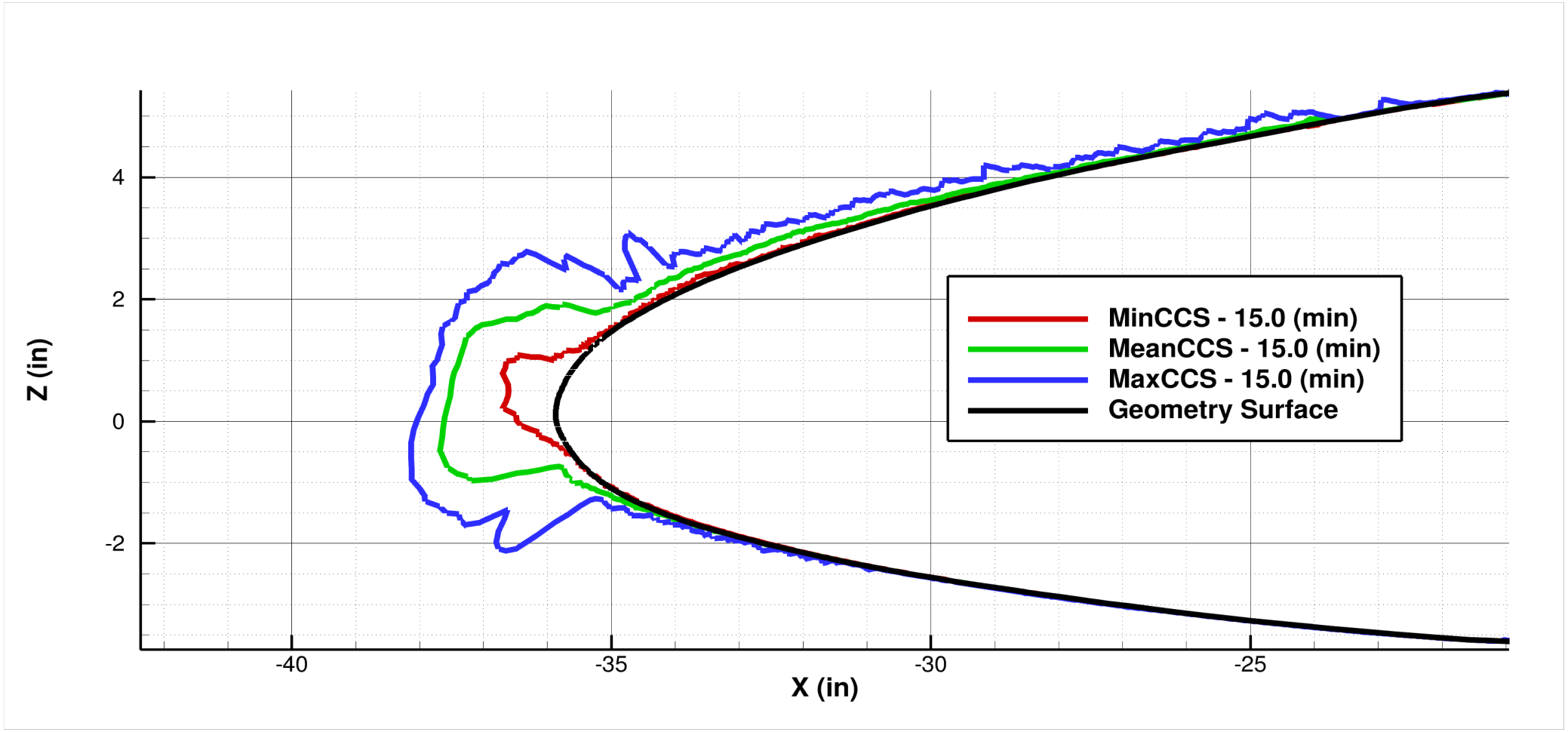
Ice Shape Profiles – Spray Time = 7.5 Minutes



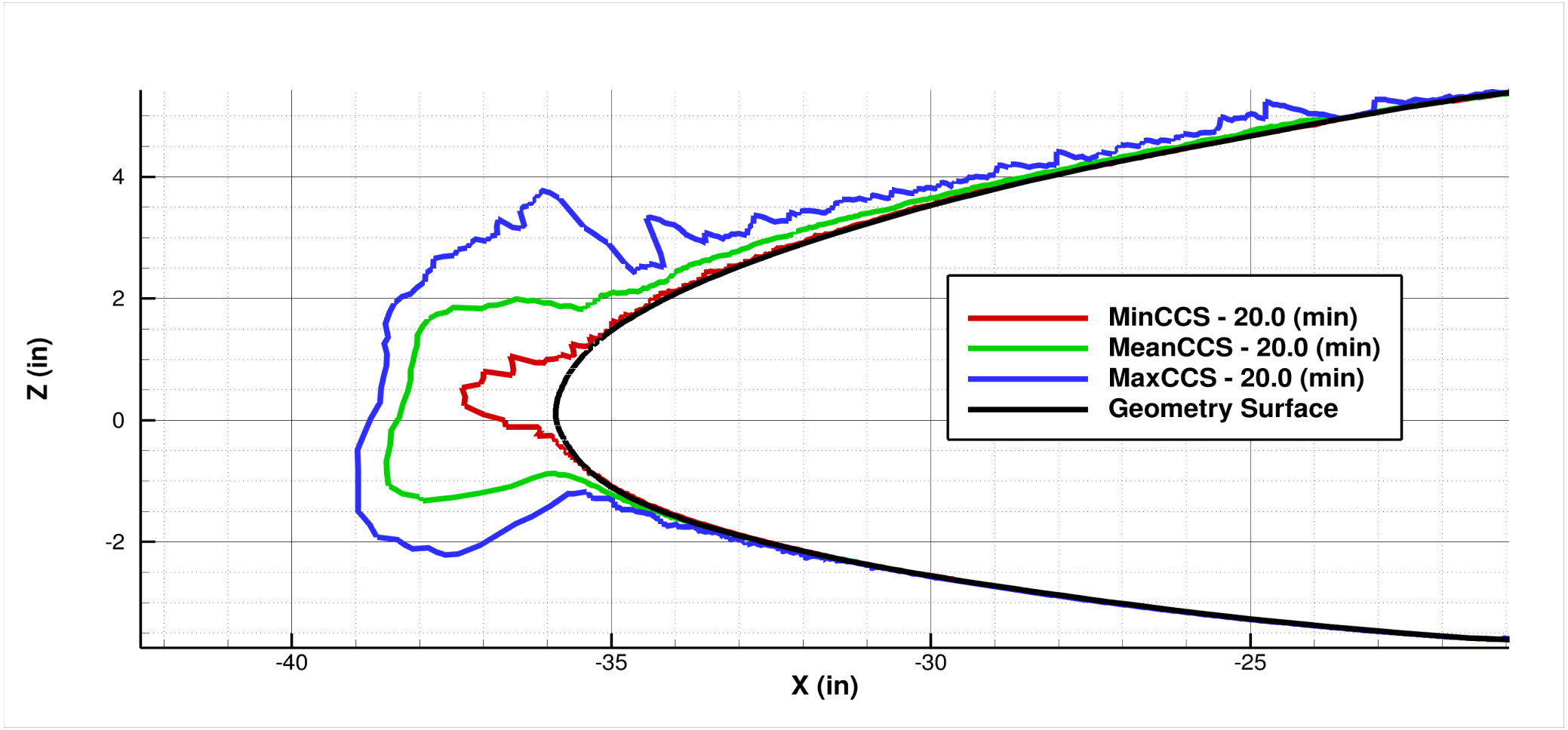
Ice Shape Profiles – Spray Time = 10.0 Minutes



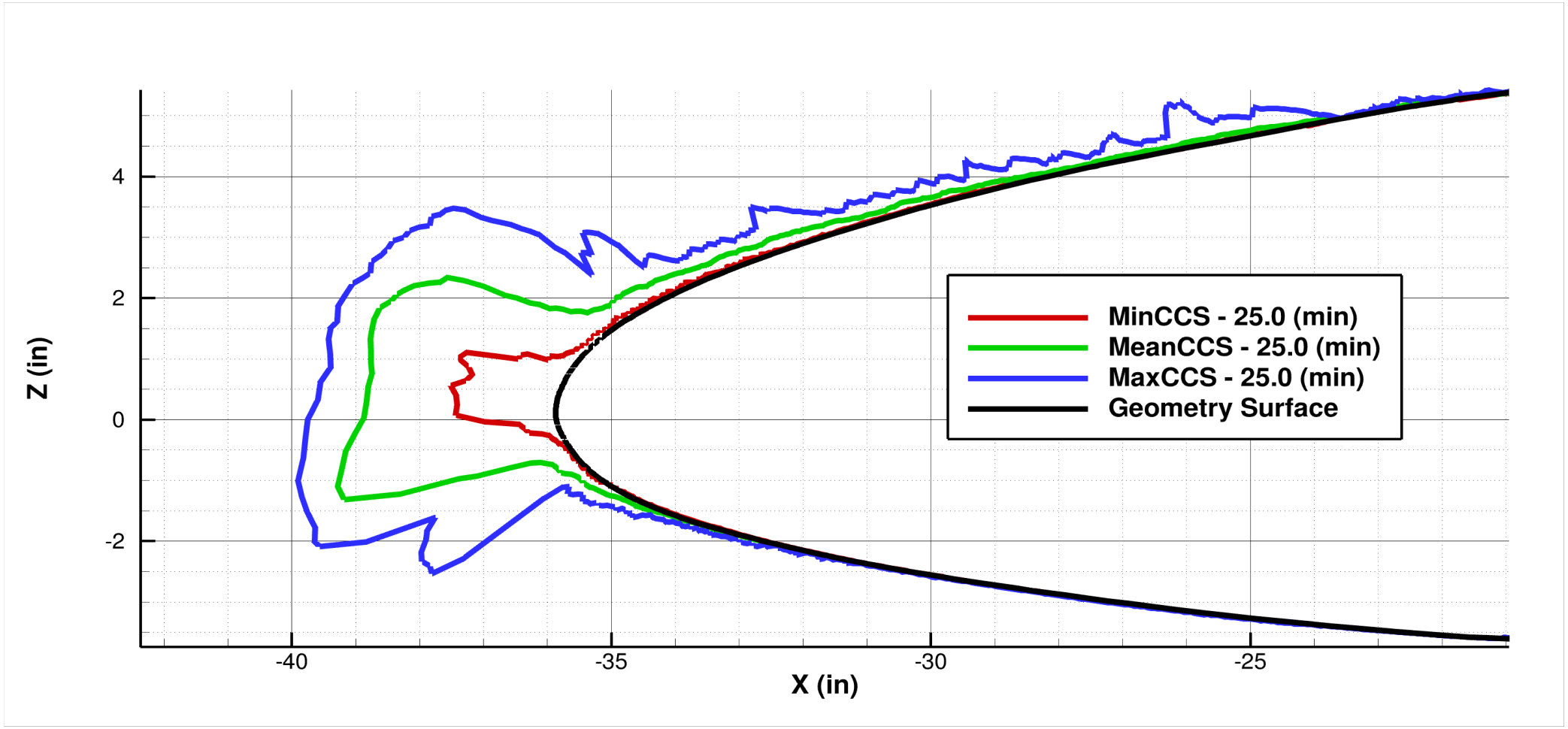
Ice Shape Profiles – Spray Time = 15.0 Minutes



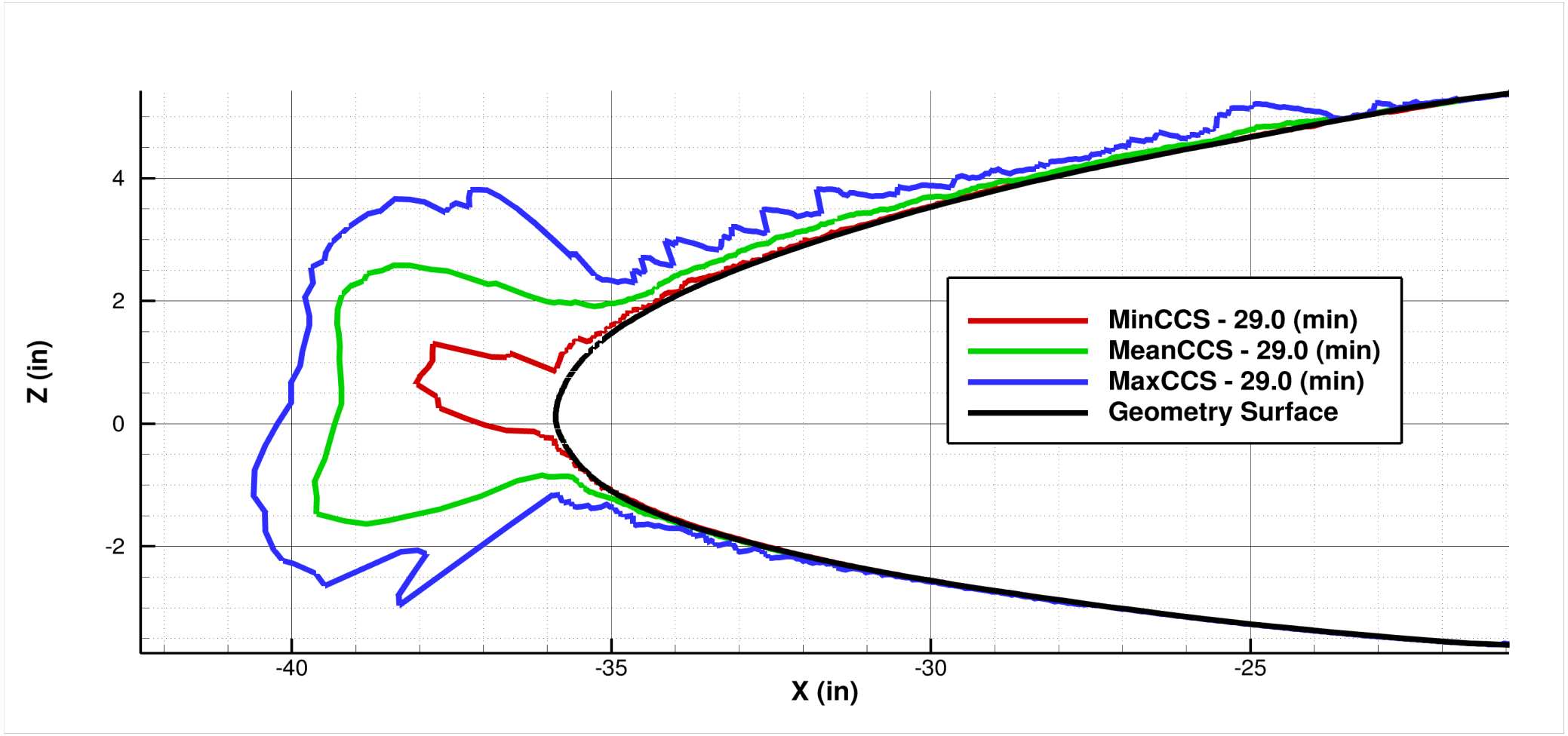
Ice Shape Profiles – Spray Time = 20.0 Minutes



Ice Shape Profiles – Spray Time = 25.0 Minutes



Ice Shape Profiles – Spray Time = 29.0 Minutes



Summary

- Geometry contains a mounting plate, a ceiling gap, and a unique region for extracting icing properties
- Cp data is provided for a means of CFD validation at three Y locations and the attachment region on the leading edge
- The IRT 7-bin MVD = 25 μm cloud distribution is given for analysis along with the 8 independently run spray times of: 2.5, 5.0, 7.5, 10.0, 15.0, 20.0, 25.0, and 29.0 minutes
- Experimentally measured ice mass data is provided along with the values of Bulk Volume and Bulk Density
- Experimentally measured ice shape profiles from the laser scanned ice shape data is provided
- Future revisions and edits to this document are to be expected

References

[1] Ozoroski, T. A., Broeren, A. P., Porter, C. E., Lee, S., “Analysis of Ice Mass Growth Over Time on the CRM65 Midspan Hybrid Model,” *AIAA Aviation 2024 Forum, 2024*.

[2] Steen, L. E., Ide, R. F., Zante, J. F. V., and Acosta, W. J., “NASA Glenn Icing Research Tunnel: 2014 and 2015 Cloud Calibration Procedures and Results,” *NASA TM Paper*, 2015. doi: 2015-218758.