

# Sixth High-Lift Prediction Workshop (HLPW-6)

RANS Technical Focus Group (TFG)

Boris Diskin and Mike Park

January 28, 2026

# Outline

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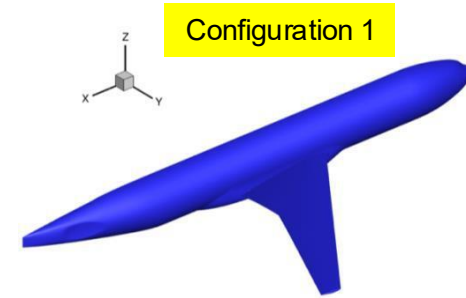
# Background

# HLPW-5 Test Cases

- **Case 1: Verification study**

Config. 1: Wing-body geometry with clean wing

$Re_{MAC} = 5.6 \times 10^6$ ,  $M_\infty = 0.2$ ,  $\alpha = 11^\circ$



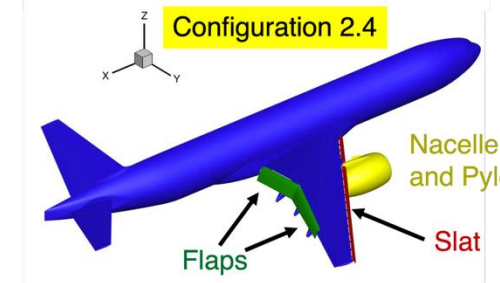
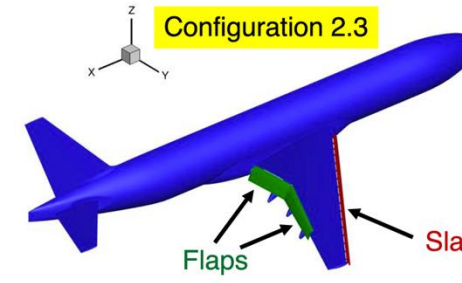
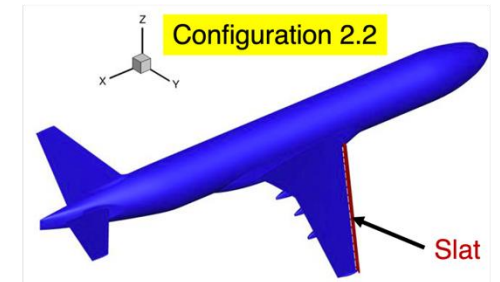
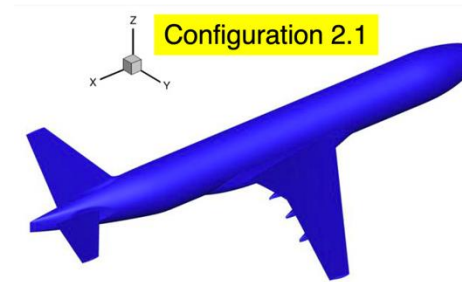
- **Case 2: Configuration buildup study**

- Config. 2.1: Wing, fuselage, flap support fairing, empennage
- Config. 2.2: added slat to Config. 2.1
- Config. 2.3: added flaps to Config. 2.2
- Config. 2.4: incorporated nacelle in Config. 2.3

$Re_{MAC} = 5.4 \times 10^6$  (Config. 2.1) and  $5.9 \times 10^6$  (Configs. 2.2 - 2.4),  $M_\infty = 0.2$

Range of angles of attack from low to  $CL_{max}$  and beyond

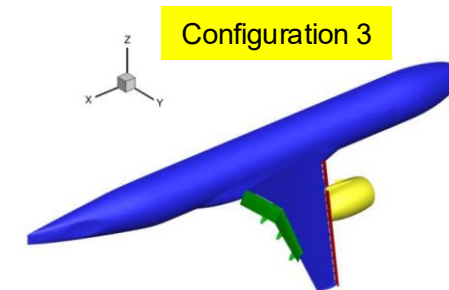
ONERA experiment for Cases 2.2, 2.3, and 2.4



- **Case 3: Reynolds number variation study**

$Re_{MAC} = 1.05 \times 10^6$ ,  $5.49 \times 10^6$ ,  $16 \times 10^6$ , and  $30 \times 10^6$ ,  $M_\infty = 0.2$

Range of angles of attack from low to  $CL_{max}$  and beyond



# HLPW-5 Fixed-Grid RANS TFG Summary

B. Diskin, C. L. Rumsey, L. Wang, and P. S. Iyer, AIAA 2025-0046

- Consistent RANS solutions established for Case 1 and configuration 2.1 ( $\alpha \leq 14^\circ$ )
  - Iterative convergence and grid convergence for selected solutions
  - Importance of well-posed RANS models, grids that place degrees of freedom in right locations, and strong iterative solvers
  - Sufficient accuracy to distinguish between solutions to different RANS models
- For configurations 2.2 – 2.4 and Case 3, RANS solutions are inconsistent at high angles of attack
  - RANS solutions (deltas) qualitatively follow trends for configuration buildup and Reynolds number increase
  - RANS model accuracy for these configurations could not be assessed
    - ✓ Lack of iterative convergence and grid convergence
    - ✓ Inconsistent spurious “pizza” separation patterns observed
- RANS predictions in comparison with ONERA experiment for configurations 2.2, 2.3, and 2.4
  - Some agreement for low angles of attack
  - For high angles of attack
    - ✓  $C_L$  is lower than experiment; comparable for some solutions for configuration 2.2
    - ✓  $C_D$  has small relative difference from experiment; higher for configuration 2.2
    - ✓  $C_m$  is poorly predicted

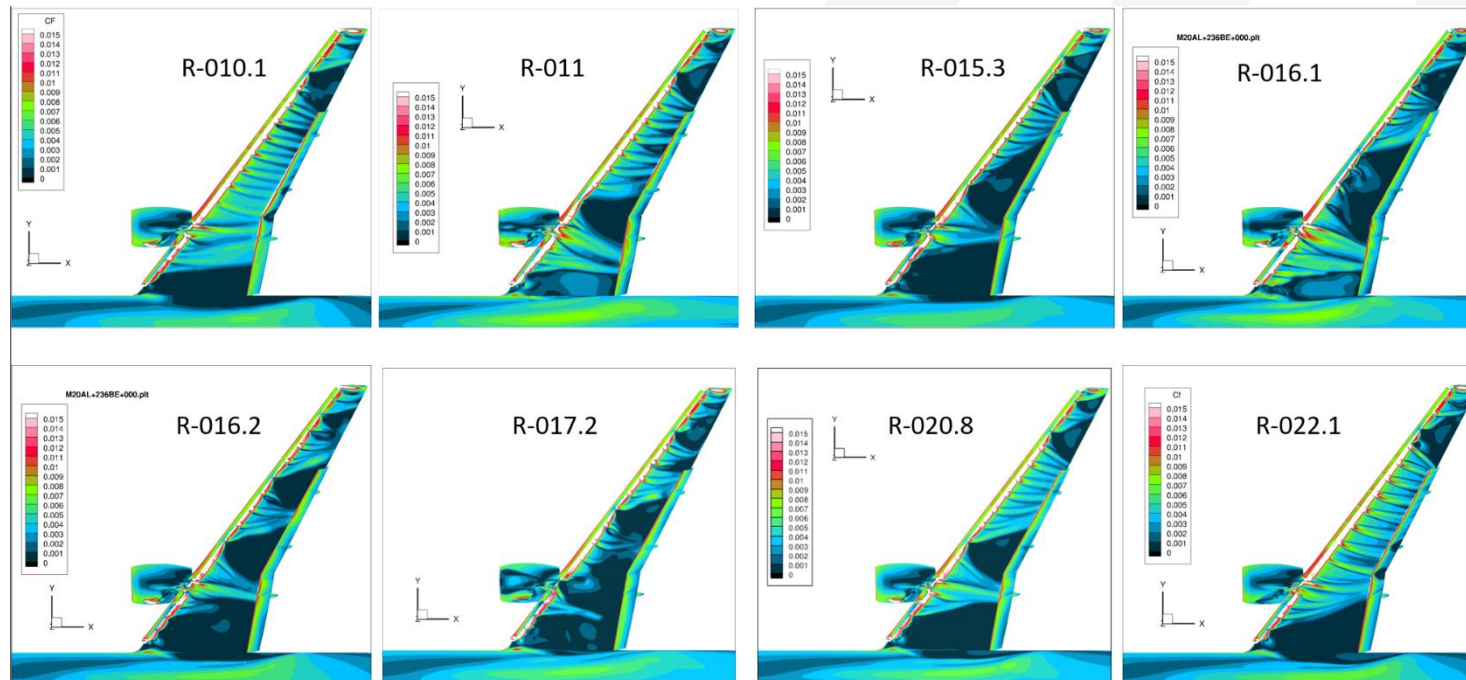
# HLPW-5 Adapted-Mesh RANS TFG Summary

M. A. Park, AIAA 2025-0047

- Adapted-mesh results are consistent with RANS select solutions and show improved force and moment consistency at lower angles of attack
- Case 1: Forces and moment are consistent with RANS TFG submissions for SA and SA-QCR2000-R(Crot=1) turbulence models. Goal-based drag metric approached fine-mesh result with less degrees of freedom
- Case 2.2 had most submissions and good consistency between those submissions at lower angles of attack; variation increased at higher angles of attack at onset of spurious "pizza" separation patterns
- The difference between adapted SA and SST turbulence models is less than the difference between independent grid series
- Addition of flaps (increasing lift) created larger variation than addition of slat, but number of submissions decreased, making trends difficult to extract
- Mesh-adapted RANS solutions improve force and moment consistency at lower angles of attack, showing correct trends in turbulence model sensitivity when compared to wind tunnel measurements

# RANS Solution Challenges for HLPW-5 Configurations with High-Lift Devices

- Spurious pizza separation at high angles of attack on fixed and adaptive meshes
- Insufficient iterative and grid convergence
- No agreement between solvers



Spurious separation in RANS solutions (skin friction) for Case 2.4

# Post-Workshop RANS Studies

- Modified Spalart-Allmaras models demonstrated delay in onset of pizza-slice separation
- Removal of slat brackets led to improved iterative and grid convergence and improved agreement between solvers
- Improved iterative convergence for Cases 2.2, 2.3, and 2.4 (and Case 3) reported with Selective Frequency Damping method
  - Pizza-slice separation still observed at convergence on the nominal grids
  - Grid convergence was not shown
- Several teams collaborated on investigation of sources of differences between RANS solutions for HLPW-5 configurations
  - Study presented at APC-10 workshop, July 2-4, 2025, Tokyo, Japan
- URANS solutions attempted and produced mixed results; some were able to get rid of pizza, some showed pizza

# Introduction of HLPW-6

RANS TFG Perspective

- HLPW website: <https://aiaa-hlpw.org/> **Bookmark and check frequently!**
- See Adam's kick-off presentation  
[https://aiaa-hlpw.org/assets/HLPW6/HLPW6\\_Launch\\_v1.pdf](https://aiaa-hlpw.org/assets/HLPW6/HLPW6_Launch_v1.pdf)
- Workshop goals (borrowed from HLPW website)
  - Assess numerical prediction capability (meshing, numerics, turbulence modeling, high-performance computing requirements, etc.) of current-generation CFD technology/codes for swept, medium-to-high-aspect ratio wings for landing/take-off (high-lift) configurations
  - Develop practical modeling guidelines for CFD prediction of high-lift flow fields
  - Determine elements of high-lift flow physics that are critical for modeling to enable development of more accurate prediction methods and tools
  - Enhance CFD prediction capability for practical high-lift aerodynamic design and optimization
- Specific HLPW-6 RANS TFG goal
  - Understand and mitigate spurious separation patterns (aka pizza slices) appearing behind slat brackets in RANS solutions for high-lift aerodynamic flows at high angles of attack

- HLPW publications

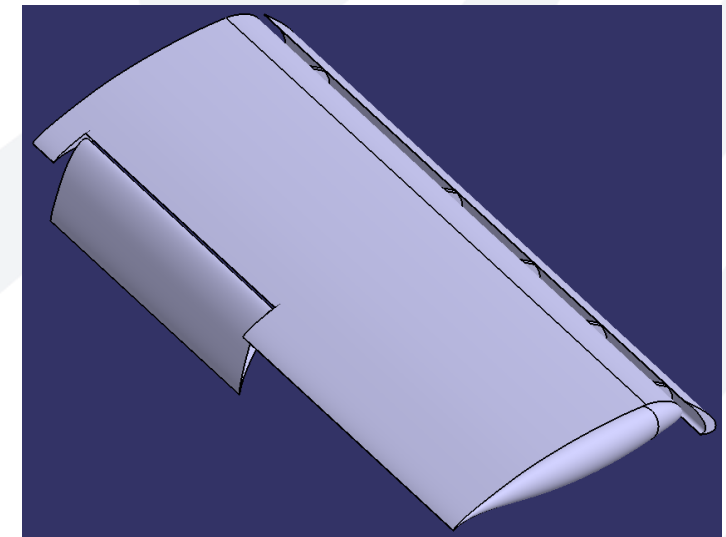
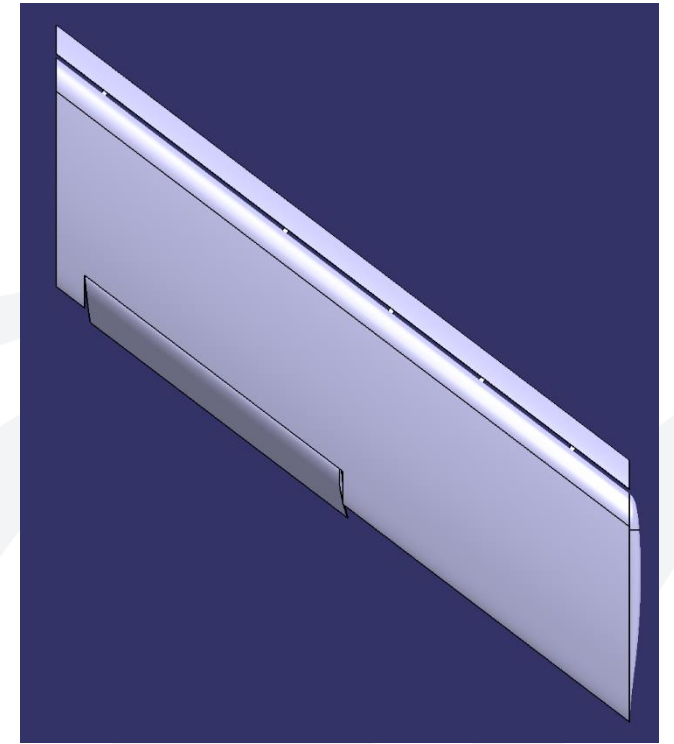
- We are collecting publications related to CRM-HL Ecosystem
- Please send relevant publications in Bibtex format

- Tecplot complementary licenses

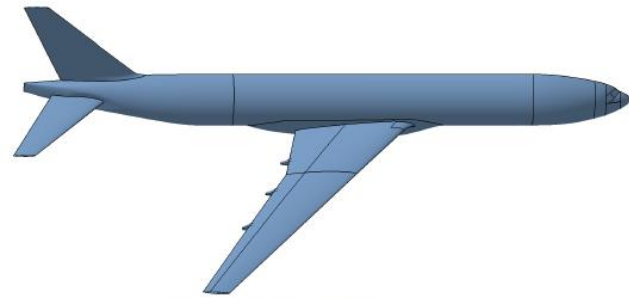
- Offered for duration of HLPW-6
- Requests should be made to Gibson Adams [g.adams@tecplot.com](mailto:g.adams@tecplot.com)
- Options for support with visualizing data

# Test Case 1 (TC 1): CRM-HLS

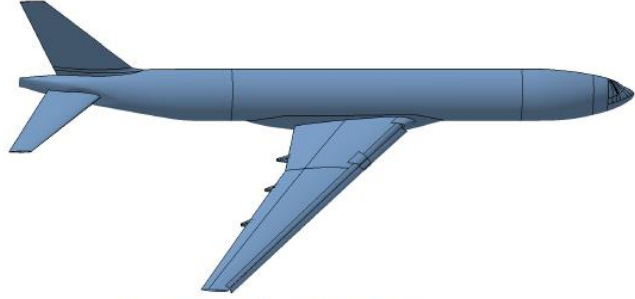
- High-Lift Simplified configuration, developed by Boeing / University of Washington collaboration
- Features finite span wing, full span slat, partial span flap
- Free air with  $y=0$  symmetry,  $Re_{MAC} = 3.55 \times 10^6$ ,  $M=0.2$ ,  $MAC = 30$  in
- Angles of attack:  $10^\circ$ ,  $15^\circ$ ,  $20^\circ$ ,  $25^\circ$ ,  $30^\circ$ ,  $35^\circ$
- **Targets slat bracket wake separation on 2nd from outboard bracket**
- No experimental data yet, but maybe mid-workshop
- Scale-resolving solutions should be available sooner
- Many geometric variations possible
  - slat bracket width / depth
  - removable flap
  - removable slat
  - deflection changes, etc.



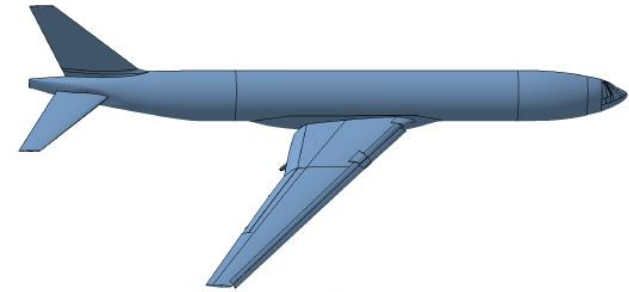
# HLPW-6 Test Case 2 (TC 2)



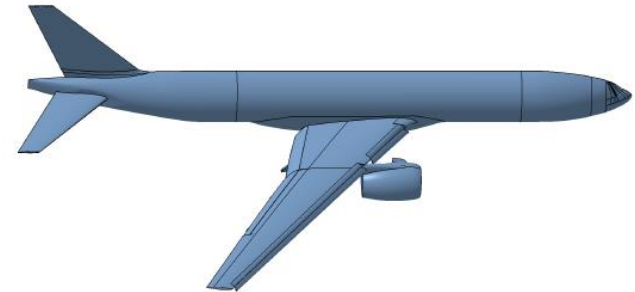
(a) TC2.1, CRM-HL-WBHV Configuration



(b) TC2.2, CRM-HL-WBSHV Configuration



(c) TC2.3, CRM-HL-WBSFHV Configuration



(d) TC2.4, CRM-LDG-HV Configuration

- HLPW-6 TC 2 is based on HLPW-5 TC 2
- HLPW-6 cases/conditions TBD
- RANS TFG focuses on TC 1 and TC 2
- Lessons learned in TC 1 studies to be applied to TC 2 configurations

For HLPW-6 Test Cases 3 and 4 see kick-off presentation

[https://aiaa-hlpw.org/assets/HLPW6/HLPW6\\_Launch\\_v1.pdf](https://aiaa-hlpw.org/assets/HLPW6/HLPW6_Launch_v1.pdf)

# TFG Info

- 89 people (e-mail addresses) on RANS TFG distribution list
  - 12 countries
  - 5 government organizations
  - 10 aerospace companies
  - 11 academic institutions
  - 11 commercial software developers
- TFG leads
  - Mike Park (FlexCompute)      [mike@flexcompute.com](mailto:mike@flexcompute.com)
  - Boris Diskin (NASA)      [boris.diskin@nasa.gov](mailto:boris.diskin@nasa.gov)

# RANS TFG Key Questions:

- Can we compute iteratively and grid converged RANS solutions for TC 1?
- Can we achieve agreement between converged RANS solutions computed by different solvers for TC 1 at low, middle, and high angles of attack?
- Is TC 1 geometry prone to spurious ‘pizza slice’ separation patterns similar to those observed in RANS solutions at high angles of attack for the HLPW-5 TC 2.2-2.4?
- Can spurious ‘pizza slice’ separation patterns be mitigated with better grid resolution and/or iterative convergence? If yes, what are requirements for grid resolution (both on surface and in volume) and levels of convergence to avoid spurious separation?
- Do we observe multiple solutions of the Spalart-Allmaras (SA) turbulence model for TC 1 and, if we do, what changes in the turbulence model should be made to ensure well-posedness (solution existence, uniqueness, and continuous dependence on the input parameters)?
- What lessons learned from TC 1 can be applicable to more complex CRM-HL configurations such as TC 2.4?

## Optional:

- How do geometrical features (bracket shape / spacing between brackets, anything else) affect spurious separation in the RANS solutions?

# Schedule of Mini-Workshops

New proposal is to align mini-workshops with AIAA conferences

- June 2026: Mini-workshop 1: Preliminary RANS solutions for TC 1; comparison with SR TC 1 solutions
- January 2027: Mini-workshop 2: Updated RANS solutions for TC 1; Comparison with experiment  
Geometric variations of TC 1, first application of lessons learned to TC 2, RANS model modifications
- June 2027: HLPW-6: RANS solutions for TC 2 (Config 2.4); single Re, limited number of angles of attack. Final report
- January 2028: HLPW-6 special sessions at SciTech-28

# Dates and Links

- Kick-off January 20, 2026
- HLPW-6 June 2027 in conjunction with AIAA Aviation-27 Forum

Link to HLPW-6 website: <https://aiaa-hlpw.org/> **Bookmark and check frequently!**

- Mini-workshops aligned with AIAA conferences
- RANS TFG meetings bi-weekly, on Wednesday, at 10 am US Eastern Coast time starting on January 28, 2026

- Link to MS TEAMS for RANS TFG meetings:

[https://teams.microsoft.com/dl/launcher/launcher.html?url=%2F\\_%23%2Fmeet%2F25656796098352%3Fp%3Dhoi7KqCHwWAWF8TBCI%26anon%3Dtrue&type=meet&deeplinkId=c9438561-703d-4acc-9fc8-d77df126eff4&directDl=true&msLaunch=true&enableMobilePage=true&suppressPrompt=true](https://teams.microsoft.com/dl/launcher/launcher.html?url=%2F_%23%2Fmeet%2F25656796098352%3Fp%3Dhoi7KqCHwWAWF8TBCI%26anon%3Dtrue&type=meet&deeplinkId=c9438561-703d-4acc-9fc8-d77df126eff4&directDl=true&msLaunch=true&enableMobilePage=true&suppressPrompt=true)

- Link to NASA's Turbulence Modeling Resource website: <https://turbmodels.larc.nasa.gov/>

# RANS TFG Proposed Activities toward Mini-Workshop 1

- January-March 2026:
  - Separate initial work between subgroups tasked with conducting quick (2-8 weeks) narrow focus activities and providing recommendations for RANS TFG
  - Subgroups report progress bi-weekly
  - Proposed narrow focus activities
    1. Visualization and characterization of bracket wakes
    2. Iterative and grid convergence for TC 1 with SA model on families of fixed grids
    3. Solutions on adapted grids
    4. Verification of SST-Vm model and assessment SST-Vm solutions for TC 1
  - By April, summarize all recommendations and select grids and output data for mini-workshop 1
- April-June 2026:
  - Compute TC 1 solutions with SA and SST-Vm models
  - Present individual TC 1 solutions and a preliminary summary at mini-workshop 1
  - Compare with SR TC 1 solutions

# Activity 1: Visualization and Characterization of Bracket Wakes

- Recommend views, surface and off-body data to collect, etc.
  - Generate representative solutions for TC 1 with and without pizza
  - Recommend ways to characterize bracket wake and its interaction with boundary layer on main wing
  - Recommend submittal forms for TC 1 solutions
- JAXA group performed some bracket wake characterization in AIAA 2026-1564
  - Good starting point
  - JAXA agreed to lead this Activity 1 subgroup
- Please volunteer to contribute to Activity 1 subgroup by sending e-mail to TFG leads
- Submittal forms are expected to be finalized in 6-8 weeks

# Activity 2: Iterative and Grid Convergence for TC 1 with SA Model on Families of Fixed Grids

- Generate families of grids following best practices and intended resolution
  - Mesh families to be generated by HeldenMesh, Cadence, and possibly other groups
- Assess iterative and grid convergence on those grids
  - Suggest criteria for assessment of convergence
- Assess agreement between solutions computed by different solvers on different grid families
- Assess dependence of pizza separation patterns on grid resolution
- Report findings and provide recommendations
  
- Please send e-mail to TFG leads if you would like to contribute to this activity for the next two months
- Recommendations for grid resolution and convergence criteria will be finalized in the next two months

# Activity 3: Solutions on adapted grids

- Compute TC 1 solutions on adapted grids
- Assess iterative and grid convergence on those grids and compare solutions computed by different solvers
- Assess agreement between solutions computed by different solvers on same adapted grids
- Assess persistence of pizza separation patterns in adapted solutions
- Assess possibility of multiple solutions
  
- Report findings and provide recommendations
- Please send e-mail to TFG leads if you would like to contribute to this activity for the next two months

# Activity 4: Verification of SST-Vm Model and Assessment of SST-Vm Solutions for TC 1

- Verify implementation of SST-Vm model in several codes using verification case (3D bump) from TMR website
- Compute SST-Vm solutions for TC 1 on families of fixed grids
- Assess iterative and grid convergence
- Assess agreement between solutions computed by different solvers on different grid families
- Assess dependence of pizza separation patterns on grid resolution
- Report findings and provide recommendations
- Please send e-mail to TFG leads if you would like to contribute to this activity for the next two months

Questions, Comments,  
Suggestions?