**Minutes and Notes from AIAA APA LFC DG at SciTech 2025**

Venue and Attendees

Date: 7 Jan 2025.

Time: 600 – 700 pm EST.  Location: Boardroom

Attendees are listed in Appendix A.  15 persons in attendance in total; 1 person attended on-line.

Minutes and Notes

1. Attendees introduced themselves in quick round-the-room (name, organization).  See Appendix A.

2. Dr Paul Vijgen and Dr Geza Schrauf started the DG (Discussion Group) with presenting concise intro information on Motivation and Goals of the APA-TC LFC DG/WG.

   See first pages of PowerPoint presentation provided in Appendix B.

3. Paul and Geza presented next a summary of 2025 / 2026 focus LFC DG/WG, i.e.,

   a. Prepare a Special Session at SciTech 2026 with invited speakers:
      - Summarize LFC history, lessons learned and progress in key challenges
      - Assess current *state-of-the-art* and key LFC challenges across academia, industry and government agencies with updated list of publications

      Slide 19 in Appendix B provides more details.

   b. Prepare/Conduct an initial workshop "LFC Transition-Prediction Methods":
      - Release workshop data sets before Aviation 2025
      - SciTech 2026: Workshop/Special Session with panel discussion;
      - Aviation 2026: Special Session with results

   c. Longer-term focus for LFC DG is indicated on Page 5 in Appendix B.

4. Next, Geza and Paul presented summary overview of objective and LFC test cases (prepared by Geza) for the proposed initial workshop on "LFC Transition-Prediction Methods". See slides 6 – 16 in Appendix B.

   a. Main objective for the first workshop:  Assess numerical tools for transition-location and drag prediction using simplified geometries with laminar suction.

b. For 2025/2026 Workshop, proposing three LFC analysis cases (prepared by G. Schrauf):
   - Test Case 1: Laminar boundary layer along a flat plate with suction
   - Test Case 2: Infinite-swept flow with prescribed HLFC suction velocities
   - Test Case 3: Conical flow with prescribed HLFC suction layout & perforation model

5. Paul and Geza briefly discussed slides 17 and 18 (Appendix B) to provide currently proposed status and draft schedule for the initial workshop.

6. Overall, there was general interest and agreement expressed by the attendees on the proposed approach, test cases, and schedule for the initial workshop on LFC Transition-Prediction coordinated by the LFC DG, as well as on proposed Special Session on LFC at SciTech 2026 with invited speakers.

7. Discussion and Other Business:
   a. Prof Thomas Corke and Prof Koen Groot mentioned that an effort is underway to propose a possible new AIAA ASG TC ('Transition and Instability') to AIAA leadership – to be parallel next to the APA and the FD TC's.
   b. Prof Corke recommended that the LFC DG presents a short summary of the ongoing efforts with the LFC-DG in his Transition DG on Thursday 9 Jan at 930 am. (Note: Paul and Geza presented key slides from Appendix B on 9 Jan 2025 in the Transition DG).
   c. Prof Koen Groot offered the use of the DECAF code (LST) from 2018 for this effort for interested parties.
   d. Question came on application of PSE and transport-equation transition prediction to these initial test cases. Since the initial test cases are oriented towards boundary-layer solutions, PSE could be used. The geometry information that has been prepared is by itself not yet sufficient complete to be used for RANS mean-flow prediction. (Interested participants could probably apply inverse design to generate a suitable RANS input geometry that produces the flow field provided in the test cases.)
   e. Dr Rolf Radespiel relayed that DLR has built a new wind-tunnel model with suction for testing in the DLR NWB tunnel later this year. The model consists of both an unswept and a swept spanwise segment with suction. He plans to provide details on geometry and test layout, and, if available, initial test results could be available to share at the LFC-DG at Aviation2025.
      This new test (with data in the public domain) could be a potential test case for a possible follow-on LFC-DG workshop. Since the geometry and installation in tunnel is available in 3-D CAD, this case would be amenable to RANS solutions.
   f. Concerning the need to find a long-term stable electronic storage location for the LFC-DG workshop and related information, Dr Meelan Choudari offered

the option to store it at a suitable NASA web site.  Paul plans to coordinate with Meelan.

8. The SciTech 2025 LFC-DG Meeting adjourned at 705pm EST

## Appendix A Attendees LFC DG on 7 Jan 2024 (SciTech 2025)

| Attendees | APA-TC LFC Discussion Group | | Aviation2025 | 7-Jan-25 | 600-700pm EST | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **No** | **Title** | **First Name** | **Last Name** | **Institute** | **Email** | **Alternate Email** | **Notes** |
| 1 | Dr | Chris | Axten | Penn State Univ | cja5217@psu.edu | | |
| 2 | Dr | Camli | Badrya | UC Davis | cbadrya@ucdavis.edu | | |
| 3 | Dr | David | Borgmann | Univ of Arizona | davidborgmann@arizona.edu | | |
| 4 | Dr | Meelan | Choudari | NASA Langley | m.m.choudhari@nasa.gov | | |
| 5 | Dr | Thomas | Corke | Univ of Notre Dame | tcorke@nd.edu | | |
| 6 | Dr | Jenna | Eppink | NASA Langley | jenna.eppink@nasa.gov | | |
| 7 | Dr | Koen | Groot | Univ of Wyoming | kgroot@uwyo.edu | | |
| 8 | Dr | Christoph | Hader | Univ of Arizona | chader@arizona.edu | | |
| 9 | Dr | Chris | Otto | Boeing (BCA) | christopher.otto@boeing.com | | Online |
| 10 | Dr | Pedro | Parades | NASA Langley | pedro.parades@nasa.gov | | |
| 11 | Dr | Madeline | Peck | Los Alamos/Notre Dame | mpeck@lanl.gov | mpeck3@nd.edu | |
| 12 | Dr | Rolf | Radespiel | TU Braunschweig (Retired) | rolf.radespiel@tu-braunschweig.de | | |
| 13 | Dr | Geza | Schrauf | Airbus (Retired) | contact@schrauf.de | | |
| 14 | Dr | Oğuz | Uzol | METU | uzol@metu.edu.tr | | METU = Middle East Technical University |
| 15 | Dr | Paul | Vijgen | Boeing BCA (Retired) | vijgens@frontier.com | | |
| | | | | | | | |

## Appendix B. Slide Materials as Presented at 7-Jan-2025 LFC DG (SciTech 2025)

Following pages provide the slides used during the LFC-DG meeting on 7 Jan 2025.

PPT used during
LFC DG on 7 Jan 2025
(V1.4 2 Jan 25)

# APA-TC LFC (Laminar Flow Control) DG

**SciTech2025 – Status DG and Planning for 2025/2026 Workshop**
**Tue 7 Jan 2025, 6 – 7 pm EST (Boardroom)**

Prepared by: Paul Vijgen, Geza Schrauf, Camli Badrya

2 Jan 25

**Tuesday, 7 Jan 2025**
1800-1900 APA -TC Laminar Flow Control DG

Topics:

1. Motivation and Goals APA -TC LFC DG/WG
2. Preparation 2025/2026 Workshop "LFC Transition -Prediction Methods"
   1. Objectives and Approach
   2. Proposed "Transition Prediction Test Cases" for initial Workshop
   3. Planning status, timeline and activities 2025-2026
3. Other Topics
4. Next Steps

<u>Current LFC DG Focals:</u>
Dr Camli Badrya (cbadrya@ucdavis.edu)
Dr Geza Schrauf (contact@schrauf.de)
Dr Paul Vijgen (vijgens@frontier.com)

DG - Discussion Group
WG - Working Group

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2 Jan 25

## APA-TC Laminar Flow Control DG

### Motivation for LFC DG/WG

- Integrated LFC (laminar flow control) technology could significantly enhance efficiency for aircraft where NLF benefit is limited (wing sweep, $Re_c$, $R_{bar}$)
  - HLFC technology currently not implemented on wings - due to multi-disciplinary design, integration and manufacturing/systems/operations challenges
- LFC technology has 60+ year of aerodynamic and integration studies (including full-scale flight demonstrations) – but wing application has not yet happened
- HLFC has unique challenges, e.g.:
  - Suction-surface related transition flow physics understanding and prediction methods
  - Development and validation of robust design & integration tools with suction
  - Need for robust integrated suction systems and control
  - Contamination control

- **DG/WG could help identify HLFC challenges and foster progress across academia, agencies and industry – towards wing LFC readiness**

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## Goals AIAA APA -TC LFC DG/WG

1. Provide international forum to progress LFC challenges
   - Foster collaboration opportunities (e.g., ICAS, ECCOMAS, 3AF, DLRK, etc.)
2. Bring together stakeholders/SME's from industry, academia, and agencies (NASA, DLR, ONERA, JAXA, ATI, others)
3. Foster coordination between AIAA TC stakeholders: APA, FD, CFD, Aircraft Design, Systems, Structures, other
4. Bridge "generational" knowledge gap on Laminar Flow Control (LFC)
   - DG/WG forum can help capture lessons learned
5. Build public database with suitable data sets to assess LFC analysis methods in Workshop(s)
6. Organize AIAA Invited Session/s (papers or presentations -only) on past, present and planned LFC research, incl. trends/challenges/progress
7. Organize AIAA Workshop(s) to identify HLFC challenges and foster progress
8. Maintain DG/WG continuity
   - Need additional focals; coordination of DG initiatives with other TC's; other

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## APA-TC Laminar Flow Control DG/WG

### 2025 / 2026 Focus LFC DG/WG

- **Prepare Special Session at Scitech2026 with invited speakers**
  - Summarize LFC history, lessons learned and progress in key challenges
  - Assess current *state-of-the-art* and key LFC challenges across academia, industry and government agencies with updated list of publications
- **Prepare/Conduct Initial Workshop "LFC Transition -Prediction Methods"**
  - Release Workshop data sets before Aviation 2025
  - SciTech 2026: Workshop/Special Session with panel discussion;
  - Aviation 2026: Special Session with results

### Longer-term Focus LFC DG/WG opportunities

- **Provide forum to discussion selected topics, e.g.:**
  - Forum to discuss transition physics with suction; design tools for integration and suction systems; laminar-state sensors; flow-control algorithms; operational aspects; etc.
- **Organize Session(s) on selected LFC topics at upcoming AIAA meetings**
  - Add topics in future Calls for Papers (with other TC's)
- **Provide forum for Stakeholders to recommend LFC research activities**





## APA-TC DG/WG: LFC Physics and Applications

### Planning of Initial Workshop on "LFC Transition -Prediction Methods"

- Objective: assess numerical tools for transition -location and drag prediction using simplified geometries with laminar suction
- Provide several suction LFC test cases suitable for transition -prediction method assessment
- For 2025/2026 Workshop, propose three LFC analysis cases (prepared by G. Schrauf):
  - Test Case 1: Laminar boundary layer along a flat plate with suction
  - Test Case 2: Infinite-swept flow with prescribed HLFC suction velocities
  - Test Case 3: Conical flow with prescribed HLFC suction layout & perforation model
- Possible follow-on LFC Workshop test cases :
  - Suction optimization case (based on Test Case 3 - above)
  - Other 2-D and/or 3-D suction test data set(s) with adequate geometry and data availability
  - Plan to share status on possible other test cases in future DG (Aviation2025)

## 2-D and 3-D HLFC test cases for Workshop (prepared by G. Schrauf)

**Test Case 1:** **Laminar boundary layer along a flat plate with suction**

**Test Case 2:** **Infinite-swept flow with prescribed HLFC suction velocities**

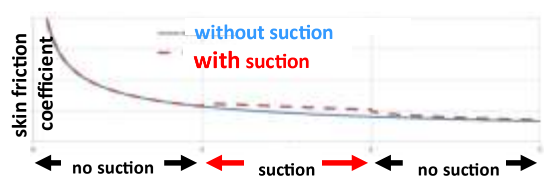
**Test Case 3:** **Conical-swept flow with a prescribed HLFC suction chamber layout and pressures**





## TC1: Flat plate with suction

**Laminar, incompressible boundary layer along a flat plate:**
- Continuous suction (no "sandpaper roughness" of the micro-perforation)
- Fully laminar analysis (no transition)
- No wave drag
- No separation




**Inputs for test case provided:**
- Free-stream conditions
- Length of the plate and the suction region
- Suction velocity
- Specification of frequencies for TS waves

**Expected results for comparison in workshop:**

(1.a) Confirm the momentum balance with suction, i.e., difference in friction drag = difference in momentum loss
(1.b) Provide velocity profiles at defined x-positions
(1.c) Provide amplification rates for Tollmien-Schlichting waves at specified frequencies
(1.d) Provide Tollmien-Schlichting N-factors for specified frequencies

# TC2: Infinite swept flow with prescribed suction distribution

**Infinite-swept wing configuration based on the NACA 64A010 profile**

Sweep angle 40°

Chord length 3.5 m (parallel to free-stream)

Spanwise extent ±0.5m

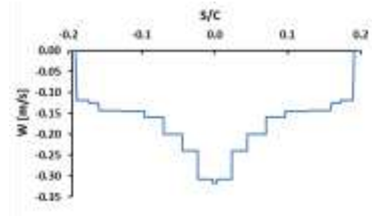
Angles of attack 0° and 2°

HLFC
Suction chamber distribution

**Free-stream conditions corresponding to**

Mach number 0.78

Flight altitude 31,000 ft




**Prescribed piecewise constant suction distribution**

Derived from ECCOMAS 2012

G. Schrauf, H. v. Geyr: "Simplified Hybrid Laminar Flow Control for Transport Aircraft." CD-ROM Proceedings of ECCOMAS 2012, September 10 -14, 2012, Vienna, Austria

**Example of suction distribution with stepwise constant suction velocities (angle of attack 0°)**

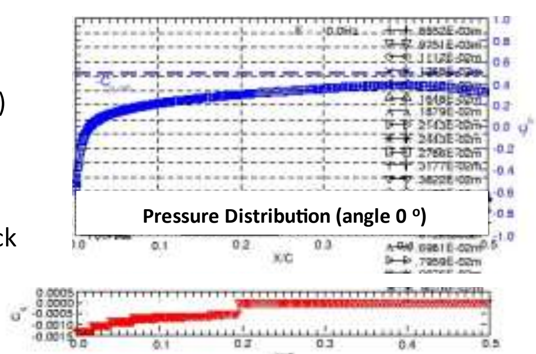




# TC2: Infinite swept flow with prescribed suction distribution

**Input for test case provided:**

- (x/c , y/c)-coordinates of the NACA 64A010 profile (in free-stream direction)
- Free-stream conditions
- Pressure distribution for each angle of attack
- Suction velocities for each angle of attack
- Input will be provided for sufficient number of stations so that no interpolation of input data is necessary




**Pressure Distribution (angle 0 °)**

**Suction Distribution (angle 0 °)**

- Specification of frequencies and wave angles for TS waves results
- Specification of wavelengths and wave angles for stationary CF waves results
- Specification of frequencies and wave angles for traveling CF waves results

# TC2: Infinite swept flow with prescribed suction distribution

**Expected results for comparison in workshop:**

(2.a) Velocity profiles (and their derivatives) at selected stations

(2.b) Amplification rates of TS waves for specified frequencies

(2.c) N-factors of Tollmien-Schlichting for specified frequencies

(2.d) Amplification rates of cross -flow modes for selected wave -lengths and frequencies

(2.e) N-factors of cross-flow modes for selected wave -lengths and frequencies

(2.f) Transition location

(2.g) Skin friction coefficient

(2.h) Total dimensional drag of a wing section with 1 -m span





# TC3: Conical flow with a prescribed chamber pressure

**Conical swept wing configuration based on the NACA64A010 profile**

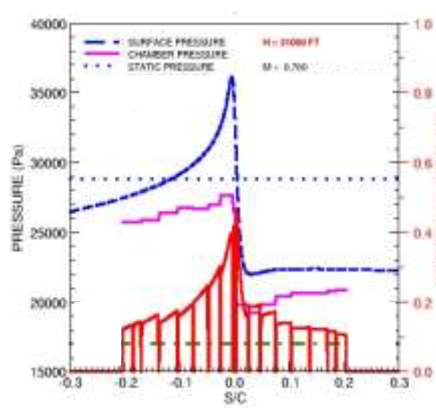
Leading-edge sweep angle 40°

Trailing-edge sweep angle 15°

Chord length 3.5 m (in free-stream direction)

Spanwise extent +- 0.5m

Angles of attack 0° and 2°




**Free-stream conditions corresponding to**

Mach number 0.78

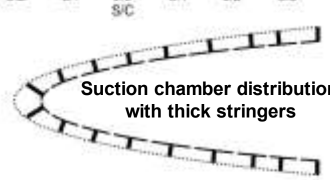
Flight altitude 31,000 ft

**Suction distribution provided**

Prescribed suction chamber layout (ECCOMAS 2012)

Prescribed pressure loss characteristics of perforated suction panel

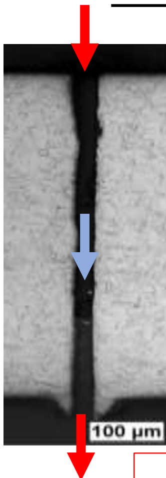
Prescribed pressures in the suction chambers




G. Schrauf, H. v. Geyr: "Simplified Hybrid Laminar Flow Control for Transport Aircraft." CD-ROM Proceedings of ECCOMAS 2012, September 10-14, 2012, Vienna, Austria

## TC3: Conical flow with a prescribed chamber pressure

Pressure loss characteristics of perforated suction skin




inviscid in-flow $\Delta p = \zeta \rho w^2 / 2$ $\zeta = 0.1$ **rounded** $\zeta = 0.5$ **sharp edge**

viscous, laminar flow (Hagen-Poiseuille) $\Delta p = 32 \mu \frac{L}{D^2} w$

inviscid out-flow $\Delta p = \zeta \rho w^2 / 2$ $\zeta = 1$

**Pressure-loss characteristic** $\Delta p_{sc} = A \frac{\mu_s}{\mu_0} w_s + B \frac{\rho_s}{\rho_0} w_s^2$

**The coefficients A and B of the pressure-loss characteristic will be provided**





## TC3: Conical flow with a prescribed chamber pressure

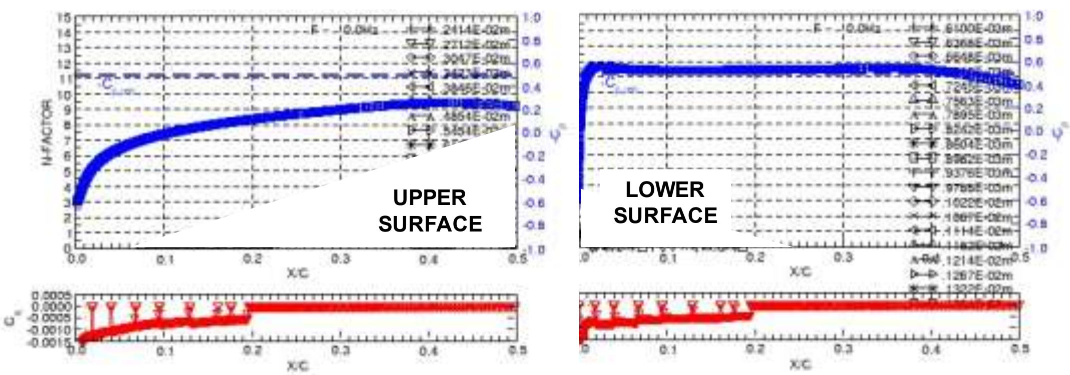
**Input for test case provided:**

- (x/c , y/c)-coordinates of the NACA 64A010 profile (in free-stream direction)
- Free-stream conditions
- Pressure distribution for each angle of attack
- Pressure loss characteristic, i.e. constants A and B
- Suction chamber layout and chamber pressures
- Input will be provided for sufficient number of stations so that no interpolation of input data is necessary

- Specification of frequencies and wave-angles for TS waves results
- Specification of wavelengths and wave-angles for stationary CF waves results
- Specification of frequencies and wave-angles for traveling CF waves results

# TC3: Conical flow with a prescribed chamber pressure

**Pressure Distribution**




**Suction Distribution**

Angle of attack 2°



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# TC3: Conical flow with a prescribed chamber pressure

### Expected results for comparison in workshop

(3.a) Distribution of the suction velocities

(3.b) Velocity profiles (and their derivatives) at selected stations

(3.c) Amplification rates of TS waves for specified frequencies

(3.d) N-factors of Tollmien-Schlichting for specified frequencies

(3e) Amplification rates of cross-flow modes for selected wave-lengths and frequencies

(3.f) N-factors of cross-flow modes for selected wave-lengths and frequencies

(3.g) Transition location

(3.h) Skin friction coefficient

(3.i) Total dimensional drag of the 1-m span wing section

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## APA-TC Workshop: LFC Transition-Prediction Methods

### Status and Draft Schedule for Initial Workshop (1/2)

- Proposed test cases for Workshop identified, inputs prepared, and outputs specified
- Server available to store Workshop test cases and results. Recommend permanent server for long-term storage and website maintenance
- Preparing for LFC Workshop flyer (Feb 2025)
- Planning to reach out to APA-TC, FD-TC and CFD Vision-2030 Integration Committees, etc
- Plan to reach out to additional organizations
  - About five (5) organizations/focals have expressed initial interest to participate
  - E.g., participants in 2017 NASA Transition Modeling Workshop and 2020/2021 AIAA CFD Transition-Modeling Workshop
- Planning to release Workshop test cases, related documentation and schedule on server by April/May 2025 - before Aviation2025 (21 – 25 July 2025)
- May/June, Workshop focals could do a virtual Q&A meeting with identified participants after release of Workshop cases – TBD

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## APA-TC Workshop: LFC Transition-Prediction Methods

### Status and Draft Schedule for Initial Workshop (2/2)

- At Aviation2025, plan to provide Workshop status at LFC DG/WG and provide additional Q&A on test cases
- Considering value/need for new Special Session at Aviation2025 to present Workshop setup and test cases to larger audience (oral presentation) - TBD (decide in Spring '25)
- At SciTech2026: if enough results are available from participants by Oct-Nov 2025, organizers can prepare status of summary results in oral presentation at proposed LFC Special Session at SciTech2026
- At Aviation2026: Anticipate Special LFC Session/Workshop with analysis of results
- By Aviation2026: Announce release of possible additional (more complicated) LFC test cases for follow-on LFC Workshop:
  - Suction optimization case (related to conical-swept wing Test Case 3)
  - Possible other 2-D and/or 3-D suction test data set(s) with adequate geometry & data availability
  - Plan status report on preparation other test cases at Aviation2025 LFC DG

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## APA-TC LFC DG/WG: LFC Special Sessionat SciTech2026

**Planning Proposed LFC Special Session at SciTech2026 (Draft)**

1. (Invited) survey paper(s) related to Recent History, Status, Opportunities and Integration Perspectives towards LFC Applications"
   - One or two (TBD) invited papers
   - Could have additional oral presentations (TBD)
2. Preliminary results LFC Workshop "LFC Transition-Prediction Methods" (invited oral presentation by Workshop focals)
3. Other topics for LFC Special Session (to be developed – open for your ideas)
   - Need inputs in time to incorporate into SciTech2026 Call for Papers





## APA-TC DG: LFC Physics and Applications

**Discussion:**

- Feedback from today's attendees on Workshop proposal and other DG topics
- Planning for next DG meeting at Aviation2025
- Request that today's attendees forward the current Workshop plan to interested SME's and organizations ( and, provide SME's contact info to focals below)
- LFC DG/WG needs additional active members to support – contact us if interested
- Contact current DG and Workshop focals with feedback and suggestions:

Dr Camli Badrya (cbadrya@ucdavis.edu)
Dr Geza Schrauf (contact@schrauf.de) – Workshop focal
Dr Paul Vijgen ( vijgens@frontier.com) – Workshop focal