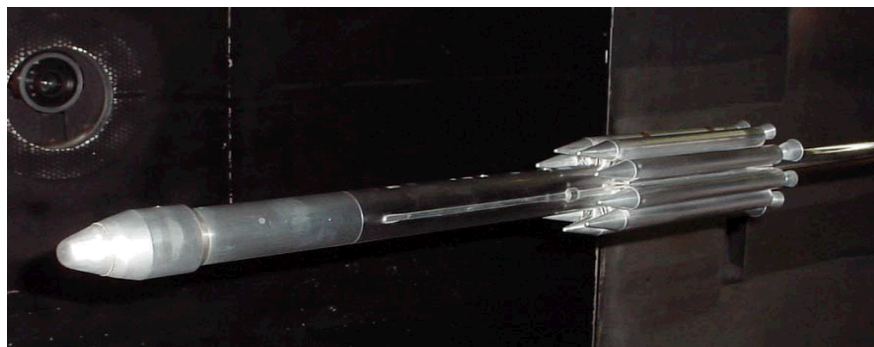
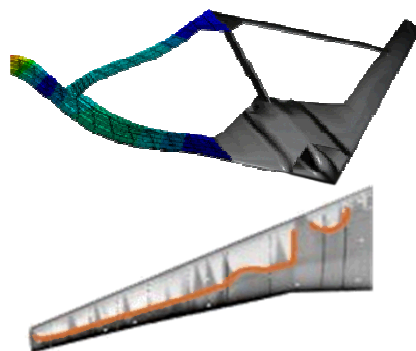




# NASA/DOD Flight Prediction Workshop

17-19 May 2016

Houston, TX



## 2016 FLIGHT PREDICTION WORKSHOP

TECHNICAL INTERCHANGE MEETING TO EVALUATE THE CURRENT CHALLENGES OF FLIGHT PREDICTION  
17 - 19 MAY 2016; GILRUTH CENTER; NASA JOHNSON SPACE CENTER



Accurate flight prediction methods are critical for all aspects of vehicle performance, handling characteristics, and structural integrity. The first NASA/Industry/DoD workshop on wind tunnel/flight correlation was held in 1981, when discrepancies arising from Reynolds number effects, aerodynamic effects, and tunnel wall and sting-interference effects posed significant barriers to experimentally-based prediction methods in use at that time. Significant advances in ground-based experimental capabilities and facilities, CFD methods, and flight test technology in the next 20 years significantly improved the tools available for predictions. In addition, numerous new production and experimental military and civil aircraft completed flight testing, offering an unprecedented experience base and data for assessing the accuracy of current prediction methods and practices. Thus, the first Flight Prediction Workshop (FPW) was held in 2002. The objective of the 2002 workshop and the current 3 day workshop for technical specialists is to provide a forum for the exchange of: experiences and lessons learned, critical assessments of the state of the art, and recommendations for further developments in flight prediction methodology. Information and opinions provided by the workshop will be incorporated in R & T planning for future government activities in aerodynamics, aerelasticity, aeroacoustics, propulsion/airframe integration, etc.



Participation in the Flight Prediction Workshop is by invitation only. The meeting is restricted to U.S. persons to permit the discussion of topics controlled by ITAR regulations.

Speakers from NASA, the Department of Defense and many aerospace companies will be participating. They include:

**NASA** AFRC, GRC, HQ, JSC, LaRC, and MSFC

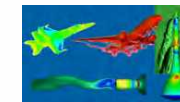
**Dept. of Defense** US Army, USN, USAF, JHU/APL

**Industry** Aerospace Corp, AMA, Aurora, Blue Origin, Boeing, Lockheed Martin, Mooney Int., Northrop Grumman, Sierra Nevada, SpaceX, Textron Aviation, and UTAS

Workshop participants will be assigned to teams for break-out discussions. The workshop will conclude with technical assessments in several areas, followed by a round-table discussion devoted to participant-led summaries of the state of the art in flight prediction methodology. The discussion will identify critical shortcomings in current methods and recommend research to improve capabilities. The individual reports will also identify factors that are currently adequately predicted. The organizing team will prepare a brief summary document of the findings after the workshop. The NASA/DoD Team will use these inputs to identify high payoff and mature areas for future planning in aerodynamics research.

During the 3-day workshop, sessions will address the following themes: Civil and Military Aircraft Flight Predictions, UAV and Launch Vehicle Flight Predictions, Prediction Methodology, and Summary & Recommendations.

Perspectives on the adequacy of existing and emerging ground and flight test facilities and CFD methods (based on experiences) are desirable. Presentations should conclude with the speaker's personal assessment of the state of the art in flight predictions, including recommendations for future research. A discussion of uncertainty and risk quantification is desired.



**Civil Aircraft** Presentations will address experiences using experimental and numerical flight predictions for civil aircraft. In particular, discussions will focus on items like: the process of addressing wind-tunnel flow and installation corrections; adjusting model data for effects of trip strips, internal drag, etc.; extrapolation of tunnel data to flight Reynolds numbers; uncertainties; and allowance for aircraft factors in the flight environment (surface contamination roughness, elasticity, etc.). Also, experiences in the use of

CFD methods for flight predictions should be included. Discussions regarding difficulties experienced in correlating ground predictions and flight results due to shortcomings in measurement, facility, CFD, or flight test capabilities are expected.

**Military Aircraft** Presentations will address the state of the art in flight predictions for fixed-wing military aircraft of all classes. In addition to the factors considered for presentations on civil aircraft, the scope of discussion should address flight prediction methods for areas unique to military aircraft, such as: maneuverability at extreme envelope conditions across the speed range, prediction of responses in carrier approach conditions, engine integration and propulsion effects, cockpit buffet characteristics, recovery from out-of-control and spin conditions, paratroop load drop characteristics, carriage and release of external stores, compatibility with low observable requirements, vertical and horizontal tail buffet, vortical lift, effectiveness of maneuver devices (chines, strakes, maneuvering flaps), jet interactions and acoustic loads, and nose-down control at extreme angles of attack.

**Launch Vehicles and Munitions** Presentations will address the state of the art in flight predictions for munitions and launch and crew vehicles of all classes. The scope of discussion should address flight prediction methods for areas unique to these classes of flight, such as: vehicle performance, acoustic environments, propulsion, flight controls, and trajectories.

Due to new product development cost and time constraints, the U.S. aerospace community needs new capabilities that will:

- Facilitate the development of new products with improved performance with less risk in less time and at less cost, and
- Permit the exploration of new, novel configurations with a minimum of flight testing

To develop a coordinated effort to address flight prediction issues and reduce flight test cost and time, the 2016 FPW has six principal goals:

1. Identify future requirements and gaps in flight prediction capability, certification, and sustainment
2. Identify requirements for computational and experimental model and tool development, characterization, validation, and information management

ment systems

3. Identify flight prediction capability goals over the next 5, 10, and 25 years
  - What types of problems should we be working?
  - What capabilities do we need?
  - What are our skill, computing, and facility gaps?
  - What are accuracy and efficiency needs for our prediction methods?
  - Priorities?
4. Identify requirements for uncertainty quantification for computational and experimental methods
5. Share best practices in computational and experimental methods through lessons learned in recent vehicle developments
6. Develop a community of practice for flight prediction

Lunches and refreshments will be available for a fee. A block of rooms have been reserved at Hilton Houston NASA Clear Lake. Finally, a no-host dinner has been organized for Tuesday at 7:00 pm at Mamaca's - NASA Houston.

For complete information about the workshop site, hotel, and costs, go to:

<http://www.nianet.org/flight-prediction-workshop/>

### Organizing POC

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### Organizing Committee Members

- NASA: Mike Fremaux, Benjamin Kirk, Dave Schuster, Rich Wahls
- USN - NAVAIR: Dave Findlay
- USAF - AFRL: Jack Benek, Gary Dale, Ryan Plumley

# Motivation for Workshop

- The last NASA/Industry/DoD workshop on Aerodynamic Flight Prediction was held 14 years earlier in 2002. Prior to that there was a wind tunnel-flight correlation workshop held in 1981.
- Provide a nonthreatening environment for sharing with and benefiting the community as a whole
- Information and opinions provided during the workshop can *potentially* be incorporated and used as guidance for R&T planning for future government activities (no government direction or formal commitments due to workshop)

# Workshop Specifics

- 2016 Flight Prediction Workshop (17 – 19 May 2016)
  - Held at Gilruth Center near NASA Johnson Space Center, Houston, TX
  - Technical Experts: Larry Leavitt (NASA-ret), Doug Ball (Boeing-ret)
  - Over 75 attendees (by invitation only, limited to U.S. Government and U.S. industry)
    - 7 NASA Centers, AFRL, NAVAIR, AMRDEC, ARL, Sandia, JHU-APL, DoD HPCMP/CREATE, Oak Ridge National Labs, USAF, Naval Air Systems Command, Boeing, Lockheed-Martin, Northrup Grumman, SpaceX, Sierra Nevada, AMA, Booze-Allen Hamilton, Mooney International, United Technology AS, The Aerospace Corporation
  - Scope compared to the 2002 workshop
    - Limited to fixed and hybrid wing vehicles plus launch vehicles. No rotorcraft. No hypersonic or EDL. No micro-UAVs.
    - Structural and acoustic load responses to unsteady forcing functions in addition to the traditional aerodynamics and flight dynamics at cruise and maneuver flight conditions

# Objective and Ground Rules

- Free and open exchange of experiences, lessons learned, and philosophies
  - To encourage the exchange process, attendance has been restricted to invited **U.S. citizens only**, the sessions are **unclassified**, and all presentations will be **oral only**.
    - Organizers did not keep any presentations; some authors chose to share
    - Technical reviewers requested copies of presentations for a limited time to write report
  - All information heard in the workshop was considered sensitive in its **raw** form.
  - Each organization in attendance **was required** to provide at least one presentation
- Primary objective was to gather critical technical assessments of the state of the art. Main theme is the assessment of the accuracy, feasibility (cost, time, etc.), and impact of prediction methods
- Community recommendations for further developments in flight prediction methodology and emphasis.
- Output of this workshop: An initial indication of the relative maturity of aero prediction methods in all critical flight areas:
  - What applications are sufficiently mature?
  - What are the critical needs?
  - Two documents summarizing the findings of the workshop – a sanitized public version will be released
  - Plan for follow-on workshops and activities in recommended areas

# Format

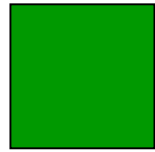
- 3 day event with approximately 2 days of 30 minute presentation slots from attendees
  - Organized by vehicle class
  - No “Motherhood” presentations—want actual experiences (with prediction/flight data) and real impact statements (except the keynote speakers)
  - Presenters encouraged to prepare no more than 20 minutes of presentation to leave ample time for immediate discussion
- 2 breakout sessions of 3 groups with group summaries at end of workshop
  - One set of questions for each session
- Wrap up statements by organizers
- Tour of Johnson Space Center

# Summary

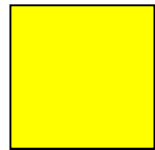
- As was the case in 2002, many of the speakers presented actual correlations of flight predictions with flight data
  - Speakers were directed present this information in 2016
  - Speakers were directed to provide a stoplight type assessment in specific areas in both 2002 and 2016
- General findings of the workshop are similar to those found in 2002, however:
  - considerable progress has been made with respect to the complexity of the problems being addressed as well as the success (in some key areas) of both experimental and computational capability utilized for flight prediction
- Mis-predictions of vehicle performance, stability and control, and aeroelastics, still exist and in almost every case, corrections result in significant cost and schedule penalties and/or mission limitations, non-optimum configurations, etc.
  - Common theme of desire for more certification by analysis type capability and achieving verification status during product development rather than completely by final flight test series.

# Industry/Government Presentations

- Include overview “Stop Light” chart up front (sample on next chart):



Good shape; methods are accurate and efficient; not a critical area



Methods good, but improvements needed



Critical shortcomings; high priority

# Sample Topic Areas for Stoplight Chart

Note: needs work to categorize areas as appropriate

- Vehicle

- • Cruise performance
- • High lift performance
- • Buffet
- • Stability and control/trim
- • Loads
- • Flutter
- • Propulsion Integration
- • High-alpha behavior
- • Maneuverability
- • Supersonic persistence
- • Transonic characteristics
- • External stores/ weapons integration
- • Aeroacoustics loads/vibration/noise
- • Tail buffet
- • Engine out behavior
- • Ground effects (static and dynamics)
- • Icing impacts/ heavy rain/ adverse environmental impacts
- • Wake vortex
- • Air drop issues
- • Ship air wake/ dynamic interface
- • Jet interactions
- • Vehicle asymmetries

- Technology

- – Reynolds numbers effects
- – Flow control devices
- – Test techniques for highly augmented aircraft (scheduled surfaces)
- – Propulsion aerodynamics integration
  - • Thrust vectoring
  - • Prop dominated effects
  - • Intake/ exhaust flows
- – Uncertainties and resolutions in process
  - • CFD validation
  - • WT data validation
- – Simulation development
- – Aero/structural coupling
- – Dynamics/unsteady flows
- – Hinge-moment predictions
- – Advanced flow measurement diagnostics
- – Unconventional configurations

- Using this type of outline, speaker can expand discussion on details for specific topics on list
- Emphasize experiences with experimental and CFD prediction methods
  - What works
  - What doesn't & why
  - Specific data for ground/flight correlation
  - Recommendations for research

# Findings (1/2)

1. All groups said that there is a need for greater fidelity and confidence in predictive tools. Perceived waning interest in physics discovery and fundamental research.
  - a. “Prediction of the onset of separated flows across the speed range (with the attendant issues of transition prediction, turbulence modeling, unsteady flows, etc.) and the character and impact of separated flow on aircraft capabilities is the single most critical fundamental issue to be addressed and should receive priority in aerodynamic R&D programs.” (Chambers 2002) **This was still the case in 2016.**
  - b. “For attached flow conditions with turbulent boundary layer on a large part of the surface, aerodynamic prediction methods are in good shape, and should not receive the highest priority in research programs. However, there are major challenges with respect to transition prediction as well as modeling and simulation for flight vehicles (subsonic and supersonic) to be designed for large extents of laminar flow.” (Chambers 2002) **Engineering quality transition prediction tools were still a need in 2016** and there are still uncertainties in real-world transition processes
  - c. In the area of modeling and simulation geometry, modeling is still one of the most labor-intensive activities. In particular, getting the geometry water-tight and ready for gridding can be very time consuming. Also, as solution adaptive grid methods become more widely used, metrics will need to be developed to estimate the error in the adapted solution.

# Findings (2/2)

2. The need to decrease vehicle weight to improve performance, coupled with new material systems, results in ever-increasingly flexible structures that drives the need for more multidisciplinary analysis and design tools. Vehicles that are both aerodynamically and structurally unstable drive the need for more multidisciplinary analysis and design tools that include active control systems as part of the analysis and design process.
3. The prediction of unsteady loads of all types (aerodynamic, aeroacoustic, vibroacoustic, and other dynamic loads) continues to be a major reliability issue for most vehicle classes and couples with the increase flexibility.
  - Propulsive intake and exhaust flows for air-breathing vehicles and rocket exhaust flows for more traditional space launch vehicles exacerbate the problems.
4. The needs for validation data range from unit problems to full scale data. In addition, instrumentation improvements are needed to gather some of this data.
5. The need for more efficient vehicles continues relentlessly. As a result, the need for multidisciplinary optimization tools containing a combination of low- and high-fidelity physics based tools will continue.

# Final Thoughts

- Some concern was expressed by participants as to the need to keep the momentum gained during this workshop moving forward.
- Suggestions included periodic meetings, the development of a catalog of validation data sets, and other future activities.
- The meeting attendees recommended that NASA (and its DoD partners) take the lead in organizing follow-on, topic-specific activities.
- An advocacy package was presented to NASA leadership for a multiyear plan to assess “CFD as a surrogate for High Supersonic Ground Test” with 4 recommended data sets to be gathered in the NASA LaRC Unitary Plan Wind Tunnel up to Mach 4.6. **Approval was granted** to fully recertify the facility and accept customers.

