G500 Takeoff Performance Testing

Clay Harden – Flight Sciences Engineering
Ben Luther – Flight Test Engineering
Todd Abler – Director Flight Operations

Gulfstream™
A GENERAL DYNAMICS COMPANY

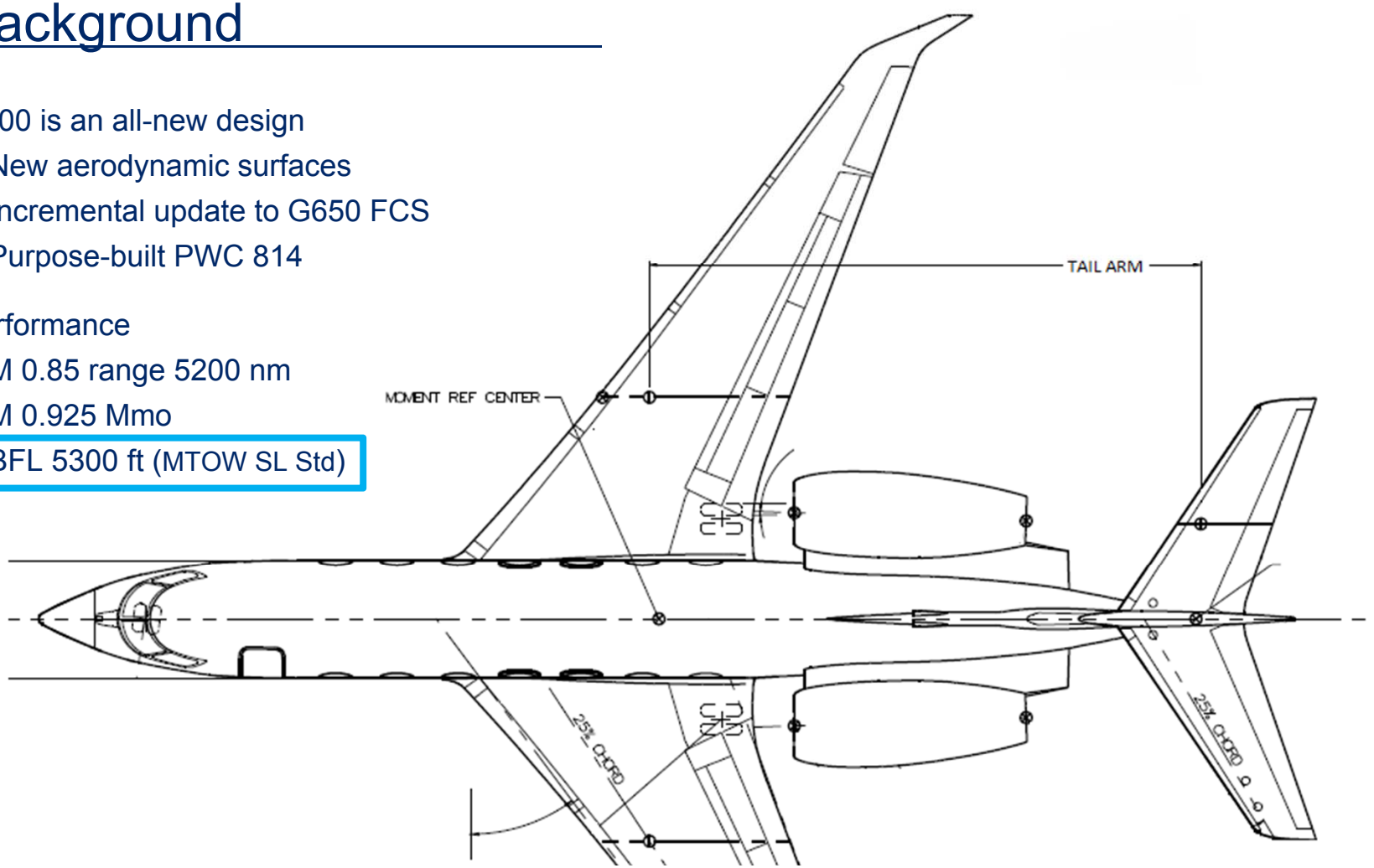
Background

G500 is an all-new design

- New aerodynamic surfaces
- Incremental update to G650 FCS
- Purpose-built PWC 814

Performance

- M 0.85 range 5200 nm
- M 0.925 Mmo
- BFL 5300 ft (MTOW SL Std)



G500

New Symmetry flight deck
Active, linked side-sticks
Touch-screen controllers
HUD + Enhanced Vision

Continuous Improvement

Stall In Ground Effect (IGE)

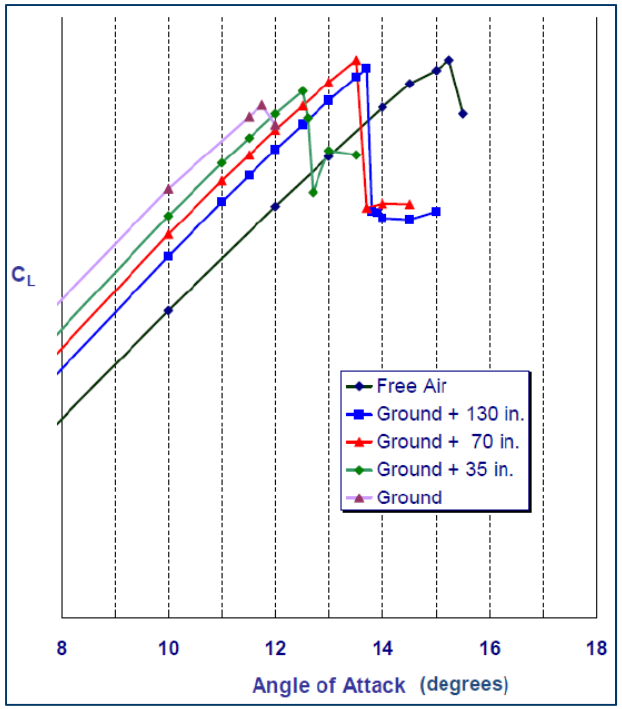
Prior FTSW presentation in 2013

- Ground Effect impact on C_{lmax}

Knowledge for the Flight Test profession

Improvements rolled into

all subsequent programs

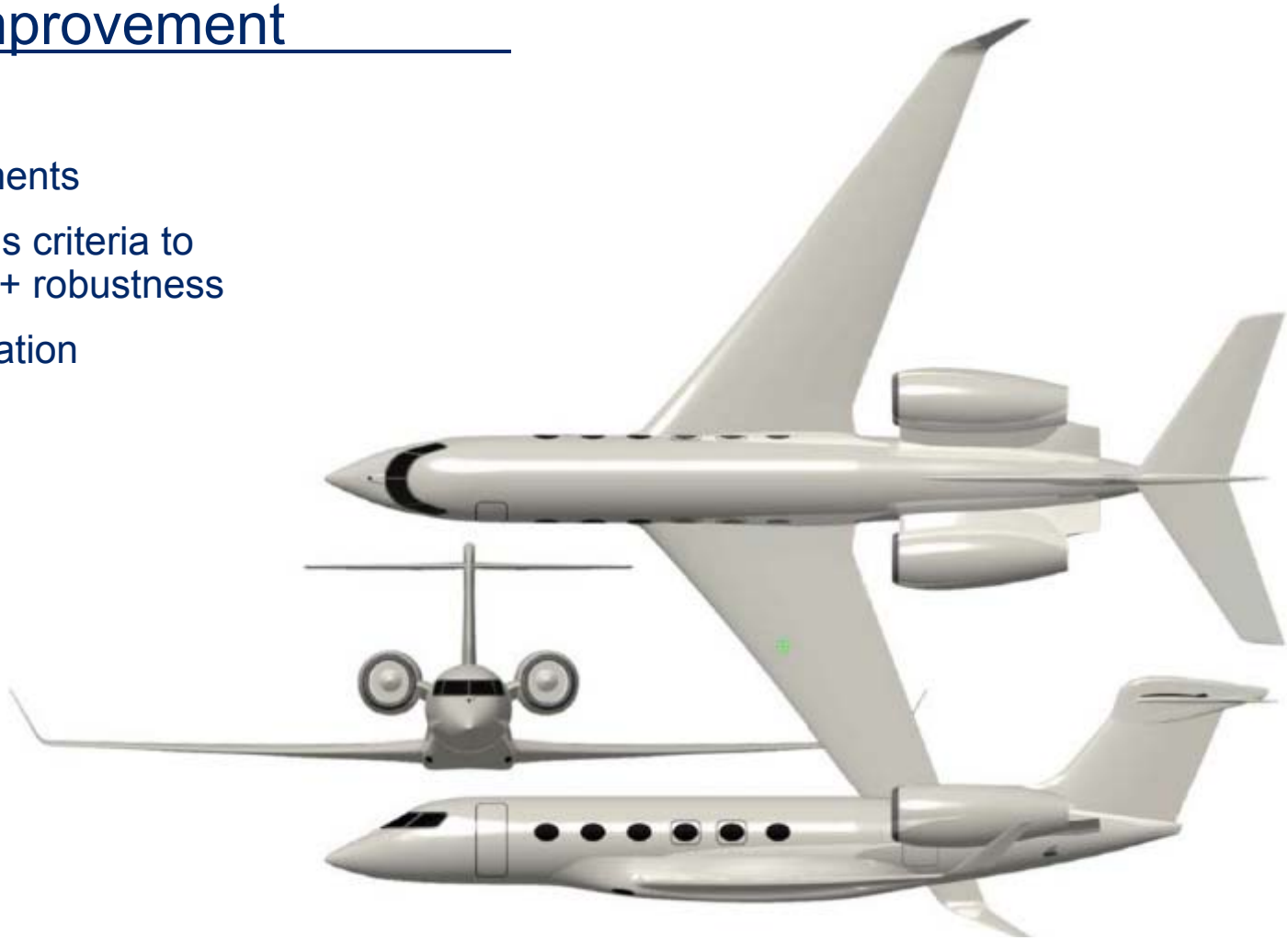


ARAC-approved FTHWG recommendations for addition to AC 25-7:

https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/09%20-%20FTHWG_Final_Report_Phase_2_RevA__Apr_2017.pdf

Continuous Improvement

- Analysis improvements
- Company V-speeds criteria to ensure test safety + robustness
- Performance validation in near-real-time



A Tale of Two Models:

bootstrap pre-flight validation, near-real-time verification

ASim:
Full Aero + Systems Simulation

- Relatively slow (approx. 1:1 time)
- 6DOF EOM
  Full FCS+CLAW
  Cockpit inputs
- Wind tunnel + CFD-based aero, including IGE effects, full mass and ground contact
- Ensures reasonable cockpit inputs reproduce speeds, verifies margins.

Takeoff.m:
Perf Simulation

- Fast iteration to select and optimize thousands of takeoff conditions
- 3DOF EOM
  Direct elevator for pitch control
- Aero C_L, C_D, C_M with IGE, simple lat/dir accounting, simple ground contact
- Optimal V_1, V_R, V_2 selection

Both are physics-based.

Both are considered 'validated'.

Speed Schedule Determination

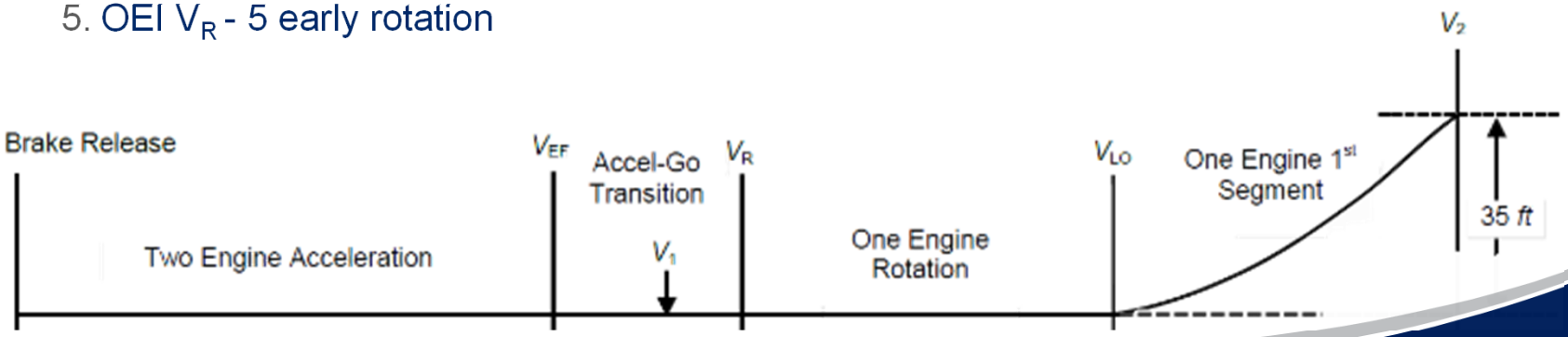
for each Weight, T/W, Flap – with Takeoff.m

Select minimum V_R using nine criteria

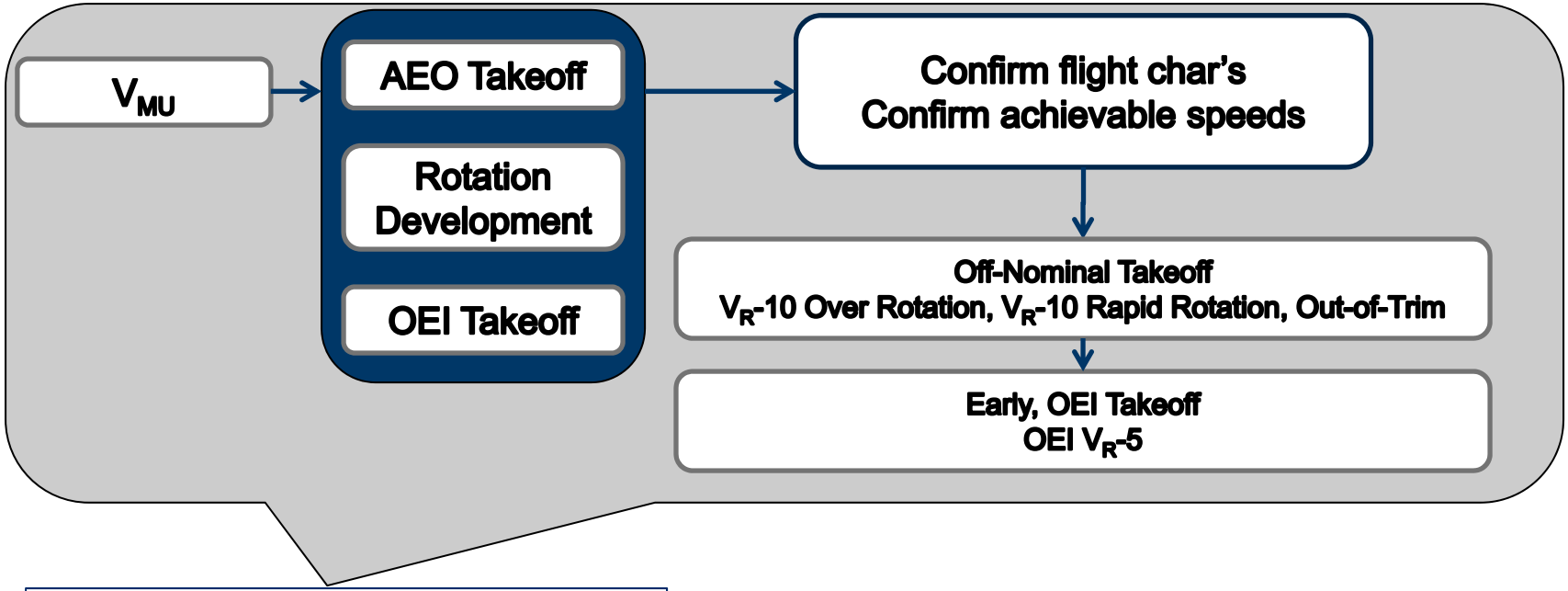
1. $V_R \geq 1.05\ V_{MCA}$
2. $V_1 \geq V_{MCG}$

AoA margin met for

3. AEO V_R -10 early, over-rotation
4. AEO V_R -10 early, rapid rotation
5. OEI V_R - 5 early rotation
6. $\theta_{LO} \leq \theta_{TGT} - \Delta$
7. $V_{LO} \geq 1.05\ V_{MU}$ for OEI max practical rot rate
8. $V_{LO} \geq 1.10\ V_{MU}$ for AEO max practical rot rate
9. $V_2 \geq V_{2min}$



Overview of Test Progression



Entire sequence repeats

- Multiple flaps settings
- Four gross weight ranges
- Multiple T/W ratios at each weight (simulating Altitude/Temperature)

Test Participant Duties

Airborne

Pilot

Pilot not-flying

Flight Test Engineer

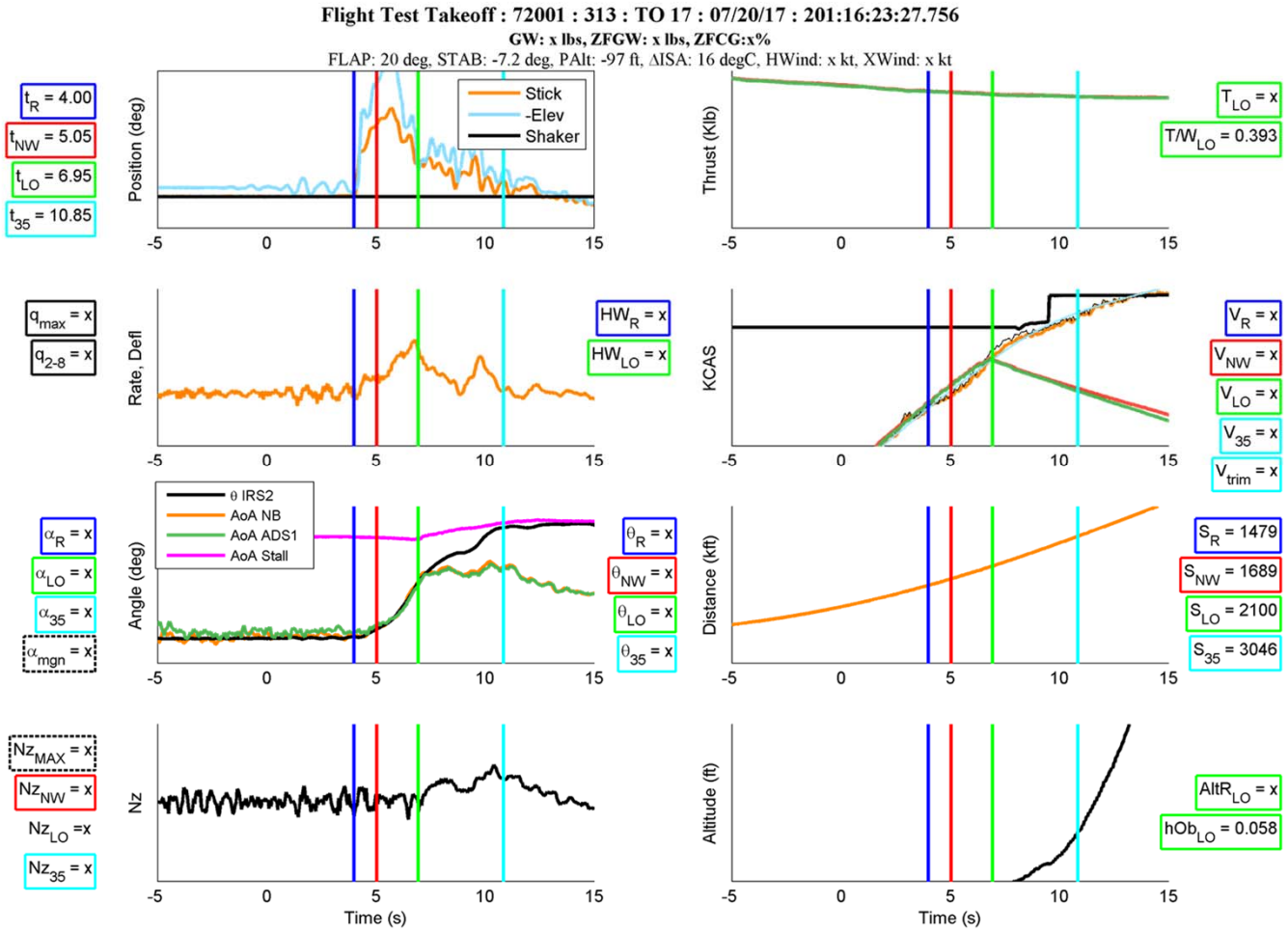
Telemetry

Flight Test Engineer

Performance Engineer

Flight Dynamics Eng.

One Team



AEO Takeoff
Engineers' View

Gulfstream™
A GENERAL DYNAMICS COMPANY

What the Pilots See – Vmu Takeoff

What the Pilots See – Vmu Takeoff

Take Aways

Good decisions

The right people, given time

Compare two models

Assurance

Gulfstream™
A GENERAL DYNAMICS COMPANY

Questions
Comments
Suggestions?

Photo Credit:
Vu Nguyen